ANNUAL REPORT

European X-Ray Free-Electron Laser Facility GmbH

2017

The European XFEL is organized as a non-profit company with limited liability under German law (GmbH) that has international shareholders.

2017

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Left to right Serguei Molodtsov, Robert Feidenhans'l, Andreas S. Schwarz, Claudia Burger (until October 2017), and Thomas Tschentscher

Opposite Laser installation on the European XFEL headquarter in Schenefeld in the week before the opening in September: Five laser beams indicate the locations of the five photon tunnels.

2017 – A fantastic year

In 2017, nearly 10 years of construction work paid off with the start of user operation. The commissioning of the accelerator began in late 2016, and the cooling down went quickly and smoothly. First lasing at a wavelength of 9 Å was achieved on 2 May 2017 on the SASE1 undulator system, lasing at 2 Å was achieved on 24 May, and the X-ray beam arrived at the end of the tunnels just before the instrument stations on 27 May. The X-ray beam reached the instruments FXE and SPB/SFX on 23 June. On the same day, first test measurements were performed on both instruments. After many years of construction, this great achievement was celebrated enthusiastically.

The year 2017 started with a successful European XFEL Users' Meeting with nearly 1000 participants, organized as usual back-to-back with the DESY Users' Meeting. The participants were invited to visit the headquarter building and the experiment hall in Schenefeld for the first time, which was a logistic challenge, but worked very well. Furthermore, the first call for proposals was announced in January, and, by March, we had received 63 proposals, 37 for the FXE instrument and 26 for SPB/SFX. The proposals were evaluated in May by the Proposal Review Panels. In total, 14 proposals were granted beamtime, 7 on FXE and 7 on SPB/SFX—at a point in time when the beam had not yet reached the instruments.

The arrival of the first X-ray beam at FXE and SPB/SFX on 23 June was perfectly timed for opening the 25th Council meeting on 29 June. With the great success of having beam in the hutches and performing first measurements with the Karabo control system, the Council decided that European XFEL was ready to officially enter the operation phase on 1 July. Furthermore, the Council decided on a sustainable operation budget that would cover the first three years of operations and on a plan to review the operation cost in 2019. At that point, the European XFEL will be closer to full operation, and we can much better estimate the efforts that are required to run the experiment programme.

In July and August 2017, the two large detectors—the Large Pixel Detector (LPD) and the Adaptive Gain Integrating Pixel Detector (AGIPD)—arrived in the experimental hall. The LPD is an in-kind delivery from the STFC in the UK and the AGIPD an in-kind delivery from DESY. These truly unique and highly advanced detectors were both quickly commissioned in order to get ready for first user operation planned for 14 September, thanks to our highly motivated and dedicated staff working around the clock.

On 1 September, the great day had finally arrived: the European XFEL facility was officially inaugurated. A fantastic event blessed by marvelous weather and many high ranking officials in attendance, including Prof. Dr. Johanna Wanka, German Minister for Education and Research; Prof. Dr. Andrei Fursenko, Aide to the President of the Russian Federation and former Research Minister; Prof. Dr. Frédérique Vidal, French Minister of Higher Education, Research and Innovation; Hamburg's First Mayor Olaf Scholz; and Schleswig-Holstein's Minister of Education, Science and Cultural Affairs Karin Prien. Everything went smoothly and our guests enjoyed seeing the facility and the experiment hall.

On 14 September, the long-awaited moment of truth had arrived: the first users came to the European XFEL. The User Office had been working hard for many months to prepare for this day and was anxiously waiting to greet our first users, who indeed showed up in great numbers: more than 100 users registered for the first experiment at SPB/SFX.

Very little time had been left for doing commissioning of the instruments. From first lasing to first users only took a little more than four months, which was a truly amazing record, something we would not have considered possible before it happened. In order to mitigate risks and manage the expectations of the first users, the first three weeks of users beamtime were labeled "user-assisted commissioning", a term that was very well accepted and meant that the users would be granted more beamtime at a later stage if the experiments could not be fully conducted.

Of the 14 experiments planned for 2017, 10 had beamtime and 4 had to be cancelled due to technical reasons. The accelerator worked very well and was stable, with 30 pulses per train, in total 300 pulses per second, a photon energy of about 9.3 keV, and bunch energies up to 1 mJ. In all, 700 Tb of data was collected. The data from the first experiments are being analyzed and the first results and publications are under way.

All said, 2017 was a fantastic year, with the start of operation and first user experiments. This was only possible due to a highly motivated and dedicated staff at European XFEL, DESY and other partners. The focus in 2017 was nearly entirely on SASE1 and the FXE and SPB/SFX instruments. In 2018, the focus of construction will shift to SASE3 and SASE2, while simultaneously keeping the user programme running on the SASE1 instruments. The SCS and SQS instruments on SASE3 are expected to go online in mid-2018. SASE2 is expected to lase in May 2018, and the MID and HED instruments will receive users in 2019.

We are all looking forward to the coming years in order to get into full operation. It will be truly exciting.

Robert Feidenhans'l

Nicole Elleuche

Managing Directors

Serguei Molodtsov

Andreas S. Schwarz

Thomas Tschentscher

Scientific Directors

Martin Meedom Nielsen

Dear Readers,

The year 2017 was a year of glorious firsts. In January, we had the first electrons in the cooled superconducting accelerator. In May, we had the first lasing. In June, we had the first light at the scientific instruments. And in September, we had the first users at the European XFEL. This success was possible only through the efforts and commitment of staff members at European XFEL and DESY, members of the Accelerator Consortium, and all the in-kind contributors, who have been working very hard to make this happen.

September was also the month of a very festive and spectacular inauguration of the European XFEL, in which Hamburg shined several lasers in the sky for the European XFEL, and the European XFEL shined right back. Past and present staff, scientists, and delegates from the member countries contributed to make this a very enjoyable and memorable occasion and a testament to the enthusiasm surrounding the project.

With all the activity in 2017, there were also many important decisions for the European XFEL Council to make. Not least was the decision to start the operation phase. The technical design report from 2006 already laid out the criteria for when the facility could be considered to have progressed from the construction phase to the operation phase and, with the help of the Scientific and Machine Advisory Committees, the Council was able to confirm the fulfilment of these criteria by the end of June. Another important decision was about the scope of the operation budget. Given that the European XFEL is the first facility of its kind, it was not a simple task to establish the basis for a sustainable operation budget. Based on the vision and mission of the European XFEL, we launched an effort to establish the background for the operation cost, which was then thoroughly scrutinized by task forces from the Administrative and Finance Committee, the Scientific Advisory Committee, and the Machine Advisory committee, coordinated by a Council working group. This was supported by a large and dedicated effort, not least from the financial and administrative staff at European XFEL and DESY. While not always as visible as scientific achievements, a well-functioning administration is essential to the success of the facility, and I would like to extend a heartfelt thank you to all involved, including the advisory committees.

In 2017, we said goodbye to the European XFEL Administrative Director, Claudia Burger, who moved to take up the post as Administrative Director at the European Southern Observatory (ESO). On behalf of the Council, I would like to take this opportunity to thank Claudia for her long commitment and many contributions to the European XFEL. By the end of the year, the Council was able to appoint Nicole Elleuche as her successor. We are looking forward to Nicole joining European XFEL in 2018.

The vision of European XFEL is to offer optimal research opportunities to academic and industrial users, providing a unique light source, excellent scientific infrastructure, and excellent user service. Excellent science requires excellent infrastructure, not least in terms of accelerator, optical lasers, instruments, detectors, data acquisition and handling, and support laboratory infrastructure. But it also requires adequate and transparent administrative procedures, access to data and computing resources before and after experiments, and a place for users to work, relax, and recharge. Importantly, the quality of the science depends on the quality and innovative nature of the proposals submitted. High standards are ensured by review panels, evaluating proposals based on scientific merit.

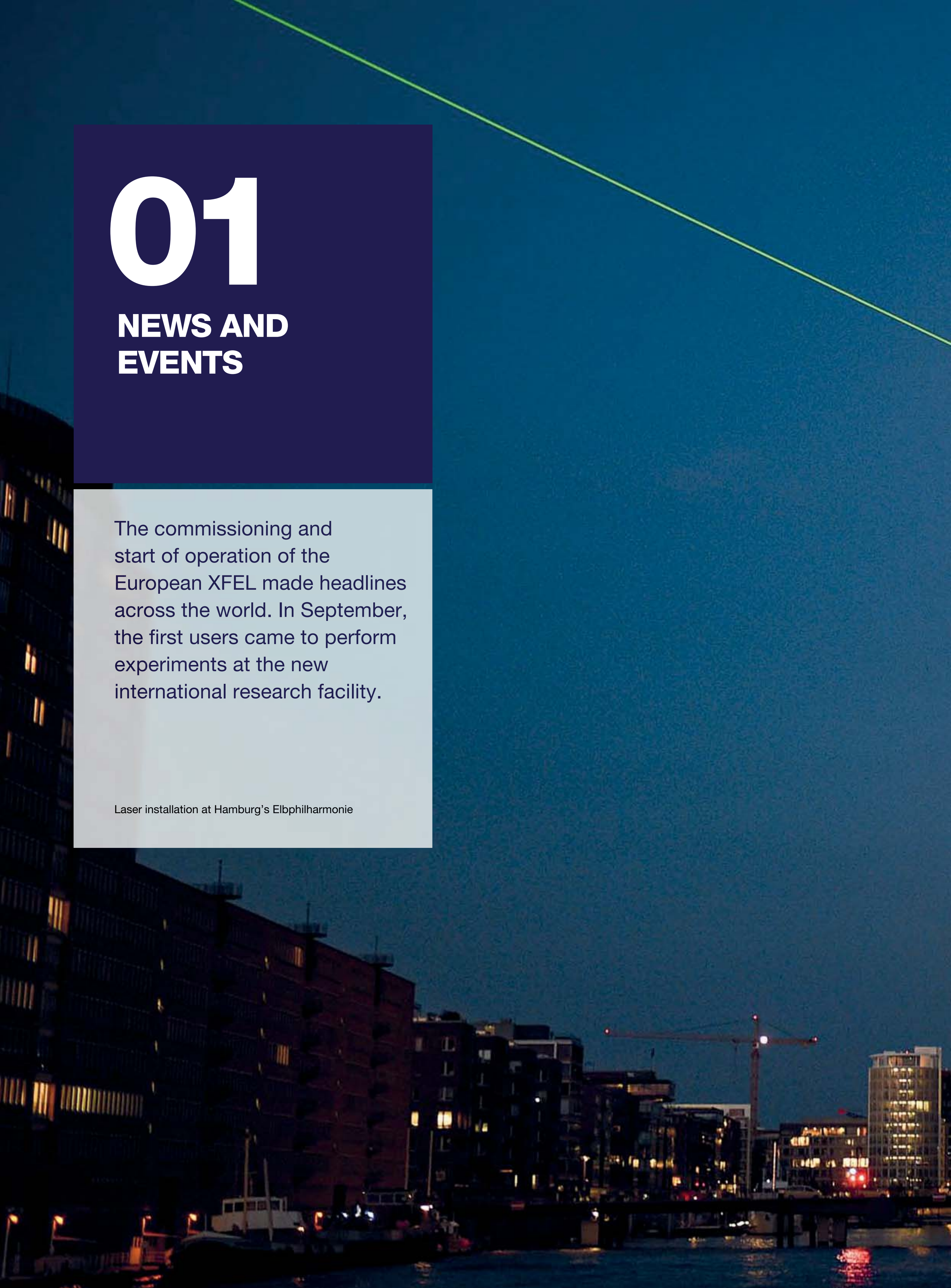
It will be a priority to develop new scientific directions and ideas by engaging scientific communities in the member countries in X-ray FEL science and by using the synergy between the accelerator operated by DESY and the photon systems and instruments operated by European XFEL to foster excellent science. Scientific ideas may inspire innovations in running the accelerator and vice versa. The European XFEL is well prepared to accommodate new instruments, and, while the last of the initially planned six instruments are being brought on line for the users, there are already upgrade plans for both the instruments and the accelerator. The Scientific and Machine Advisory Committees will help make sure that we maintain and develop our position as the world's best facility for X-ray science, and the Council will continue to closely follow these and other issues as they develop in the operation phase.

Martin Meedom Nielsen

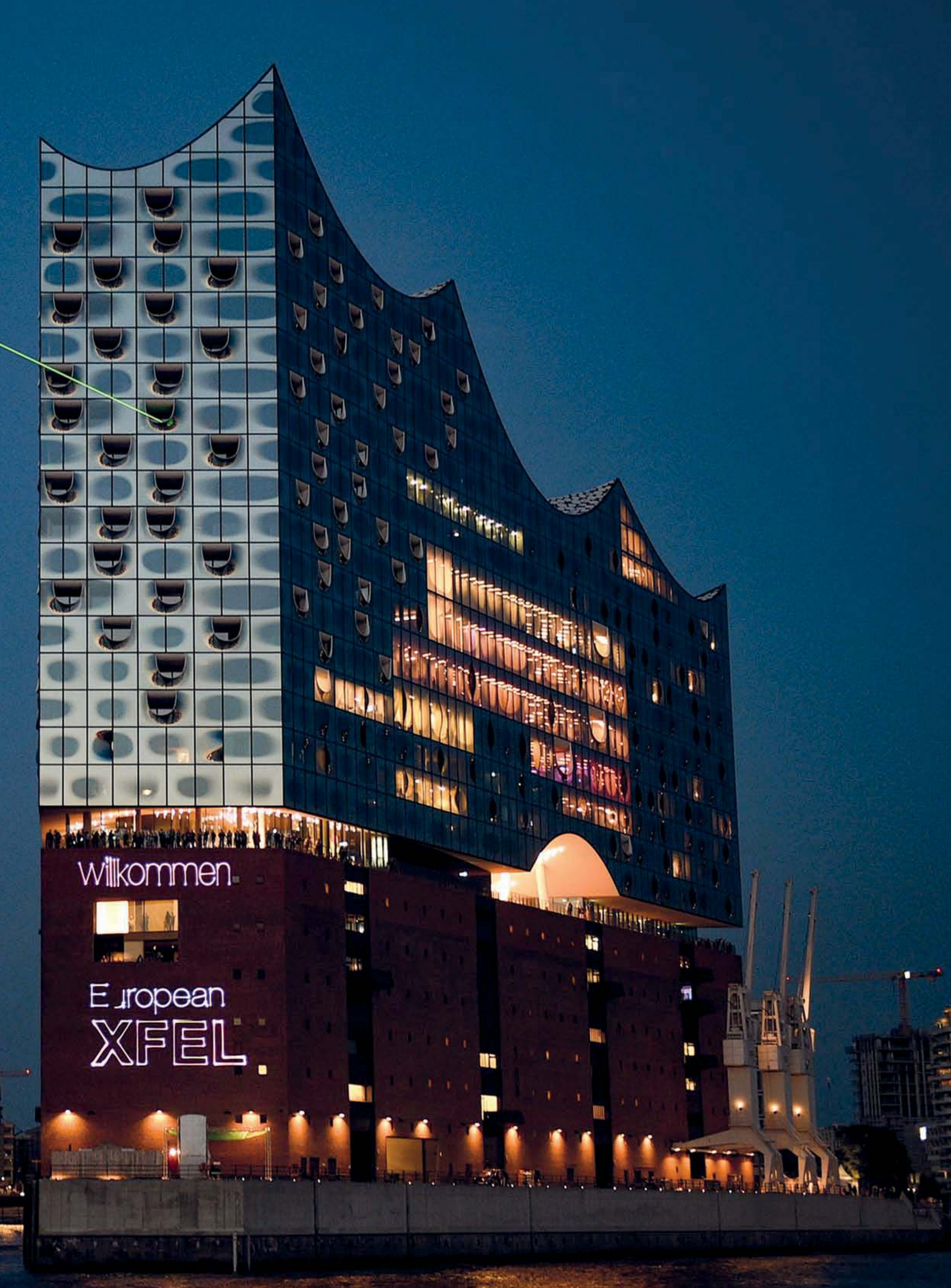
Chairman of the European XFEL Council

01 NEWS AND EVENTS

The commissioning and start of operation of the European XFEL made headlines across the world. In September, the first users came to perform experiments at the new international research facility.



Laser installation at Hamburg’s Elbphilharmonie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European
XFEL

January 2017

1 January
Robert Feidenhans'l starts as Chairman of the Management Board

Prof. Robert Feidenhans'l starts as the new Chairman of the Management Board. The European XFEL Council appointed Feidenhans'l as successor to Prof. Massimo Altarelli in September 2016.

7 January
First electrons in the -271°C cooled main accelerator

An important milestone is reached: The first electrons are guided from the injector into the superconducting main linear accelerator, which is cooled to -271°C (2 K). After passing through the first four accelerator modules and a subsequent bunch compressor section, they are captured in an electron dump.

24 January
First call for proposals

For the first time, scientists can submit their proposals for experiments at the European XFEL. The first call for applications for "beamtime" is published on the website. The first two instruments for which proposals can be submitted are FXE and SPB/SFX.

25 January
Great expectations: Last Users' Meeting before start of operation

The European XFEL Users' Meeting, which is held in conjunction with the DESY Photon Science Users' Meeting, is attended by 1100 scientists. The Users' Meeting includes plenary talks on soft X-ray experiments and a poster session. Among the participants are 26 students and young scientists who attend on bursaries dispensed by European XFEL.

February 2017

2 February
DFG funds investigation of exoplanets at European XFEL

The German Research Foundation (DFG) awards a grant to a research unit led by the University of Rostock, including scientists from European XFEL who investigate planets outside our solar system. The interdisciplinary collaboration comprises theory, planetary modelling, and experiments, including experimental investigations of materials under extreme conditions, such as those found inside of planets, at the European XFEL and other institutes. The DFG funds the project for the next three years with around 2 million euro.

28 February
Hamburg Senate visits European XFEL

As part of a session of the Hamburg's Senate, members of the city–state's main governing body—including Mayor Olaf Scholz and Senator for Science, Research, and Equality Katharina Fegebank—visit European XFEL. Schleswig-Holstein Minister for Social Affairs, Health, Science, and Equality Kristin Alheit also attends the session.

April/May 2017

17 April

Particle accelerator for the European XFEL operational

European XFEL partner DESY successfully commissions the facility's superconducting particle accelerator, which drives the X-ray laser. The accelerator is now operational across its full length and a key component for the 3.4 km long laser.

2 May

European XFEL generates its first laser light

European XFEL generates its first X-ray laser light. The X-ray light has a wavelength of 0.8 nm—about 500 times shorter than that of visible light. At first lasing, the laser has a repetition rate of one pulse per second. The X-ray light is absorbed and measured shortly before arriving in the underground experiment hall.

June 2017

23 June

First beam in the experiment hall

European XFEL celebrates successfully guiding the X-ray laser beam into the experiment hall—another important milestone. Scientists, engineers, and guests in the control room of the SPB/SFX instrument in the experiment hall see the first X-ray laser beam reach the SPB/SFX optics hutch. Shortly thereafter, the beam also reaches the FXE instrument.

23 June

Representatives of the diplomatic corps visit European XFEL

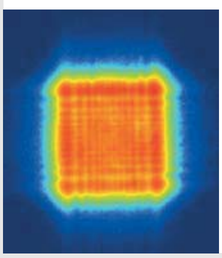
More than 20 representatives of the diplomatic corps, including many ambassadors from Europe, Asia, Africa, and Oceania, visit European XFEL. The federal government of Schleswig-Holstein invited the members of the diplomatic corps as part of the Kieler Woche in Kiel.

July 2017

July 2017

European XFEL starts operation phase

European XFEL enters its operation phase. The European XFEL Council agrees that the conditions for the start of operation have been satisfied and releases the funds designated for the operation phase. Prof. Martin Meedom Nielsen, chairman of the European XFEL Council, says that the member states are very pleased and excited about the great achievements made at European XFEL. In order to qualify for the transition from the commissioning phase, the facility had to meet a number of pre-determined technical requirements: The pulses of the X-ray laser at a wavelength of maximally 2 Å (0.2 nm) had to reach a typically high intensity and remain stable. The two scientific instruments of the first beamline also had to be sufficiently equipped so that the first scientific experiments could be carried out.



August 2017

5 August

First users invited to European XFEL

The first 14 groups of scientists are invited to carry out their ambitious research projects at the facility starting in September 2017. More than 60 user groups answered a call for proposals issued in early 2017 for access to the scientific instruments FXE and SPB/SFX. The project proposals were evaluated by international committees of experts on the basis of scientific merit and technical feasibility.

21 August

European XFEL installs its most advanced "eye" yet

European XFEL completes the development and successful installation of its first advanced detector. The Large Pixel Detector is a cutting-edge X-ray "camera" developed by European XFEL and the Science and Technology Facilities Council (STFC) in the UK. It is the first X-ray light detector to record at a rate of 4.5 MHz—4.5 million pictures per second, fast enough to keep up with the European XFEL's high repetition rate of 27 000 pulses per second.

28 August

Hamburg shines for the European XFEL

Five strong laser lights shine westwards through Hamburg's evening sky to Schenefeld at a height of 50 m. A message in the eleven languages of the European XFEL partner countries is projected on the base of Hamburg's new concert hall, the *Elbphilharmonie*, welcoming the European XFEL to the metropolitan area of Hamburg. In Schenefeld, five other lasers at the same height highlight the underground paths of the European XFEL tunnels.

September 2017

1 September
European XFEL inaugurated

Research ministers and 800 guests from across Europe join the European XFEL directors to officially start the research operation of the facility with the first two experiments. Prof. Dr. Johanna Wanka, German Minister for Education and Research, stresses the importance of the new facility and expects groundbreaking insights into the nanocosmos. Together with Wanka, Hamburg Mayor Olaf Scholz, and Schleswig-Holstein Minister of Education, Science, and Cultural Affairs Karin Prien, European XFEL Managing Director Robert Feidenhans'l greets the first external researchers of the new international research facility on stage. Later, European XFEL scientists inform the ministers and guests about the upcoming experiments. At the SPB/SFX instrument, they press a button to start the first experiment at the European XFEL to determine the structure of a biomolecule in a model experiment.

14 September
First users at European XFEL

The first users start the commissioning experiments and collect scientific data. 14 groups are invited to conduct experiments at the European XFEL until March 2018, each for about five days, with 12 hours of beamtime per day.

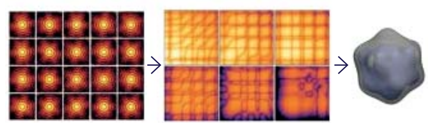
18 September
European XFEL at "Highlights der Physik"

From 18 to 23 September, European XFEL is one of 50 exhibitors of the *Highlights der Physik* science festival in Münster. The annual event is hosted by the German Federal Ministry of Education and Research (BMBF), the German Physical Society (DPG), and the University of Münster (WWU).

October/November 2017

10 October
New approach to imaging single biological particles

As part of a collaboration, scientists at European XFEL publish an article in the journal *Physical Review Letters* presenting a novel approach for processing data from single biological particles. The new method overcomes problems of traditional approaches. The lead author from European XFEL is Ruslan Kurta, and one of the co-authors is SPB/SFX leading scientist Adrian Mancuso.



4 November
European XFEL at Hamburg Night of Science

Over 20 000 visitors come to the DESY campus on the occasion of the Hamburg Night of Science and the DESY open day. Highlights presented by European XFEL included setting up a burglar alarm with laser beams, exploring tunnels in virtual reality, and posing for infrared photos. Visitors also enjoy a laser show and a presentation by European XFEL Managing Director Robert Feidenhans'l.

02
FACTS AND FIGURES

European XFEL began operating the world's most powerful X-ray light source in 2017. With many strong collaborations across the world and a highly motivated staff, European XFEL looks forward to enabling cutting-edge research at the facility.

The staff and council of European XFEL

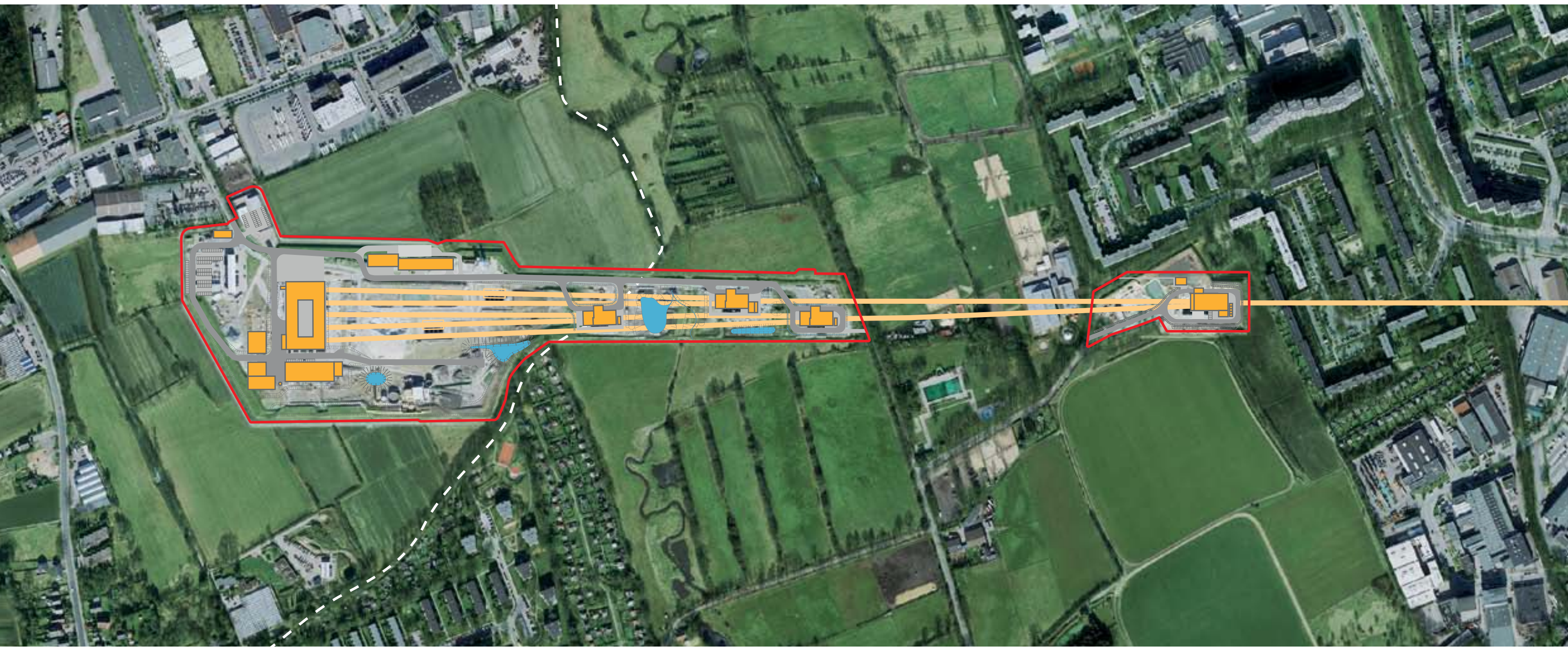


Figure 1 Aerial view of the European XFEL facility. **Left to right** Schenefeld, Osdorfer Born, and DESY-Bahrenfeld sites.

AT A GLANCE

The European XFEL is a research facility that opens up new research opportunities for science and industry. The 3.4 km long X-ray FEL started operation in September 2017 and generates ultrashort X-ray flashes for photon science experiments with a peak brilliance that is a billion times higher than that of the best synchrotron X-ray radiation sources.

Brilliant X-ray flashes for new research opportunities

With a repetition rate of up to 27 000 pulses per second and an outstanding peak brilliance, the world's largest X-ray laser produces ultrashort X-ray flashes that allow researchers to map the atomic details of viruses, decipher the molecular composition of cells, take three-dimensional images of the nanoworld, film chemical reactions, and study processes like those occurring deep inside planets.

The European XFEL is located mainly in tunnels 6 to 38 m underground with inner diameters of up to 5.3 m, roughly that of a subway tunnel. The 3.4 km long facility runs from the DESY research centre in Hamburg to the town of Schenefeld in the German federal state of Schleswig-Holstein (Figure 1). The new facility comprises three sites: the DESY-Bahrenfeld site with the injector complex, the Osdorfer Born site with one distribution shaft, and the Schenefeld campus site, which hosts the underground experiment hall with a large laboratory and office building on top. The latter serves as the company headquarters.

European XFEL GmbH

As of December 2017, 11 countries are participating in the European XFEL project: Denmark, France, Germany, Hungary, Italy, Poland, Russia, Slovakia, Spain, Sweden, and Switzerland. The United Kingdom joins the European XFEL as the twelfth member state in March 2018. The international partners have entrusted the construction and operation of the facility to the non-profit European X-Ray Free-Electron Laser Facility GmbH, which was established in October 2009 as a limited liability company under German law. The facility is a joint effort of many partners. The company cooperates closely with its largest shareholder, DESY, a research centre of the Helmholtz Association, and with other organizations worldwide. As of December 2017, European XFEL employs more than 380 people.

Construction costs

Construction of the European XFEL facility started in early 2009. Commissioning started in 2016. User operation with one beamline and two instruments started in September 2017.

The construction costs, including commissioning, amount to 1.22 billion euro (at 2005 price levels). Currently, the host country, Germany (federal government, city-state of Hamburg, and state of Schleswig-Holstein) covers 58% of the costs. Russia contributes 27%, and each of the other international shareholders between 1% and 3%. To a great extent, the European XFEL facility is realized by means of in-kind contributions by shareholders and partners.

STAFF

In 2017, the European XFEL workforce of employees, students, and guests grew from 337 to 397 (+18%).

The number of employees increased as follows:

- Scientists: 183 (+27)
- Engineers: 100 (+12)
- Technical staff: 57 (+14)
- Administrative staff: 57 (+7)

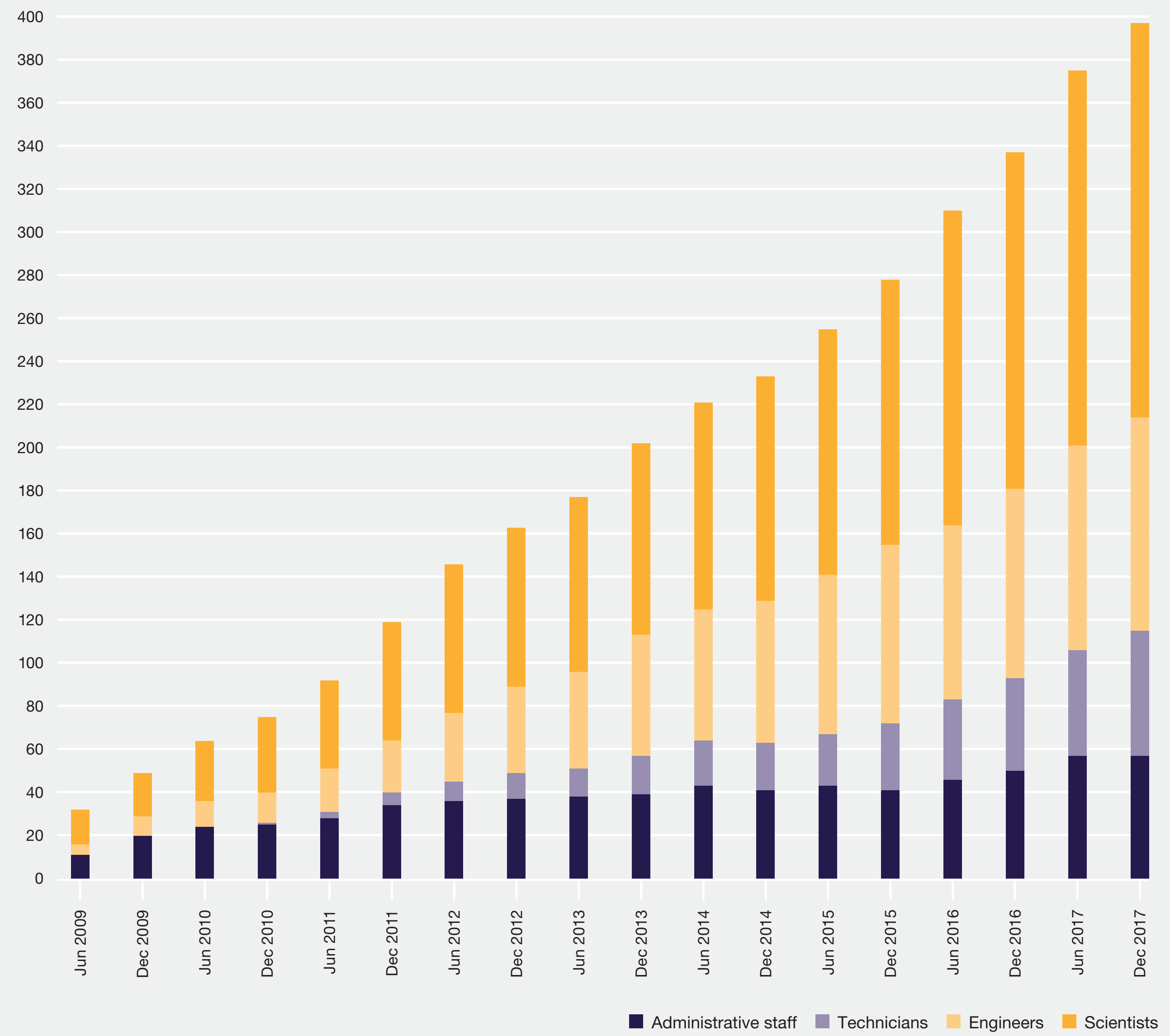


Figure 1 Overall growth in the number of employees, students, and guests (2009–2017).

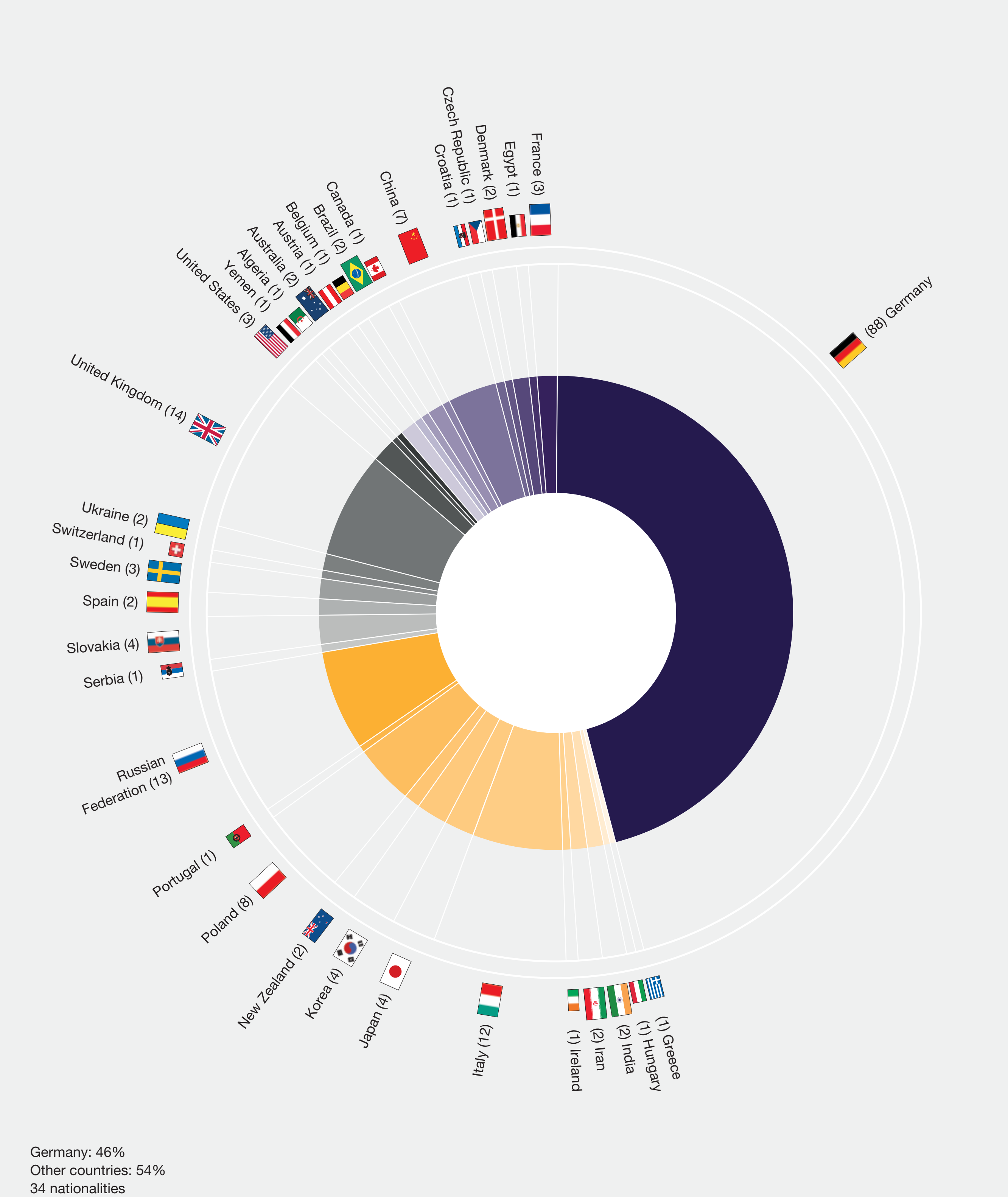


Figure 2 Nationalities of scientific staff

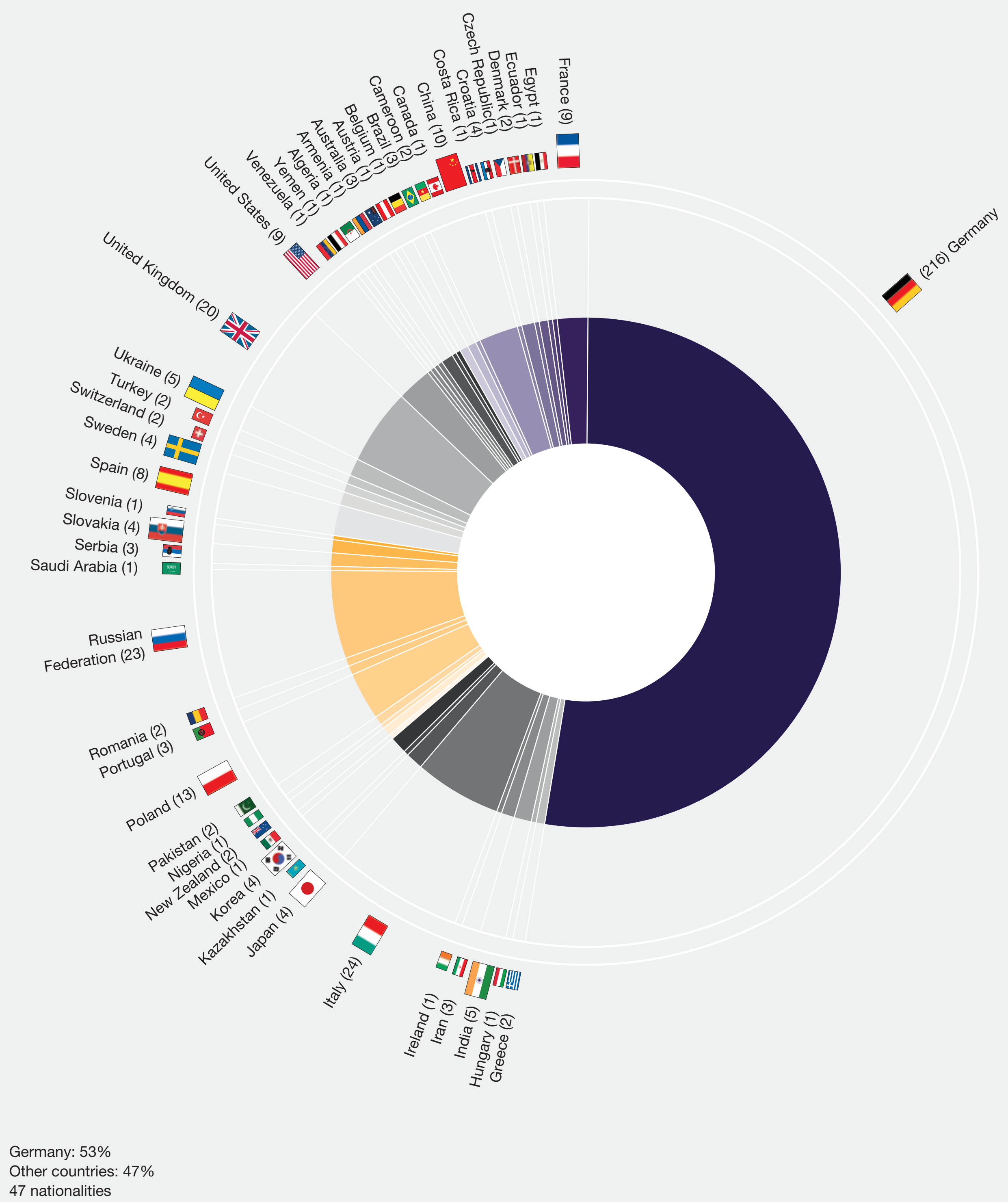


Figure 3 Nationalities of entire (scientific and non-scientific) staff

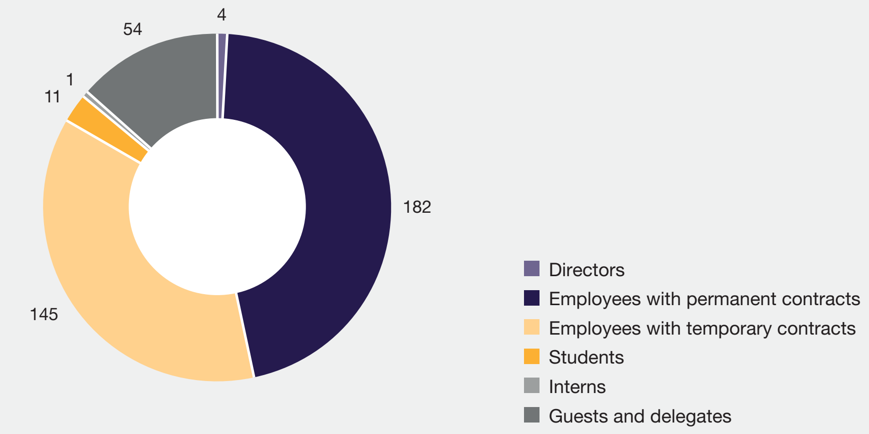


Figure 4 Contractual status of staff (2017)

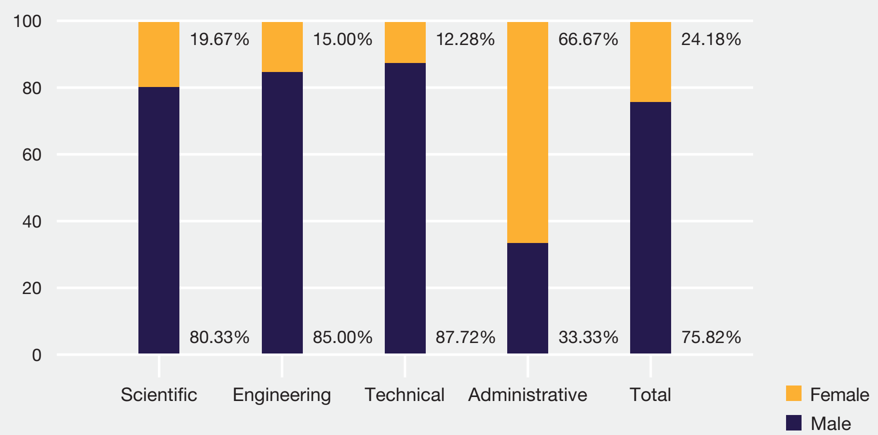


Figure 5 Gender of staff by work area (2017)

The share of employees with German citizenship remained unchanged at 55%. An increase at the scientific staff by 4% was mirrored by a correseponding decrease at the non-scientific staff.

A total of 47 (+6 from 2016) nationalities are now represented within the company.

At the end of 2016, 24% (+1%) of all employees and 20% (+1%) of scientists employed at European XFEL were female.

The average employee age was slightly above 39 (39.3), which means +0.6 compared to 2016.

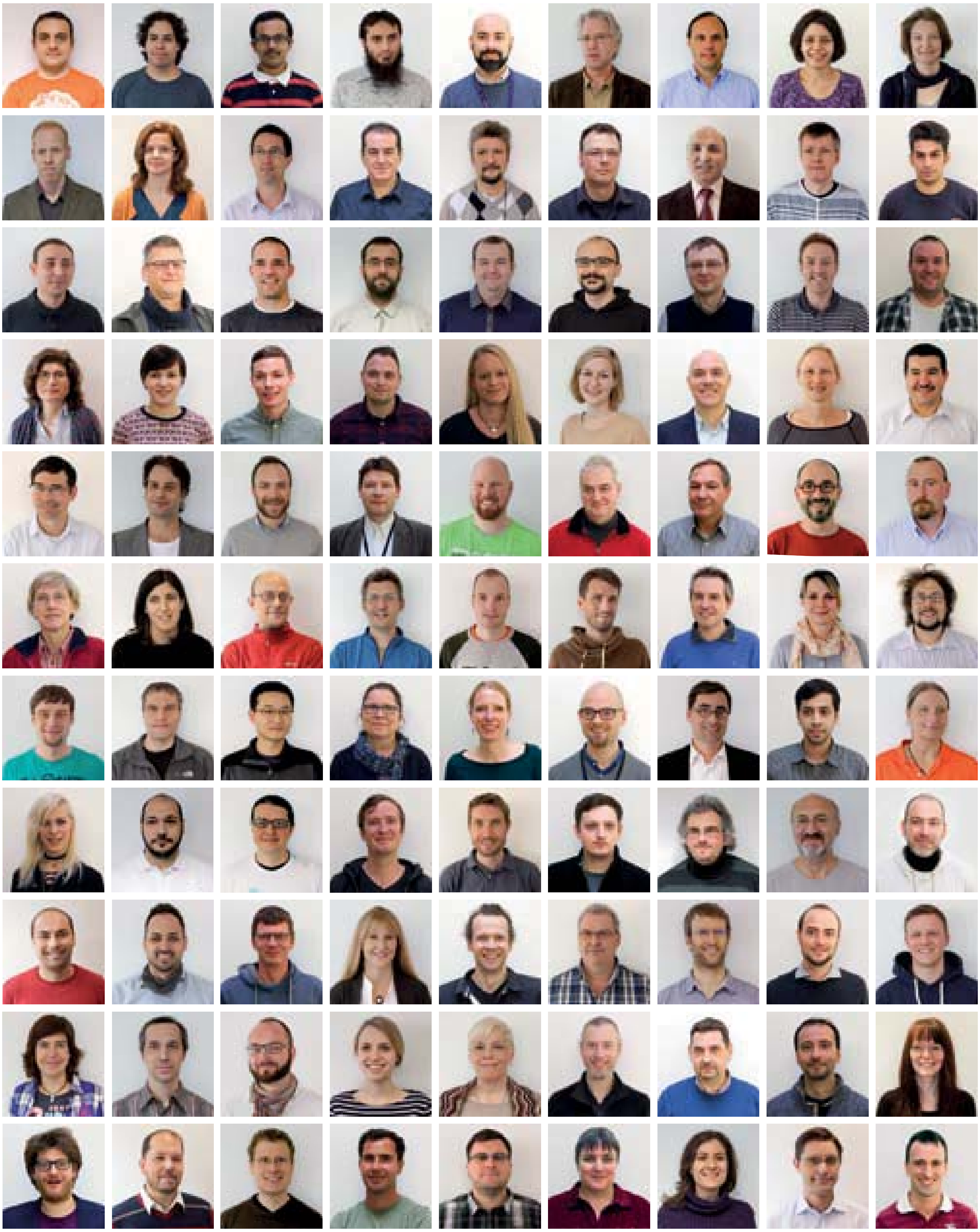
Staff of European XFEL as of 31 December 2017

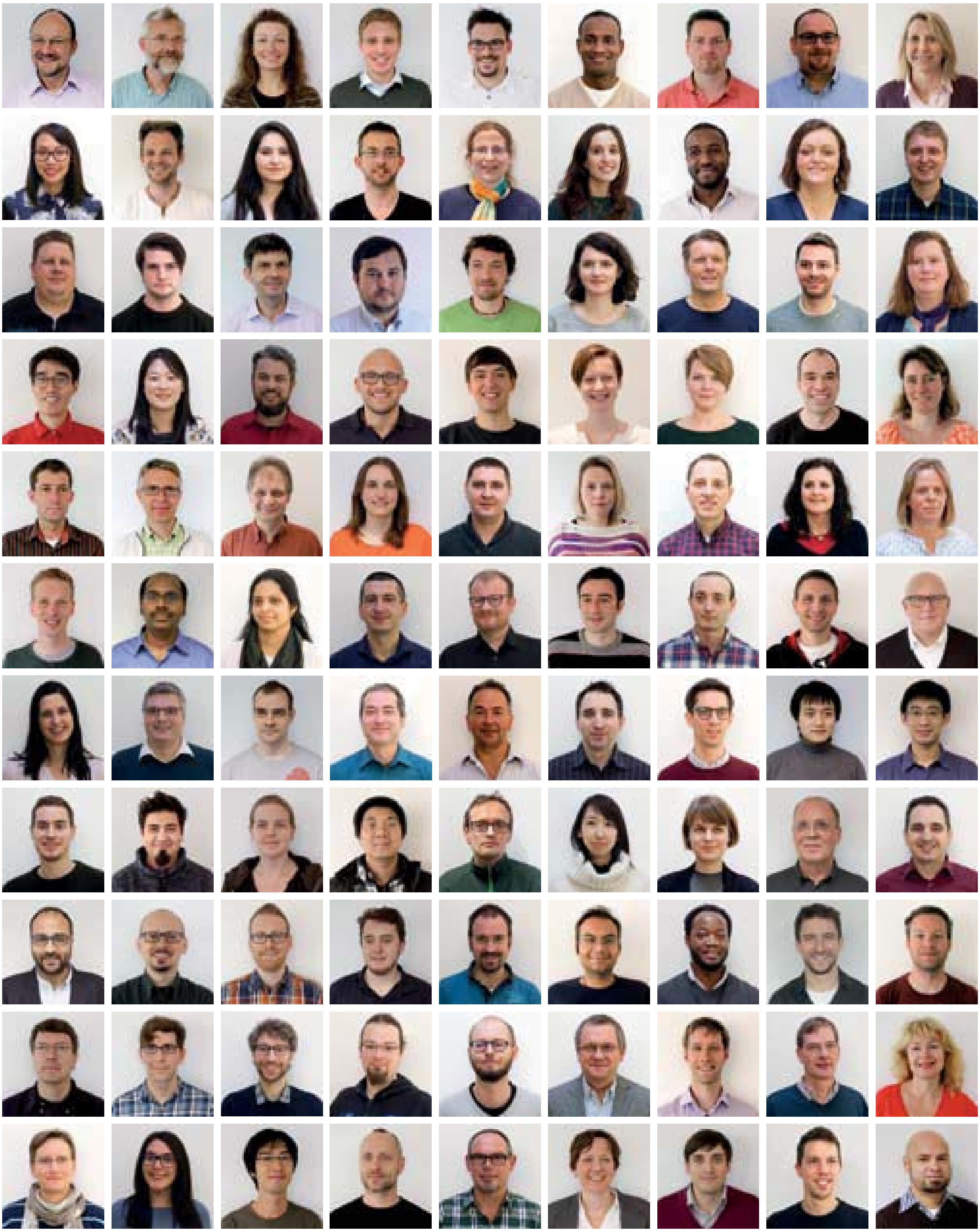
Abeghyan, Suren
Agarwal, Naman
Ahmed, Awais
Al-Qudami, Nasser
Alves Lima, Frederico
Ament, Kurt
Amirova, Alena
Ansaldi, Gabriele
Ansari, Zunaira
Appel, Karen
Appleby, Graham
Aresté, Mónica
Arnold, Mathias
Arslan, Süleyman
Babies, Frank
Bagha-Shanjani, Majid
Ballak, Kai-Erik
Bamaga, Hazem
Banjafar, Mohammadreza
Baranašić, Bernard
Baranasic, Kristina
Bartelt, Thorsten
Bartmann, Alexander
Bartsch, Tobias
Batchelor, Lewis
Baumann, Thomas
Bazhenov, Vasilii
Bean, Richard
Beck, Philip
Beg, Marijan
Behrens, Lukas
Bertini, Silvia
Biedermann, Nicole
Bieler, Oliver
Biesterfeldt, Heinz-Peter
Boll, Rebecca
Bondar, Valerii
Bonucci, Antonio
Bösenberg, Ulrike
Boukhelef, Djelloul
Boyd, Eric
Bressler, Christian
Britz, Alexander
Brockhauser, Sandor
Broers, Carsten
Brüggmann, Ulf
Carley, Robert
Choi, Tae Kyu
Chungath Jossey, Dibin
Coppola, Nicola
Cunis, Sabine
Da Costa Pereira, Maria Helena
Danilevski, Cyril
De Fanis, Alberto
Deinert, Sascha
Deiter, Carsten
Delitz, Jan Torben
Delmas, Elisa
Derevianko, Illia
Di Felice, Massimiliano
Dickert, Bianca
Dietrich, Florian
Dietze, Thomas
Dommach, Martin
Dong, Xiaohao
Dornack, Kerstin
Dörner, Katerina
Dupuich, Emil
Ebbesen, Kay
Ebeling, Bernd
Ehsan, Wajid
Eidam, Janni
Eilers, Janna
Ekmedzic, Marko
Elizondo, Jorge
Emes, Dino
Emmerich, Ralf
Emons, Moritz
Engelmann, Oleg
Englisch, Uwe
Esenov, Sergey
Falk, Torben
Fangohr, Hans
Feidenhans'l, Robert
Feldmann, Thomas
Ferreira Maia, Luís Goncalo
Filippakopoulos, Kimon
Finze, Denis
Fischer, Tobias
Flade, Marco
Flammer, Meike
Flucke, Gero
Fobian, Michael
Fortmann-Grote, Carsten
Frank, Alexander
Frankenberger, Paul
Freijo Martín, Idoia
Freund, Wolfgang
Freyermuth, Tobias
Fritz, Mareike
Fritz-Nielen, Kitty
Galler, Andreas
Galler, Julia
Gawelda, Wojciech
Geloni, Gianluca
Gembalies, Imke
Gerasimova, Natalia
Gertz, René
Geßler, Patrick
Giewekemeyer, Klaus
Giovanetti, Gabriele
Göde, Sebastian
Gorelov, Evgeny
Goretzky, Birgit
Göries, Dennis
Graceffa, Rita
Grünert, Jan
Grychtol, Patrik
Guhlmann, Florian
Haas, Tobias
Hagitte, Magdalena
Hagitte, Martin C.
Hallmann, Jörg
Hauf, Steffen
Heberling, Sven
Heeßel, Gabriela
Hickin, David
Holz, Christian
Huynh, Sylvia
Izquierdo, Manuel
Januschek, Friederike
Jardon Bueno, Nerea
Jezynski, Tomasz
Jidda, Mahadi Umar
Jones-Krüger, Rebecca
Kane, Daniel
Karabekyan, Suren
Kataev, Aleksandr
Kaukher, Alexander
Kellert, Martin
Kern, Elsa
Kersting, Lorenz
Khakhulin, Dmitry
Kiel, Daniela
Kim, Chan
Kim, Yoonhee
Kirkwood, Henry
Kirsch, Jan
Kitel, Matthäus
Klačková, Ivana
Klimovskaia, Anna
Knaack, Manfred
Kniehl, Sandra
Knoll, Martin
Koch, Andreas
Köhler, Martin
Kohlstrunk, Nicole
Kondraschew, Alexander
Konôpková, Zuzana
Korsch, Timo
Köster, Janice Elaine
Kozielski, Sigrid Susanne
Kruse, Kai
Kucharska, Julita
Kujala, Naresh
Kujala, Siriyala Devi
Kurta, Ruslan
Kuster, Markus
La Civita, Daniele
Laksman, Joakim
Lang, Philipp-Michael

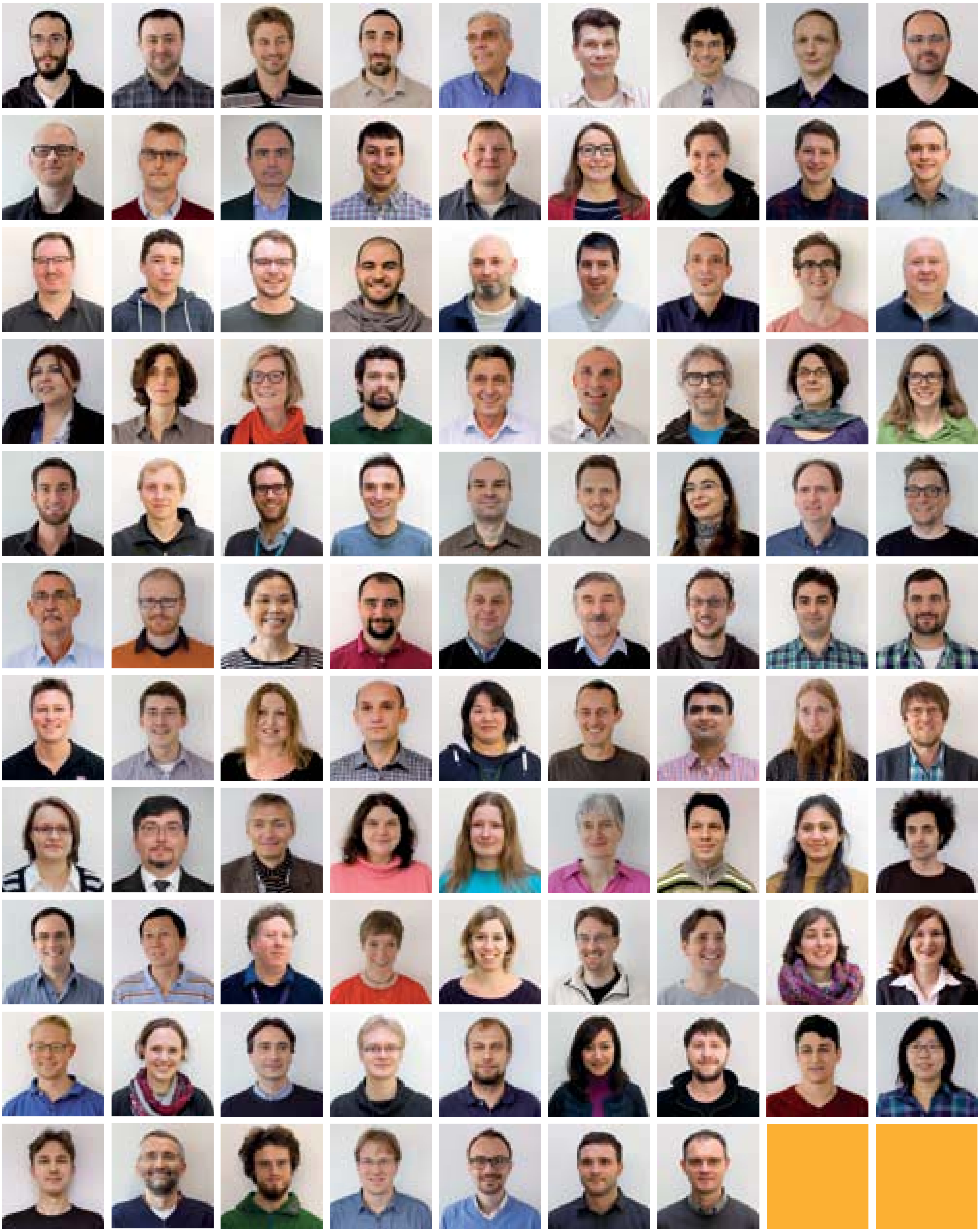
Lange, Torsten
Larsson, Tea
Laub, Malte
Lawrence, Drew
Le Guyader, Loic
Le Pimpec, Frédéric
Lederer, Maximilian Josef
Legrand, Alexis
Letrun, Romain
Li, Yuhui
Liu, Jia
Lobato Sola, Iker
López Morillo, Luis
Lorenzen, Kristina
Lu, Wei
Madsen, Anders
Makita, Mikako
Makroczyová, Jana
Malso, Michael
Maltezopoulos, Theophilos
Mancuso, Adrian
Manetti, Maurizio
Manning, Bradley Jacob
Martens, Eike-Christian
Mazza, Tommaso
McBride, Emma Elizabeth
Meger-Farshad, Danuta
Mekinda, Léonce
Mercadier, Laurent
Meyer, Marko
Meyer, Michael
Meyn, Frederik
Meza Gervacio, Iffni
Michelat, Thomas
Mills, Grant
Möller, Johannes
Molodtsov, Serguei
Montaño, Jacobo
Moore, James
Mulá Mathews, Gabriella
Multhaup, Liona
Münnich, Astrid
Music, Valerija
Nakatsutsumi, Motoaki
Neumann, Maik
Ohnesorge, Joshua
Ossipova, Valeriya
Osterland, Christiane
Ovcharenko, Yevheniy
Pahl, Deike
Pallas, Florent
Palmer, Guido
Parenti, Andrea
Parlicki, Patryk
Pergament, Mikhail
Petrich, Michaela
Pflüger, Joachim
Pieper, Wolfgang
Piergrossi, Joseph
Piórecki, Konrad
Planas Carbonell, Marc
Poljancewicz, Bartosz
Poppe, Frank
Porro, Matteo
Preißkorn, Florian
Preston, Thomas
Previtali, Gianpietro
Prollius, Michael
Quondam, Giulia
Raab, Natascha
Ramilli, Marco
Reifschläger, Jörn
Reimers, Nadja
Reiser, Mario
Rennhack, Nils
Rio, Benoit
Risch, Johannes
Rodrigues Fernandes, Bruno Jesus
Ropers, Dennis
Round, Adam
Rüscher, Jan Christoph
Rüter, Tonn
Rychev, Mikhail
Saffari, Pouneh
Samoylova, Liubov
Sander, Marieke
Santos, Hugo
Sauermann, Wolf-Ulrich
Sayar, Sonay
Schaper, Jörg
Scherz, Andreas
Scherz, Sabrina
Schlappa, Justine
Schlee, Stephan A.
Schmidt, Andreas
Schmidtchen, Silja
Schmitt, Rüdiger
Schneider, Phil
Schölmerich, Markus
Scholz, Markus
Schön, Torsten
Schrage, Marco
Schulz, Carola
Schulz, Joachim
Schulz, Sebastian
Schwarz, Andreas S.
Serkez, Svitozar
Shayduk, Roman
Shie, Halimah
Signe Takem, Cedric Michel
Sikorski, Marcin
Silenzi, Alessandro
Sinn, Harald
Sleziona, Vivien
Sorin, Alexander
Sotoudi Namin, Hamed
Sprenger, Uta
Stäps, Christoph
Stawniczy, Andrew
Stoica, Cristiana Monica
Stoica, Eduard
Sukharnikov, Konstantin
Sztuk-Dambietz, Jolanta
Szuba, Janusz
Tanikawa, Takanori
Tebah, Wolfgang Azipon
Teichmann, Martin
Thorpe, Ian
Thute, Prasad
Tietz, Tobias
Tolkiehn, Jan
Tomin, Sergey
Trapp, Antje
Tschentscher, Thomas
Turcato, Monica
van Hees, Brunhilde
Vannoni, Maurizio
Venkatesan, Sandhya
Villanueva Guerrero, José
Violante, Adriano
Wang, Jinxiong
Watts, David
Wegner, Ulrike
Weidenspointner, Georg
Weinhausen, Britta
Wellenreuther, Gerd
Wiggins, John
Wilson, Rosemary
Winterhoff, Gundel
Wißmann, Laurens
Wittmaack, Frederike
Wolff Fabris, Frederik
Wrona, Krzysztof
Wu, Peggy
Wünschel, Mark
Yakopov, Mikhail
Yang, Fan
Yaroslavtsev, Alexander
Youngman, Christopher
Zach, Juri
Zalden, Peter
Zastrau, Ulf
Ziolkowski, Pawel
Zozulya, Alexey

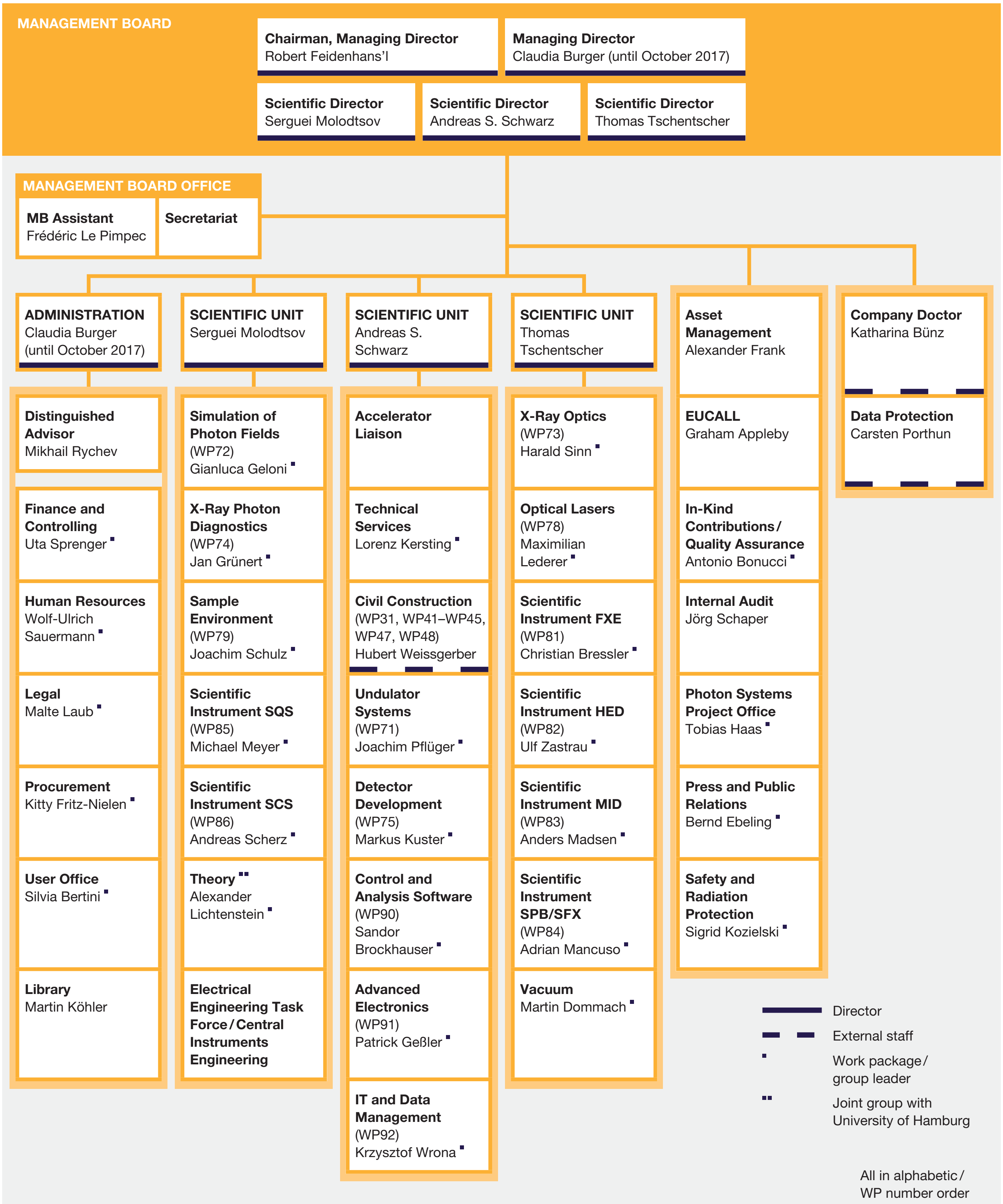
Guests of European XFEL as of 31 December 2017

Achner, Alexander
Baehtz, Carsten
Bahns, Immo
Behlau, Georg
Berghäuser, Andreas
Bielecki, Johan
Bömer, Christina
Brun, Bernd
Chen, Gang
Danilov, Mikhail
Di Dio Casfio, Samuele
Diez, Michael
Dobryjanowicz, Michal
Engelke, Jan
Fridlyanov, Maxim
Gül, Yasmin
Han, Huijong
Harder, Manuel
Häseler, Hauke
Häseler, Sönke
Hassan, Mohamed
Hauser, Jens
Herrmann, Maik
Höppner, Hauke
Ilchen, Markus
Jarosiewicz, Tobiasz
Kadek, Alan
Kagels, Björn
Kirchgessner, Manfred
Kjellsson, Ludvig
Kluyver, Thomas
Kurtzke, Konstantin
Liebetrau, Andreas
Mehrjoo, Masoud
Messerschmidt, Marc
Möller, Dominik
Morgenroth, Wolfgang
Norden, Andreas
Otte, Florian
Pelka, Alexander
Pogan, Ronja
Round, Ekaterina
Sato, Tokushi
Schottroff, Jannis
Schubert, Robin
Smirnov, Petr
Stern, Stephan
Strohm, Cornelius
Tian, Qing
Toncian, Monika
Toncian, Toma
Uetrecht, Charlotte
Vagovic, Patrik
Wagner, René
Wollenweber, Lennart









Organization of the European X-Ray Free-Electron Laser Facility GmbH (December 2017)

BUDGET

The overall budget for the construction phase of the European XFEL project amounts to around 1.25 billion euro (2005 value). The value increased due to a further contribution by the new member state, the United Kingdom. Forty-six percent of the project volume is contributed in kind by the various partners. The remaining fraction, amounting to more than 0.8 billion euro (current value), is contributed in cash to the company by its shareholders and associated partners. At the end of 2017, as the construction of the European XFEL progresses, almost 90% of the total cash budget has been spent.

The council decides on the annual budget available to cover all project expenses during the corresponding year. The total European XFEL payment budget in 2017 amounted to 140.5 million euro (M€). Thereof 57% was related to the construction phase; the rest could be spent for the operation phase.

Major activities

One major activity in 2017 was "Machine and technical infrastructure", with a budget of 59.4 M€ (42%). Within this activity, 28 M€ was spent on the operation of the accelerator, while 8 M€ was devoted to civil construction and another 17 M€ was used for the technical infrastructure of the headquarters building and the experiment hall. For the other major activity, "Beamlines and experiments", the payment budget was 53.9 M€ (38%). Of this, the largest fraction, 31.2 M€, was still spent on capital investment due to the ongoing construction phase during most 2017. In addition, a budget of 14.9 M€ was used for commissioning.

The total European XFEL payment budget in 2017 amounted to 140.5 million euro, 57% of which was related to the construction phase. The rest could be spent for operation.

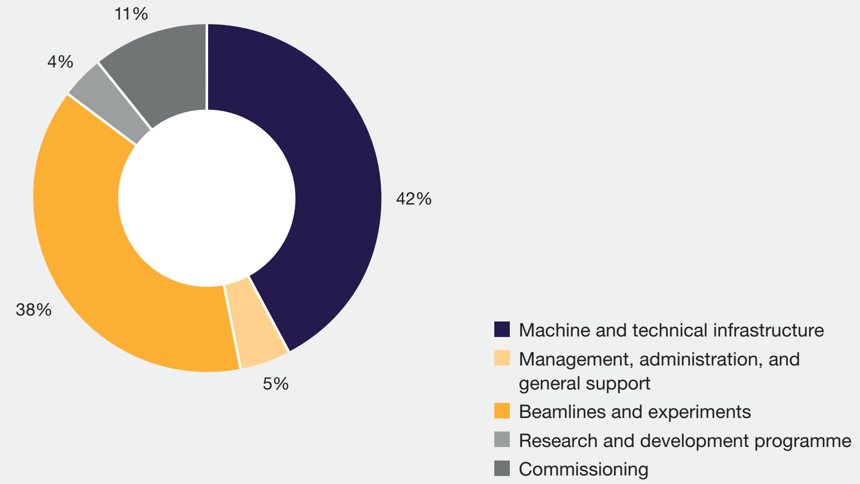


Figure 1 Payments by major activity in 2017

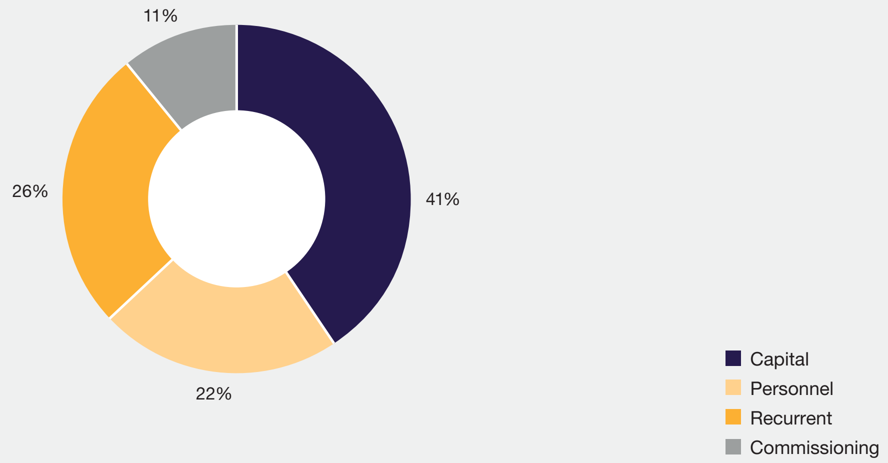


Figure 2 Payments by budget items in 2017

Budget items

The main portion (41%) of the 2017 payment budget was related to capital investment. Compared with the previous year, the portion decreased as the operation phase started and the recurrent payments became more important. The personnel costs of 31.3 M€ include personnel from DESY and the European XFEL.

Outlook for 2018

For the budget year 2018, an annual payment operation budget of 118.4 M€ was approved. In addition, for the finalization of the construction phase, a further 52 M€ was approved.

SHAREHOLDERS

The European XFEL, organized as a non-profit company with limited liability (GmbH) under German law, has international shareholders. The shareholders are designated by the governments of the international partners who commit themselves in an intergovernmental convention to support the construction and operation of the European XFEL.

Shareholders of the European XFEL GmbH (December 2017)	
Denmark	DASTI (Danish Agency for Science, Technology and Innovation)
France	CEA (Commissariat à l'Énergie Atomique et aux Énergies Alternatives) CNRS (Centre National de la Recherche Scientifique)
Germany	DESY (Deutsches Elektronen-Synchrotron)
Hungary	NRDI Office (National Research, Development and Innovation Office)
Poland	NCBJ (National Centre for Nuclear Research)
Russia	NRC KI (National Research Centre "Kurchatov Institute")
Slovakia	Slovak Republic
Sweden	Swedish Research Council (Vetenskapsrådet)
Switzerland	Swiss Confederation

Future shareholders of the European XFEL GmbH	
Italy	INFN (Istituto Nazionale di Fisica Nucleare) CNR (Consiglio Nazionale delle Ricerche)
Spain	Kingdom of Spain
United Kingdom	UKRI-STFC (United Kingdom Research and Innovation – Science and Technology Facilities Council)

ORGANS AND COMMITTEES

The European XFEL Council is the supreme organ of the company. It functions as the shareholder assembly and decides on important issues of company policy.

European XFEL Council	
Chairman	Martin Meedom Nielsen (DTU, Kongens Lyngby)
Vice Chairman	Lars Börjesson (Chalmers University of Technology, Gothenburg)
Delegates	
Denmark	Morten Scharff (DASTI, Copenhagen)
France	Maria Faury (CEA, Paris) and Amina Taleb-Ibrahimi (CNRS, Paris)
Germany	Helmut Dosch (DESY, Hamburg), Beatrix Vierkorn-Rudolph (BMBF, Bonn) until 30 June 2017, and Volkmar Dietz (BMBF, Bonn) since 1 July 2017
Hungary	Dénes Lajos Nagy (Wigner Research Centre for Physics, Hungarian Academy of Sciences, Budapest)
Poland	Grzegorz Wrochna (NCBJ, Otwock-Świerk)
Russia	Mikhail Kovalchuk (NRC KI, Moscow), Sergey Salikhov (Ministry of Education and Science, Moscow) until 31 May 2017, and Andrey Anikeev (Ministry of Education and Science, Moscow) since 1 June 2017
Slovakia	Karel Saksl (Institute of Materials Research, SAS, Košice) and Pavol Sovák (P.J. Šafárik University, Košice)
Sweden	Johan Holmberg (Swedish Research Council, Stockholm) and Ingmar Persson (Swedish University of Agricultural Sciences, Uppsala)
Switzerland	Bruno Moor (State Secretariat for Education, Research and Innovation, Bern) and Gabriel Aeppli (PSI, Villigen)

European XFEL Council	
Secretary	
	Malte Laub (European XFEL, Schenefeld, Germany)
Vice Secretary	
	Meike Flammer (European XFEL, Schenefeld, Germany)

The European XFEL Management Board is composed of two managing directors (*Geschäftsführer*, in the sense of German law on companies with limited liability) and three scientific directors.

At the end of 2016, Chairman of the Management Board Massimo Altarelli retired. In September of that year, the European XFEL Council had appointed Robert Feidenhans'l as the new chairman of the European XFEL Management Board. He began his duties on 1 January 2017.

European XFEL Management Board	
Chairman	Robert Feidenhans'l
Administrative Director	Claudia Burger (until 15 October 2017)
Scientific Director	Serguei Molodtsov
Scientific Director	Andreas S. Schwarz
Scientific Director	Thomas Tschentscher

Advisory committees support European XFEL in various matters:
Administrative and Finance Committee, Machine Advisory Committee,
Scientific Advisory Committee, In-Kind Review Committee, Detector Advisory Committee,
Laser Advisory Committee, and the Proposal Review Panels for the scientific instruments
that are available for users.

Administrative and Finance Committee (AFC)	
Chairman	Xavier Reymond (State Secretariat for Education, Research and Innovation, Bern)
Delegates	
Denmark	Morten Scharff (DASTI, Copenhagen)
France	Salah Dib (CEA, Paris), Laurent Pinon (CNRS, Paris) until April 2017, and Stéphanie Dupuis (CNRS, Paris) since September 2017
Germany	Michael Budke (BMBF, Bonn) until September 2017 and Christian Harringa (DESY, Hamburg)
Hungary	Barbara Tóth-Vizkelety (NRDI Office, Budapest)
Poland	Zbigniew Gołębiewski (NCBJ, Otwock-Świerk)
Russia	Valeriy Nosik (NRC KI, Moscow)
Slovakia	Pavol Sovák (P.J. Šafárik University, Košice) and Lukáš Zendulka (Ministry of Education, Science, Research and Sport)
Sweden	Katrin Brandt (Swedish Research Council, Stockholm) until January 2017 and Hanifeh Khayyeri (Swedish Research Council, Stockholm) since February 2017
Switzerland	Peter Allenspach (PSI, Villigen) and Doris Wohlfender-Bühler (State Secretariat for Education, Research, and Innovation, Bern) since January 2017
Secretary	
	Uta Sprenger (European XFEL, Schenefeld, Germany)
Vice Secretary	
	Deike Pahl (European XFEL, Schenefeld, Germany)

In-Kind Review Committee (IKRC)	
Chairman & Russian Delegate	Leonid V. Kravchuk (INR, Moscow, Russia)
Vice Chairman & Swiss Delegate	Volker Schlott (PSI, Villigen, Switzerland)
Delegates	
Denmark	Søren Schmidt (DTU, Kongens Lyngby)
France	Alex Mueller (CNRS, Paris)
Germany	Reinhard Brinkmann (DESY, Hamburg)
Hungary	Gyula Faigel (Wigner Research Centre for Physics, Hungarian Academy of Sciences, Budapest)
Italy	Carlo Pagani (INFN Sezione di Milano, LASA, Milan)
Poland	Krzysztof Meissner (NCBJ, Otwock-Świerk)
Slovakia	Stefan Molokac (Cryosoft Ltd, Košice)
Spain	Teresa Martínez De Álvaro (CIEMAT, Madrid)
Sweden	Håkan Danared (ESS AB, Lund)
European XFEL GmbH	Andreas S. Schwarz (for the accelerator) and Thomas Tschentscher (for the beamlines)
Secretary	
	Antonio Bonucci (European XFEL, Schenefeld, Germany)
Lawyer	
	Malte Laub (European XFEL, Schenefeld, Germany)

Machine Advisory Committee (MAC)	
Chairwoman	Camille Ginsburg (Fermilab, Batavia, Illinois, USA)
Members	
	Caterina Biscari (CELLS–ALBA, Cerdanyola del Vallès, Spain)
	Ángeles Faus-Golfe (LAL, Orsay, France)
	Zhirong Huang (SLAC, Menlo Park, California, USA)
	Andreas Jankowiak (HZB, Berlin, Germany)
	Heung-Sik Kang (PAL, Pohang, Korea)
	Leonid V. Kravchuk (INR, Moscow, Russia)
	Pantaleo Raimondi (ESRF, Grenoble, France)
	Richard Walker (Diamond Synchrotron, Oxfordshire, UK)
	Andrzej Wolski (University of Liverpool, UK)

Scientific Advisory Committee (SAC)	
Chairman	Stefan Eisebitt (MBI, Berlin, Germany)
Members	
	Rafael Abela (PSI, Villigen, Switzerland)
	Olga A. Olekseeva (IC RAS, Moscow, Russia)
	Mike Dunne (SLAC, Menlo Park, California, USA)
	Guillaume Fiquet (IMPMC, Paris, France)
	Gerhard Grübel (DESY, Hamburg, Germany)
	Maya Kiskinova (Elettra Sincrotrone Trieste, Italy)
	Inari Kursula (University of Oulu, Finland; CSSB, Hamburg, Germany)
	Anders Nilsson (Stockholm University, Sweden)

Scientific Advisory Committee (SAC)	
	Keith Nugent (La Trobe University, Melbourne, Australia)
	Christoph Quitmann (MAX IV, Lund, Sweden)
	Ian Robinson (UCL, London, UK)
	Ilme Schlichting (MPI for Medical Research, Heidelberg, Germany)
	David Stuart (University of Oxford and Diamond Synchrotron, Oxfordshire, UK)
	Linda Young (ANL, Argonne, Illinois, USA)
Secretary	
	Gianluca Geloni (European XFEL, Schenefeld, Germany)

Detector Advisory Committee (DAC)	
Chairman	Jörn Wilms (University of Erlangen, Germany)
Members	
	Roland Horisberger (PSI, Villigen, Switzerland)
	Christopher J. Kenney (SLAC, Menlo Park, California, USA)
	David Quarrie (LBNL (retired), Berkeley, California, USA)
	John Arthur (SLAC, Menlo Park, California, USA) until 15 December 2017
	Jens Meyer (ESRF, Grenoble, France)
	Eric Eikenberry (DECTRIS Ltd. (retired), Baden, Switzerland)
	Kay Rehlich (DESY, Hamburg, Germany)

Laser Advisory Committee (LAC)	
Chairman	Uwe Morgner (Laser Zentrum Hannover, Germany)
Members	
	Giulio Cerullo (Politecnico di Milano, Italy)
	Miltcho Danilov (Elettra Sincrotrone Trieste, Italy) since April 2016
	Mike Dunne (SLAC, Menlo Park, California, USA) until April 2016
	Patrick Georges (Institut d’Optique, Paris, France)
	Robert Schoenlein (LBNL, Berkeley, California, USA)
	William E. White (SLAC, Menlo Park, California, USA)
	Jonathan Zuegel (University of Rochester, USA)
Secretaries	
	Oliver Mücke (CFEL and DESY, Hamburg, Germany) and Andreas Galler (European XFEL, Schenefeld, Germany)

Proposal Review Panel: FXE Instrument	
Chairman	Villy Sundström (Lund University, Sweden)
Members	
	Majed Chergui (Ecole Polytechnique Fédérale de Lausanne, Switzerland)
	Frank de Groot (Utrecht University, the Netherlands)
	Thomas Elsässer (MBI, Berlin, Germany)
	Jerome Hastings (SLAC, Menlo Park, USA)
	Adela Muñoz Páez (University of Sevilla, Spain)
	Alexander Soldatov (Southern Federal University, Rostov-on-Don, Russia)
	Metin Tolan (Technical University Dortmund, Germany)
	Michael Wulff (ESRF, Grenoble, France)

Proposal Review Panel: SPB/SFX Instrument	
Chairwoman	Sine Larsen (University of Copenhagen, Denmark)
Members	
	Gyula Faigel (Wigner Research Centre of Physics, Hungarian Academy of Sciences, Budapest, Hungary)
	Elspeth Garman (University of Oxford, United Kingdom)
	Cameron Kewish (Australian Synchrotron, Clayton, Australia)
	Inari Kursula (University of Bergen, Norway, and University of Oulu, Finland)
	Victor Lamzin (EMBL, Hamburg, Germany)
	Thomas Möller (TU Berlin, Germany)
	Christian Riekel (ESRF, Grenoble, France)
	Christian Schroer (DESY, Hamburg, Germany)

COOPERATION

European XFEL has established an extensive international research network with partners around the world. Cooperation and partnership agreements with research organizations serve to further advance X-ray laser science and help scientists to prepare for the unique research opportunities at the new facility. In 2017, European XFEL signed a memorandum of understanding (MoU) with ELI Beamlines, a collaboration agreement with its Polish shareholder, and entered a cooperation on structural analysis of viral particles. Additionally, European XFEL entered several EU programmes and joined a new consortium comprising the accelerator-based light sources of Europe.

Cooperations with research institutions

CAEP

European XFEL and the China Academy of Engineering Physics (CAEP) collaborate on selected activities of common interest in the development, construction, and commissioning of X-ray FEL technology through sharing knowledge, resources, equipment, and personnel. A framework collaboration agreement was signed in Hamburg on 26 March 2015.

CLPU

European XFEL and the Spanish Center for Ultrashort Ultraintense Pulsed Lasers (CLPU) in Salamanca cooperate to develop new ultrafast optical lasers to analyse physical and chemical processes in conjunction with the X-ray beams of the European XFEL. In combination with the unique features of the European XFEL, new optical laser technologies will enable scientists to film ultrafast processes, such as chemical and biochemical reactions that provide a basis for the development of more efficient industrial production processes or new medical products and devices. An MoU was signed on 10 October 2011 and was prolonged in 2016 for a further five years.

CNRS

In addition to becoming a shareholder of European XFEL in 2014, Centre National de la Recherche Scientifique (CNRS), one of France's largest research organizations, signed a collaboration agreement with European XFEL regarding the design, development, construction, and delivery of a MHz prototype non-collinear optical parametric amplifier (NOPA) through the Cluster of Research Infrastructures for Synergies in Physics (CRISP) framework.

DESY

The relationship between European XFEL and its main shareholder, Deutsches Elektronen-Synchrotron (DESY) in Germany, is unique. The two partners collaborate on the construction, commissioning, and eventual operation of the facility, based on a long-term agreement, among others.

ELI Beamlines

European XFEL and the Institute of Physics of the Czech Academy of Sciences agree to enhance scientific collaboration with the Extreme Light Infrastructure (ELI) Beamlines facility in Dolní Břežany, Czech Republic, including an exchange of personnel, performance of joint research and workshops, collaboration in the ELIBIO project, development of high-repetition–rate targetry, information exchange on user access, and joint development of instrumentation, among other goals. An MoU was signed in Prague on 28 April 2017.

FELs of Europe

European research facilities that operate or develop X-ray FELs and advanced short-pulse and coherent light sources cooperate to promote FEL science and technology in Europe and to provide the experimental conditions needed by a large, multidisciplinary user community. An MoU was signed in May 2012. Other members are Ankara University in Turkey, CNRS in France, DESY in Germany, Elettra Sincrotrone Trieste in Italy, HZB in Germany, HZDR in Germany, INFN in Italy, MAX IV Laboratory in Sweden, NCBJ in Poland, PSI in Switzerland, Radboud University in the Netherlands, SOLEIL in France, and STFC in the UK.

HAW Hamburg

European XFEL and Hamburg University of Applied Sciences (HAW Hamburg) cooperate in science and engineering education. The main focus is to give undergraduate students practical experience in their degree programmes. A cooperation agreement was signed on 2 December 2013.

HZB

An MoU for a collaboration was signed on 11 March 2010 by European XFEL and Helmholtz-Zentrum Berlin (HZB) in Germany. The goal is to establish specific collaborations to develop optical components in soft X-ray optics and diagnostics, especially with respect to the expertise at the BESSY synchrotron at HZB. In 2013, European XFEL signed an additional cooperation agreement with HZB in the framework of the Helmholtz Virtual Institute “Dynamic Pathways in Multidimensional Landscapes”.

Kurchatov Institute

European XFEL cooperates with National Research Centre “Kurchatov Institute” in Moscow, Russia, in calculating radiation parameters and organizing European XFEL schools for young scientists.

LBNL

European XFEL and Lawrence Berkeley National Laboratory (LBNL) in Berkeley, California, USA, established a framework for proposed cooperation in the area of the development and use of free-electron lasers in an MoU signed in Hamburg on 16 April 2013.

Max Planck Society
On 24 November 2014, European XFEL signed a research agreement with the Max Planck Society, represented by the Semiconductor Laboratory ("Halbleiterlabor") in Munich, Germany, on "Cooperation within the framework of the production of Silicon Drift Detector (SDD) sensors for the DSSC 1 Megapixel Detector".

NCBJ
European XFEL and the National Center for Nuclear Research (NCBJ) in Świerk, Poland, collaborate on FEL technology, particularly in the field of data management. A Collaboration Agreement was signed on 24 November 2017.

Osaka University
European XFEL and the Osaka University in Japan agreed to jointly appoint a scientist to promote education and research. An MoU was signed on 16 December 2014. On 4 September 2015, European XFEL and Osaka University signed a framework collaboration agreement to share knowledge, resources, equipment, and personnel on high energy density science research.

PTB
European XFEL and Physikalisch-Technische Bundesanstalt Braunschweig und Berlin (PTB) cooperate on ultrahigh precision metrology for metre-long X-ray mirrors. A collaboration agreement was signed on 9 December 2015.

RSC
European XFEL and the RIKEN SPring-8 Center (RSC) in Sayo, Hyogo, Japan, intend to collaborate on the development of technologies for the enhanced utilization of X-ray FELs. An MoU was signed on 23 February 2015.

SLAC
Regular contacts with SLAC National Accelerator Laboratory in Menlo Park, California, provide an important opportunity to gain hands-on experience at an X-ray FEL in operation, the Linac Coherent Light Source (LCLS).

Southern Federal University
European XFEL and Southern Federal University in Rostov, Russia, stated their interest in establishing a joint programme in education and research.

Shubnikov Institute of Crystallography
European XFEL and Shubnikov Institute of Crystallography of the Russian Academy of Sciences (IC RAS) cooperate in the growth and handling of crystals for optical elements as well as in organizing European XFEL schools for young scientists in Moscow.

STFC

The Science and Technology Facilities Council (STFC) in Swindon, UK, develops the Large Pixel Detector (LPD) as well as hardware elements for the readout and data acquisition architecture. A prolongation of a 2010 cooperation agreement was signed on 30 January 2013. The new phase of the agreement includes production of the LPD detector.

Technological Institute for Superhard and Novel Carbon Materials

European XFEL and Technological Institute for Superhard and Novel Carbon Materials (FSBI TISNCM) in Troitsk, Moscow, Russia, agreed to develop an in-line seeding monochromator for the high power and high repetition rate of the European XFEL based on synthetic diamonds. The collaboration agreement was signed in August 2012. An additional collaboration agreement, signed in December 2014 between European XFEL, DESY, and FSBI TISNCM, established cooperation on accelerator physics and technology, the use of synchrotron radiation for basic and applied research, and the development and use of FELs through exchanges of information, personnel including students, and equipment.

Turkish Accelerator Center

European XFEL collaborates with Turkish Accelerator Center (TAC) in the development of scientific instrumentation for highly coherent, ultrashort-pulse X-ray light sources and their scientific use. An MoU was signed in May 2012 with Ankara University, Turkey, the coordinator of TAC.

“Umbrella” Federated Identity Management System

On 31 March 2015, European XFEL signed an MoU with ALBA Synchrotron in Spain, DESY in Germany, Diamond Light Source in the UK, Elettra Sincrotrone Trieste in Italy, ESRF in France, Instruct Academic Services in the UK, HZB in Germany, ILL in France, KIT in Germany, PSI in Switzerland, STFC in the UK, and SOLEIL in France. The purpose of this MoU is to establish an efficient, long-term collaboration between the partners in order to develop, implement, and operate a unique, persistent, trans-facility user identification system that will function across Europe.

University of Hamburg

European XFEL and the School of Mathematics, Informatics and Natural Sciences (MIN) at the University of Hamburg, Germany, cooperate in research and teaching. The main focus is on exchanging know-how, implementing joint research projects, providing mutual access to experimental facilities, and promoting undergraduates, Ph.D. students, and young scientists. A contract was signed on 15 August 2011.

University of Milan

The University of Milan in Italy will provide a pulsed microplasma cluster source setup and seconded scientific staff to the Small Quantum Systems (SQS) scientific instrument group, on the basis of a framework collaboration agreement signed on 16 June 2015.

University of Rostock

European XFEL and the University of Rostock, Germany, agreed on a framework for cooperation and common procedures for the appointment of professors. A collaboration agreement was signed on 5 June 2014.

University of Siegen

European XFEL and the University of Siegen in Germany exchange scientific information and know-how, cooperate on joint and individual research projects, teach students and junior scientists, share experiment equipment, and conduct in-house and external user research. A cooperation agreement was signed on 20 September 2016.

VISAVIX

The Heinrich-Pette-Institute, Leibniz-Institut für Experimentelle Virologie; the University of Greifswald; and European XFEL collaborate on the Viral Structural Analysis via Intense X-Ray Pulses (VISAVIX) project, which aims to develop special methods for studying viral structures at facilities such as the European XFEL. A cooperation agreement was signed on 23 August 2017.

Participation in EU programmes

CALIPSOplus

The aim of the Convenient Access to Light Sources Open to Innovation, Science, and to the World (CALIPSOplus) project is to remove barriers for access to world-class accelerator-based light sources in Europe and in the Middle East. To this end, more than 82 500 hours of trans-national access are provided to these research infrastructures and specific programmes are in place to teach new users how to successfully use synchrotrons and FELs. Dissemination activities targeting industry are complemented by tailor-made support and access programmes for this user group. In parallel, the consortium is collaborating on constantly developing technology to keep the facilities at the cutting edge. Within CALIPSOplus, several facilites are cooperating with European high-tech industries in the MooNpics project in order to develop new metrology and diagnostics capabilities towards producing and aligning single–nanometre precision mirrors for diffraction-limited X-ray optics. CALIPSOplus launched on 1 May 2017 and will run for four years and has received EU funding from the EU Horizon 2020 research and innovation programme under grant agreement No. 730872.

CREMLIN

The project Connecting Russian and European Measures for Large-scale Research Infrastructures (CREMLIN) will improve and strengthen the relations and networks between European and Russian research infrastructures at scientific and at research policy level. CREMLIN will enhance science cooperation between six Russian megascience facilities and European infrastructures, develop research policies involving all relevant stakeholders from science and policy with respect to the EU and the Russian Federation, and establish an effective exchange platform of findings and results within Russian megascience projects while stimulating and ensuring mutual learning across various disciplines and European and

Russian communities. CREMLIN began in October 2015 and encompasses 13 European research infrastructures and 6 Russian megascience facilities. CREMLIN has received funding from the EU Horizon 2020 research and innovation programme under grant agreement No. 654166.

EDAX

A research project entitled "Excited state Dynamics from Anti-Stokes and non-linear resonant inelastic X-ray scattering" (EDAX) was funded with 2.5 million euro by the European Research Council in 2016. For four years, scientists under the leadership of Alexander Föhlisch from the University of Potsdam in Germany will study pathways to the determination and control of the functionality and chemistry of materials at various synchrotron and X-ray laser facilities using nonlinear resonant inelastic X-ray scattering (RIXS). European XFEL, one of the venues for this research, receives a portion of the EDAX funding to supply equipment for implementation of RIXS instrumentation at the facility. EDAX has received funding from the EU Horizon 2020 research and innovation programme under grant agreement No. 669531.

EOSCpilot

The European Open Science Cloud (EOSC) will offer 1.7 million European researchers and 70 million professionals in science and technology a virtual environment with open and seamless services for storage, management, analysis and re-use of research data, across borders and scientific disciplines by federating existing scientific data infrastructures, today scattered across disciplines and member states. European XFEL is a consortium member of the EOSC pilot project. EOSCpilot has received funding from the EU Horizon 2020 research and innovation programme under grant agreement No. 739563.

EUCALL

Since October 2015, the EU is funding a 7 million euro effort to bring laser and X-ray research infrastructures together through the European Cluster of Advanced Laser Light Sources (EUCALL). The two types of large-scale X-ray research infrastructures in Europe collaborate for the first time in a comprehensive way on technical, scientific, and strategic issues. One of the main goals are substantial scientific and technological contributions by creating and exploiting sustainable synergies between laser-driven and accelerator-driven X-ray research infrastructures. EUCALL is coordinated by European XFEL. The project involves six accelerator-based X-ray research centres and five optical laser infrastructures, as well as the collaborations FELs of Europe and Laserlab Europe. EUCALL has received funding from the EU Horizon 2020 research and innovation programme under grant agreement No. 654220.

OpenDreamKit

The Open Digital Research Environment Toolkit for the Advancement of Mathematics (OpenDreamKit) provides substantial funding to the open source computational mathematics ecosystem and in particular popular tools such as LinBox, MPIR, SageMath, GAP, Pari/GP, LMFDB, Singular, MathHub, and the IPython/Jupyter interactive computing environment. From this ecosystem, OpenDreamKit will deliver a flexible toolkit enabling research groups to set up Virtual Research Environments, customized to meet the varied needs of research projects in pure mathematics and applications, supporting the full research life-cycle from exploration, through proof and publication, to archival and sharing of data and code. European XFEL is a consortium member of OpenDreamKit, which has received funding from the EU Horizon 2020 research and innovation programme under grant agreement No. 676541.

Memberships in research cooperations

Development and Use of Accelerator-Driven Photon Sources

European XFEL participates in the German–Russian bilateral funding programme “Development and Use of Accelerator-Driven Photon Sources”. Several projects have been approved.

EIROforum

EIROforum is a collaboration between eight European intergovernmental research organizations (EIROs): EMBL, ESRF, European Consortium for the Development of Fusion Energy (EUROfusion), European Organization for Nuclear Research (CERN), European Southern Observatory (ESO), European Space Agency (ESA), European XFEL, and Institut Laue-Langevin (ILL). The mission of EIROforum is to combine resources, facilities, and expertise to support European science in reaching its full potential. EIROforum also publishes a free journal, *Science in School*, which promotes inspiring science teaching.

Hard X-ray FEL collaboration

LCLS in the USA, SACLA in Japan, SwissFEL in Switzerland, PAL-XFEL in Korea, and the Hamburg FEL projects (FLASH at DESY and European XFEL) collaborate, share project information, and identify topics of common interest in a meeting series.

LEAPS

The League of European Accelerator-Based Photon Sources (LEAPS) is a strategic consortium initiated by the directors of the synchrotron and free-electron laser user facilities in Europe. Its primary goal is to actively and constructively ensure and promote the quality and impact of the fundamental, applied, and industrial research carried out at their respective facilities to the greater benefit of European science and society. LEAPS comprises 16 national and international facilities in Denmark, France, Germany, Italy, the Netherlands, Poland, Spain, Sweden, Switzerland, and the United Kingdom, including European XFEL. LEAPS launched in Brussels on 13 November 2017.

Physics on Accelerators and Reactors of Western Europe

In November 2010, European XFEL joined the “Physics on Accelerators and Reactors of Western Europe” programme of the Russian Ministry of Education and Science. The programme funds research stays of Russian scientists at large leading European research facilities.

USER CONSORTIA

Currently, six user consortia contribute to the construction of scientific instruments, to the ancillary instrumentation, and to the technical infrastructure:

- The **Integrated Biology Infrastructure Life-Science Facility at the European XFEL (XBI)** user consortium, together with European XFEL, provides biological laboratory space, sample preparation and characterization facilities, and scientific support for the European XFEL users. The XBI laboratory is located on the ground floor of the European XFEL main building. All steps from sample expression and purification, through to preliminary characterization and injection testing are supported. The laboratory operates at biological safety levels S1 and S2. User support was provided during the first run between September and November 2017. The sample preparation and characterization possibilities available in the XBI laboratory distinguish the European XFEL from other FEL facilities, enabling experiments that are difficult or impossible to carry out without a dedicated laboratory. Current members of the user consortium are Arizona State University, EMBL, Uppsala University, the University of Oulu, the University of Hamburg and University Hospital Eppendorf, and the Slovak Academy of Sciences. The XBI laboratory is open to all users of the European XFEL.

- The **Serial Femtosecond Crystallography (SFX)** user consortium proposed to build and currently implements a second interaction chamber for nanocrystallography and sample screening in the SPB/SFX instrument hutch, reusing the transmitted X-ray FEL beam. This proposal includes sample injectors for the first interaction area and a large 4 Mpx AGIPD detector for the second interaction area. This proposal is led by DESY and includes strong Swedish, UK, and Slovak contributions.

- **DataXpress** is a user consortium providing a data analysis toolkit and hardware aimed at solving the data and reconstruction challenge for single particle and nanocrystal coherent diffraction experiments at the European XFEL. This proposal is led by DESY.

- The **Helmholtz International Beamline for Extreme Fields at the European XFEL (HIBEF)** user consortium proposed to contribute two high energy optical lasers, a high field pulsed magnet instrument, and a number of scattering diagnostics to be integrated into the HED instrument. The ultrashort pulse high intensity laser is under procurement at present. The construction of the nanosecond high energy laser is under way at STFC. A laser building could house future upgrades of these optical lasers and would provide offices for the staff to build up and operate these systems. This proposal is led by HZDR and includes DESY, both research centres of the Helmholtz Association, plus many partners outside of Germany.

- The **COMO** consortium addresses the provision of state-, size-, and isomer-selected samples of polar molecules and clusters for study using soft and hard X-ray FEL radiation. It is building an additional sample delivery setup that can be attached to the European XFEL instruments, in particular SQS and SPB/SFX. This proposal is led by DESY.

- The **Heisenberg Resonant Inelastic X-ray Scattering (h-RIXS)** user consortium proposes to build a high resolution spectrometer complementing the capabilities of the SCS instrument and facilitating RIXS-type experiments. The funds are secured, and the conceptual design of the spectrometer is finalized. This consortium is about to order optical elements for the spectrometer. Current members are the University of Potsdam, DESY, and the University of Milan.

SHORT HISTORY OF EUROPEAN XFEL

In the 1990s, DESY and international partners developed a proposal for a new research institution in the Hamburg area: a large-scale facility comprising a linear collider for particle physics and an X-ray FEL for photon science. As a European facility to be implemented in collaboration with other countries, the X-ray FEL part of the project got the go-ahead from the German Ministry of Education and Research (BMBF) in 2003. The new research institution was formally established in late 2009 with the signature of the intergovernmental Convention by an initial group of 10 countries and the foundation of the European X-Ray Free-Electron Laser Facility GmbH, a non-profit limited liability company under German law in charge of the construction and operation of the European XFEL facility.

1980–1984

The idea of a single-pass FEL for short wavelengths is introduced in the independent work of A. M. Kondratenko and E.L. Saldin (1980) and R. Bonifacio, C. Pellegrini, and L.M. Narducci (1984). The latter authors coin the term “self-amplified spontaneous emission”, or “SASE”, to describe the amplification process on which the European XFEL will eventually rely.

1992

In an international collaboration at a test facility at DESY, scientists begin to develop and test the technology for the Tera-Electronvolt Energy Superconducting Linear Accelerator (TESLA) project. This technology will eventually form the basis for the European XFEL.

1997

The international TESLA collaboration led by DESY publishes a conceptual design report for TESLA, a linear collider with an integrated X-ray laser facility.

Figure 1 Experiment section of the TESLA test facility at DESY in 1997

2000

Scientists at the TESLA test facility at DESY achieve a world first by generating shortwave laser light in the ultraviolet range (80–180 nm) using the pioneering SASE FEL principle on which the European XFEL is based.

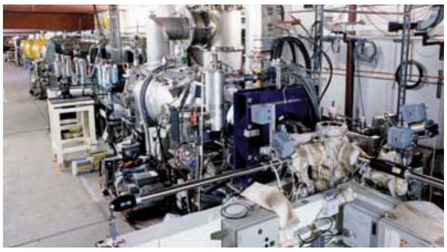


Figure 2 Accelerator section of the TESLA test facility at DESY in 1999

Figure 3 On 22 February 2000, the FEL at the TESLA test facility produces a laser beam for the first time—with the shortest wavelengths ever generated by an FEL.

2001

The TESLA collaboration publishes a technical design report (TDR) for TESLA.

The FEL at the TESLA test facility demonstrates the greatest possible light amplification at 98 nm. A user programme with first experiments starts soon afterwards.

2002

A TDR for an X-ray laser laboratory with a dedicated linear accelerator in a separate tunnel is published as a supplement to the TESLA TDR.

2003

The German government decides to cover around half of the investment costs for the dedicated X-ray laser facility described in the TESLA TDR supplement, provided the rest is borne by European partner countries. This decision leads to intense negotiations on funding and participation.

A site near DESY is chosen for the new X-ray laser facility, so it can make use of existing DESY infrastructure.

The 100 m long TESLA test facility is extended to a total length of 260 m and modified into an FEL user facility for photon science experiments with vacuum-ultraviolet and soft X-ray radiation.

2004

The German federal states of Hamburg and Schleswig-Holstein ratify a treaty that provides the legal basis for the construction and operation of the X-ray laser facility. Among other things, the states agree on a joint public planning approval procedure, including an environmental impact assessment.

Figure 4 On 29 September 2004, Schleswig-Holstein's Minister President Heide Simonis (right) and Hamburg's Mayor Ole von Beust sign a state treaty that provides the legal basis for the construction and operation of the X-ray laser.

2005

At the beginning of the year, nine countries—France, Germany, Greece, Italy, Poland, Spain, Sweden, Switzerland, and the UK—sign a Memorandum of Understanding (MoU) in which they agree to work jointly on a governmental agreement for the construction and operation of the X-ray laser facility. Together with Denmark, Hungary, the Netherlands, Russia, Slovakia, and the European Union (EU), whose representatives are present as observers, the signatory countries form an International Steering Committee (ISC) that coordinates the preparations for the construction of the X-ray laser. By the end of the year, the MoU has also been signed by China, Denmark, Hungary, and Russia.

User operation begins at the new 260 m long DESY FEL, which is also used for studies and technological developments related to future projects, such as the European XFEL. Soon afterwards, the facility, which has been setting records for the shortest wavelength produced with an FEL, is renamed "Free-Electron Laser in Hamburg", or "FLASH".

2006

In July, the DESY XFEL project group and the European XFEL project team, established in Hamburg through the MoU, publish a TDR for the proposed European XFEL facility. In 580 pages, 270 authors from 69 institutes in 17 countries describe the scientific and technical details of the research facility.

In August, the State Authority for Mining, Energy and Geology (LBEG) of Lower Saxony, which is in charge of the public planning approval procedure for the European XFEL, gives the formal go-ahead for the realization of the facility.

In October, the European Strategy Forum on Research Infrastructures (ESFRI) committee of the EU publishes the first European roadmap for new large-scale research infrastructures. The European XFEL facility is among the first of the 35 projects on the list to proceed to the construction phase.

2007

In January, 260 scientists from 22 countries meet at DESY in Hamburg for the first European XFEL Users' Meeting.

In June, the German research ministry officially launches the European XFEL. Germany and the 12 interested partner countries—China, Denmark, France, Greece, Hungary, Italy, Poland, Russia, Spain, Sweden, Switzerland, and the UK—agree to construct a startup version of the facility, comprising 6 of 10 scientific instruments, with the aim to upgrade it as soon as possible to the complete facility with 10 instruments. The launch signals the start of the calls for tender for civil construction.

In July, the four-year Pre-XFEL project is launched. This project is funded by the EU and designed to support the foundation of the European XFEL as a major new research institution in Europe. The main purpose of the project is to provide all technical, legal, and financial documents necessary for the foundation of a company to build and operate the European XFEL facility.

In October, Slovakia officially joins the European XFEL project by signing the MoU.

Figure 5 The European XFEL is officially launched on 5 June 2007.
Left Valérie Pécresse, French Minister of Higher Education and Research; Peter Harry Carstensen, Minister President of Schleswig-Holstein; Annette Schavan, German Federal Minister of Education and Research; Ole von Beust, Mayor of the City of Hamburg; and Andrej A. Fursenko, Minister of Education and Science of the Russian Federation
Right Annette Schavan, Ole von Beust, and Peter Harry Carstensen

2008

In September, the European XFEL ISC adopts the contents of the "Convention concerning the Construction and Operation of a European X-ray Free-Electron Laser Facility", the legal foundation of the European XFEL GmbH.

In December, contracts are awarded for civil engineering works at the three European XFEL sites: Schenefeld (Schleswig-Holstein), Osdorfer Born (Hamburg), and DESY-Bahrenfeld (Hamburg).

Figure 6 Signing of the building contracts for the three underground construction lots for the European XFEL facility on 12 December 2008

Figure 7 In 2008, European XFEL moves into its current headquarters at Albert-Einstein-Ring 19, near the DESY site.

2009

In January, construction of the European XFEL facility officially starts in Schenefeld, Osdorfer Born, and DESY-Bahrenfeld.

In October, the European X-Ray Free-Electron Laser Facility GmbH is officially registered in the Hamburg commercial register.

In November, representatives from 10 partner countries—Denmark, Germany, Greece, Hungary, Italy, Poland, Russia, Slovakia, Sweden, and Switzerland—sign the European XFEL Convention and Final Act in the Hamburg city hall, thus establishing the European XFEL GmbH.

Figure 8 On 30 November 2009, representatives from 10 partner countries sign the European XFEL Convention and Final Act.
Left to right Mauro Dell'Ambrogio, State Secretary, State Secretariat for Education and Research, Switzerland; Peter Honeth, State Secretary, Ministry of Education and Research, Sweden; Andrej A. Fursenko, Minister of Education and Science of the Russian Federation; Prof. Jerzy Szwed, Undersecretary of State, Ministry of Science and Higher Education, Poland; Ole von Beust, Mayor of Hamburg; Giuseppe Pizza, State Secretary, Ministry for Education, Universities and Research, Italy; Prof. Frieder Meyer-Krahmer, State Secretary, Federal Ministry for Education and Research, Germany; Dr. Peter Ammon, State Secretary, Federal Foreign Office, Germany; Prof. Mikulás Supín, Director General, Division of Science and Technology, Ministry of Education of the Slovak Republic; Dr. Christos Vasilakos, Representative of the General Secretariat for Research and Technology in the Permanent Delegation of Greece at the European Union; István Varga, Minister for National Development and Economy, Hungary; Hans Müller Pedersen, Deputy Director General of the Danish Agency for Science, Technology and Innovation; and Peter Harry Carstensen, Minister President of Schleswig-Holstein

2010

In February, France signs the European XFEL Convention and Final Act, thereby bringing the number of partner countries to 11.

In May, European XFEL and DESY sign a long-term agreement on future collaboration. DESY will continue to provide administrative services and lead the international Accelerator Consortium that is constructing the 1.7 km long superconducting accelerator, including the electron source. After completion, DESY will take over the operation of the accelerator on behalf of European XFEL.

In July, the first tunnel boring machine powers up and construction of the tunnels for the European XFEL begins.

By the end of the year, Denmark, Germany, Poland, Russia, Slovakia, and Sweden have appointed shareholders to join the European XFEL GmbH. (For a complete list of shareholders, see “Shareholders” earlier in this chapter.)

Figure 9 First tunnel and borer christening ceremony on the European XFEL construction site Schenefeld on 30 June 2010

2011

In January, the second tunnel boring machine for the European XFEL starts drilling the photon tunnels beneath the Schenefeld campus.

In June, the first topping-out ceremony for one of the underground buildings of the European XFEL facility is celebrated on the DESY-Bahrenfeld construction site.

Scientists demonstrate that the parameters of the X-ray flashes generated by the new facility can be improved beyond the original design, based on research at SLAC and DESY in Zeuthen.

At the end of the month, the Pre-XFEL project is officially concluded. All remaining duties and tasks are officially handed over to the European XFEL GmbH.

In July, the first tunnel boring machine reaches its final destination on the DESY-Bahrenfeld site, thereby completing the 2010 m long tunnel for the accelerator.

In October, Spain signs the European XFEL Convention and Final Act, thereby bringing the number of partner countries to 12.

Figure 10 First tunnel boring machine after its arrival in the final shaft

2012

In February, construction of the 2010 m long accelerator tunnel of the European XFEL facility, including the concrete floor, is completed.

In May, research activities resume at one of Hamburg's deepest underground workplaces. Three research teams contributing to the European XFEL move into their laboratories in a former experiment building of the Hadron-Electron Ring Accelerator (HERA), a particle accelerator at DESY that was switched off in summer 2007.

In June, an important milestone is reached: the construction of the network of tunnels is completed. The event is marked by a celebration with more than 400 participants—including guests from politics and science, as well as staff from collaborating companies.

In July, about 200 scientists from more than 20 countries in Europe, America, and Asia participate in the "Science at FELs" conference, the world's first major international conference dedicated exclusively to science with X-ray FELs. The conference is organized jointly by DESY and European XFEL.

In December 2012, Gianluca Geloni (European XFEL), Vitali Kocharyan (DESY), Evgeni Saldin (DESY), and Paul Emma (LBNL) are awarded the Innovation Award on Synchrotron Radiation by the Association of Friends of Helmholtz-Zentrum Berlin. They are honoured for their invention of a self-seeding method that significantly improves X-ray FELs.

Figure 11 Arrival of the second tunnel boring machine in the final reception shaft on 4 June 2012

2013

In June, another milestone is reached: the underground civil engineering work for the European XFEL is completed, and the underground construction is almost finished. Over three years, about 3500 construction workers have moved more than 500 000 m^3 of earth and used 150 000 m^3 of concrete and 28 t of steel for underground construction. About 300 guests from politics, academia, administration, and business gather to celebrate in Schenefeld.

In September, the installation of the European XFEL injector begins at the DESY-Bahrenfeld site. The injector includes a special high-precision, water-cooled electron source, called a radio frequency gun.

In December, more than half of the European XFEL's 92 undulator segments are fully tuned. Tuned segments are placed into storage, awaiting installation in the tunnels.

2014

In May, the X-Ray Optics and Beam Transport group installs the first components of the X-ray laser's photon system in the photon tunnels.

Also in May, construction of the future European XFEL headquarters building (XHQ) starts.

In August, the first completed and tested accelerator module is installed in the tunnel. By the end of the year, about a quarter of the 101 required modules have been produced at CEA in Saclay, France. Seventeen of these modules are tested at DESY in 2014.

Figure 12 The European XFEL headquarters building (XHQ) under construction in December 2014

Figure 13 Installation of the first completed and tested accelerator module in the tunnel in August 2014

2015

In February, European XFEL celebrates the topping-out of its headquarters building in Schenefeld. More than 350 guests—including representatives from the German federal government, the states of Hamburg and Schleswig-Holstein, the consular corps, politics, and the European XFEL Council and employees—attend the event.

In May, a feasibility study of external experts comes to the conclusion that a visitor or science centre on the European XFEL campus in Bahrenfeld would be well received within the region.

Another important milestone is reached in December, when the injector accelerates the first electrons at the European XFEL. The injector produces a series of bunches that pass through the 45 m long injector beamline. The electrons make the full trip from start to end of the injector in 0.15 ms, achieving near light speed.

The assembly of the 100 modules for the main accelerator also progresses rapidly. At the end of the year, 59 of them are installed in the tunnel.

Figure 14 Topping-out ceremony for the headquarters building on 18 February 2015

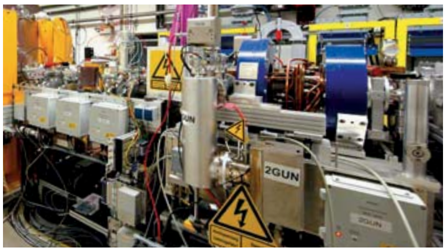


Figure 15 The European XFEL electron injector in December 2015

2016

In March, the installation of the 35 segments of the first of three undulators is completed. Each of the three undulators is at maximum 210 m long and will produce X-ray laser light exceeding the intensity of conventional X-ray sources a billion times over. The undulator installation is a major step towards the completion of the European XFEL.

In June, the new headquarters in Schenefeld is inaugurated. Guests from politics, administration, and the diplomatic corps celebrate the event alongside the European XFEL Council and employees from European XFEL and DESY. All of the approximately 300 European XFEL employees had moved from the previous headquarters at Albert-Einstein-Ring in Hamburg to the new research campus a few days before.

In July, DESY successfully concludes seven months of tests of the first section of the particle accelerator for the European XFEL. The 30 m long injector performs much better than expected.

In October, European XFEL begins the commissioning of the X-ray laser. Around 350 guests from around the world and employees of European XFEL and DESY celebrate the big milestone in Schenefeld. In one of the underground tunnels near the experiment hall (XTD9), representatives of the partner countries mount an approximately 2 m long beamline tube, one of the final still-missing pieces of the starting configuration.

In November, European XFEL announces it will build a canteen and a 50–60 room guest house on its campus in Schenefeld.

Figure 16 Start of commissioning on 6 October 2016

2017

In January, Prof. Robert Feidenhans'l starts as Chairman of the Management Board. The European XFEL Council appointed him as successor to Prof. Massimo Altarelli, who had served as chairman from the foundation of the company in 2009 and retired in December 2016.

In May, the European XFEL generates its first X-ray laser light, which has a wavelength of 0.8 nm, about 500 times shorter than that of visible light. At first lasing, the laser has a repetition rate of one pulse per second. The X-ray laser light of the European XFEL is generated from the electron beam of a superconducting linear accelerator in a photon tunnel containing an undulator, a 210 m long stretch of X-ray generating devices.

In June, the X-ray beam reaches the experiment hall and the instruments SPB/SFX and FXE.

In July, European XFEL officially enters the operation phase. The European XFEL Council agrees that the conditions for the start of operation have been satisfied and releases the funds designated for the operation phase.

In September, the European XFEL is inaugurated in an international event with 800 guests. At the SPB/SFX instrument, the first experiment at the European XFEL is started. The week before, the official opening is announced in eleven languages at the Elbphilharmonie concert hall in Hamburg, with posters and announcements all over Hamburg and at the airport, and with strong lasers pointing from the Elbphilharmonie and other buildings in Hamburg towards the European XFEL, and other lasers pointing from Schenefeld back to Hamburg. The pre-opening and opening events receive huge national and international media coverage.

Figure 17 Laser installation from the Elbphilharmonie in Hamburg (left) and from roof of the European XFEL main building in Schenefeld (right). Hamburg says 'welcome' to European XFEL, and the facility sends five laser beams highlighting the underground tunnels to Hamburg.

03

FACILITY

European XFEL shifted from construction to operation phase in 2017. While users began to come to Schenefeld, planning and construction continued with a workshop and storage building, a canteen, a guesthouse, and an undulator hall.

Aerial view of the Schenefeld research campus

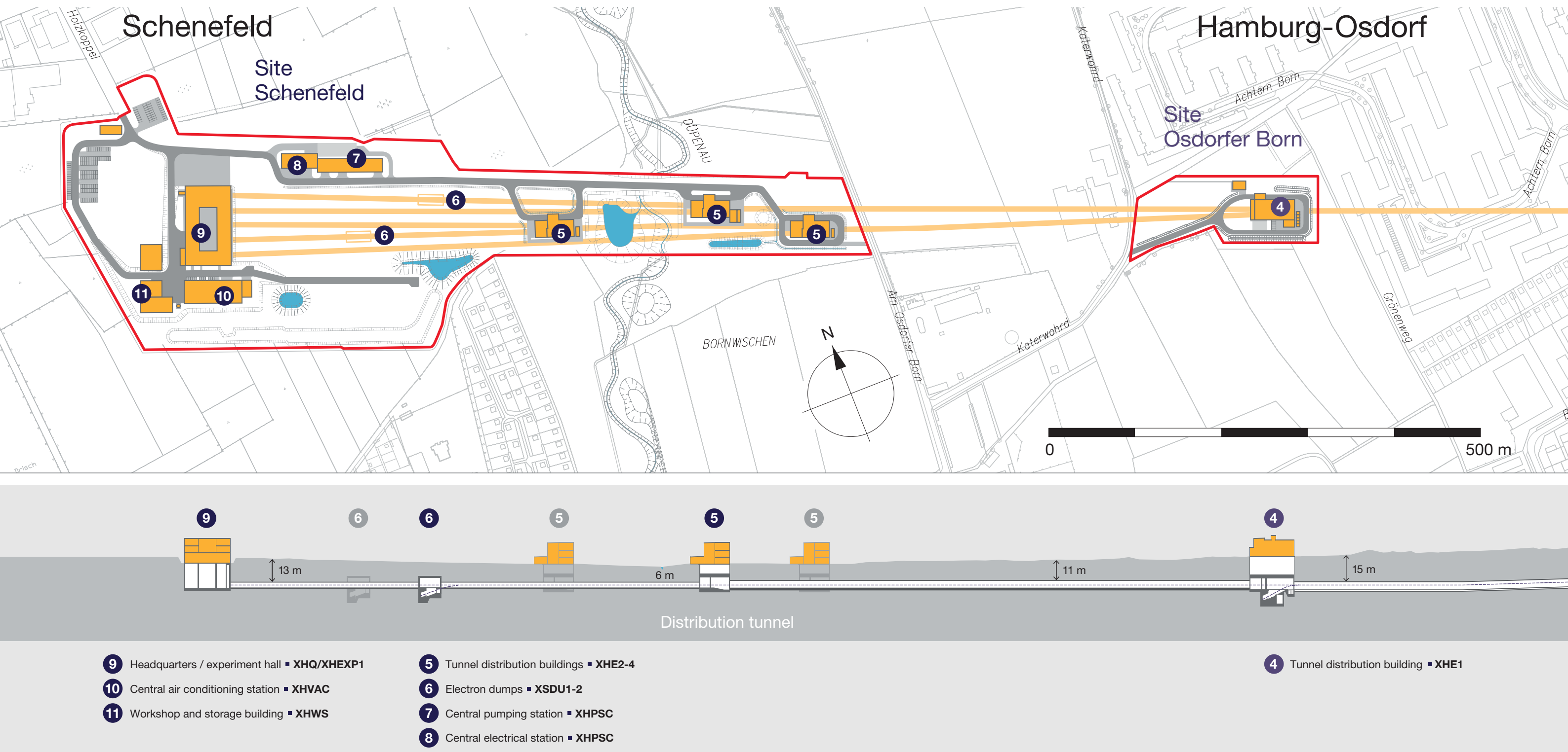


Figure 1 Layout of the European XFEL facility

CIVIL CONSTRUCTION

In 2017, civil construction work focused on the construction of the workshop and storage building, the construction of the canteen building, and the planning of the guest house and a new undulator hall. Landscape work and infrastructure installations continue on the Schenefeld campus.

Overview

The overall layout of the European XFEL facility is shown in Figure 1. The top view indicates the dimensions and the placement in the surrounding area. The side cross-sectional view shows the ground profile and the various shaft buildings. The facility is approximately 3.4 km long and stretches from DESY in Hamburg-Bahrenfeld all the way to the southern edge of the city of Schenefeld in the German federal state of Schleswig-Holstein. It consists of a large network of tunnels for the accelerator and the photon beamlines plus eight shaft building complexes, corresponding surface buildings, and assorted building structures for peripheral technical equipment (for example, pump housing, generators, and air conditioning). Most of the facility is located underground. The network of tunnels has a total length of about 5.77 km.

User operation of the facility started in autumn 2017, with first scientific groups coming to the Schenefeld site to carry out their experiments in a large underground experiment hall below the laboratories and offices of the European XFEL headquarters building (XHQ). Figure 2 shows a schematic of all the underground and surface buildings of the European XFEL facility.

Status—December 2017

In 2017, virtually all civil construction activities concentrated on the Schenefeld campus site. The workshop and storage building (XHWS) is nearing completion. The civil construction of the canteen building (XHC) has started, and the planning of a guest house (XHG) and a hall for the mechanic characterization of undulator segments (XHU) is ongoing.

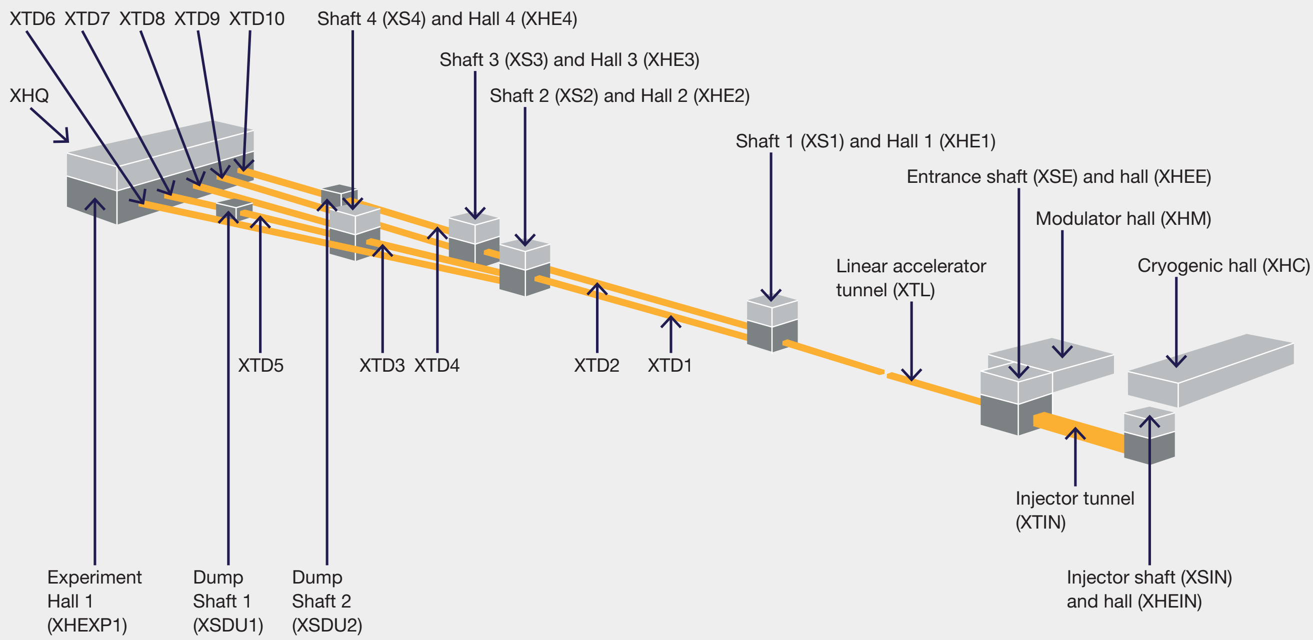
DESY-Bahrenfeld and Osdorfer Born sites

On the DESY-Bahrenfeld and Osdorfer Born sites, the only remaining work concerns the realization of the environmental compensation measures as prescribed in the plan approval documents (for example, the planting of bushes and trees).

Schenefeld campus

On the Schenefeld campus, construction of XHWS proceeded. The building will house the electrical and mechanical workshop, a warehouse area for the reception and storage of goods, and office space for employees, mainly from the Technical Services group. XHWS is located next to XHQ and the building providing the air conditioning to the experiment hall and tunnels (XHVAC). Figure 3 shows XHWS in June 2017. Final work is ongoing inside (carpeting and cleaning). Personnel are scheduled to move into the building in March 2018.

The planning for XHC was finalized in early 2017, and construction started in the summer. Figure 4 shows a picture of the cellar of XHC, which was finished in December 2017, before the pouring of the concrete ground floor plate. Figure 5 shows an artist's view of XHC when completed, with XHQ and the plaza in front.



Type
X = XFEL
H = Hall
S = Shaft
T = Tunnel

Building
C = Cryo (cooling)
D = Distribution (switchyard tunnel)
DU = Dump (beam absorber)
E = Entrance
EE = Entrance hall of entrance shaft
EXP = Experiment
HQ = Headquarters
IN = Injector
L = Linear accelerator
M = Modulator

Figure 2 Buildings of the European XFEL facility

Figure 3 Workshop and storage building (XHWS) in August 2017

Figure 4 Civil construction site for the canteen building (XHC) in December 2017

Figure 5 Artist's view of the completed canteen building (XHC) next to the central headquarters building (XHQ) and the plaza

The planning of two further buildings was started in 2017: the guest house (XHG) and the undulator hall (XHU). XHG will provide 59 rooms to accommodate users performing experiments at the European XFEL. A second guest house of the same size is already anticipated, the construction of which will start after experience with the first building has been gathered and analysed.

XHU will house two climatized hutches for high-precision magnetic measurement benches, which are needed to characterize the undulator structures used to generate the high-intensity X-ray laser light for user experiments at the European XFEL. Currently, these measurements are performed at a laboratory on the DESY campus, but the space there will be needed for other purposes in the future.

Summary and forecast

In 2017, all essential milestones in civil construction were met. Costs for civil construction overall remained within the budget ceiling foreseen for the year.

In 2018, most of the work will focus on finalizing the construction of XHC, which will be ready for use by winter, and starting the construction of XHG and XHU, with completion of the latter two buildings expected in 2019.

Implementation of the environmental compensation measures will continue, as will the overall landscaping. ■

TECHNICAL SERVICES

The Technical Services (TS) group is responsible for the planning and commissioning of the entire infrastructure on the Osdorfer Born and Schenefeld sites, as well as the operation of the facilities in Hamburg Bahrenfeld, such as the HERA South hall and various buildings on the DESY campus.

Installation and commissioning

An ongoing assignment for the TS group throughout the year was supervising the planning and monitoring of the incorporation of technical equipment into the SASE1–SASE3 hutches.

For the inauguration on 1 September, the entire SASE1 system had to be ready for operation. Therefore, the commissioning of the SASE1 technical infrastructure became the main focus of the TS group. Furthermore, it was also important to finish the structural fire protection of the SASE1 beamline in order to get permission to operate from the authorities.

In addition to the technical tasks, it was also necessary to organize the extensive cleanup work on the entire facility site in order to be ready for the day of inauguration.

The commissioning of the SASE1 technical infrastructure was the main focus of the Technical Services group in 2017, including the structural fire protection in order to get permission to operate from the authorities.

Tunnel climate control for SASE2 and SASE3

Another major task for the TS group was the planning and design of the precision climate control (PKG) of the undulator tunnels. To keep the quality of the X-ray beam at a high level, a constant environmental temperature of 21 ± 0.1°C needs to be maintained at the outlet of the PKG unit. SASE1 climate control has been running trouble-free since 2016. During 2017, the installation and commissioning of SASE2 and SASE3 systems could be accomplished successfully.

Figure 1 View of the technical installations of SASE1 in the XHEXP1

The group assisted with the planning of the future campus canteen, undulator hall, and guest house.

Building infrastructure installations and planning

The plan for the technical outfitting of the campus canteen (XHC) was improved during the year, and the legal procedure for financing and constructing public-sector infrastructures (*Zuwendungsverfahren Bau*) was initiated in December 2016.

XHC will offer seats for 150 people, and the kitchen will have the capacity to serve up to 450 meals during a given lunch period. Construction started in April 2017, and the canteen is scheduled to be operational in spring 2019.

The group also looked after the planning of the guest house (XHG) and the undulator hall (XHU).

Rectification of deficiencies

Members of the Facility Management team were also involved in the repair of some technical defects, especially on the laboratory floor.

Outlook for 2018

In early 2018, the TS group will move to the new workshop and storage building (XHWS) on the Schenefeld campus. The offices will be ready by the end of February and will also host members of the Photon Systems Project Office (PSPO), Electrical Engineering Team (EET), Asset Management, and Procurement and Logistics groups.

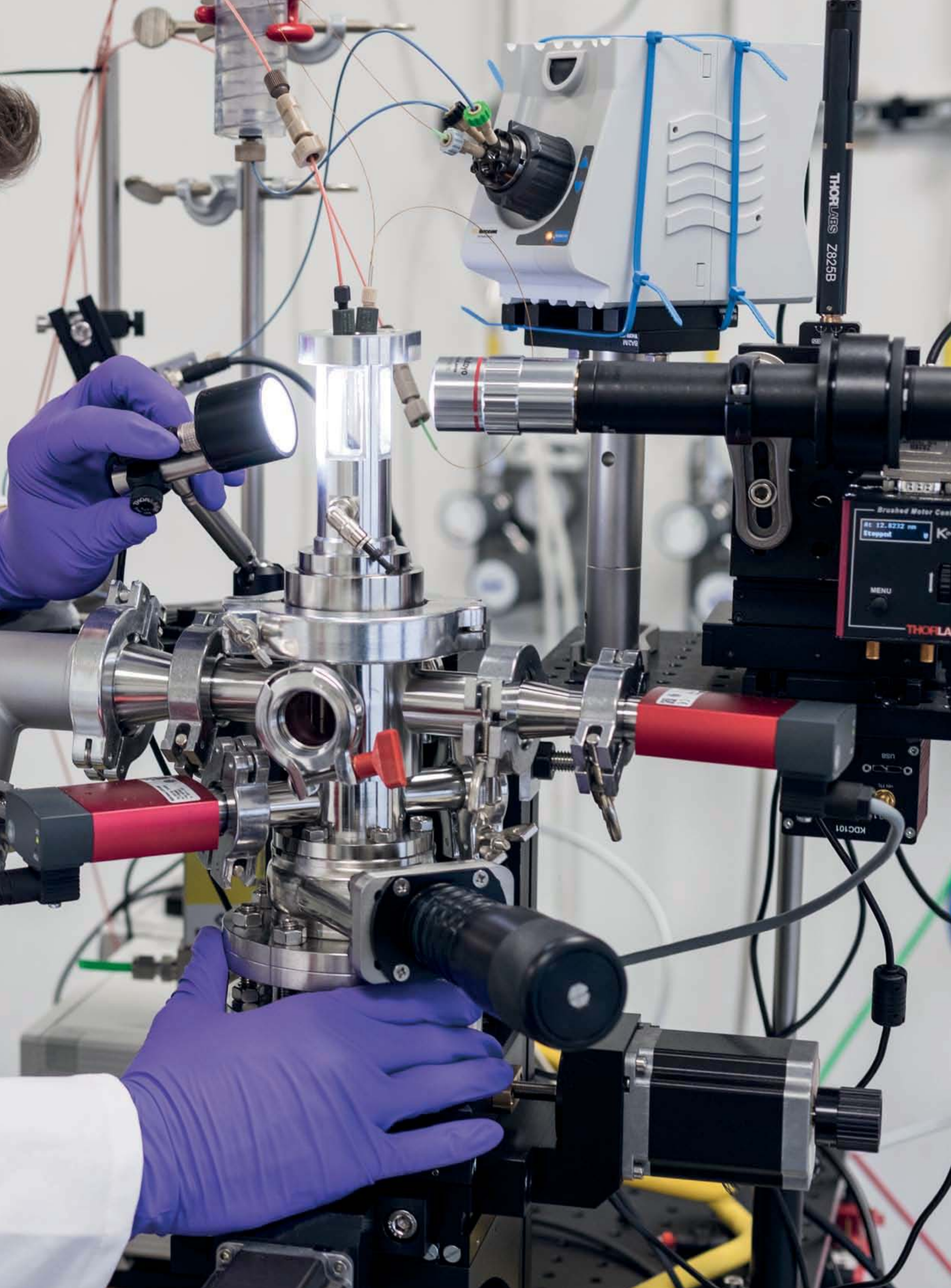
TS will also be involved in the planning of the undulator hall (XHU) as well as a user and staff office building that will also house a high-powered optical laser contributed by the Helmholtz International Beamline for Extreme Fields at the European XFEL (HIBEF). ■

Group members
Süleyman Arslan, Wolfgang Tebah Azipon (until 31 October 2017, not shown), Tobias Bartsch (Facility Management), Heinz-Peter Biesterfeld (from 1 January 2017, not shown), Bernd Brun (guest from RMN Ingenieure GmbH), Ulf Brüggmann, Uschi Conta (until 15 February 2017), Ralf Emmerich (not shown), Oleg Engelmann (Facility Management), Christian Holz (Facility Management, not shown), Lorenz Kersting (group leader), Jan Oliver Kirsch, Alexander Kondraschew (Facility Management), Hrvoje Kristic (until 30 September 2017), Michael Malso (Facility Management), Torsten Schön, Marco Schrage, Carola Schulz (Facility Management team leader), Christoph Stäps (from 1 July 2017; Facility Management, not shown), Tobias Tietz (from 1 July 2017; Facility Management, not shown), and Frederike Wittmaack

04 IN-KIND CONTRIBUTIONS

Twenty-one institutes in nine countries contributed to the construction of the European XFEL through in-kind contributions. The Accelerator Consortium, which involved many of these contributions, successfully completed its work in 2017.

Preparing the aerosol sample injector, a Swedish contribution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IKC OVERVIEW

European XFEL shareholders contribute to construction costs in cash or in kind. In-kind contributions (IKCs) can take the form of component delivery, staff secondment, or both. To date, 78 IKCs by 21 institutes from 9 different countries are under way for a total of 602 million euro (M€).

Summary of 2017

Fifty-nine milestones were reached in 2017. Many milestones were part of the commissioning of the linear accelerator. Out of the 103 cryomodules delivered in total, 97 are installed in the injector and the accelerator. Eighty-eight of them were commissioned in the accelerator in 2017 and used for the first experiments.

Overall contributions

In 2017, adjustments were made in the relative amounts of some IKCs. The total value of IKCs under way was approximately 602 M€, including contracts to Russian institutes (Table 1).

Countries contributing in kind

To date, eight countries are effectively implementing IKCs: Denmark, France, Germany, Italy, Poland, Spain, Sweden, and Switzerland.

Abbreviation	Country	Number of IKCs	IKC value (k€)
DK	Denmark	2	4 087
FR	France	4	36 000
DE	Germany	36	446 023
IT	Italy	3	33 000
PL	Poland	5	19 131
RU	Russia	13	42 087
ES	Spain	4	8 071
SE	Sweden	9	4 882
CH	Switzerland	2	8 835
Total		**79**	**602 119**

Table 1 Projected IKC amounts by country (in 2005 prices) in thousands of euro (k€) as of December 2017

Russian contributions are considered somewhat differently than the IKCs from these eight countries because the Russian shareholder decided to send its full contribution to European XFEL in cash rather than in kind. Russian institutes intending to contribute to the project are awarded manufacturing contracts, which are then managed with the same procedures as IKCs. To date, European XFEL and five Russian institutes have concluded 13 manufacturing contracts.

Some of the Russian IKCs were successfully completed in previous years (e.g. RU11 for Work Package 12 by NIIEFA, “Production and Delivery of ‘warm’ magnets” RU09 for Work Package 17 by IHEP, “Production and Delivery of Mechanical Components and Scintillators for the Beam Loss Monitors” RU17 for Work Package 12 by BINP, “125 ‘warm’ magnets of type XQA” and RU25 for Work Package 12 by BINP, “Production and delivery of 22 coil sets for XQK ‘warm’ magnets”).

Fifty-nine milestones were reached in 2017. Many milestones were part of the commissioning of the linear accelerator. Eighty-eight cryomodules were commissioned in the accelerator and used for the first experiments.

Contributing institutes

As of December 2017, a total of 21 institutes are contributing in kind to the European XFEL facility (Table 2).

IKRC recommendations

The In-Kind Review Committee (IKRC) advises European XFEL concerning proposed IKCs. The committee is composed of one representative from each contracting party and two representatives from European XFEL (one for the accelerator, one for the photon beamlines). In-person or virtual meetings of the IKRC are scheduled one to three times per year, depending on the number of proposals to discuss.

In total, 75 proposals have received favourable recommendations from the IKRC since the start of the project.

Allocations of IKCs

Official allocation of IKCs to the proposing institutes is made after recommendation by the IKRC.

IKCs with a 2005 value below 1 M€ can be allocated directly by the European XFEL Management Board, while IKCs of higher values are allocated by the European XFEL Council after analysis and recommendation by the European XFEL Administrative and Finance Committee (AFC).

Since the start of the project, a total of 79 IKCs have been allocated.

Milestone validation

The progress of each contribution is monitored through specific milestones, the criteria of achievement being detailed explicitly in the corresponding IKC agreement. Each milestone is connected to a crediting allotment for the shareholder or to the payment of an invoice

Country	Abbreviation	Institute	Location	Work packages
DK	DTU	Technical University of Denmark – Physics Department	Risø	81–84
FR	CEA	Commissariat à l'Énergie Atomique et aux Énergies Alternatives	Saclay	3, 9, 17
	CNRS	Centre National de la Recherche Scientifique	Orsay	5
DE	DESY	Deutsches Elektronen-Synchrotron	Hamburg, Zeuthen	1–5, 7–21, 28, 32–36, 38–40, 45, 46, DECO
IT	INFN	Istituto Nazionale di Fisica Nucleare	Milan	3, 4, 46
PL	NCBJ	National Center for Nuclear Research	Świerk	6, 91
	IFJ-PAN	Henryk Niewodniczański Institute for Nuclear Physics	Kraków	10, 11
	WUT	Wrocław University of Technology	Wrocław	10
RU	BINP	Budker Institute of Nuclear Physics of SB RAS	Novosibirsk	8, 10, 12, 13, 19, 34
	IHEP	Institute for High Energy Physics	Protvino	13, 17, 20
	INR	Institute for Nuclear Research RAS	Troitsk	18
	JINR	Joint Institute for Nuclear Research	Dubna	74
	NIIEFA	D.V. Efremov Scientific Research Institute of Electrophysical Apparatus	St. Petersburg	12
ES	CELLS	Consortium for the Exploitation of the Synchrotron Light Laboratory	Barcelona	71
	CIEMAT	Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas	Madrid	11, 71
	UPM	Universidad Politécnica de Madrid	Madrid	34
SE	KTH	Royal Institute of Technology	Stockholm	73
	MSL	Manne Siegbahn Laboratory	Stockholm	12, 71
	SU	Stockholm University	Stockholm	28, 71
	UU	Uppsala University	Uppsala	14, 79, 84, 85
CH	PSI	Paul Scherrer Institut	Villigen	16, 17

Table 2 Institutes contributing in kind to the European XFEL facility

in case of contracts with Russian institutes. The validation of milestones follows a specific procedure established in 2011.

In total, 409 milestones have been completed since the start of the project. All related documentation is stored in a specific IKC database for future traceability.

Fifty-nine milestones were completed and validated in 2017. Each involved a certificate signed by the work package leader and the Accelerator Consortium coordinator or the responsible scientific director and submitted for approval to the management board. Each certificate includes a link to the supporting documentation stored in a database.

The contributing shareholders receive official notification of the completion of each milestone.

In total, 409 milestones have been completed since the start of the project. All related documentation is stored in a specific IKC database for future traceability.

Progress of IKCs

In 2017, all deliverables related to accelerator installation and commissioning were completed. Out of the 103 cryomodules delivered to DESY, 97 are installed in the accelerator tunnel. Eighty-eight of these were fully commissioned in 2017 and used for the first experiments.

Only a few of the IKCs that were successfully completed are highlighted below, in particular those where the quality assurance and asset management was documented in detail, allowing all related milestones to be credited.

The following IKCs, among others, were completed:

- **CH03, “Beam position monitor system”, by PSI for Work Package 17, “Standard electron beam diagnostics”**
  The radiofrequency (RF) beam position monitor (BPM) system of the European XFEL was developed by a collaboration of PSI (CH03), DESY (DE17), and CEA Saclay (FR04) as part of Work Package 17 (WP17), “Standard electron beam diagnostics”.

  The RF BPM system measures the position and charge of the electron beam, individually for each electron bunch, at about 460 locations in the accelerator. The BPMs also generate interlock signals in case of beam walk-off, and their timing system interface enables precise correlation with other accelerator subsystems via bunch-synchronous time stamps. The control and maintenance interface of the BPM system allows remote access of all relevant data and functions by the European XFEL control system and remote maintenance software.

After some FEL BPM R&D activities in the European XFEL's preparatory phase (starting already in 2006), PSI specifically developed, produced, tested, and delivered the BPM electronics for CH03 during the construction phase. The modular BPM electronics consist of a custom crate, RF front ends for the button and cavity BPMs, analogue-to-digital converter (ADC) mezzanines, and a digital back end, including field programmable gate array (FPGA) firmware and embedded software for the approximately 460 RF BPMs (either cavity, button, or re-entrant) in the European XFEL accelerator. PSI also took care of the integration of the RF front end of the re-entrant cavity BPM (developed by CEA Saclay) into this modular system.

After testing BPM prototypes and pre-series units at PSI accelerators and FLASH, the installation, installation, pre-beam commissioning, and beam commissioning of the BPM system at the European XFEL was done collaboratively by PSI, DESY (which contributed the vacuum parts and related mechanics of the button and cavity BPM system), and CEA Saclay. The cavity BPMs reach sub-micrometre position resolution for single bunches down to bunch charges of 50 pC, compared to ~4.5 μm resolution for the button BPMs in the warm transfer lines and ~8 μm for the buttons in the cold linear accelerator. The achieved relative charge resolution is typically <0.07% for cavities and <0.03% for buttons at higher bunch charges, with an absolute resolution limit of ~10 fC at very low bunch charges. The BPM system has proven to be very useful for charge transmission and beam loss measurements during first beam commissioning. Meanwhile, it is one of the most important backbone systems for operation. Its reliable function is one key issue for stable operation of the entire facility. Maintenance and further improvement of the system are handled within the framework of a maintenance contract with PSI.

- **CH04, "Transverse intra-bunch train feedback system", by PSI for Work Package 16, "Lattice"**
  The intra-bunch train feedback (IBFB) system corrects the transverse beam position of each individual electron bunch in the European XFEL accelerator using a combination of feedback and adaptive feed-forward algorithms that allow a stabilization of the transverse electron beam position and thus of the X-ray intensity and pointing stability.

  During the Swiss participation in the European XFEL preparatory phase, the PSI team investigated the technical feasibility of the IBFB, including studies that involved the design and production of prototype components. The purpose of CH04 was to finalize the conceptual design and to develop, fabricate, install, and commission the final versions of the different IBFB subsystems provided by PSI.

The deliverables of the PSI contribution to WP16 consisted of the following components:

- BPM electronics for nine cavity BPMs with sub-micrometre resolution and sub-microsecond latency
- Four stripline kicker magnets, each equipped with two RF power amplifiers
- Electronics (called “IBFB core electronics”), including internal firmware and software, that receives the BPM data and calculates corrective kicks from the data via feedback and/or feed-forward algorithms, both for the horizontal plane and for the vertical plane. The electronics apply these kicks to the beam by driving the aforementioned RF power amplifiers accordingly, with the possibility to apply individual kicks to each bunch in a bunch train (i.e. macropulse).

The vacuum parts of the IBFB BPMs (“BPM pickups”) are identical to the ones used within the framework of CH03. They are provided by DESY.

Swiss contributions completed in 2017 included the beam position monitor system, which measures the position and charge of the electron beam, and the transverse intra-bunch train feedback system, which corrects the transverse beam position of each individual electron bunch in the accelerator. Both systems are vital for the stability of the entire facility’s operation.

After successful pre-beam tests of the IBFB system at PSI, it was installed in the European XFEL tunnel system in 2016 and successfully commissioned with beam in 2017. By combining an ultrafast intra-train feedback with adaptive feed-forward algorithms, the IBFB stabilized the electron beam at the location of both the IBFB (upstream of the beam distribution system) and the SASE1 undulator down to the desired level of a few micrometres, thus supporting the generation of X-ray beams with high pointing stability and low-intensity fluctuations during the first user runs.

- **PL01, “Design, production, test, and delivery of the higher-order mode couplers and the beamline absorbers”, by NCBJ for Work Package 6, “HOM couplers”**
  The final objective of PL01 was to develop and produce a system that can effectively dump higher-order modes (HOMs) in superconducting cavities and absorb HOM travelling waves between cryomodules of the European XFEL accelerator. It involved the design, production, test, and delivery of HOM couplers, pickup output lines, and beamline absorbers (BLAs) for travelling HOMs in the superconducting cavities. The HOM couplers are used to extract and dissipate the RF energy present in the cavity due to the excitation of HOMs by the electron beam.

Polish contributions completed in 2017 included higher-order mode couplers, which extract and dissipate the RF energy present in the accelerator’s superconducting cavities, and programmable logic controller crates for the control systems of all six scientific instruments.

The low-frequency part of the HOM spectrum (below the cut-off frequency of the beam tube) is extracted by HOM couplers (placed in the 2 K environment) and transmitted via coaxial lines to external loads. Each nine-cell cavity is equipped with two HOM couplers placed close to the end cells. The high-frequency part of the HOM spectrum (propagating modes) is dissipated in the BLAs installed between the cryomodules. The propagating HOM power is around 3.7 W/cryomodule for operation with 27 000 bunches/s of the nominal charge of 1 nC. The power dissipated in the BLAs is transferred to the 70 K environment by a copper stub brazed directly to the absorbing ceramic ring. The stub holds the ring in a stainless-steel vacuum chamber thermally isolated from the 2 K region by a flexible bellows.

NCBJ took responsibility for the following tasks:

- Conceptual design (the BLA design is based on DESY technology using absorbing rings)
- Manufacturing drawings
- Production of all components
- Quality control
- Completion and subassembly of the BLAs
- Factory acceptance tests

For the 17.5 GeV linear accelerator, which includes 824 cavities, NCBJ delivered the following components:

- 1616 HOM antennas, sets of HOM transmission lines, each consisting of a niobium antenna brazed to an N-type cold feedthrough cable, RF room temperature vacuum feedthrough, and RF matched load
- 808 HOM RF pickup antennas to measure the FM accelerating field amplitude in the superconducting cavities
- 108 BLAs, based on lossy ceramic rings and housed in thermally isolated stainless-steel boxes

The cold feedthrough vacuum leak rates were less than 10^{-10} mbar l/s, and the niobium tip accepted the RF power without quenching. The tests performed at DESY on over 30 specimens delivered from three different vendors proved the suitability of the chosen version. The feedthroughs were tested together with the cavities. The HOM couplers did not show heating above the critical temperature of 9 K, when tested in 10% duty factor pulse mode at the specified gradient of 23 MV/m. The feedthroughs fulfilled the vacuum and cleanness specifications for beam vacuum components.

- **PL08, “Production of programmable logic controller crates for six instruments”, by NCBJ for Work Package 91, “Advanced Electronics”**

  A crucial aspect of data acquisition and controls is the monitoring and control of sensors (pressure, temperature, voltages, and so on), vacuum components (valves, gauges, and so on), and motion components (motors, encodes, and so on), which are used in all the tunnels and instruments of the European XFEL. This is done with distributed programmable logic controllers (PLCs). The actual implementation consists of special small terminals, which have to be selected and combined depending on the equipment to be monitored and controlled in that specific location. These modules had to be mounted in mechanical 19" rack–mountable enclosures (called crates), including standardized connectors, wiring, and other elements. Each of the 19" crates already manufactured consists of two slot-in modules, which include the electronics and connectors described above. These crates are installed in racks close to the required location and connected to the equipment as well as to the PLC control network.

  The key parts of PL08, including the procurement of all required components, manufacturing (assembly), and testing of 100 unique, individually equipped and wired 19" crates (for example, 200 slot-in modules), were performed in Poland, based on detailed electrical and mechanical CAD designs (provided by European XFEL). The tested modules, along with related documentation such as testing protocols, were shipped to European XFEL.

- **RU18, “Design, production, and delivery of vacuum components”, by BINP for Work Package 8, “Cold vacuum”**
  The final objective of RU18 was the design, production, and delivery of three types of vacuum components:

  - 106 pump lines for power couplers
  - 848 bellows for pumping ports of power couplers
  - 848 cavity bellows

  The collaboration of BINP on the subject started in 2009 with R&D on the galvanic coating of complex vacuum elements for WP08.

  The pump lines and bellows are integral parts of the coupler and beam vacuum systems. They are installed and connected to the couplers outside of the modules and ensure the vacuum connection between the couplers and pumps. The cavity bellows are installed between the cavities of the module strings. They provide a somewhat flexible vacuum connection of the individual cavities and compensate for length variations during the warm–cold cycles of the superconducting accelerator. The bellows’ inner convoluted surface is coated with a high-quality uniform galvanic copper film to provide good electrical conductivity between conducting elements. The pump lines, bellows, and cavity bellows were manufactured, cleaned for ultrahigh-vacuum (UHV), and tested by BINP. After factory acceptance tests, they were packed individually under clean conditions and delivered to DESY, where they were cleaned according to particle-free UHV cleaning procedures.

- **RU24, “Design, production, and delivery of cryogenic equipment”, by BINP for Work Package 13, “Cryogenics”**
  The contribution of BINP consisted in the detailed design, production, control, delivery, assembly, installation, and commissioning of cryogenic components used for the supply of liquid helium to the superconducting accelerator. BINP manufactured, assembled, and tested the components. After acceptance tests, the equipment was partially dismounted, packed under clean conditions, and delivered to DESY, where it was assembled and installed in the European XFEL entrance shaft (XSE) by BINP staff. Commissioning of the components was performed by BINP staff in collaboration with DESY.

  In accordance with the WP13 development plan, BINP took responsibility for the detailed design, production, and functional test of the European XFEL linear accelerator valve box (XLVB) and of the cryogenic components of the injector (XICE), including the injector transfer line, valve box, feed box, feed cap transfer line, feed cap, and end cap. Moreover, BINP took care of the assembly, installation in XSE, and *in situ* testing of all the components.

- **DE09, “Supervision of cavity strings assembly”, by DESY for Work Package 9, “Cavity string assembly”**
  The final objective of DE09 was to transfer the know-how of the string assembly procedures developed at DESY over several years to the French institute CEA/IRFU in Saclay, which actually performed the assembly of the 103 cavity strings necessary for the accelerator complex of the European XFEL. Furthermore, this IKC included the completion, preparation, and shipping to Saclay of the quadrupole package for each accelerator module, as well as the support of the assembly work done by CEA/IRFU. The long-term experience of the DESY team was used to the benefit of the assembly team.

  The complete accelerator module assembly operation for the European XFEL was performed by CEA/IRFU in Saclay, including the cavity string assembly (part of WP09) and the module to vacuum vessel assembly (part of WP03). CEA/IRFU was responsible for subcontracting the assembly and the quality control to an industrial company, using the newly built assembly infrastructure, which includes a complex of cleanrooms and assembly halls with dedicated tooling.

  In the first phase, DESY supported the definition of infrastructure at CEA/IRFU and accompanied its installation and commissioning. Some prototype module assembly was used for technology and knowledge transfer. DESY personnel supported the training of CEA/IRFU staff, who afterwards acted as supervisors for the subcontracted industrial company. The knowledge transfer was finished with the start of the assembly of the series modules. During the assembly campaign, DESY acted as a consultant and supported the addressing of non-conformities.

  The assembly of the European XFEL accelerator modules included the integration of a quadrupole package consisting of a superconducting quadrupole magnet provided by WP11, a cold beam position monitor provided by WP17, and a gate valve provided by WP08. These components were cleaned and pre-assembled into one unit that was then integrated into the string at Saclay. DESY took care of receiving the components and producing the quadrupole packages in the DESY cleanroom. The work ended with the delivery of the assembled units to Saclay.

Photos of activities going on in 2017 at the collaborating institutes are shown in Figures 1–8.

Figure 1 Beam position monitors (IKC DE17 by DESY, CH03 by PSI, and FR04 by CEA)

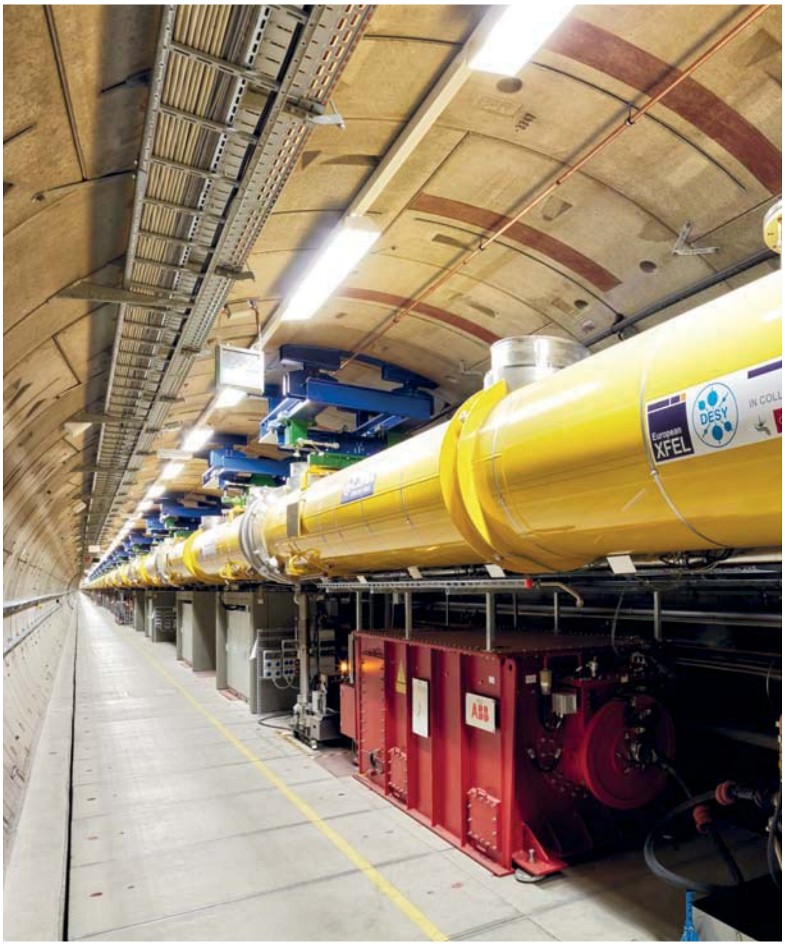


Figure 2 Modules in the first section of the linear accelerator (IKC DE33 and DE03 by DESY, FR02 and FR03 by CEA). Many other institutions contributed components for the modules, such as power couplers (IKC FR01 by CNRS), vacuum lines, and cold vacuum parts (IKC RU18 by BINP).

Figure 3 Cryogenic component installed in the first section of the linear accelerator (IKCs DE33 and DE13 by DESY, IKC RU24 by BINP)

Figure 4 PLC crates (IKC PL08 by NCBJ)

Figure 5 Cavity string (DE09 by DESY, FR02 and FR03 by CEA)

Figure 6 Linear accelerator installation status overview report in DESY's Engineering Data Management System, taken during the project; the EDMS is the central engineering collaboration and documentation platform for the European XFEL, where civil construction plans, 3D models, and review results are stored (IKC DE40).

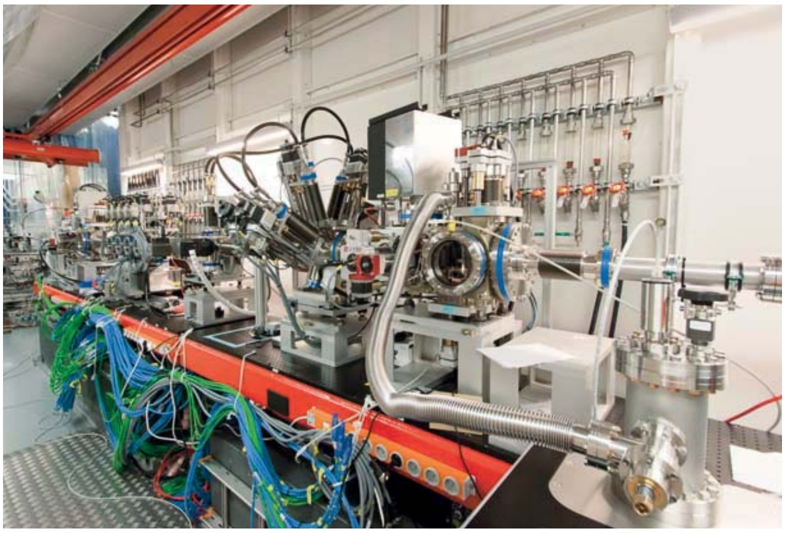


Figure 7 Components installed in the FXE instrument (DK01 by DTU)

Figure 8 Personnel interlock (DE38 by DESY)

Outlook for 2018

In 2018, a large number of milestones should be achieved in the ongoing IKCs. The finalization of SASE2 and all the hutches will complete the deliverables expected in kind. Antonio Bonucci will work on the finalizing the in-kind contributions while also setting up the Industrial Liaison Office, which will facilitate private-sector innovation.

Group member
Antonio Bonucci

ACCELERATOR CONSORTIUM

The European XFEL Accelerator Consortium, which consisted of 17 European research institutes coordinated by DESY, was established in 2010 with the goal of constructing the accelerator complex of the European XFEL. In 2017, the accelerator was commissioned together with the beam transport system through the SASE1 and SASE3 undulators, leading to first observation of SASE radiation on 2 May. This remarkable success, which concluded the work of the Accelerator Consortium, was achieved thanks to the dedicated work of DESY, its consortium partners, and the European XFEL groups responsible for the photon systems.

The accelerator complex of the European XFEL comprises an electron injector system including bunch compressors, a 17.5 GeV superconducting linear accelerator, a beam distribution and transport system through the undulators, beam dumps, and extensive infrastructure needed to operate all the installations. Most of the in-kind contributions of the consortium members (Table 1) to the accelerator complex were delivered during the construction phase, while the commissioning of the accelerator was the final in-kind contribution of DESY. The commissioning effort was planned as a series of sequential steps with the goal to establish beam transport to subsequent sections as soon as possible.

Cryogenic system commissioning

The European XFEL cryogenic system consists of two overhauled strings of the helium cryoplant for the former HERA collider at DESY, a new distribution box and transition line to the European XFEL accelerator entrance shaft, cold compressors to reach 2 K, further distribution boxes to distribute the helium towards the injector, and finally the long uninterrupted cryostring of the linear accelerator together with its transfer and bypass lines. Cooldown of the linear accelerator from room temperature to 4 K was achieved in December 2016, with no leaks occurring. Startup of the cold compressors enabled the start of accelerator commissioning at 2 K at the beginning of January 2017. Regulation loops were optimized in the following weeks, until the pressure of the 2 K helium circuit could be kept constant well below the requirement of ±1%. Most remarkable is that this stability can also be maintained during fast changes of the cryogenic load, as they do occur for instance during a sudden shutdown of the accelerator radiofrequency (RF). Even superconducting cavities generate some heat during RF operation. If the RF shuts down, this heat input from the cavities into the helium circuit stops, causing a change in pressure that could entail a break of cold compressor operation. In such a case, inner system heaters immediately take over the RF heat load, thus keeping the pressure constant.

Beamline commissioning

The European XFEL injector had been commissioned independently in 2016 in parallel to the ongoing accelerator installation in the remaining tunnels. Within the six-month commissioning period, most of the design parameters of the injector could be reached or even exceeded.

After the cooldown of the complete accelerator, the injector was re-commissioned with fixed bunch charge, and first electrons could be injected into the main accelerator tunnel (XTL) directly after authority approval was granted in mid-January 2017. Beamline commissioning was performed in parallel to the low-level RF (LLRF) commissioning, with the first electron beam transported to the beam dump at the end of the linear accelerator by the end of February. Trajectory response measurements proved very useful in validating the optics model and

Abbreviation	Institute	City	Country
CEA/IRFU	Commissariat à l'Énergie Atomique et aux Énergies Alternatives – Institut de Recherche sur les Lois Fondamentales de l'Univers	Saclay	France
CNRS/IN2P3	Centre National de la Recherche Scientifique – Institut National de Physique Nucléaire et de Physique des Particules	Orsay	France
DESY	Deutsches Elektronen-Synchrotron	Hamburg/Zeuthen	Germany
INFN-LASA	Istituto Nazionale di Fisica Nucleare, Laboratorio Acceleratori e Superconduttività Applicata	Milan	Italy
IFJ-PAN	Henryk Niewodniczanski Institute for Nuclear Physics	Kraków	Poland
NCBJ	National Center for Nuclear Research	Świerk	Poland
WUT	Wrocław University of Technology	Wrocław	Poland
BINP	Budker Institute of Nuclear Physics of SB RAS	Novosibirsk	Russia
IHEP	Institute for High Energy Physics	Protvino	Russia
INR	Institute of Nuclear Research RAS	Moscow	Russia
NIIEFA	D.V. Efremov Scientific Research Institute of Electrophysical Apparatus	St. Petersburg	Russia
CIEMAT	Centro de Investigaciones Energéticas. Medioambientes y Tecnológicas	Madrid	Spain
UPM	Universidad Politécnica de Madrid	Madrid	Spain
MSL	Manne Siegbahn Laboratory	Stockholm	Sweden
SU	Stockholm University	Stockholm	Sweden
UU	Uppsala University	Uppsala	Sweden
PSI	Paul Scherrer Institut	Villigen	Switzerland

Table 1 European XFEL Accelerator Consortium members

were possible right from day one thanks to the excellent performance of the beam position monitor (BPM) system. Other diagnostic devices, such as screens, toroids, beam loss monitors, and dark current monitors, were also available immediately. The BPM resolution exceeds expectations, with sub-micrometre resolution for the cavity BPMs.

Linear accelerator commissioning

The front-end electronics for LLRF and high-power RF as well as beam diagnostics, vacuum, and cryo control is installed in shielded racks in the tunnel. The newly developed Micro Telecommunications Computing Architecture (MTCA.4) electronics standard is used throughout the installation. About 250 crates in the tunnel benefit from the enhanced remote monitoring and maintenance capabilities, thus reducing the need for time-consuming on-the-spot interventions to a minimum.

The LLRF commissioning was given highest priority. For each of the RF stations, a sequence of steps had to be performed. Frequency tuning, RF signal checks, coupler tuning, coarse power-based calibration, and closed-loop operation were achieved without beam, and after establishing beam transport (typical 30 bunches, 500 pC), cavity phasing and beam-based calibration followed. While the first RF station in the linear accelerator section L1 needed one week of commissioning, the three stations in L2 could be handed over to operations after another week. Work in L3 then progressed in parallel on all 15 available stations. The possibility to time-shift the RF pulse of the stations with respect to each other allowed the parallel operation of the stations on or off the beam and thus simultaneous beam commissioning.

While the first RF station in the linear accelerator needed one week of commissioning, the three stations in the second accelerating section could be handed over to operations after another week. Work on the third section then progressed in parallel on all 15 of its stations, until finally 22 RF stations were commissioned for initial operation.

The phase and amplitude stability was measured within the regulation loop to be better than 0.01° and 0.01%, respectively. Preliminary beam energy jitter measurements gave an upper limit for the rms relative energy jitter of 10^{-4} at the end of the linear accelerator.

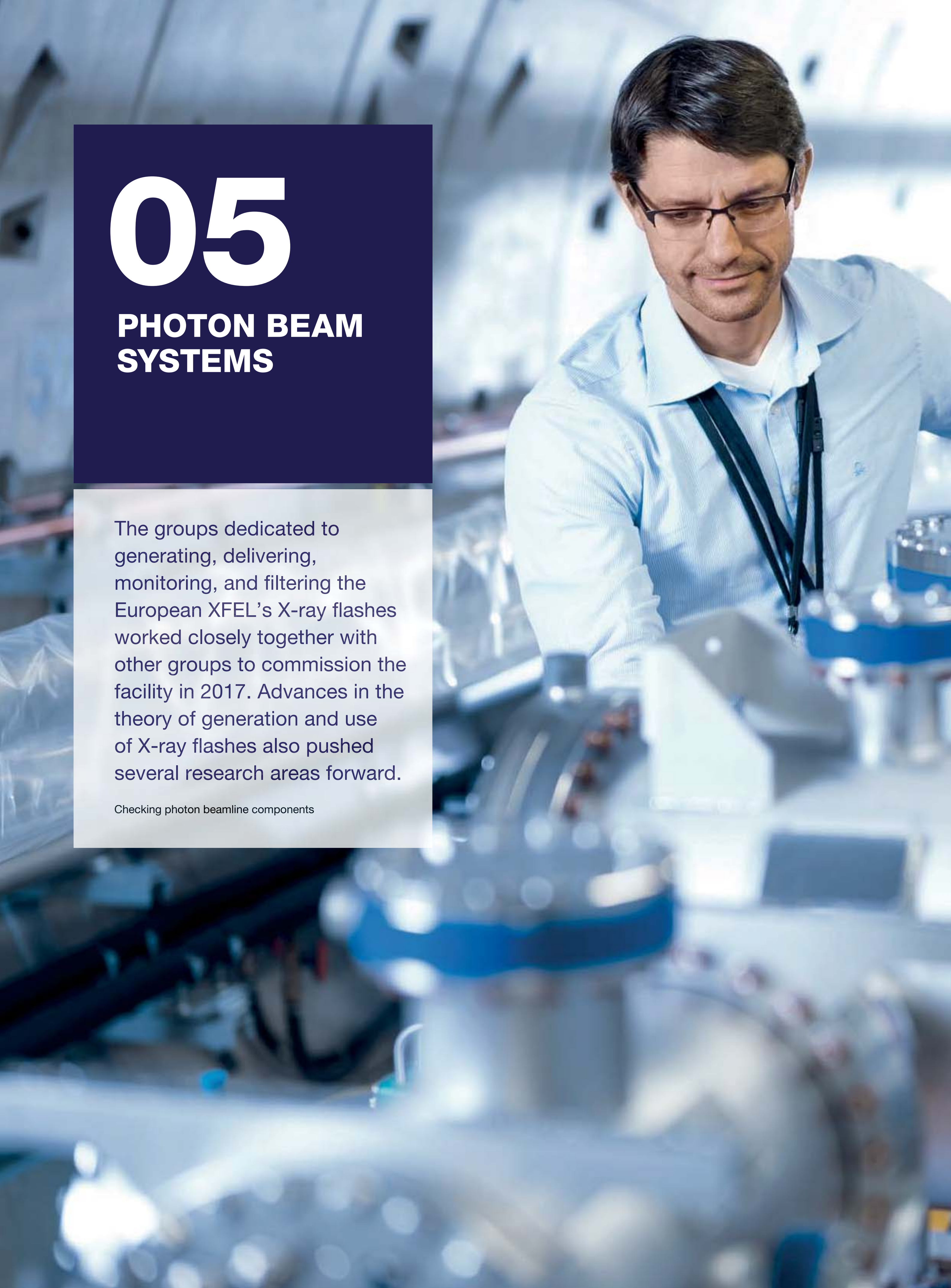
Figure 1 Members of the DESY-led European XFEL Accelerator Consortium celebrate the completion of the accelerator complex and the successful initial commissioning on 2 May 2017.

As of December 2017, 22 out of the 24 installed RF stations are commissioned and reach about 80% of the gradient limit obtained from previous module test results. It is expected that further fine-tuning of the regulation loops will increase this value in the future. The maximum energy reached so far with all available stations on the beam is 14.9 GeV.

First lasing

After obtaining the operation permission for the "northern branch" of the beam distribution system on 26 April, the first electron beam was transported through the 1 km long beam transport line to the SASE1 undulator the next day. At long photon wavelengths, the expected FEL gain length is on the order of a few metres, thus exponential gain would be expected even without a proper aligned undulator trajectory. After some empirical tuning of the compression and the undulator trajectory, first lasing at a wavelength of about 0.9 nm was observed on 2 May.

Further steps to achieve lasing at shorter wavelength included beam-based alignment and more systematic tuning of longitudinal and transverse bunch properties, leading to lasing at 0.2 nm on 24 May. Photon systems commissioning by the European XFEL commissioning team started with the availability of first photons, and the SASE1 beam was guided towards the experiment hutches of the SPB/SFX and FXE experiments on 21 June.

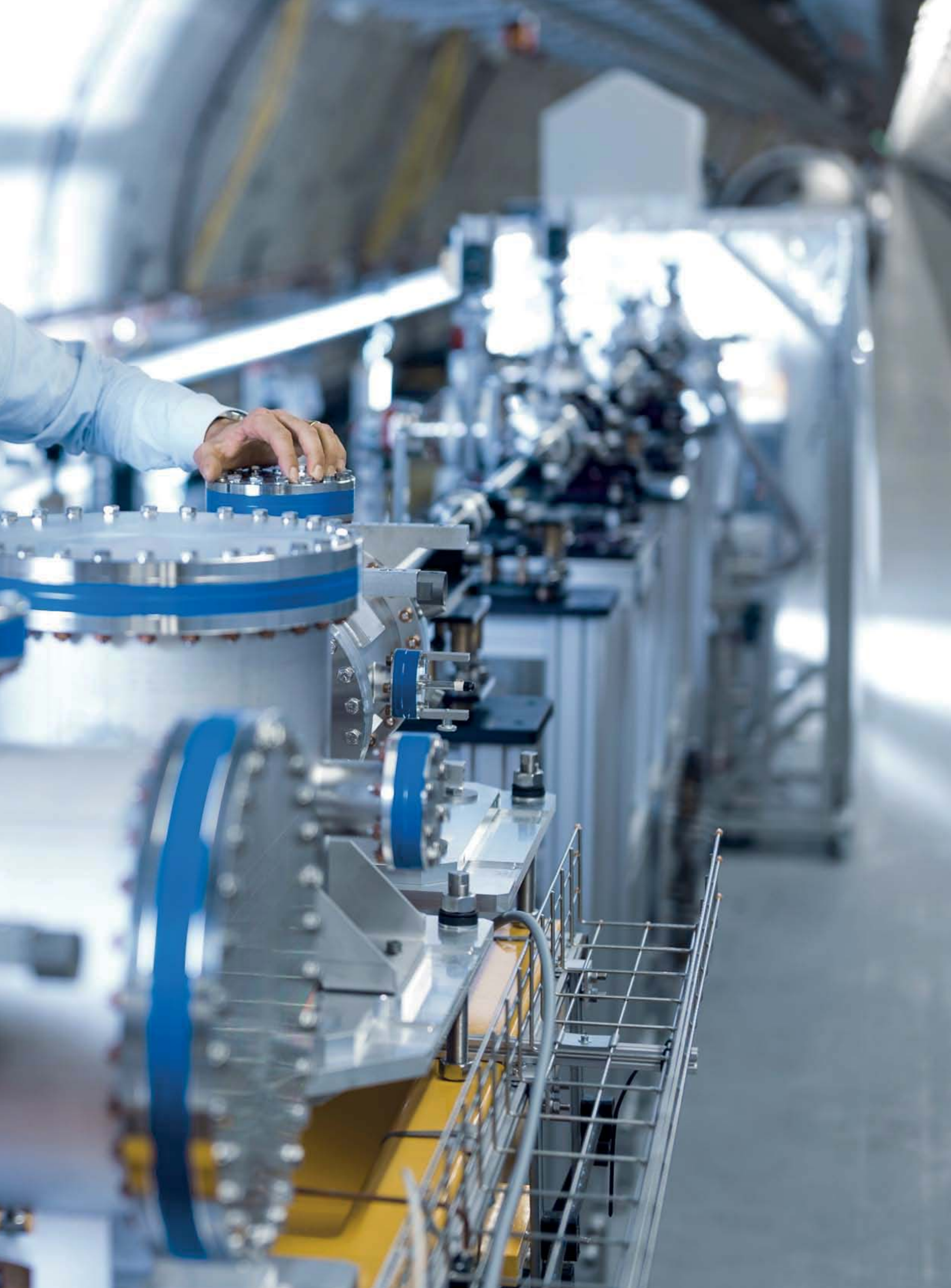


05

PHOTON BEAM SYSTEMS

The groups dedicated to generating, delivering, monitoring, and filtering the European XFEL’s X-ray flashes worked closely together with other groups to commission the facility in 2017. Advances in the theory of generation and use of X-ray flashes also pushed several research areas forward.

Checking photon beamline components



UNDULATOR SYSTEMS

The European XFEL includes three undulator systems—periodic magnetic structures in which the electrons generate the X-ray radiation. The hard X-ray systems, SASE1 and SASE2, are more than 200 m long and comprise 35 undulator segments with a period length of 40 mm. The soft X-ray system, SASE3, is about 120 m long and contains 21 segments with a period length of 68 mm. During the construction phase, the Undulator Systems group has been responsible for the design, production, installation, and commissioning of these systems in close cooperation with DESY. During the operation phase, the responsibilities of the group will include the operation and proactive maintenance of the 91 undulator segments as well as the development of new types of insertion devices, such as a helical afterburner for generating light with variable polarization.

SASE1, SASE2, and SASE3 undulator systems

In 2017, the group focused on getting SASE1 and SASE3 operational, as both systems use the same electron beam. Special care was taken while integrating the device level controls based on Beckhoff hardware and TwinCAT software into the DOOCS accelerator control system. Commissioning with beam concentrated on SASE1, while the beam passed through SASE3 with all undulator gaps kept fully open.

First lasing of SASE1 was achieved on 2 May. Shortly afterwards, great progress was made in steering the electron beam through the 220 m long undulator system while simultaneously preserving the overlap between the electron beam and the laser field to better than 20 μm using the beam-based alignment technique developed by the group together with DESY. Eventually, lasing at photon energies around 9 keV was reliably obtained, enabling user operation to start in September.

In parallel, all hardware components of the SASE2 system were installed in the XTD2 tunnel in very much the same way as in SASE1 and SASE3. In December, the air conditioning system and the enclosure were installed and commissioned. Figure 1 shows a downstream view along the SASE2 undulator system starting at Cell 27. One undulator segment is visible through the transparent wall elements. As of December 2017, SASE2 installation is more than 95% complete.

Helical afterburner for SASE3

The project to build a helical afterburner for SASE3 continued. The European XFEL Council approved a corresponding budget, and a collaboration contract was concluded with PSI. The overall project

Figure 1 View along the SASE2 undulator system

schedule is closely tied to that of the Athos beamline of SwissFEL. Both devices will use the same magnet design, called APPLE-X. The magnet design work was finished. The mechanical re-design work started in October.

First operational experience

Since May 2017, the SASE1 undulator system has been operated using the DOOCS control system. Activities of the group concentrated on providing and monitoring the conditions required for lasing.

Undulators operated in linear accelerators are prone to radiation damage of the NdFeB magnet material, which can result in severe deterioration of the undulator and its radiation properties. This applies especially to the European XFEL, as it is driven by a superconducting accelerator whose duty cycle is more than two orders of magnitude higher than that of accelerators in competing projects. The following precautionary measures were therefore realized: An online dosimetry system using radiation-sensing field effect transistors (RadFETs) was installed on each undulator by DESY and commissioned in cooperation with the Undulator Systems group. The system allows for continuous and time-resolved dosimetry. In front of each system, a diagnostic undulator (DU)—a short U40-type undulator with only eight poles—was installed, which can be easily de-installed, measured in the lab, and re-installed. The DU is a direct indicator for radiation damage. Beam loss monitors between the undulator segments are used during operation. A 200 m long collimator section in front of the undulators is used to remove halo particles from the electron beam.

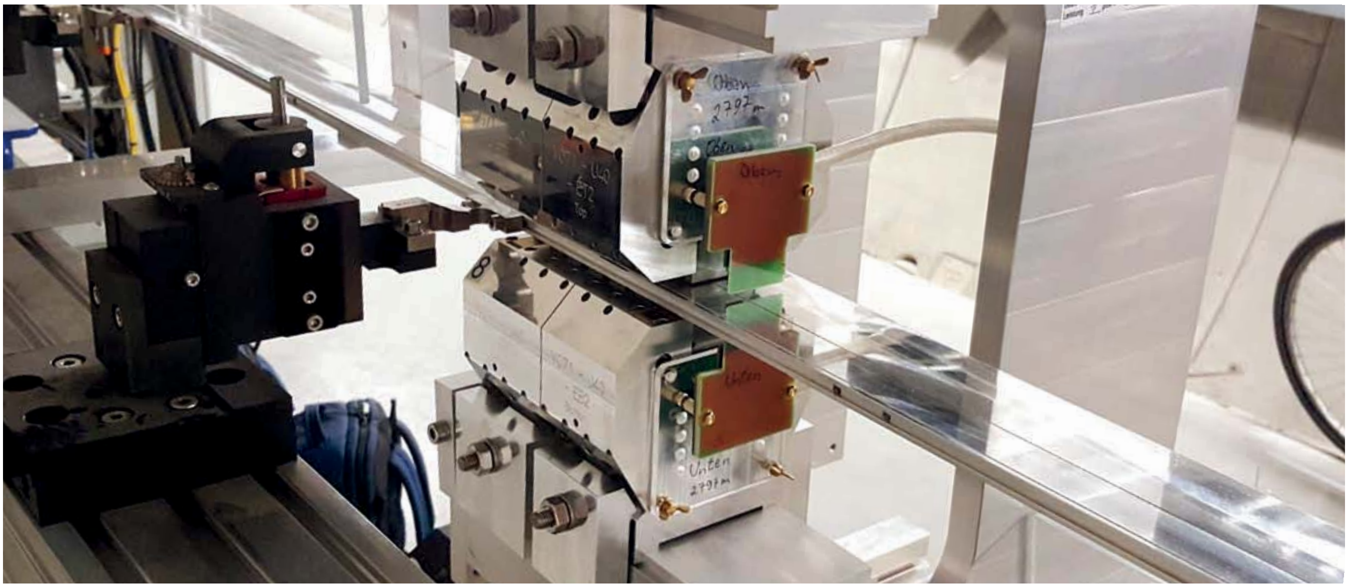


Figure 2 Diagnostic undulator with two RadFET sensors, one on the upper and one on the lower structure

The operation of SASE1 with beam was continuously monitored using the RadFET system. Figure 2 shows the DU located about 5 m upstream of the first SASE1 undulator segment, with two RadFET sensors installed. On the undulator segments, the sensors are mounted in the same fashion.

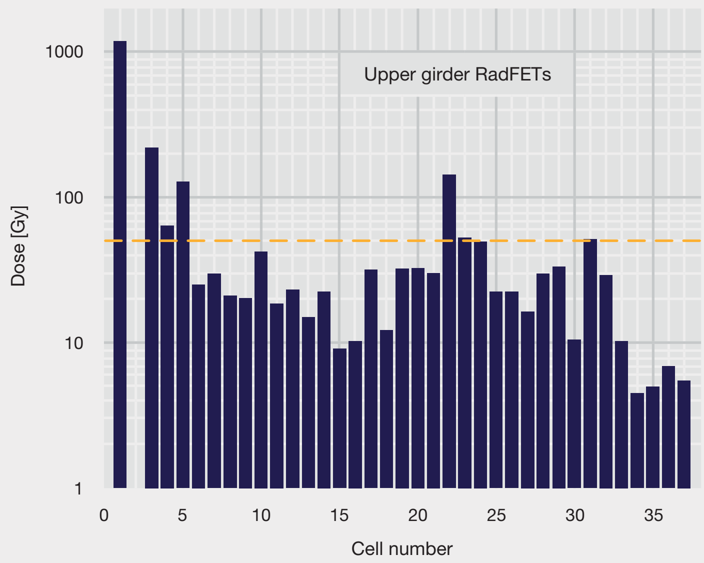


Figure 3 Total doses on the SASE1 undulator segments as of 27 November 2017. The dashed line corresponds to the 50 Gy limit.

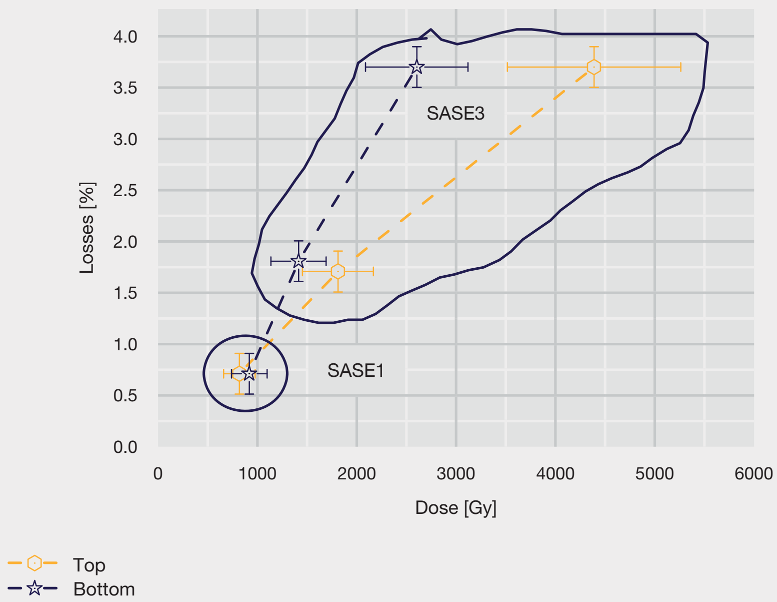


Figure 4 Magnetization losses as a function of doses measured on the SASE1 and SASE3 DUs

Figure 3 shows the total doses on the top RadFETs of the SASE1 undulator segments as of 27 November 2017. Cell 1 corresponds to the DU, which has the highest dose. The 35 undulator segments extend from Cell 3 to Cell 37. As Figure 3 shows, doses vary significantly by almost a factor of 100. This exposure pattern was quite stable. A similar system was operated in SASE3. Here, DU doses were even higher, but the doses on the undulator segments were much lower, as the undulator gaps were kept open.

For direct observation of radiation damage, the SASE1 DU was re-measured once, the SASE3 DU three times. The observed magnetization losses on the poles as a function of the doses are plotted in Figure 4. Losses up to 3.7% were observed. From Figure 4, a degradation rate of 0.91±0.22%/kGy was derived. Assuming an acceptable degradation of $4x10^{-4}$, which corresponds to the Pierce parameter, would result in a tolerable dose of only 50 Gy (dashed line in Figure 3). Dose measurements were made with 2 to 30 electron bunches only, but it was already demonstrated that dose exposure is proportional to the number of bunches.

The doses shown in Figure 3 include the whole period from April to November 2017. A large fraction of the doses is due to commissioning and startup problems. Although dose exposures as of the end of 2017 have been considerably reduced, weekly dose increases are still too high and need to be lowered significantly, especially for long pulse trains.

Plans for 2018

- **SASE1**
  The group will continue to support SASE1 operation. Depending on dose exposure, selected undulators will eventually be de-installed for re-measurements.
- **SASE3**
  The SASE3 system is ready for beam. Commissioning is planned for spring 2018.
- **SASE2**
  SASE2 installation is very advanced. Mechanical commissioning will start at the end of January 2018. Vacuum chambers will be aligned so that all undulator gaps can be closed to 10 000 ± 0.001 mm and limit switches and hard stops will be adjusted. Then the RadFETs sensors and finally the air coil correctors will be installed. SASE2 is expected to be ready for beam by the end of March 2018.
- **Helical afterburner**
  The specific mechanical and magnetic design modifications required for operation in SASE3 will be completed. A prototype of the magnet structure will be tested in the summer. Planning of the electron optics and tunnel infrastructure will start at European XFEL and DESY. The production of the four segments for SASE3 is tied to the production of the Athos undulator at PSI and therefore cannot start before February 2020. Completion is estimated for spring 2021.
- **Undulator operation**
  To support future undulator operation, two types of countermeasures against radiation damage were started and will be continued. As an active countermeasure, radiation losses need to be significantly reduced. The low-loss regions seen in Figure 3 around Cells 15 and 34, which have lower doses by one to two orders of magnitude, show some potential. More efforts including halo studies, beam optical studies, and collimator studies were already initiated by the operation team and will be continued. As a passive countermeasure, a pool of 10% spare undulators is being built up, which can be exchanged against damaged ones, thus precluding voids in the undulator systems. Procurement is in progress. In addition, refurbishment procedures for damaged undulators are being implemented. However, at least one and a half years are needed for full implementation. Avoiding exposure and keeping the undulator systems intact would of course be the best solution. The potential of passive countermeasures is limited to a few exchanges per year once a pool of spares is available. Operational experience in 2018 will show if these plans are sufficient or more effort is needed. ■

Group members
Suren Abeghyan, Majid Bagha-Shanjani, Uwe Englisch, Gang Chen (guest from CAEP, China, not shown), Suren Karabekyan, Peng Li (visiting scientist from CAEP, China, until May, not shown), Yuhui Li, Wei Liu (graduate student from USTC, Hofei, China, May to November, not shown), Joachim Pflüger (group leader), Florian Preißkorn (not shown), Tao Wei (guest from CAEP, China, until May, not shown), Frederik Wolff-Fabris, Marc Wünschel, and Mikhail Yakopov

SIMULATION OF PHOTON FIELDS

The Simulation of Photon Fields (SPF) group studies and helps to implement advanced FEL schemes for improving the characteristics of the X-ray photon beams at the European XFEL. The SPF group also assists other groups with simulations of radiation properties, generates theoretical knowledge, and develops software needed for these tasks.

Progress in 2017

In 2017, the SPF group investigated advanced FEL schemes and supported the implementation of hard X-ray self-seeding (HXRSS) at SASE2 and multiple-colour capabilities at SASE3. The group took part in the commissioning of the European XFEL, both on the accelerator side and on the X-ray optics side, and collaborated with selected users, instrument groups, and support groups, linking together different scientific activities. Finally, the group further developed the software OCELOT, both as a simulation framework and as an online tool used during commissioning and operation.

External collaborations

Aside from internal cooperation, the SPF group collaborated with scientists from other facilities, in particular with DESY researchers Ilya Agapov, Winfried Decking, Martin Dohlus, Gunangyao Feng, Oleg Gorobtsov, Vitali Kocharyan, Shan Liu, Evgeni Saldin, and Igor Zagorodnov. THz generation techniques were studied with Michael Gensch and Serguey Kovalev (HZDR), Sarah Casalbuoni (ANKA), and Vivek Asgekar (Pune University in India), and attosecond generation methods with Alexei Grum-Grzhimailo and Elena Gryzlova (Lomonosov Moscow State University in Russia). Kaishang Zhou (SINAP) and Bohdana Sobko (Lviv University in Ukraine) visited SPF as students. Visits of Nicolay Smolyakov and Evgeny Fomin (NRC KI Synchrotron) were supported by the EDYN EMRAD project, jointly funded by BMBF and the Russian Ministry of Science and Education in the context of the Ioffe Röntgen Institute.

HXRSS at SASE2

SPF group members Svitozar Serkez and Gianluca Geloni continued to support the developments of the HXRSS project at SASE2 within a larger international effort, collaborating on performance simulations with Kocharyan, Liu, and Saldin. The setup is currently under construction and promises nearly Fourier-limited X-ray pulses with a brightness several times higher than that of pulses produced by SASE. The setup will also be used for ultrashort radiation pulse measurements and two-colour generation. Geloni and Serkez also collaborated with Wei Lu (MID group) and Zhou to study synergies of two-colour generation at SASE2 with the MID split and delay line.

Two-colour pulses at SASE3

Together with Michael Meyer (SQS group), Harald Sinn (X-Ray Optics group), and Decking, Serkez and Geloni continued to work on two-colour generation, where different parts of the SASE3 undulator are tuned to and radiating at different wavelengths, while a magnetic chicane and an optical chicane between the two parts provide a variable delay [1]. A proposal to build this device at SASE3 was approved within the Finnish Research Infrastructure (FIRI) project of the Academy of Finland, “Femtosecond-scale dynamics of matter at the European XFEL”, coordinated by Edwin Kukk (Turku University in Finland).

Polarization control

Serkez and Geloni began to develop a method for ultrafast polarization shaping, where a microbunched, energy-chirped electron beam radiates in two consecutive APPLE-X undulators. The result is an X-ray pulse that is linearly polarized, but with a polarization plane rotating at the rate of several tens of teraradians per second.

The group assessed available methods for the production of attosecond pulses at X-ray FELs. They also analysed the importance of the X-ray laser-enhanced attosecond pulse technique, emphasizing possible applications to sequential ionization processes at the European XFEL.

Attosecond pulses

Group members Serkez, Sergey Tomin, and Geloni, together with Meyer, Feng, Gzyzlova, and Grum-Grzhimailo, assessed available methods for the production of attosecond pulses at X-ray FELs. They also analysed the importance of the X-ray laser-enhanced attosecond pulse technique proposed at LCLS, emphasizing possible applications to sequential ionization processes in atoms in the soft X-ray regime at the European XFEL.

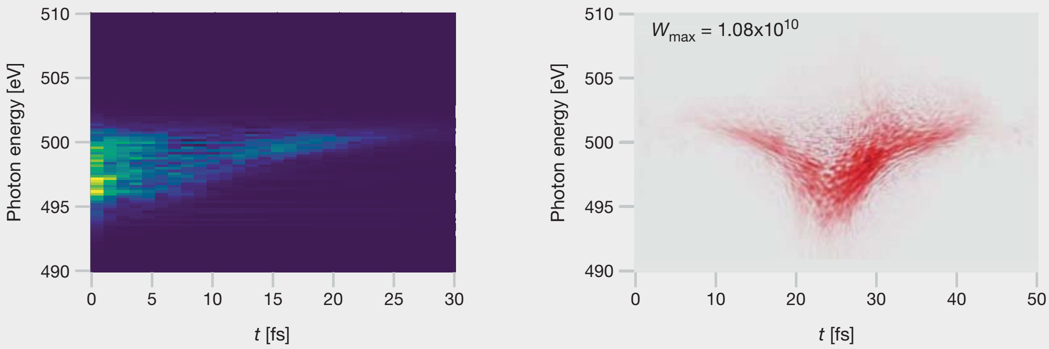


Figure 1 Comparison of a reconstructed autocorrelation function, in this example from simulated spectra (left), and the Wigner distribution function (right). (W_{max} = maximum value of the Wigner distribution function, or brightness)

THz generation

Group members Takanori Tanikawa and Geloni, together with Suren Karabekyan (Undulator Systems group) and Kovalev, Gensch, Casalbuoni, and Asgekar, studied methods for THz generation based on a superconducting afterburner. They showed that superconducting undulator technology can provide THz pulses that can be timed to the X-ray FEL pulses and that feature tuneable frequency (3–30 THz), narrow bandwidth (about 10%), and stable carrier envelope phase, with fields in the MV/cm range.

External seeding

Tanikawa continued to investigate high-gain harmonic generation (HGHG) techniques. He showed that, once implemented in one of the European XFEL empty tunnels, a two-stage HGHG setup could potentially generate few-femtosecond, 80 GW seeded pulses at 2 nm wavelength. Echo-enabled harmonic generation (EEHG) is currently being investigated.

FEL pulse temporal duration monitor

Serkez and Geloni, together with Gorobtsov and Naresh Kujala (X-Ray Photon Diagnostics group), started to develop an FEL pulse temporal duration monitor based on spectral correlations (Figure 1), where information is retrieved from the autocorrelation of the Wigner distribution function of the radiation pulse, which can be calculated starting from an ensemble of spectra. The goal is to obtain an online tool for estimating the temporal duration of FEL pulses based on shot-to-shot spectral measurements.

Software developments

Since 2011, the SPF group has been developing the software OCELOT, a toolkit for designing and operating FEL- and storage-ring-based light sources. It includes modules for electron beam dynamics, spontaneous emission, FEL simulation capabilities with an interface to the code Genesis, and online machine control and optimization. These capabilities can be used independently or together to build complex physical models. The development of OCELOT was supported by the EDYN EMRAD project through 2017.

Tomin, together with Dohlus, Zagorodnov, and Fomin, further advanced the beam dynamics module of OCELOT. The collaboration began to use it for start-to-end and advanced accelerator setup simulations. Serkez considerably expanded the Genesis pre- and post-processor module and developed a semi-analytical estimator of FEL properties.

Commissioning efforts, online tools, and user experiments

Tomin developed OCELOT into an online tool used during commissioning and operation of the European XFEL [2] for both machine control and optimization. The toolkit is also used at FLASH, LCLS, and at the Siberia-2 storage ring of NRC KI. A generic optimizer, an orbit correction tool, and an adaptive feedback tool have shown good performance and flexibility, as well as high potential for future developments.

The SPF group contributed to the commissioning of the European XFEL in both the electron (Tomin) and photon beam systems (Serkez and Geloni) and began to collaborate with users, providing FEL simulations for experiments.

Outlook for 2018

In 2018, the SPF group will deepen studies on novel methods for the production of X-ray pulses with special characteristics. It will be further involved in the commissioning of the European XFEL, in the support of other groups, and in the development of online tools, while continuing to develop software for fulfilling the group's tasks. ■

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This group has received third-party funding from the BMBF for the project "**EDYN_EMRAD – Study of electron beam dynamics and properties of electromagnetic radiation in free-electron lasers and storage ring-based light sources**" (call: Ioffe–Röntgen Institute).

Group members
Gianluca Geloni (group leader), Svitozar Serkez, Takanori Tanikawa, and Sergey Tomin

THEORY

The Theory group develops theoretical methods and data analysis tools to facilitate cutting-edge research at the European XFEL. Cooperation with the instrument groups and external users of the facility ensures that future experiments profit both from recent advances in theory and from the state-of-the-art properties of X-ray FEL sources. Part of the Theory group is based at UHH.

Progress in 2017

In 2017, the members of the Theory group and their collaborators studied electronic spectra of catalytic materials, photoemission spectroscopy (PES) of magnetic materials, the atomic structure of advanced materials, and the nanoscale structure of biological objects. Throughout the year, the group organized the European XFEL Theory Seminar, inviting speakers from Europe and overseas. In late 2017, the group also organized a workshop on “New trends in theory for experiments at advanced light sources”, devoted to recent developments in theoretical methods used for interpreting and designing experiments at FELs and synchrotron radiation sources.

As part of a large international initiative, in close collaboration with Adrian Mancuso of the SPB/SFX group, Jeffrey Donatelli and Peter Zwart of LBNL, and Chun Hong Yoon and Andrew Aquila of LCLS, group member Ruslan Kurta developed and tested a novel approach for imaging biological particles. In cooperation with the group of Ivan Vartanyants at DESY, Boris Ostrovskii of the Russian Academy of Sciences, and Marcus Scheele and Frank Schreiber of the University of Tübingen in Germany, Kurta successfully applied scattering and imaging approaches to studies of the structure and dynamics of liquid crystals, colloidal crystals, and mesocrystals.

As part of a large international initiative, the group developed and tested a novel approach for imaging biological particles.

The Theory group also established several new collaborations. Extending the reach of work on hard X-ray spectroscopy, the group started to collaborate with Ulrike Bösenberg of the MID group on the carbon K-line spectroscopy of lithium-intercalated graphite and continued the existing collaboration with Alexander Guda of the Southern Federal University in Rostov, Russia, and Carlo Lamberti of the University of Torino, Italy, on studying catalytic processes by means of hard X-ray emission spectroscopy. Together with Justine Schlappa of the SCS group and Arata Tanaka of the University of Hiroshima in Japan, the group began to study resonant inelastic X-ray scattering

(RIXS) spectra of spin dimer systems. In collaboration with Samed Halilov of the company Designed Material Technologies in Richmond, USA, and Manuel Izquierdo of the SCS and Sample Environment groups, group member Evgeny Gorelov continued to work on the development and application of theoretical methods for interpreting surface-sensitive X-ray PES experiments [1]. The group extended the scope of PES studies by investigating pnictides, together with Alexander Yaroslavtsev of the SCS group, Oleg Kristanovski of UHH, and Ján Minár of the University of West Bohemia, Czech Republic. Collaborations with Martin Eckstein of the University of Erlangen-Nürnberg in Germany and Viktor Valmispild of UHH on out-of-equilibrium many-body methods and with Andreas Scherz of the SCS group on demagnetization dynamics in FeRh are ongoing.

New approach to imaging biological particles

Based on an idea first proposed over 40 years ago, the new method goes beyond the traditional crystallography and single-particle imaging (SPI) approaches for structure investigations [2]. Using the multi-tiered iterative phasing (MTIP) algorithm, it enables *ab initio* reconstructions of the structure of biological particles from the experimentally measured cross-correlation data (Figure 1). The new approach bypasses the problem of orientation determination encountered in conventional SPI approaches, thereby significantly improving the process of structure recovery. Another advantage of the method is that it does not rely on symmetry constraints, which makes it possible to observe additional features of the particle shape. When applied to scattering data from aerosolized single virus particles measured at LCLS, the approach revealed the nanoscale structure of the viruses, with deviations from

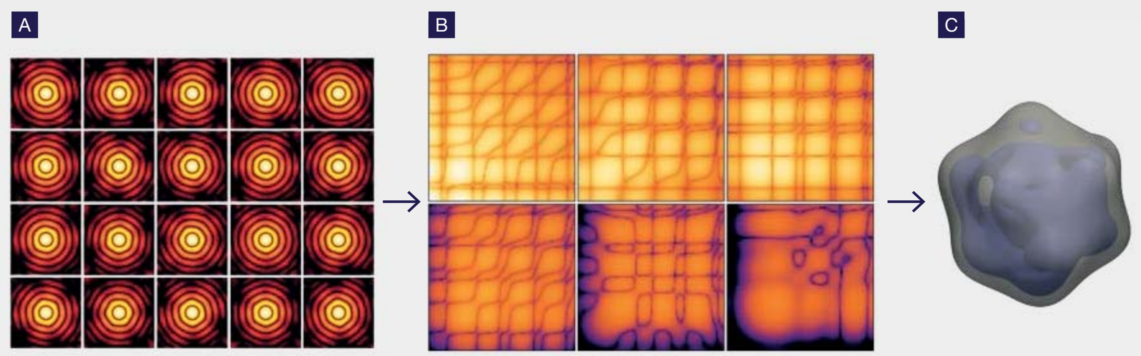

Figure 1 Schematic illustration of the novel imaging approach. In an X-ray FEL experiment, many X-ray diffraction snapshots (A) are measured from reproducible biological particles. This large X-ray data set is then reduced to a much more compact set of correlation data (B), which represents a comprehensive fingerprint of the 3D structure of a particle. The correlation data are used to reconstruct the 3D structure of a particle (C) by two methods, model-based structure analysis and iterative phase retrieval by MTIP.

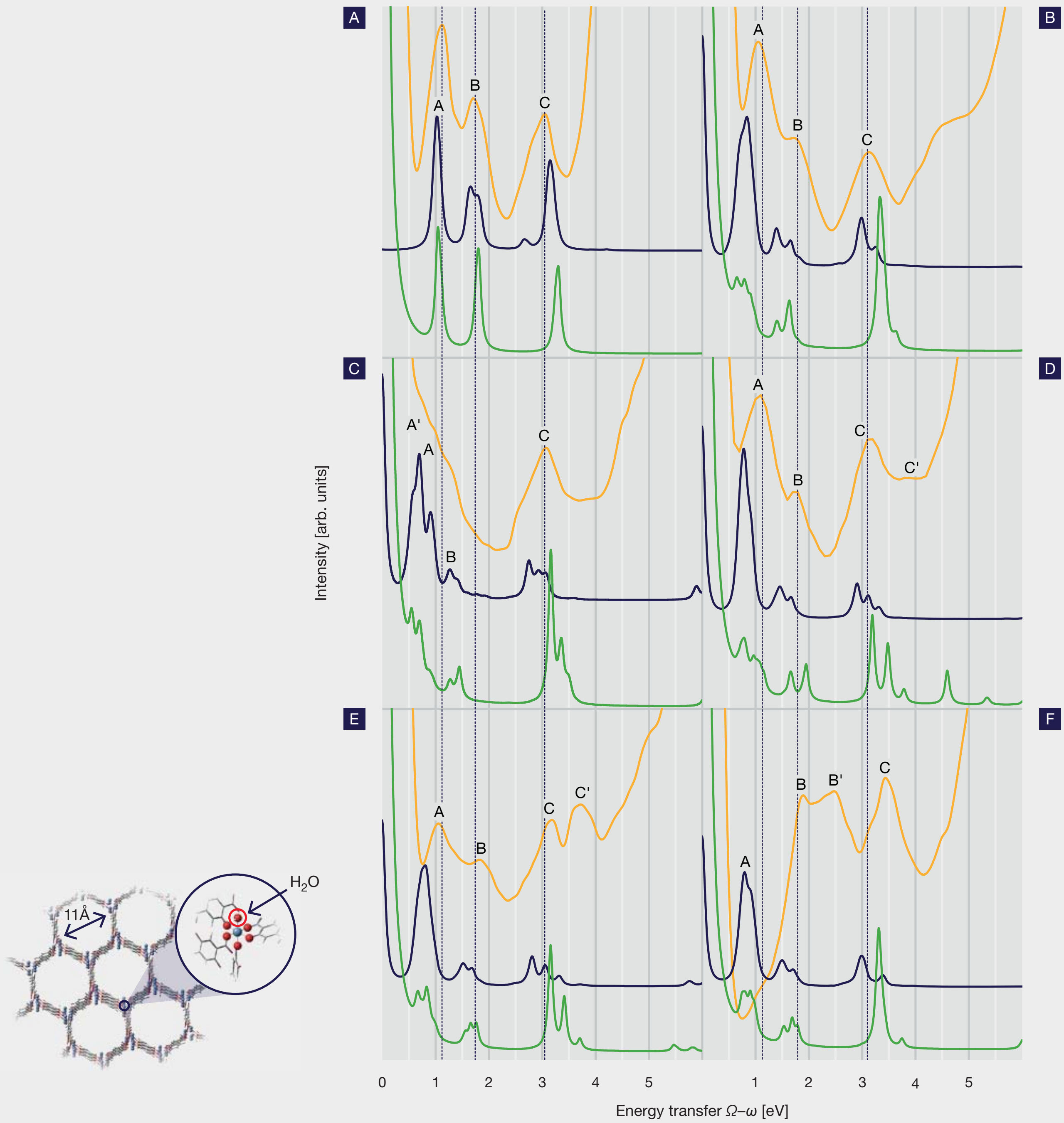

Figure 2 Studies of the metal–organic framework CPO-27-Ni.
Left Crystal structure. The position of water as an admolecule at the nickel centre is shown in the inset.
Right Comparison of experimental resonant-valence-to-core X-ray emission spectroscopy (RVtC-XES) spectra (yellow), simulated RVtC-XES spectra (blue), and simulated non-resonant inelastic X-ray scattering (NIXS) spectra (green). (A) NiO, the reference system. (B) CPO-27-Ni + H_2O. (C) CPO-27-Ni. (D) CPO-27-Ni + CO. (E) CPO-27-Ni + H_2S. (F) CPO-27-Ni + NO.

the expected icosahedral symmetry. It is envisioned that the full potential of the approach can be explored in multiple-particle experiments at X-ray FELs, with the aim to increase the resolution of the recovered structures and to reduce the radiation damage of biological particles.

X-ray spectroscopy of correlated materials

Adopting the Korringa–Kohn–Rostoker (KKR) method, the Theory group performed calculations of photoelectron spectra for imperfect (001) surfaces of $LaCoO_3$ perovskite. Alongside KKR, the group applied a realistic many-body density functional theory plus dynamical mean-field theory (DFT+DMFT) method in order to understand the behaviour of transition metal pnictides from angle-resolved PES experiment data. The recently developed realistic many-body cluster approach was used to describe RIXS dispersion in the spin dimer system $TlCuCl_3$. These projects are being carried out in collaboration with the SCS group. The group further considered possibilities to study catalytic processes in the metal–organic framework CPO-27-Ni ($C_8H_6Ni_2O_3$) *in situ* by means of hard X-ray spectroscopy (Figure 2 right, Panel (B)) and calculated the hard X-ray absorption spectra for lithium-intercalated graphite.

Non-equilibrium correlated systems in strong electric fields

Using the recently developed microscopic approach to non-equilibrium many-body dynamics of the generic Hubbard model, the Theory group studied the response of correlated materials to strong ultrashort electromagnetic pulses. In particular, the group investigated the response of the electronic structure of a two-dimensional lattice to a strong electromagnetic pulse as a function of the pulse parameters (duration, strength, frequency, and polarization).

The group studied the response of correlated materials to strong ultrashort electromagnetic pulses. In particular, the group investigated the response of the electronic structure of a 2D lattice to a strong electromagnetic pulse as a function of the pulse parameters.

In the framework of its collaboration with the SCS group, the Theory group continued to study the demagnetization process in FeRh during pump–probe experiments by means of time-dependent density functional theory.

Outlook for 2018

In 2018, Kurta will focus on the further extension and application of scattering and imaging approaches for X-ray FELs. He will contribute to X-ray data analysis and simulations within existing joint projects at LCLS and European XFEL. He also envisions establishing new collaborations with external groups interested in biological imaging with X-ray FELs. Gorelov will extend existing collaborations with the SCS group and establish a new one with the Sample Environment and FXE groups. The ongoing collaborations devoted to hard X-ray spectroscopy will continue. The further development of the out-of-equilibrium DMFT method will offer the possibility to describe PES experiments for correlated materials with temporal resolution, taking into account details of the pump pulse. ■

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X-RAY OPTICS

The X-Ray Optics group is responsible for the X-ray optics in the photon tunnels, including the development of mirror systems, monochromators, and further beamline elements, such as shutters, slits, and collimators. In 2017, the X-ray beam transport system for the SASE1 undulator beamline was commissioned and put into operation.

Progress in 2017

Until the end of April, the X-Ray Optics group focused on completing the installation and technical commissioning of the SASE1 X-ray beam transport system. After first lasing was achieved on 2 May, the commissioning of the SASE1 transport system with beam started on 12 May in collaboration with the DESY Accelerator team, the European XFEL–LCLS Photon Commissioning team [1], and the European XFEL X-Ray Photon Diagnostics group. By 23 June, the X-ray laser beam could be delivered into the experiment hutches of the SPB/SFX and FXE instruments, where it was then used to commission the instruments. The first user experiments at the SASE1 beamline started on 14 September, about four months after the first lasing.

Changes to the group

In 2017, group member Natalia Gerasimova switched to a joint appointment in the SCS instrument group and the X-Ray Optics group. Xiaohao Dong left the X-Ray Optics group at the end of the year to start his new appointment at the Shanghai Synchrotron Radiation Facility in China. Vivien Sleziona completed her bachelor thesis (“Development of a Pitch Oscillator for Hard X-Ray Self-Seeding at the European XFEL”) under the supervision of Wolfgang Hillert (UHH). Valerija Music joined the group as a master student under the supervision of Christian Schroer (UHH).

Commissioning of the SASE1 X-ray beam transport system

The most essential components of the X-ray beam transport system are the offset and distribution X-ray mirrors, the slits, the solid attenuator, and—from the point of view of X-ray diagnostics—the imagers and the gas monitor systems. Those components were commissioned first, allowing a quick alignment of the FEL beam right to the end of the about 1 km long SASE1 beam transport system. The stepper motors and the vacuum systems are controlled using Beckhoff programmable logic controller (PLC) systems (whose firmware was developed by the

Advanced Electronics group) and Karabo software (developed by the Control and Analysis Software group). An overview of the SASE1 beam transport system as it appears on the Karabo top-level graphical user interface is shown in Figure 1.

During the 2017 commissioning period, scanning capability and data acquisition tools were still being developed and not yet available for commissioning activities. Instead, the beam properties were optimized and characterized iteratively with imagers and X-ray gas monitor systems. The first beam observed on the screen in front of the SPB shutter at the end of the photon tunnels is shown in Figure 2. The vertical beam size of 3.2 mm agreed well with the expected beam size obtained from the theoretical divergence at the photon energy of 6.2 keV. In the horizontal direction, the beam size should be the same as in the vertical direction. However, it was found to be enlarged by more than a factor of two (see discussion below).

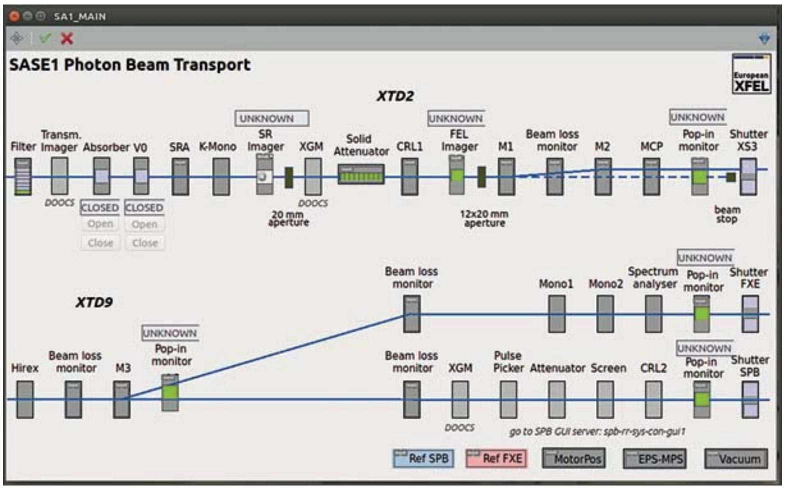


Figure 1 Top-level panel (“scene”) of the Karabo control system for the SASE1 X-ray beam transport system. The first element is the “Filter” on the top left, located about 180 m behind the source point of the SASE1 undulator. Consequent beamline components are then shown from left to right, continuing in the second line and branching off at the “M3” position into the FXE and SPB beamlines. The shutters “FXE” and “SPB” are located about 900 m from the source position in front of the experiment hall. (Key: V0 = valve, SRA = synchrotron radiation aperture, K-Mono = *K* monochromator, SR = spontaneous radiation, XGM = X-ray gas monitor, CRL = compound refractive lenses, M = mirror, MCP = multichannel plates, Hirex = high-resolution hard X-ray single-shot spectrometer, Mono = monochromator)

By 23 June, the X-ray laser beam could be delivered into the experiment hutches of the SPB/SFX and FXE instruments, where it was then used to commission the instruments. The first user experiments at the SASE1 beamline started on 14 September, about four months after the first lasing.

The halo visible in light blue in Figure 2 around the FEL beam results from spontaneous radiation, predominantly at the same photon energy of 6.2 keV as the lasing peak. Sharp edges and cuts in this halo originate from the SPB solid attenuator immediately in front of the screen. The vertical stripes visible within the FEL beam are caused by polishing errors and edge effects of the mirrors M1 and M2. Distortions of this magnitude were expected from wavefront simulations done with hypothetical mirror polishing errors in the conceptual design report for the X-ray optics and beam transport system [2]. The fact that the polishing errors lead only to small distortions in the beam profile is an indication of the excellent quality of the mirror polishing.

An unexpected problem that was noticed in the early commissioning phase was related to the large horizontal beam size shown in Figure 2: It originated from the setting of the bender of the M2 mirror, which caused a concave radius of the mirror surface of about 20 km. This bending of M2 led to an intermediate horizontal focus behind the M3 mirror and consequently a diverging of the beam towards the SPB screen.

This relatively strong bending of M2 could not be corrected by tuning the bender, as was intended in its design. The reason turned out to be the ambient temperature in the XTD2 undulator tunnel where the M2 mirror is located: The calibration of the bender system was done in the metrology laboratory at about 21°C, while the average temperature in the tunnel at the M2 location reached 28°C during operation. According to the previously characterized temperature dependence of the bending mechanism (see *European XFEL Annual Report 2015*, pp. 100–103), this large temperature difference was consistent with the observed strong

References

[1] Members of the 2017 Photon Commissioning team:
Karen Appel, Ulrike Bösenberg, Gianluca Geloni, Natalia Gerasimova, Markus Ilchen, Manuel Izquierdo, Andreas Koch, Zuzanna Konopkova, Naresh Kujala, Yuhui Li, Marc Messerschmidt, Liubov Samoylova, Svitozar Serkez, Harald Sinn, Marcin Sirkorski, Sergey Tomin, Peter Zalden, and, as guests, Valerija Music, and Yiping Feng (LCLS)

[2] Conceptual Design Report: X-Ray Optics and Beam Transport
H. Sinn, J. Gaudin, L. Samoylova, A. Trapp, G. Galasso
XFEL.EU TR-2011-001 (2011)
doi:10.3204/XFEL.EU/TR-2011-002

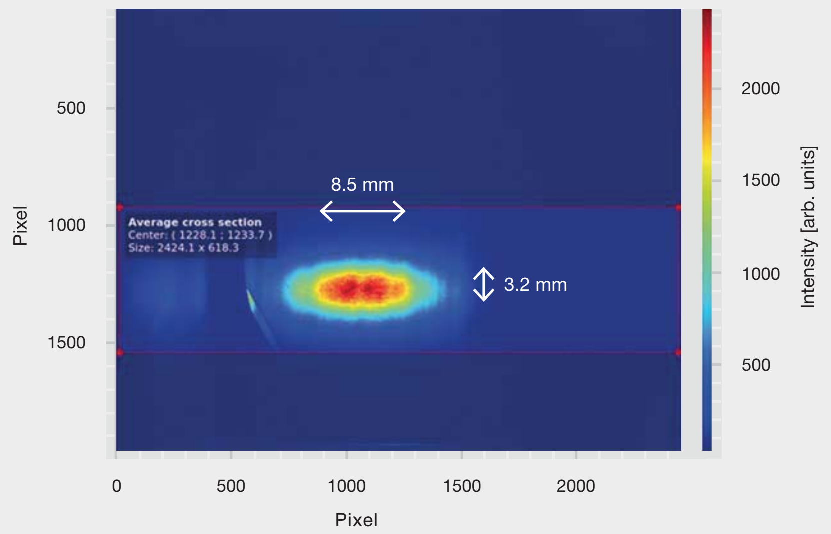


Figure 2 First X-ray beam arriving on the SPB screen in front of the experiment hall on 27 May 2017

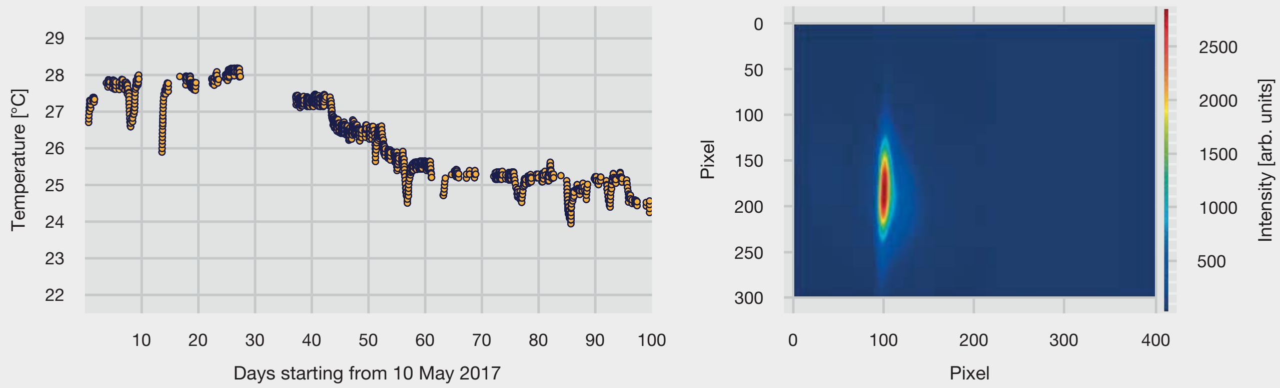


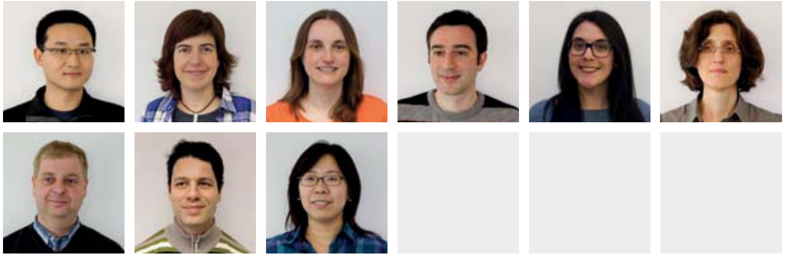
Figure 3
Left Ambient temperature in the XTD2 tunnel close to the M2 position. The plot starts on 10 May 2017, after which the tunnel temperature was lowered by 3°C over a period of two months to enable the full functionality of the M2 bender system.
Right The X-ray beam after the correction.

mirror bending. The solution was then to lower the tunnel temperature in steps until eventually, at 25°C, full functionality of the bending system was achieved (Figure 3).

Outlook for 2018

In early 2018, photon commissioning of the SASE3 beamline system will begin. The SASE2 beam transport system will be technically commissioned, and photon commissioning will start towards the middle of 2018. ■

This group has received third-party funding from the European Union's Horizon 2020 Research and Innovation Programme for the project "**CALIPSOplus - Convenient Access to Light Sources Open to Innovation, Science and to the World**" (Grant Agreeement No. 730872) and from the **TR-XPRES** user consortium (UHH and the University of Kiel).



Group members
Immo Bahns (Ph.D. student, UHH, not shown), Xiaohao Dong, Idoia Freijo Martín, Natalia Gerasimova (jointly with the SCS instrument group, not shown), Nicole Kohlstrunk, Daniele La Civita, Valerija Music (master student), Liubov Samoylova, Harald Sinn (group leader), Vivien Sleziona (bachelor student, not shown), Petr Smirnov (guest, not shown), Antje Trapp (not shown), Maurizio Vannoni, and Fan Yang

VACUUM

The Vacuum group is responsible for designing, installing, and operating the photon vacuum system between the undulators in the underground tunnels and the scientific instruments in the experiment hall. This task includes the support of the instrument groups in vacuum-related issues. To ensure reliable operation of the facility, the Vacuum group sets standards and guidelines for the design and handling of vacuum components.

Progress in 2017

The focus for the first part of the year was exclusively on completing the SASE1 beamline in preparation for the start of user operation in September. In addition, the Vacuum group built up and commissioned the SASE3 vacuum beam transport system and started the installation in the SASE2 tunnels XTD1 and XTD6.

The Vacuum group supported the instrument groups during installation of beamline components and helped with the simulation and design of beam transport systems inside the experiment hall and of vacuum roughing lines for the instrument setups.

Important progress was made on the vacuum control systems. The SASE1 control system was put into operation in early 2017, with only small modifications necessary during the year. The SASE3 system was wired up, and the group defined the vacuum interlock conditions and the graphical user interface to the control software.

Changes to the group

In February 2017, Eike-Christian Martens left the group to work for the HED instrument group. In June, Phil Schneider finished his bachelor thesis on the characterisation of a fine dosing valve for ultrahigh-vacuum (UHV) applications (University of Applied Sciences Lübeck in Germany). He continued to work for the group as a vacuum engineer from July on, focusing on the SASE2 tunnel installation. Also in July, Michaela Petrich joined the group as a vacuum engineer, mainly working on the beamline control system. Two student assistants joined the group in 2017, working on cleaning vacuum parts, managing assets, and assisting the staff during installation of the beam transport systems.

Figure 1 Preparation of a non-evaporable getter (NEG) pump prior to installation on the vacuum chamber of the SASE3 soft X-ray monochromator

Beam transport systems

The vacuum system of the SASE1 beamline and its control system were successfully commissioned in early 2017 to allow first lasing in the spring, followed by early user operation in September.

In 2017, the Vacuum group finished the installation of all the vacuum beam transport components for the SASE3 photon beam transport system inside the XSDU2 dump shaft and the XTD10 tunnel (Figure 1). The electronic racks were equipped with all beamline control hardware and programmable logic controller (PLC) crates, which were prefabricated in the vacuum laboratory. Cables from the racks to the devices were installed by an external company and connected. The wiring of many beamline components was performed in 2017 in order to allow first operation of the SASE3 beamline in spring 2018. Shortly after installation, the Vacuum group, in close collaboration with the Advanced Electronics group, started local testing of the individual electronic devices in the tunnels before the devices were added to the PLC loop. Subsequently, integration into the Karabo control system framework and interlock tests were performed to enable reliable remote operation of the vacuum system.

All components of the SASE2 vacuum system were delivered in 2017 and have been partly installed (Figure 2). Work on SASE2 was performed whenever the high priority given to work at the beamlines SASE1 and SASE3 allowed. The photon beamline components in XTD1 were installed and are now ready for technical commissioning (Figure 3). Furthermore, the external partner Pfeiffer Vacuum Components & Solutions delivered almost 1000 m of DN100 vacuum beam pipe. A large number of 18 m long pipes were joined together in XTD6 under cleanroom conditions by orbital welding, as was done for SASE1 two years ago.

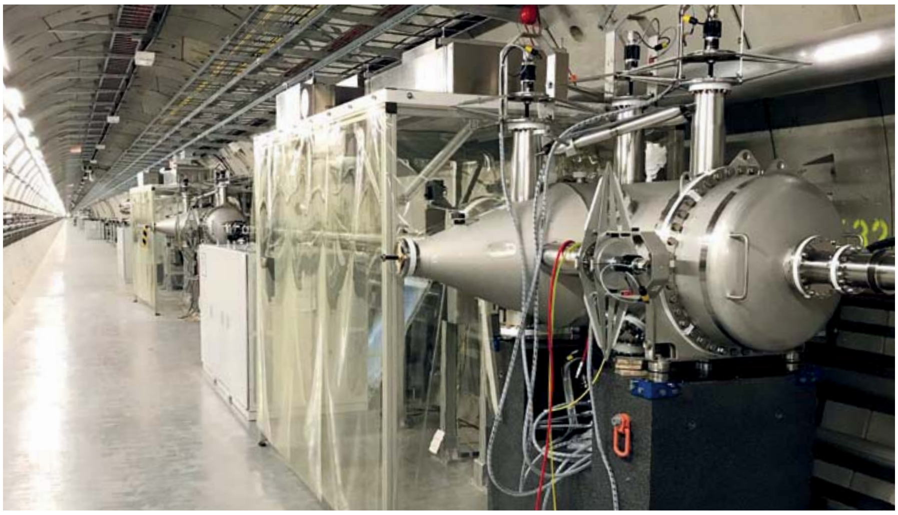


Figure 2 Downstream view into XTD6 with vacuum chamber of Mirror 1 and adjacent cleanroom for installation of the mirror substrate

SASE3 gas attenuator

After the first technical commissioning, and despite limited access to XTD10 due to the start of operation in May, the long SASE3 gas attenuator beamline sector was successfully brought to “ready for beam” status. Besides a second fine-alignment campaign of the numerous small clear apertures inside it, the vacuum system was thoroughly tested, ensuring that UHV conditions are attainable and that the system can be remotely controlled. In the first months of 2018, the system will be prepared for sufficient performance in terms of beam intensity absorption during the first SASE3 commissioning with beam and subsequent operation.

After the first technical commissioning, the long SASE3 gas attenuator beamline sector was successfully brought to “ready for beam” status.

Differential pumping systems

Following up on the previously deployed differential pumping systems for noble gases, the last modules were successfully installed in the SASE2 beamline. The customized versions of the girder-mounted design—hanging and bridge version (Figure 3)—were installed in XTD1 and will be technically commissioned in February 2018. Finally, with the installation of the differential pumping system surrounding the X-ray gas monitor in the HED beamline in XTD6, all 10 systems will be set in their final position.

Figure 3 Installation of a differential pumping system in XTD1 with the help of the DESY Hall Service and Transport group. The electron beamline is already installed on the right side of the tunnel.

Scientific instrument support

Besides the beamline installation activities in the photon tunnels, the Vacuum group intensified work on projects supporting the instrument groups. For example, the group performed studies and compiled a concept for a sonic delay line to be installed at the SPB/SFX instrument to prevent damage on a detector in case of an accidental X-ray window break. The group also facilitated the assembly of vacuum components in the SPB/SFX optics hutch. The SCS and MID groups consulted the Vacuum group regarding the design of a central roughing line for their experiment hutches.

The group carried out residual gas analysis on different components and performed leak tests in the vacuum lab, where maintenance and repair of vacuum pumps also took place. Together with the X-Ray Optics and DESY Radiation Protection groups, the Vacuum group performed studies to prove the concept of a burn-through monitor for the beamline front-ends.

Group members
Bianca Dickert, Massimiliano Di Felice, Martin Dommach (group leader), Janni Eidam, Denis Finze (not shown), Henrik Liebel (student, until February), Eike-Christian Martens (until January), Frederik Meyn, Liona Multhaup (student, not shown), Maik Neumann, Joshua Ohnesorge (student, not shown), Michaela Petrich (not shown), Benoit Rio, Phil Schneider, Jannis Schottroff (not shown), and Raúl Villanueva Guerrero

Outlook for 2018

The large amount of installation activities in the tunnels will continue in 2018. The Vacuum group will complete the SASE2 beam transport system, while SASE1 is in operation and SASE3 is commissioned. The start of operation of the SASE3 gas attenuator, which is the largest device designed and built by the Vacuum group, is planned for spring 2018. Activities for commissioning and further development of the beamline control system together with the X-Ray Optics, Advanced Electronics, and Control and Analysis Software groups will go on. The group will also continue to provide vacuum-related support to the instrument groups. ■

X-RAY PHOTON DIAGNOSTICS

The X-Ray Photon Diagnostics group is responsible for designing, constructing, commissioning, and operating the diagnostic devices that monitor the X-ray photon pulses generated by the European XFEL. The main success of the group in the first half of 2017 was the commissioning with beam of the SASE1 diagnostics, the support of SASE tuning, and the detection of first lasing in SASE1. In the second half of the year, the group commissioned further devices and delivered more powerful diagnostics for machine operation and the first user experiments.

Changes to the group

In January 2017, Theo Maltezopoulos joined the group as a physicist for gas-based diagnostics with a focus on the X-ray gas monitor (XGM).

Gas-based online diagnostics

The XGM measures the photon pulse energy and beam position in single-shot, pulse-resolved, and non-invasive mode. It is used by the machine operators for tuning of the SASE X-ray generation process and by the experiments for sorting data according to the fluctuating SASE energy. The group has received a total of six XGM units from DESY, where they were designed and constructed.

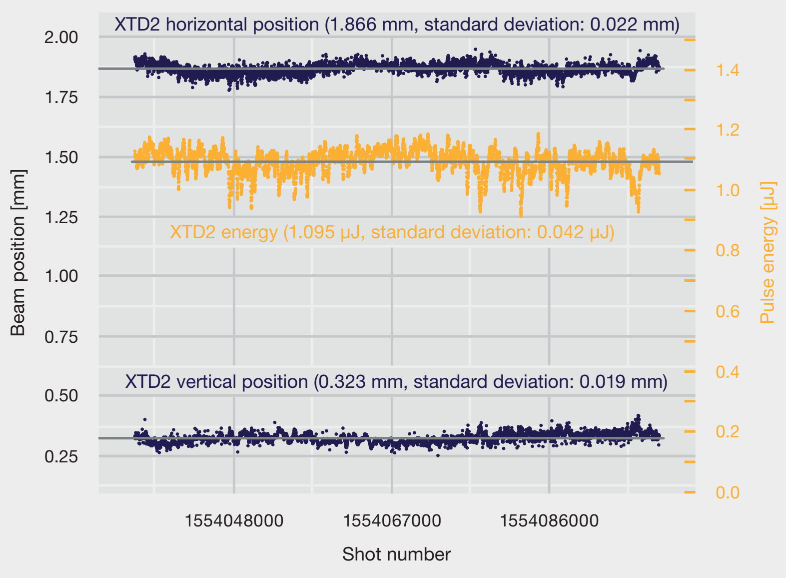


Figure 1 Photon pulse energy and beam position measurements in SASE1 (XTD2) at a wavelength of 0.133 nm. Values up to 1500 µJ at photon energies around 9 keV were routinely obtained.

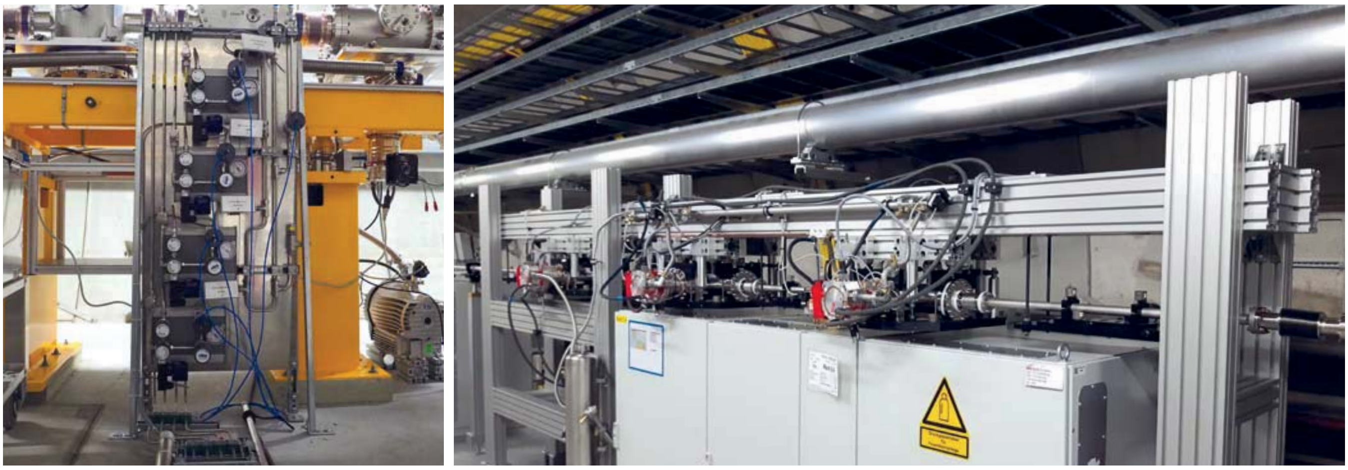


Figure 2 Infrastructure for gas-based online diagnostics.
Left Gas panel in XTD2 at the XGM.
Right Hanging differential pumping stage in SASE3.

In early 2017, two XGMs in the SASE1 tunnels XTD2 and XTD9 were made fully operational, including low-level control by programmable logic controllers (PLC), high-level control by Karabo for the vacuum part, and implementation into the DOOCS accelerator control system. In spring 2017, SASE1 commissioning started successfully. Both XGMs were operated 24/7 and used for SASE tuning and later on for data streaming to user data acquisition (Figure 1). The XGM in SASE3 (XTD10) was mounted to the beamline, fully cabled, and integrated into PLC, Karabo, and DOOCS. It is ready for first SASE3 X-ray generation, expected in early 2018. In summer 2017, two more XGMs were placed into the tunnels XTD1 and XTD6 for SASE2. Integration into the local infrastructure is ongoing.

After its return from an experimental campaign in the USA, the photoelectron spectrometer (PES) was disassembled, and the microchannel detectors and drift tubes were investigated and repaired or replaced where necessary. Improvements, such as gate valves and water-cooling, finally allowed the installation of the PES in XTD10, where it was aligned and connected to the beamline. Several components and parameters, such as gate valves and voltages, can already be controlled in Karabo.

An extensive rare-gas supply system provides four highly pure gases (krypton, neon, xenon, and nitrogen) to the online diagnostic devices in all photon tunnels. Pressurized air, data cables, bypass, and injection connections were implemented. This gas supply was available for the first lasing in SASE1, and it has been operating smoothly ever since. The gas panels are connected to their respective devices in the tunnel and remotely controlled by Karabo in all technically commissioned tunnels. The system is also controlled by the building control system for personnel safety reasons. The initial selection of highly purified gases, which included argon instead of neon, was modified, with argon replaced for operational reasons.

The differential pumping stages (Figure 2) separating the XGM and PES vacuum are hanging below a bridge across an electronics rack. They were completely installed in SASE3, despite the complication that after closure of the tunnel, it was only possible to work there for short periods of time during accelerator downtimes. The entire device is fully controllable by Karabo, and final commissioning will be performed when the PES is fully operational (planned for the April 2018 shutdown).

Invasive diagnostics

The various imagers help to align the photon beam downstream of mirrors and other optical components, to understand unexpected effects, and to characterize beam properties, such as the position, size, and shape of the beam (see Chapter 8). In 2017, the focus was on the installations and commissioning in the tunnels. All 25 diagnostic imagers are now installed in the SASE tunnels (see Ref. [1] for a review of the photon system installations). The imagers in SASE1 perform as expected. No radiation damage has been observed so far. The commissioning of the imagers in the other beamlines continues.

Group members Andreas Koch and Naresh Kujala were members of the European XFEL photon commissioning team, supporting the alignment and optimization of the photon beam from the first lasing until user operation in September and beyond.

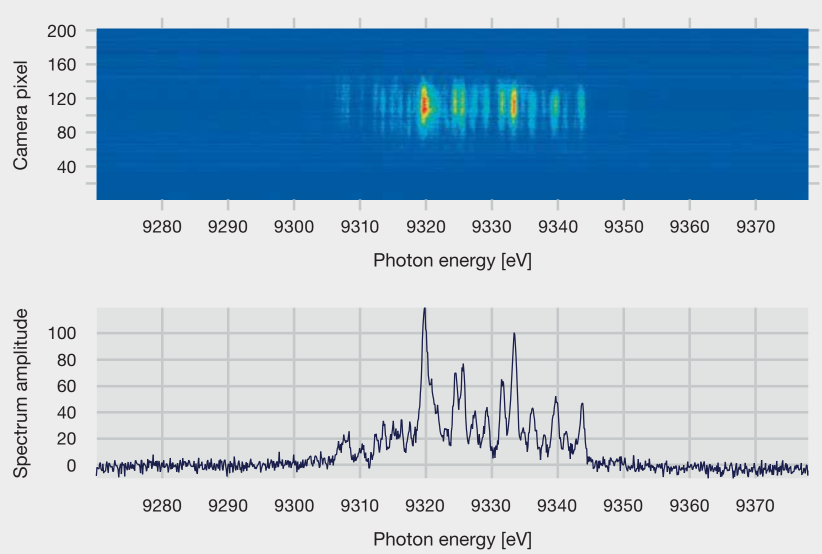


Figure 3 Single-shot SASE spectrum at 9.33 keV.
Top Spectrum (transverse beam profile vs. photon energy).
Bottom Cross-section lineout at the centre of the top plot.

The high-resolution hard X-ray (HIREX) diagnostic single-shot spectrometer, which was installed in the SASE1 tunnel XTD9 in 2016, was commissioned with SASE lasing beam in August 2017. HIREX has two main parts: a grating and a crystal chamber. Figure 3 shows a single-shot spectrum of a SASE pulse in single-bunch mode, recorded using a bent (r = 75 mm) Si111 crystal and reflection 333. The machine parameters for this spectrum were 14 GeV electron energy, 9.330 keV photon energy, and 400 μJ pulse energy.

The filter chambers in all three SASE beamlines are installed and under vacuum. The K monochromator installation in the SASE3 beamline is completed, and technical commissioning has started. The vacuum installation of the K monochromator in SASE2 is finished. Two commissioning experiments were performed with the SASE1 K monochromator and spontaneous-radiation imager in July and November 2017. Wolfgang Freund, Jan Grünert, Andreas Koch, and Jia Liu tested several undulator commissioning methods and developed image-processing routines for calculating the undulator K value and the beam pointing of single undulator segments.

The photon arrival time monitor prototype is assembled and will be installed in the SPB/SFX experiment hutch in 2018. Meanwhile, ongoing temporal diagnostics activities [2] include a collaboration on terahertz/infrared streaking with DESY, LCLS, and TU München, measurements of SASE pulses from FLASH and LCLS, and material response studies, including material excitation, cascading, and relaxation dynamics, by theoretical analysis with the theory group of Beata Ziaja at DESY and experimentally under irradiation with high-repetition-rate X-ray pulses from the European XFEL.

Outlook for 2018 and beyond

The year 2018 will again be challenging for the X-Ray Photon Diagnostics group, with an intricate combination of tasks and milestones: SASE1 diagnostics have to be operated to prepare and support user runs—while, at the same time, SASE3 systems are commissioned with beam and SASE2 systems are installed and technically commissioned. The group will support first lasing in SASE3 and later SASE2. Towards the end of 2018, the group will gradually move from final installations and commissioning to regular operation of the installed systems and exploration of the full design parameter range, closely following the progress of the electron beam accelerator commissioning. This will continue into 2019 until full performance of all systems is achieved. In parallel, the group will explore possibilities to retrofit imagers with single-pulse gating and will be developing and constructing additional and new diagnostic devices, such as a HIREX for SASE2, THz streaking–based pulse length monitoring, a PES for hard X-rays, and wavefront sensors. ■

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Appl. Sci. **7** (6), 592
doi:10.3390/app7060592

[2] **Advanced temporal characterization of free electron laser pulses at European XFEL by THz photoelectron spectroscopy**
J. Liu, J. Grünert
Proc. of SPIE **10103**, 101030E (2017)
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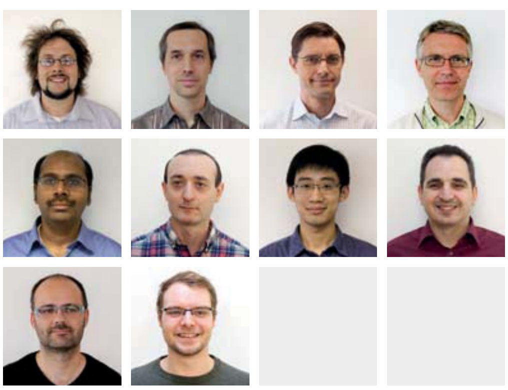


Group members
Florian Dietrich, Torben Falk (not shown), Wolfgang Freund, Jan Grünert (group leader), Andreas Koch, Naresh Kujala, Joakim Laksman, Jia Liu, Theophilos Maltezopoulos, Marc Planas, Johannes Risch, and Sonay Sayar (not shown)

PHOTON SYSTEMS PROJECT OFFICE

The Photon Systems Project Office (PSPO) group is planning and coordinating the installation and commissioning of beamline components in the photon tunnels as well as the installation and commissioning of scientific instruments and infrastructure in the experiment hall. The group ensures the CAD integration of the various computer models of the facility's components and coordinates a company-wide risk management system.

Changes to the group

In 2017, Dennis Ropers was hired as project engineer and Frederike Wittmaack, who had already been an intern in the group, joined as documentation assistant and technical clerk. She shares her works jointly with PSPO and the Technical Services group between PSPO and the Technical Services group.

Installation and commissioning in the photon tunnels

From January through May, PSPO focused on planning and coordinating the commissioning of the SASE1 photon beamline in the tunnels XTD2 and XTD10. New beamline components had to be brought into operation simultaneously with new control electronics and new software. PSPO organized a “SASE1 readiness” effort with daily stand-up meetings to closely monitor progress and resolve technical and resource conflicts. PSPO also held longer review meetings every Friday. This intense effort continued throughout 2017.

Figure 1 Electron beamline (right) and photon beamline (left) in the tunnel XTD1 looking downstream. The large blue steel structure provides support for the very sensitive X-ray gas monitor. The electron beamline is complete, and final installation activities are taking place on the photon beamline.

Figure 2 Test of the smoke extraction system in the experiment hall performed by introducing special artificial smoke

First lasing at the beginning of May and the subsequent rapid commissioning of the photon beam transport and diagnostic systems were achieved by bundling all forces on SASE1. This included all the technical support groups and was vital to getting SASE1 ready for instrument commissioning and user operation. The former started at the beginning of June, and the first user groups came in September.

The SASE3 photon beamline had second priority during this period. Work on SASE3 is restricted by the fact that the corresponding tunnel is not accessible during SASE1 beam operation. Hence, work in the SASE3 tunnel could be carried out only during shutdown periods, in August and October, during which PSPO again closely coordinated and monitored installation and commissioning efforts.

Work also continued on finishing the SASE2 beamline (Figure 1). The photon beamline components directly behind the SASE2 undulator in XTD1 are now fully installed and ready for technical commissioning. Interlock tests could be performed at the very end of the year. However, the cabling for some of the photon beamline components still needs to be done. It was tendered together with the cabling for the SASE2 instruments and will be carried out by the end of February 2018. In XTD6, work will most likely extend into March 2018.

Construction, installation, and commissioning in the experiment hall

In 2017, PSPO planned and supervised the construction of the SASE3 and SASE2 hutches and their infrastructure in the experiment hall. At the same time, the group coordinated and monitored the final instrument installation and the subsequent commissioning of the SASE1 instruments. PSPO also facilitated the granting of authorization to operate by the respective local authorities. A particularly important step was a test of the smoke extraction system, which was carried out successfully in February (Figure 2).

As part of the “SASE1 readiness” effort, PSPO supported the commissioning of the FXE and SPB/SFX instruments with stand-up meetings every second day of the week and a review meeting every Friday. In addition to the Advanced Electronics (AE), IT and Data Management (ITDM), and Control and Analysis Software (CAS) groups, this also included the Optical Lasers and Detector Development groups.

In the SASE3 area, civil construction activities finished in 2017, and focus moved onto installation of the technical infrastructure. The layout of the air delivery plenums and cleanroom curtains in the instrument and laser hutches was revised during the year owing to changes in the requirements of the instrument and laser groups. The hand-over of the hutches will take place in early 2018, and the infrastructure is foreseen to be operational in March 2018. The bulk of the instrument installation and commissioning will start at this date in order to minimize the risk of damaging sensitive equipment.

In the SASE2 area, civil construction also ended in 2017, and the installation of the technical infrastructure is proceeding in parallel with the one in SASE3.

Electronics and cable planning

The design and planning of electronics and cabling are performed in close collaboration between the Electrical Engineering Team (EET) and the AE, ITDM, and instrument groups. All manufacturing and installation activities in this area are tendered and provided by industrial contractors. The PSPO group plans, coordinates, and monitors the internal processes and organizes the tendering efforts for IT cables, racks, and instrument cables.

Figure 3 Motor and encoder cables installed in the SPB/SFX instrument

In the SASE1 instruments, all deliverables were available and ready for tests in April 2017 (Figure 3). However, in May, the floor of the experiment hall was flooded due to a malfunction in a cooling water circuit. Several hundred connectors had to be replaced, as serious corrosion was observed on connectors that had not been connected to instrument components and were lying in the water. Thanks to the dedicated effort of all involved groups and the industrial partner for these cables, the incident did not lead to delays.

In SASE3, the installation of racks and IT cabling was completed in 2017 and the installation of electronics and instrument cables started. The latter will be finished in early 2018.

For the SASE2 instruments, installation of racks and IT cabling started at the very end of 2017 and will extend into 2018. For the electronics and the instrument cables, the schedule is driven by the availability of planning resources within the AE group and EET, the manufacturing time of the electronics, and the confectioning and installation of the instrument cables by the respective contractors. PSPO coordinates these different players. The period in which the deliverables will become available spans almost the entire year 2018, starting with the cables required for finishing the SASE2 tunnels in April.

CAD integration

In addition to routine tasks, such as maintaining and updating the existing CAD models, PSPO is preparing the transition from the CAD program SolidEdge to the successor program NX. This transition follows a similar effort at DESY in order to take advantage of existing know-how and resources. As a pilot project, the CAD models of the SASE2 instruments, MID and HED, will be converted in early 2018 so that the responsible engineers can gain experience with the new software. A complete migration of all CAD models at European XFEL will start after the SASE2 instruments begin operating in 2019.

Risk management

The PSPO group continues to track several hundred risks in its risk catalogue. Two risk reports with the most salient entries were prepared in 2017 and submitted to the European XFEL Management Board, Administrative and Finance Committee (AFC), and Council. PSPO also adjusted the risk management guideline document for the operation phase of the facility.

Group members
Mónica Aresté, Uschi Conta (until February 2017), Sabine Cunis, Tobias Haas (group leader), Sissy Kähler (intern, July–August 2017, not shown), Konrad Piórecki, Dennis Ropers, Niko Saaristo (until January 2017), Adriano Violante, Gerd Wellenreuther, and Frederike Wittmaack

Outlook for 2018

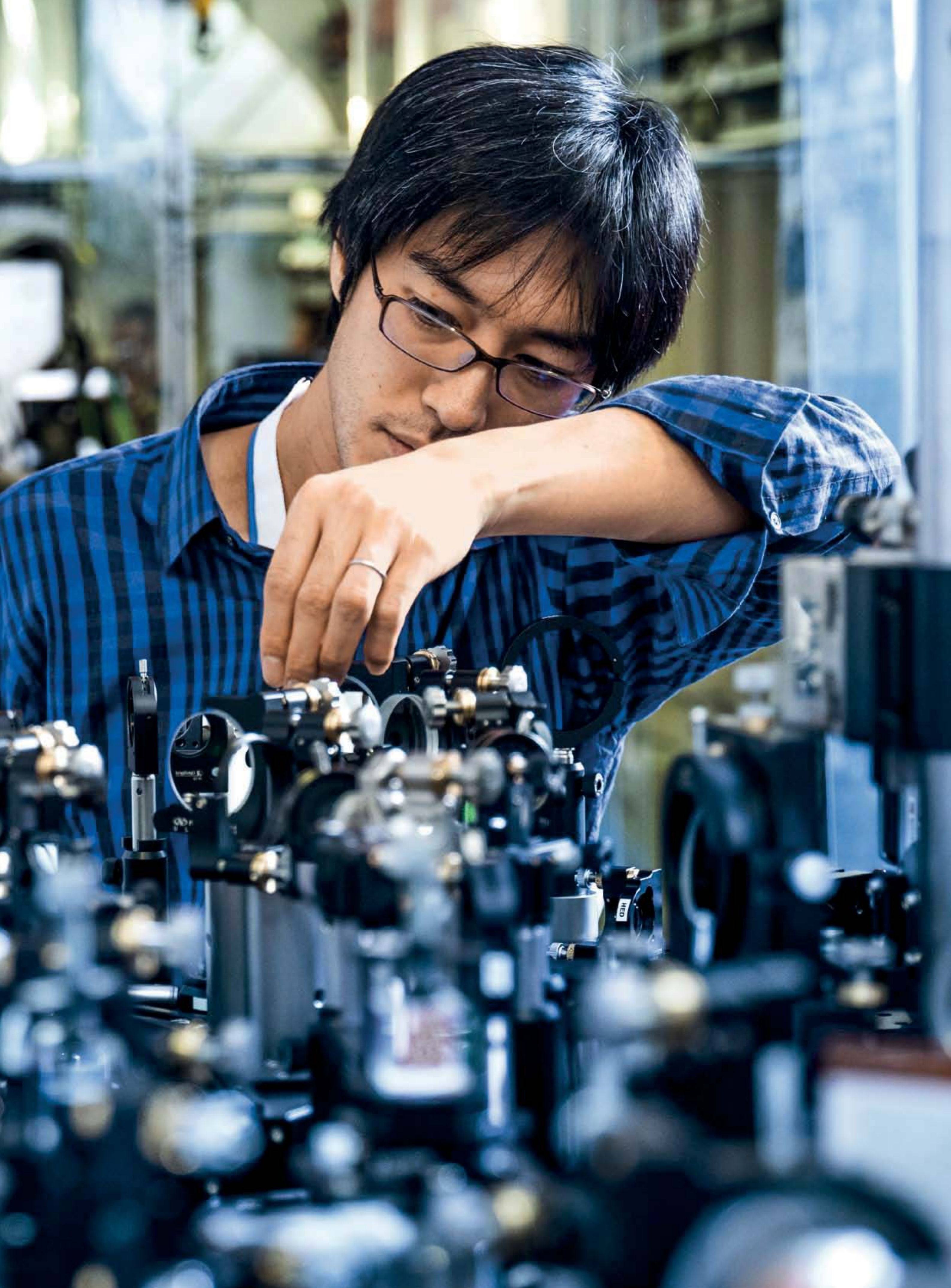
In 2018, instrument operation in SASE1, instrument installation and commissioning in SASE3, and finishing of infrastructure installation as well as instrument installation and commissioning in SASE2 will all happen in parallel. These complex interdependent activities need to be planned, coordinated, and monitored. This challenging situation will continue well into 2019, as installation and commissioning of user consortia–contributed additions will rapidly follow in all three experiment areas. ■

06

SCIENTIFIC INSTRUMENTS AND EQUIPMENT

In 2017, after years of planning and construction, the first two scientific instruments as well as the corresponding sample delivery systems and optical lasers were commissioned. The first users arrived, and the development on the other four instruments continued at full speed.

Setting up pump–probe laser systems



SCIENTIFIC INSTRUMENT FXE

The Femtosecond X-Ray Experiments (FXE) instrument enables ultrafast pump–probe experiments on extremely short time scales—100 fs and below—for a broad scientific community. In 2017, the FXE group mainly focused its efforts on the successful commissioning of the instrument and the first user experiments. The group is currently upgrading the design opportunities of a few additional components in research campaigns using laboratory laser sources, synchrotron storage rings, and X-ray FEL sources. In addition, the group is engaged in a related research programme, primarily about understanding correlated electronic and structural dynamics occurring during photochemical reactions.

Progress in 2017

In 2017, all vital components of the FXE instrument were tested with beam, including the high-power slit system, solid attenuators, beam imaging units and beryllium compound refractive lenses, (Figure 1). The robot arm was equipped with a 2D detector and a fast strip detector. First time-resolved experiments on a reference sample using the synchronised Tangerine MHz laser system were performed in September. Right afterwards, user operation started. In total, seven experiments were allocated during the September to December period. In the first round with three external experiments, the FXE beamline scientists kept pace with user demands and residual commissioning of vital components. These demands included the capability to fine-tune the timing between the laser and X-ray FEL pulses to better than 1 ps, enabling two experiments to record femtosecond X-ray data. One

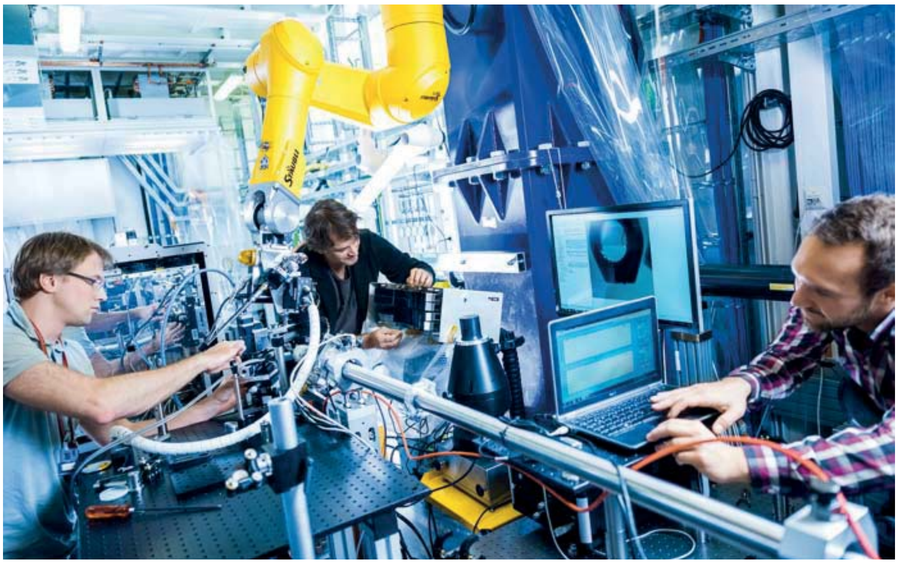


Figure 1 Sample environment area of the FXE instrument, consisting of a beam transport pipe (front) guiding the X-ray beam onto the sample below the orange robot arm, which holds one of the detectors. FXE scientists are preparing the complicated setup for the next user experiment. The shiny 1 Mpx LPD detector can be seen in the background.

experiment suffered from a damaged laser compressor grating, which left the team recording time-resolved diffraction patterns with the much-weaker laser oscillator beam. These users will return for their experiments in May 2018.

Changes to the group

In January 2017, Ph.D. student Alexander Britz passed his final exam at UHH, defending his thesis on “Ultrafast X-Ray Spectroscopies of Transition Metal Complexes Relevant for Catalysis”. Before relocating for a research associate position at SLAC, he aided the FXE group as a scientist with the demanding commissioning and early user experiment periods. Florian Otte and Tae-Kyu Choi started their Ph.D. thesis in the group, and Kay Ebbesen completed his bachelor thesis in chemistry following the first pump–probe experiments at the FXE instrument.

In total, seven experiments were allocated to perform experiments at FXE during the September to December period. The FXE beamline scientists kept pace with user demands and residual commissioning of vital components.

Research activities

As in previous years, the FXE group carried out experiments at various synchrotron and X-ray FEL sources. In May 2017, Sebastian Schulz, Andreas Galler, Ph.D. students Michael Diez and Christina Bömer, and colleagues from LCLS measured the relative arrival time of femtosecond hard X-ray and optical laser pulses with few-femtosecond precision using a fast-flowing liquid sample at SACLA. Such high-precision measurements are crucial for timing ultrafast experiments at the FXE instrument at MHz repetition rates. The results were achieved in the scope of the European Cluster of Advanced Laser Light Sources (EUCALL) project. Schulz and other colleagues provide important input for future FXE optimization.

The FXE group performed many experimental campaigns at synchrotron light sources (ESRF, Diamond, and PETRA III) regarding non-linear X-ray optics and regular X-ray spectroscopy on cobalt and copper compounds, as well as preliminary investigations of inelastic X-ray scattering. Additionally, in June 2017, Wojciech Gawelda and Frederico Lima joined an experimental campaign at SACLA with the goal of studying the ultrafast wavepacket dynamics of a copper-based photocatalyst model compound.

Teaching and educational activities

During the summer semester 2017, Andreas Galler and Christian Bressler taught the course “Light–Matter Interactions: Atoms, Molecules, and (Non)Linear Optics” at UHH, with the support of guest lecturers Michael Meyer of the SQS instrument group and Ulf Zastrau of the HED instrument group. Bressler also received support from Zastrau for his lecture “How to read, understand, and assess the quality of experimental publications”. A new lecture, “New Experiments with XFEL Sources”, was started at UHH (with several lecturers from European XFEL), which provides the European XFEL facility with enhanced visibility among the university students and delivers an overview of the scientific opportunities at the facility.

Altogether, the FXE group members are very active on the Hamburg research scene: Dmitry Khakhulin, Sebastian Schulz, and Peter Zalden are associate members of CUI with Ph.D. students Christina Bömer (SFB925), Alexander Britz, and Michael Diez, while Andreas Galler and Wojciech Gawelda are principal investigators at the IMPRS-UFAST graduate school and Tae-Kyo Choi is an IMPRS doctoral student (financed by European XFEL).

Outlook for 2018

In 2018, the FXE group will improve the status of the FXE instrument while supporting new experimental campaigns by external scientists in the European XFEL user operation periods. The group will resume teaching activities at UHH during the summer semester in cooperation with the HED, SCS, and SQS groups and engage in experimental campaigns at the European XFEL and PETRA III.

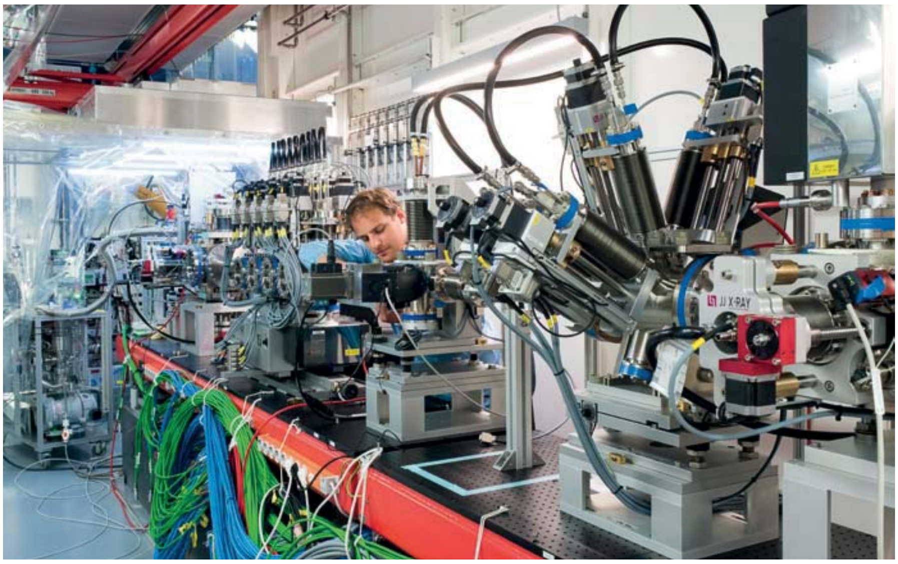


Figure 2 Michael Diez preparing an experiment at the FXE instrument

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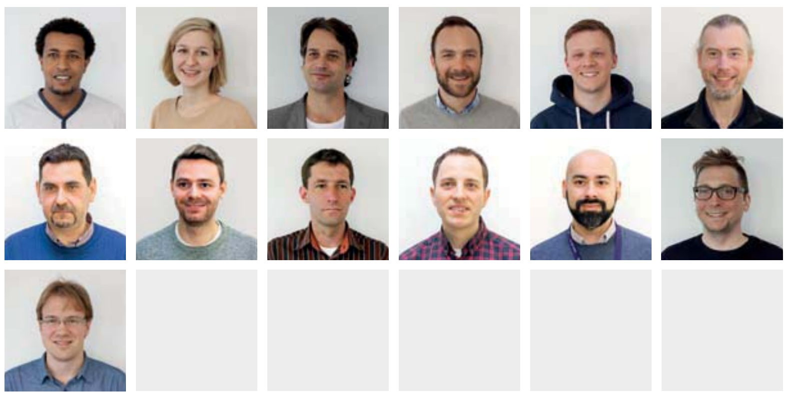
T. Tschentscher, C. Bressler, J. Grünert, A. Madsen, A.P. Mancuso, M. Meyer, A. Scherz, H. Sinn, U. Zastrau
Appl. Sci. **7**, 592 (2017)
doi:10.3390/app7060592

This group has received third-party funding from the European Union's Horizon 2020 Research and Innovation Programme for the project "**EUCALL - European Cluster of Advanced Laser Light Sources**" (Grant Agreement No. 654220) and from the German Federal Ministry for Economic Affairs and Energy as well as the European Union's European Social Fund for the project "**WaveEye**".



Group members
Tadesse Assefa (until January 2017), Christina Bömer (Ph.D. student, supported by SFB925), Christian Bressler (group leader), Alexander Britz (Ph.D. student, after graduation: scientist), Tae-Kyu Choi (Ph.D. student, IMPRS-UFAST, not shown), Michael Diez (Ph.D. student, CUI, not shown), Kay Ebbesen (bachelor student, not shown), Paul Frankenberger, Andreas Galler, Wojciech Gawelda, Dmitry Khakhulin, Martin Knoll, Timo Korsch, Frederico Alves Lima, Florian Otte (Ph.D. student, supported by TU Dortmund, not shown), Sebastian Schulz (supported by EUCALL), and Peter Zalden

SCIENTIFIC INSTRUMENT HED

The High Energy Density Science (HED) group designs, installs, and operates the HED scientific instrument—a unique platform combining hard X-ray FEL radiation with the capability to generate extreme states of matter. In 2017, the HED group installed the first beamline components while supervising the ongoing construction activities.

Progress in 2017

In 2017, the HED group built, received, tested, and installed first instrument components and drew up control requirement documentation. As of December 2017, the main vacuum chamber (Interaction Chamber 1, IC1), part of the X-ray delivery components, and the laser beam transport system are installed, and the baseline X-ray detectors have passed the factory acceptance test. Together with the Helmholtz International Beamline for Extreme Fields at the European XFEL (HIBEF) user consortium (UC), the group is preparing to receive two high-power lasers in 2018. The group is also approaching the user community to help design a successful early science programme.

Changes to the group and the HIBEF UC

In 2017, the group significantly increased its manpower for the installation phase. Joining the HED group were scientists Mikako Makita and Thomas Preston as well as mechanic Eike Martens. Coordinator Cornelius Strohm came to the HIBEF UC from DESY, and laser scientist Hauke Höppner and engineers Monika Toncian, Dominik Möller, Andreas Berghäuser, Mohamed Hassan, and Samuele Di Dio Cafiso joined the HIBEF UC group of HZDR.

Engineering and instrument installation

As of December 2017, media installation in the experiment hutch is almost complete, while IT and power cables are being laid and air conditioning units installed. HED integration engineer Andreas Schmidt supervises the infrastructure installation. In May, the Japanese company Toyama installed the primary vacuum vessel, IC1 (Figure 1). Grooves were cut into the experiment floor to later house rails for the IC2 chamber, and the IC2 vessel design was approved for tendering. The group contracted the photon arrival time monitor and a high-resolution monochromator. Mechanical engineer Ian Thorpe continues to lead the manufacturing and assembly of these instrument components. Electronics planning and finalization of cabling design for HED instrumentation progressed significantly under electronics

Figure 1 IC1 vacuum chamber during installation at the HED instrument

engineer Konstantin Sukharnikov in collaboration with European XFEL support groups. In cooperation with HED engineers, technicians Thomas Feldmann and Eike Martens assembled, tested, and installed X-ray components at the instrument and in the photon tunnel.

Scientific and technological achievements

The HED instrument scientists worked on completing the design of the last components and on procuring them. Karen Appel supervised the final design of a high-resolution monochromator (master thesis project of Lennart Wollenweber), the delivery and tunnel installation of the split and delay line, the design and fabrication of the X-ray beamline components, and the integration of HIBEF UC X-ray instrumentation. Motoaki Nakatsutsumi coordinated the final design of the photon arrival time monitor, the procurement of optics, mounts, and optomechanics for the pump–probe laser and two high-power lasers (in cooperation with the HIBEF laser group), and the design and installation of the interlocks. Sebastian Göde managed the factory acceptance test of ePIX detector modules at SLAC, together with other European XFEL groups, and the procurement of JUNGFRAU detectors from PSI. Delivery of both detector types is foreseen for spring 2018. Göde also cooperated with the Sample Environment group on testing jets as targets for high-repetition-rate experiments.

Together with Alexander Pelka, who organized the HIBEF UC contributions, Zuzana Konôpková coordinated the integration of a laser heating concept for a diamond anvil cell setup, for which she was awarded DFG funding. In collaboration with the Sample Environment group, which designed a fast sample scanner and a sample cassette exchange, Mikako Makita compiled the HED requirements on software controls and future target fabrication. She also chose and procured fine diamond gratings for the beam imaging unit. Makita, Appel, and Thorpe achieved significant progress on the fabrication of the single-shot X-ray spectrometer, a contribution from CAEP. Appel and Konôpková joined the European XFEL Photon Commissioning team and worked on the setup and commissioning of the SASE1 photon beam transport system. The science case for a kJ laser at HED was discussed in a teleconference.

Research activities and conferences

In 2017, group members were involved in five experiments at LCLS and one at FLASH, as well as in experiments at high-power laser facilities (DRACO at HZDR, JETI at the University of Jena in Germany) and at synchrotrons (PETRA III, ESRF). The experiments focused on high-pressure mineralogy, X-ray scattering and high-resolution X-ray imaging from laser-compressed matter, proton acceleration and plasma instabilities and their impact on laser-driven protons from cryogenic hydrogen targets, Fourier-domain interferometry of relativistic laser plasmas, emission spectroscopy from metals excited with hard X-rays, and optical properties of XUV-heated water. Preston successfully analysed the data of an LCLS campaign led by the HED group in November 2016.

HED scientists presented results and details about the European XFEL and the HED instrument on 32 conferences in 15 countries. The HED group (Nakatsutsumi) and the HIBEF UC (Toncian) jointly coordinated a user workshop on concepts for experiments with the HED high-intensity laser, held in April at European XFEL. Appel was part of a team organizing the weekly European XFEL science seminar, which features talks from outstanding external scientists. She also coordinated a BMBF project on self-sustained chemical reactions in solids, together with guest scientist Wolfgang Morgenroth.

Publications

Within the network of the international HED community, group members analysed data, drafted the results, and published several journal articles. In particular, Göde and co-workers published a paper on relativistic electron streaming instabilities that modulate proton beams in laser–plasma interactions [1]. Nakatsutsumi and co-workers from HED and the HIBEF UC published an article on femtosecond laser-generated high-energy-density states that can be studied at X-ray FELs. Both publications address pioneering techniques that will also contribute to the scientific success of the HED instrument. Finally, Nakatsutsumi and co-workers successfully finalized the analysis of previous experimental data on proton acceleration and magnetic field generation, which is now accepted for publication [2].

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M. Nakatsutsumi, Y. Sentoku, A. Korzhimanov, S.N. Chen, S. Buffechoux, A. Kon, B. Atherton, P. Audebert, M. Geissel, L. Hurd, M. Kimmel, P. Rambo, M. Schollmeier, J. Schwarz, M. Starodubtsev, L. Gremillet, R. Kodama, J. Fuchs
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doi:10.1038/s41467-017-02436-w

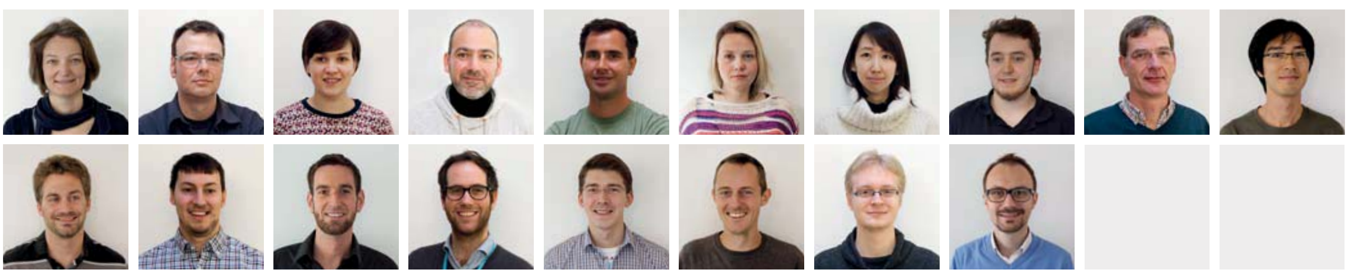
Third-party funding and teaching

Ph.D. student Markus Schölmerich joined the group in 2017. He is supervised by Appel in the framework of a research unit funded by DFG. Nicole Biedermann continued her Ph.D. work in another DFG research unit. Konôpková identified a Ph.D. candidate for a project on high-pressure Earth science in the diamond anvil cell, funded by DFG, who will start in February 2018. Ulf Zastrau taught a course at the University of Rostock and two courses at UHH. Attracted by the latter, master student Lennart Wollenweber joined the HED group in October 2017. Makita gave a lecture at the ELI summer school in Romania.

This group has received third-party funding from the DFG for the following projects: Matter Under Planetary Interior Conditions–High-Pressure, Planetary and Plasma Physics (FOR 2440), subproject SP7 “**Dynamic compression experiments on rock-forming materials at free-electron lasers**”; Structures, properties and reactions of carbonates at high temperatures and pressures (FOR 2125), subproject “**X-ray fluorescence and X-ray absorption spectroscopy studies towards element distribution processes between carbonates and mantle phases in the lower mantle**”; and project “**structural analyses of iron, periclase, and carbon under megabar pressures through static compression experiments with double-stage diamond anvil cells**”. The group also received external funding from the Volkswagen Foundation for the Peter Paul Ewald Fellowship for the project “**Phase Transition Kinetics in Extreme States of Matter: A Novel Setup for in situ Diffraction at X-ray FELs**”, from the Alexander von Humboldt Foundation for the project “**Electron–Ion Interactions in Warm Dense Matter**”, and from the **HIBEF** user consortium. The group also receives a split and delay line from the University of Münster via funding from BMBF.

Outlook for 2018

In spring 2018, the precision air conditioning will be running, which is a prerequisite for installing the HIBEF TW laser in the laser bay. The laser beam transport system will be completed. In summer, all X-ray beamline components should be installed and motors and vacuum tested after initial assembly in the HED lab. The ePIX and JUNGFRAU X-ray detectors will be delivered, and their implementation into the local infrastructure will begin. The University of Münster in Germany will provide the interior of the split and delay line. First lasing at SASE2 is expected in mid-2018. In autumn, the HED group will perform end-to-end tests of the controls. By early 2019, the HED group will be ready to start X-ray commissioning of the instrument.



Group members
Karen Appel, Carsten Baehtz (guest, HIBEF coordinator), Andreas Berghäuser (guest, HIBEF engineer, not shown), Nicole Biedermann (Ph.D. student funded by DFG, jointly with University of Potsdam), Thomas Feldmann, Sebastian Göde, Zuzana Konôpková, Mikako Makita, Eike Martens, Emma McBride (postdoc at LCLS, not shown), Wolfgang Morgenroth (guest, BMBF project with University of Frankfurt), Motoaki Nakatsutsumi, Alexander Pelka (guest, HIBEF scientist), Thomas Preston, Andreas Schmidt (jointly with MID), Markus Schölmerich (Ph.D. student funded by DFG, jointly with University of Rostock), Cornelius Strohm (guest, HIBEF coordinator for DESY contributions, not shown), Konstantin Sukharnikov (jointly with MID), Ian Thorpe, Lennart Wollenweber (master student, with UHH), and Ulf Zastrau (group leader)

SCIENTIFIC INSTRUMENT MID

The Materials Imaging and Dynamics (MID) group is responsible for building one of the scientific instruments of the European XFEL. The MID instrument will enable studies of structure and dynamics in condensed matter by means of X-ray scattering and imaging with particular emphasis on coherence experiments. In 2017, the group received the bulk part of the equipment, and installations started. First beam is expected at the end of 2018.

Progress in 2017

In 2017, most instrument components were delivered and tested at European XFEL, and preparations for instrument installation started. Despite utilities and infrastructure installation in the MID hutches being well under way but not yet complete, first instrument components were installed in the photon tunnel and the optics hutch. The MID laboratories in the HERA South hall were transferred to the European XFEL headquarters building in Schenefeld. The group was also involved in several measurement campaigns at LCLS, ESRF, and PETRA III.

MID group in 2017

Three new scientists, Johannes Möller, Markus Scholz, and Roman Shayduk, started in 2017. Thomas Roth left the group for a position at ESRF, and Birthe Kist graduated with a master degree in engineering from TUHH. Iker Lobato joined MID as electronics technician, and Konstantin Sukharnikov, an electrical engineer with the HED group, now works 50% for MID. Wolfgang Tebah started as student assistant.

Instrument construction and testing

Together with Xiaohao Dong from the X-Ray Optics group, the MID group tested two monochromators and installed them in the MID optics hutch and photon tunnel. The beam shutter, compound refractive lens (CRL) units, slits, attenuators, and a differential pumping section will be installed as soon as the hutches are ready. Parts for additional beam imagers and a diagnostic station were delivered in 2017, and the devices are currently being assembled. A first factory acceptance test (FAT) of the large X-Ray Scattering and Imaging Setup (XSIS) took place at the manufacturer's site in 2017. A second FAT is foreseen for January 2018, after which XSIS will be installed. The experiment hutch will also host a cryocooled double mirror system, the mechanics of which was delivered and approved in 2017. The mirror substrates are currently awaiting coating at HZG. Two cleanroom tents were erected in the experiment hall to support the forthcoming instrument installation.

A hard X-ray split and delay line (SDL) is under construction in cooperation with the group of Stefan Eisebitt at MBI and TU Berlin [1]. The project is financed through a BMBF Verbundforschungsprojekt grant. The principle of the SDL device is sketched in Figure 1. The incoming X-ray FEL beam is split into two equal parts that are sent out on different trajectories, denoted upper and lower branch (UB/LB). The splitting is achieved by Bragg scattering either by an ultrathin crystal (optical splitting) or by a regular crystal intersecting only the lower half of the beam (geometrical splitting). The SDL design is symmetric, so the same approach is used to recombine the split beams, which have now accumulated a time delay determined by the path length difference (PLD) between the UB and LB. The SDL provides a maximum delay of 800 ps, corresponding to a PLD of 24 cm. To obtain a jitter of 10 fs or less, the PLD must be stable down to 3 μm. The jitter depends critically on the stability of the crystals in the UB, the positions of which are

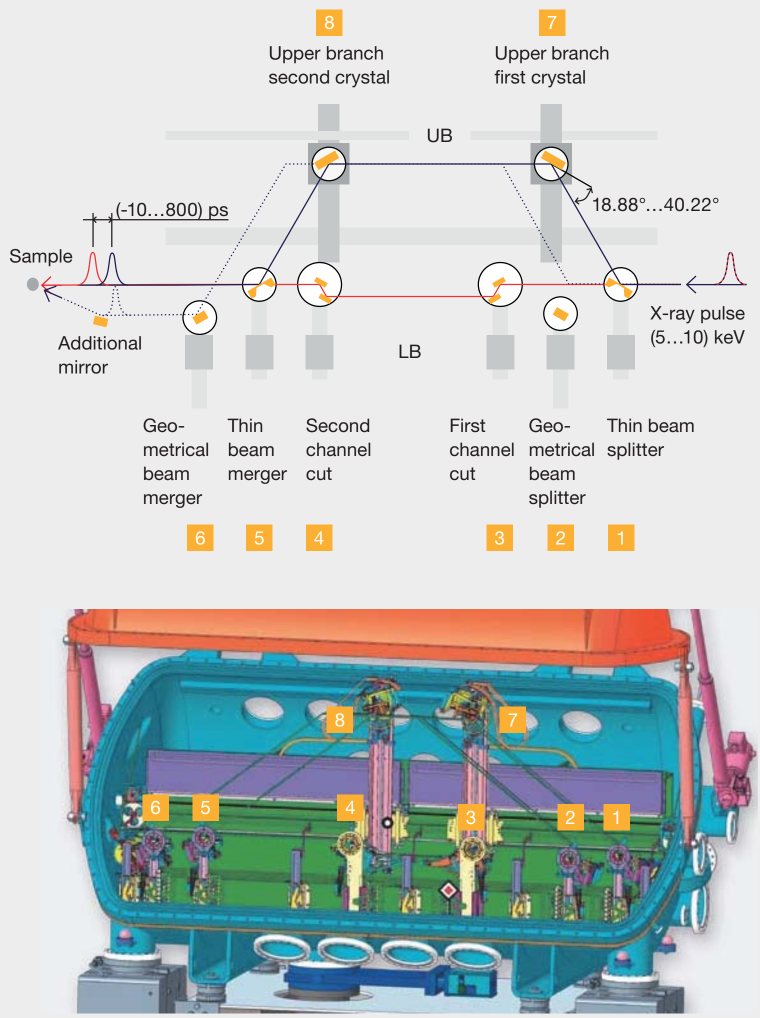


Figure 1 Principle of the hard X-ray SDL.
Top Sketch of the SDL.
Bottom Drawing of the device being manufactured [1].

closely monitored by interferometers. Initial tests have indicated that the target jitter is within reach. The SDL is based on silicon perfect crystals and operates from 5 to 10 keV in a fully motorized fashion, so the time delay can be changed *in situ*. The whole design is in vacuum and integrated into the beamline without the use of windows. An SDL serves many purposes, e.g. studies of ultrafast dynamics in the time domain, pump–probe scattering and imaging, and quantum optical experiments. Similar projects are under way at SACLA and LCLS.

Research and development

Non-invasive and pulse-resolved monitoring of SASE beam intensity and position are of outmost importance for experiments at the European XFEL. A non-invasive detector can be placed continuously in the beam, providing *in situ* beam diagnostics during the experiments. Together with collaborators in Germany, Russia, the UK, and the USA, the MID group built and tested solid-state ion chambers based on low-*Z* materials [2]. The beam traverses a sandwich made of a semiconductor material between two electrode plates, in this case diamond with beryllium electrodes evaporated on both sides. A different design with diamond-like carbon electrodes was also tested. The low-*Z* materials mitigate single-shot ablation damage, which is a particular problem with SASE beams. Another challenge for such detectors is the speed required to be compatible with the MHz repetition rate of the European XFEL. The collaboration successfully tested its custom-made detectors at LCLS with good results (Figure 2). In particular, a dead time of much less than 220 ns was achieved with good detector linearity. The possibility of beam position monitoring was also demonstrated.

The MID group pursued several scientific projects in 2017, e.g. testing the limits of coherent diffraction imaging in materials science

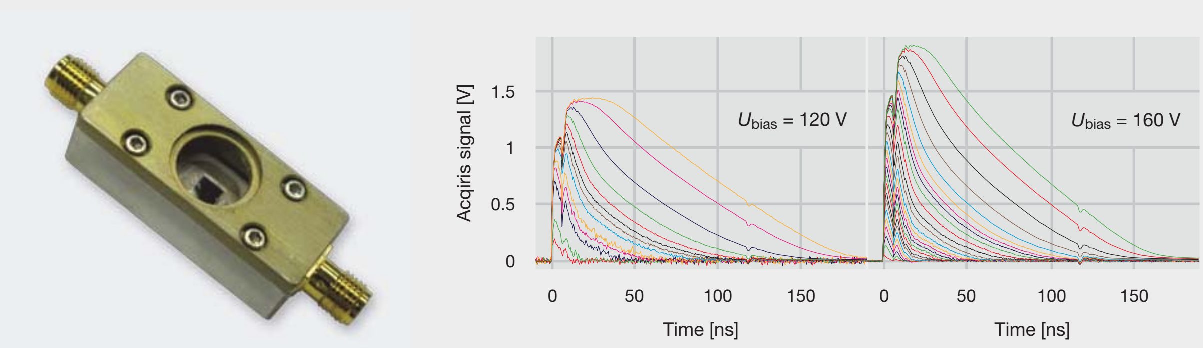


Figure 2 Beryllium–diamond–beryllium detector for non-invasive pulse-resolved beam intensity monitoring.
Left Photograph of the detector.
Right Voltage curves from fast digitiser (Acquiris) showing the temporal detector response for two different bias voltages. The different curves correspond to different intensities of the LCLS beam (maximum ~7x10^{10} photons/pulse) [2].

to visualize domain boundaries in crystalline structures. The group also carried out X-ray photon correlation spectroscopy experiments with extremely low photon rates in the detector (10^{-2} photons/pixel or less) to investigate micelle and protein dynamics. Both research areas are closely connected with the future possibilities for and challenges of experiments at the MID instrument, e.g. developing methods for coherent nanofocused beams and advanced statistical analysis for weak speckle patterns.

Outlook for 2018

All baseline positions in the MID group have been filled, so no further recruitments are expected in 2018. The main interaction chamber and detector motion system of the instrument will be installed in the experiment hutch in early 2018. The plan is that MID receives beam during the second half of 2018 to perform first commissioning. MID will be included in the third call for proposals, which will be launched in 2018, with accepted experiments scheduled to take place from the end of 2018 to summer 2019. The optical femtosecond laser and the SDL are under construction but will not be available for early user experiments.

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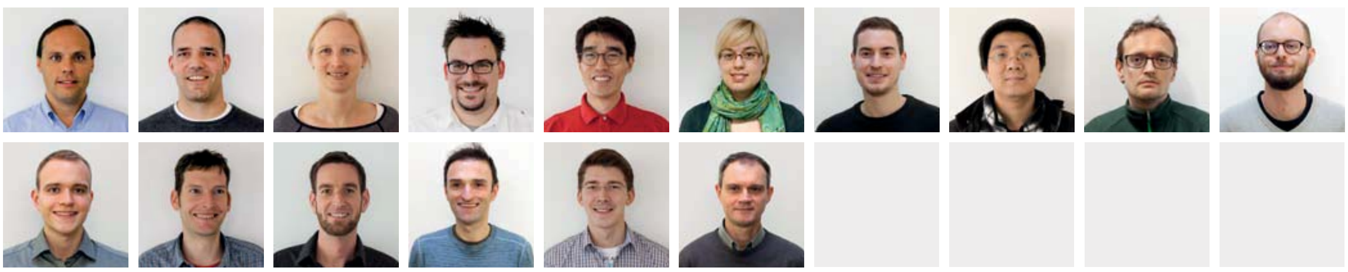
This group receives a polarizer-polarimeter setup from the University of Jena, a cryogenic jet sample injection system from the University of Frankfurt, and a split and delay line from MBI and TU Berlin, all via funding from BMBF.



Group members
Gabriele Ansaldi, Wolfgang Azipon Tebah (student assistant, not shown), Alexander Bartmann, Ulrike Bösenberg, Jörg Hallmann, Chan Kim, Birthe Kist (student, until October 2017), Iker Lobato, Wei Lu, Anders Madsen (group leader), Johannes Möller, Mario Reiser (Ph.D. student), Thomas Roth (until January 2017), Andreas Schmidt (jointly with HED), Markus Scholz, Roman Shayduk (not shown), Konstantin Sukharnikov (jointly with HED), and Alexey Zozulya

SCIENTIFIC INSTRUMENT SCS

The Spectroscopy and Coherent Scattering (SCS) instrument will enable time-resolved X-ray scattering experiments to unravel the electronic and structural properties of condensed-matter systems on relevant space–time dimensions. In 2017, the SCS group continued to test the instrumentation in the temporary assembly area in the experiment hall and worked on instrument components foreseen for operation in 2019.

Progress in 2017

In 2017, the group moved the SCS assembly area from the HERA South hall at DESY to the European XFEL experiment hall in Schenefeld and nearly finished testing and debugging device components. In December 2017, the company JTEC Corporation in Japan delivered three super-polished X-ray optics that will provide micrometre-sized X-ray beam spots at the sample position. The SCS group advanced the design and procured instrument components foreseen for the instrument operation in 2019, while infrastructure installation in the experiment hutch continued. The group commissioned a highly reliable, stable, turn-key, high-repetition-rate femtosecond laser system in the SCS laser laboratory and started to develop an optical apparatus for THz generation that will complement the capabilities of the SCS instrument.

Changes to the group

Natalia Gerasimova took up a joint position in the SCS and X-Ray Optics groups as an instrument scientist and soft X-ray optics specialist. Martin Teichmann, a former core developer of the Karabo framework in the Control and Analysis Software group, moved to the SCS group as a scientific programmer to develop the SCS instrument controls. In the summer, Naman Agarwal, enrolled in the IMPRS Ph.D. programme, started working on THz-driven magnetization dynamics under the supervision of SCS group leader Andreas Scherz and Theory group leader Alexander Lichtenstein. Student assistant Lukas Behrens supports the group in the installation work in the experiment hutch.

KB mirror system and super-polished X-ray optics

The Kirkpatrick–Baez (KB) focusing mirror system passed the factory acceptance test in November 2017 and is currently stored at FMB Oxford in the UK until installation of sensitive equipment into the SASE3 experiment hutch can start in March 2018. The three superpolished X-ray optics delivered by JTEC Corporation in December 2017 will be

Figure 1 SCS instrument scientist Robert Carley inspects the superpolished X-ray focusing optics from JTEC Corporation at the Diamond Light Source prior to metrology.

mounted in high-precision benders after coating and metrology steps (Figure 1). Once installed in the KB system, the X-ray optics will provide an X-ray beam spot down to 1 μm in diameter at the sample position.

The company Toyama in Japan delivered the forward-scattering fixed-target (FFT) experiment chamber in April 2017. The FFT chamber was moved into the cleanroom tent in the SCS assembly area where it is being equipped with sample environment and diagnostics before installation in the experiment hutch in 2018.

In early 2017, the Heisenberg Resonant Inelastic X-Ray Scattering (h-RIXS) user consortium and the SCS group completed the technical specification of the h-RIXS spectrometer, the X-ray resonant diffraction (XRD) experiment chamber—the second baseline experiment chamber of SCS—and the chemistry station. The company Bestec in Germany started the design in 2017 and will construct the entire system including the XRD experiment station in 2018. The integration of the h-RIXS spectrometer and the experiment stations into the SCS instrument is foreseen in 2019 during the summer shutdown as a major upgrade of the instrument. Users will then be able to study elementary excitations of condensed matter and chemistry in the energy and momentum domain.

Research activities

Group members Robert Carley and Laurent Mercadier commissioned a high-repetition-rate femtosecond laser system in 2017. Together with Ph.D. candidate Naman Agarwal, they started to develop an optical apparatus for THz generation enabling THz-driven femtosecond spectroscopy studies of materials. While setting up the system in the laser laboratory, the group investigated the laser-driven first-order phase transition in FeRh samples using a narrow-band THz source provided by the team of the TELBE facility at HZDR. The experiments were carried out in close collaboration with the HZDR team of Michael Gensch in December 2017.

In collaboration with Giacomo Ghiringhelli from Politecnico di Milano in Italy and Martin Beye from DESY, the group performed experiments at FERMI under the direction of Ghiringelli and group member Justine Schlappa with the aim to explore opportunities for studies using three-wave mixing of X-ray and optical frequencies on complex materials. The key challenge is to overcome the radiation damage caused by the intense X-ray and optical pulses, as fixed targets cannot be easily replenished at even moderate repetition rates of X-ray laser sources. However, these initial studies may pave the way for non-linear X-ray spectroscopy methods in the future, which are well-known cornerstones in the optical science community.

Peter Paul Ewald Fellow Loïc Le Guyader, who was seconded to LCLS in 2015, returned in summer 2017 after participating in several experimental campaigns in collaboration with the group of Hermann Dürr. One of the studies investigated the inhomogeneous magnetic switching behaviour in granular FePt layers and linked this occurrence to the near-field modification of the laser radiation around the FePt nanoparticles [1].

Outlook for 2017

In 2018, the SCS instrument hutch construction and infrastructure installation in the experiment hall will be completed. The start of instrument installation is foreseen in March 2018 when sensitive components can be moved into the experiment hutch. The instrument commissioning with X-ray beam will start in August 2018, and the SCS group awaits first users in mid-November 2018.

This group has received third-party funding from the Volkswagen Foundation for the Peter Paul Ewald Fellowship for the project “**Towards Ultrafast and Nanoscale control of Exchange (TUNE)**”, from the European Union’s Horizon 2020 Research and Innovation Programme for the project “**EDAX - Beating Complexity through Selectivity: Excited-State Dynamics from Anti-Stokes and non-linear resonant inelastic X-ray scattering**” (Grant Agreement No. 669531), from the h-RIXS user consortium, and from BMBF for the project **TR-XPES** (UHH and University of Kiel).

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doi:10.1021/acs.nanolett.7b00052

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SCIENTIFIC INSTRUMENT SPB/SFX

The Single Particles, Clusters, and Biomolecules and Serial Femtosecond Crystallography (SPB/SFX) group is responsible for developing and operating the scientific instrument for structural investigations of crystalline and non-crystalline matter, in particular biological molecules. Major achievements in 2017 include the installation and commissioning of the day-one SPB/SFX instrument, the first run of user experiments, and continued research including publications on FEL wave field characterization, modelling of single-particle imaging experiments, peak-finding algorithms in serial crystallography, and three-dimensional reconstruction of single viruses from X-ray FEL data.

Summary of 2017

In 2017, the SPB/SFX instrument transitioned from installation phase to commissioning and finally first user operation in autumn. The group completed the installation of the day-one instrumentation and commissioned all components with beam. In the first user run, seven experiments, which covered a large spectrum of instrument capabilities and included serial femtosecond crystallography, laser pump / X-ray probe experiments, and single-particle imaging (SPI), were scheduled at the SPB/SFX instrument. In parallel, the planning and design of the downstream interaction region continued, with the installation of the in-air setup foreseen for late 2018. The group continued its scientific activities, mainly on SPI, performing experimental single-shot wavefront measurements at FEL sources [1], modelling complete SPI experiments [2], and successfully reconstructing single virus particles from SPI data collected at LCLS.

Changes to the group

To prepare for early experiments and user support in 2017, the SPB/SFX group was further expanded. Three scientists with a strong background in SPB/SFX-relevant fields joined the group: Yoonhee Kim, Henry Kirkwood, and Romain Letrun. Mohammadreza Banjafar started late in the year as a Ph.D. student in the group’s modelling programme. The mechanical technicians Thomas Dietze and Philip Schütt strengthened the group’s technical and engineering support. Alexis Legrand joined as an electrical engineer and Cedric Signe Takem as an instrument engineer. A number of these new staff members are supported by financial contributions of the SFX user consortium. Masoud Mehrjoo successfully defended his Ph.D. thesis on single-pulse wavefront retrieval in 2017 and left for a postdoctoral appointment at FLASH.

Figure 1 The SPB/SFX instrument

Installation and instrument commissioning

In the first half of 2017, the group installed the remainder of the day-one instrumentation in the SPB/SFX optics and experiment hutches. In parallel to the installation, the Advanced Electronics group and the Control and Analysis Software group implemented the control of the components via Karabo, and the components were commissioned without beam.

The major components of the day-one instrument are the sample environment including components supplied as part of the Serial Femtosecond Crystallography (SFX) project (see “User consortia” in Chapter 2), the detection system, and their support structure. The component support structure was delivered and installed in the experiment hutch in March 2017, and the sample chamber followed shortly afterwards. A dedicated setup for instrument commissioning was installed in the sample chamber, which facilitated the simple integration and exchange of various test and calibration samples, YAG screens, or imprint targets.

The first component of the SPB/SFX instrument that was exposed to the European XFEL beam was the diagnostic screen in the XTD9 tunnel at the end of May 2017. One month later, on 23 June, first X-ray FEL radiation was delivered to the optics and experiment hutches, which marked the starting point of the instrument commissioning with beam. A beam trajectory through the full instrument was established using diagnostic screens located at various positions along the instrument. The beam was focused in the sample chamber using beryllium compound reflective lenses located in the XTD9 tunnel, and a focal spot size of 15 µm transverse size was measured at the nominal interaction point.

The first component of the SPB/SFX instrument that was exposed to the European XFEL beam was the diagnostic screen in the XTD9 tunnel at the end of May. One month later, on 23 June, the first X-ray FEL radiation was delivered to the optics and experiment hutches.

The 1 Mpx AGIPD arrived at the instrument in August 2017. The detector was installed on the component support structure and set up for crystallographic data collection with a minimum distance of about 13 cm to the interaction point in the sample chamber. The AGIPD and the data acquisition pipeline were commissioned by the AGIPD consortium and the Control and Analysis Software group in close collaboration with the Detector Development group and the IT and Data Management group. This extraordinary effort ensured that the detector was measuring dark frames within a week of its arrival

Figure 2 European XFEL Managing Directors Robert Feidenhans'l and Claudia Burger observe the first X-rays entering the SPB/SFX hutch with members of the SPB/SFX team

in the SPB/SFX hutch, recording test diffraction with the X-ray FEL beam within two weeks of its arrival, and successfully recording user data from the very first user experiment after only a few weeks (see Chapter 8, "Operations").

In-house research

Notwithstanding the significant effort invested in bringing the instrument to day-one operation, the SPB/SFX group managed to publish several research articles in 2017. The major theme continues to be probing the practical and theoretical limits of single particle imaging (SPI) with X-rays. Now-graduated Ph.D. student Mehrjoo published a single-pulse method for measuring the wavefront of an FEL beam [1], which may be a necessary measurement for high-resolution SPI in the future. Modelling work is led by Carsten Fortmann-Grote and focuses on simulating, as realistically as possible, each aspect of an SPI experiment. In a recent publication [2], the effects of pulse duration and radiation damage were explored for a small model biomolecule.

The group also continued to work on pushing the boundaries of experimental SPI, with a recent paper published in *Physical Review Letters* together with Ruslan Kurta of the Theory group and many collaborators, demonstrating the successful reconstruction of a single virus from SPI data collected at LCLS (see Chapter 5, "Theory"). This reconstruction shows the deviation of the virus from perfect icosahedral symmetry, which had not been seen by other methods.

Outlook for 2018

In early 2018, the SPB/SFX group will install two mirror optical focusing systems, which will facilitate a micrometre-scale and a 100 nm–scale focal spot across a photon energy range of 3 to 16 keV. Starting in autumn, the first components for the in-air setup of the downstream interaction region—a major contribution of the SFX user consortium—will be installed and tested. Commissioning is planned to begin in early 2019. User operation at SPB/SFX will be continued in 2018, with experiments of the second call for proposals scheduled in the second half of 2018 and the third call from the start of 2019. The group will continue to support the experiments, improving procedures and processes based on experience gained in 2017.

This group has received third-party funding from the European Union's Horizon 2020 Research and Innovation Programme for the project "**EUCALL - European Cluster of Advanced Laser Light Sources**" (Grant Agreement No. 654220) and the **SFX** user consortium.

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IUCrJ **4** (5), 560–568 (2017)
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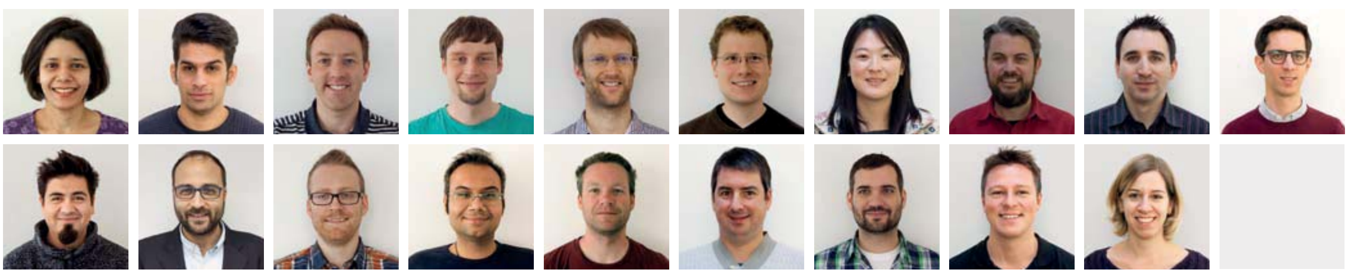

Group members
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SCIENTIFIC INSTRUMENT SQS

In 2017, the Small Quantum Systems (SQS) instrument group continued the preparation work for the main components of the instrument, the Kirkpatrick–Baez (KB) focusing optics and the two experiment chambers, dedicated to the study of atomic-like quantum systems (AQS) and nano-size quantum systems (NQS), respectively. Research activities concentrated on experiments on atomic photoionization, especially exploiting the well-defined and controllable polarization of XUV FEL and optical laser pulses as well as the spectral phase of the XUV radiation.

Construction of the SQS instrument

In 2017, the infrastructure installation in the experiment areas of the SQS instrument by external companies made good progress, providing the basis for the upcoming setup of the instrument. The tasks of the SQS group were mainly related to the preparation and tests of the various instrument components to assure their fast and unproblematic installation. In view of the installation, commissioning, and operation of the instrument, the SQS group expanded in 2017 with the hiring of an engineer, an electrical technician, and a scientist.

Specific production steps were undertaken for the following components:

- **KB focusing optics**
  Due to a long delay in the delivery of the highly polished mirrors for the focusing system of the SQS instrument, the group developed an interim solution to ensure operation of the instrument at the expected starting date in autumn 2018. The new mirrors with fixed surface curvatures will provide very similar characteristics with respect to transmission and focusing as the final ones, but lack the possibility to move the position of the focus and to change its size. The first experiments will therefore be performed at a fixed geometry.

- **Magnetic bottle electron spectrometer**
  The design of a magnetic bottle electron spectrometer (MBES), which is the last component to be made available for day-one operation of the AQS experiment chamber, was finalized (Figure 1). In comparison to the high-resolution electron time-of-flight (HReTOF) spectrometers, the MBES offers the advantage of a high collection efficiency (up to 4π sr) for electrons thanks to a strong magnet (0.5 T) steering the electrons towards the detector. The main purpose of the MBES will be measurements on extremely diluted targets and applications of electron–electron coincidences. The present design also includes a holey structure for the magnet enabling the setup to be extended towards electron–ion coincidence measurements.

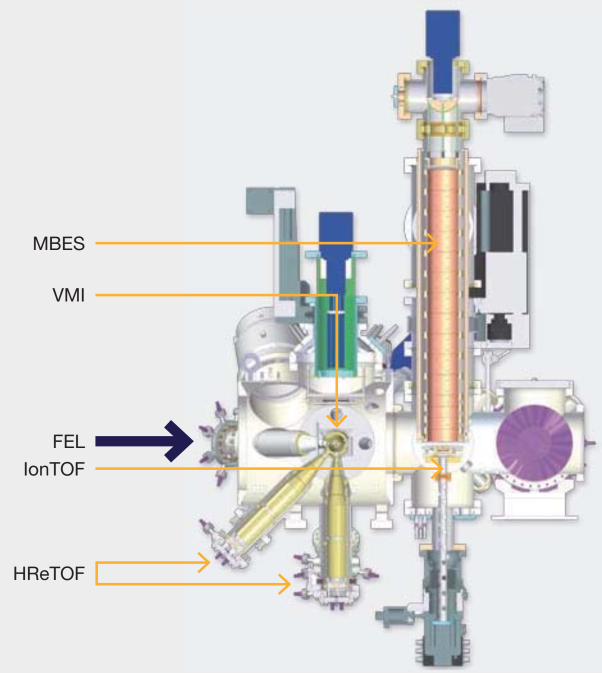

Figure 1 Layout of the AQS experiment chamber in side view, including the magnetic bottle electron spectrometer (MBES) as well as the ion time-of-flight (IonTOF), high-resolution electron time-of-flight (HReTOF), and velocity map imaging (VMI) spectrometers as baseline instrumentation

- **Add-ons for the NQS experiment chamber**
  The NQS chamber is dedicated to investigations of rare-gas and metallic clusters as well as nanoparticles and biomolecules. To enable first imaging experiments on these targets, a large-area, single-photon counting pnCCD detector was mechanically and electronically integrated into the chamber. This detector will enable high-quality single-pulse diffraction patterns to be recorded at 10 Hz repetition rate until the readiness of the final DSSC detector, which will be able to collect images at the ultimate 4.5 MHz repetition rate of the European XFEL.

- **Refocusing optics for timing and spectral diagnostics**
  The design of the beam transport section downstream of the interaction region was finalized. The section includes a pair of elliptical mirrors arranged in a KB configuration. A grating with variable line spacing will be printed on one of the two mirrors such as to disperse a small fraction of the beam for wavelength calibration and monitoring. The other part of the beam will serve for timing diagnostics. This section will not be available for day-one operation but will be installed and commissioned in 2019.

Research activities

The research activities of the SQS group in 2017 concentrated on experiments at the seeded XUV FEL FERMI in Italy.

In continuation of earlier proof-of-principle experiments, one of the new investigations took advantage of the unique possibility at FERMI to control the spectral phase of the FEL pulses. In this study, the process of single-photon laser-enabled Auger decay (spLEAD) could be observed for the first time [1] after its theoretical prediction in 2013. The measured variations in the angular distribution of the photoemission of atomic neon were caused by interferences between two pathways involving spLEAD at the FEL wavelength *ω* and a direct ionization process at wavelength 2*ω*. Since spLEAD is forbidden in the absence of electron correlation, the measurements provide a direct proof of strong electron correlations and were made possible only by the precise control of the coherent, bichromatic FEL pulses, i.e. of the relative phase of photons with wavelength *ω* and 2*ω*.

In other investigations, an intense, circularly polarized optical laser was combined with XUV FEL pulses to study circular dichroism (CD) in the multiphoton ionization of resonantly excited helium ions [2]. In these experiments, the wavelength of the XUV pulses is chosen so as to enable the excitation of a resonance in the ion, here the $He^{+}3p$ resonance. The intensity of the NIR laser, which is synchronized to and spatially overlapping with the FEL pulses, is high enough to ionize the resonant state through a four-photon process. Depending on the

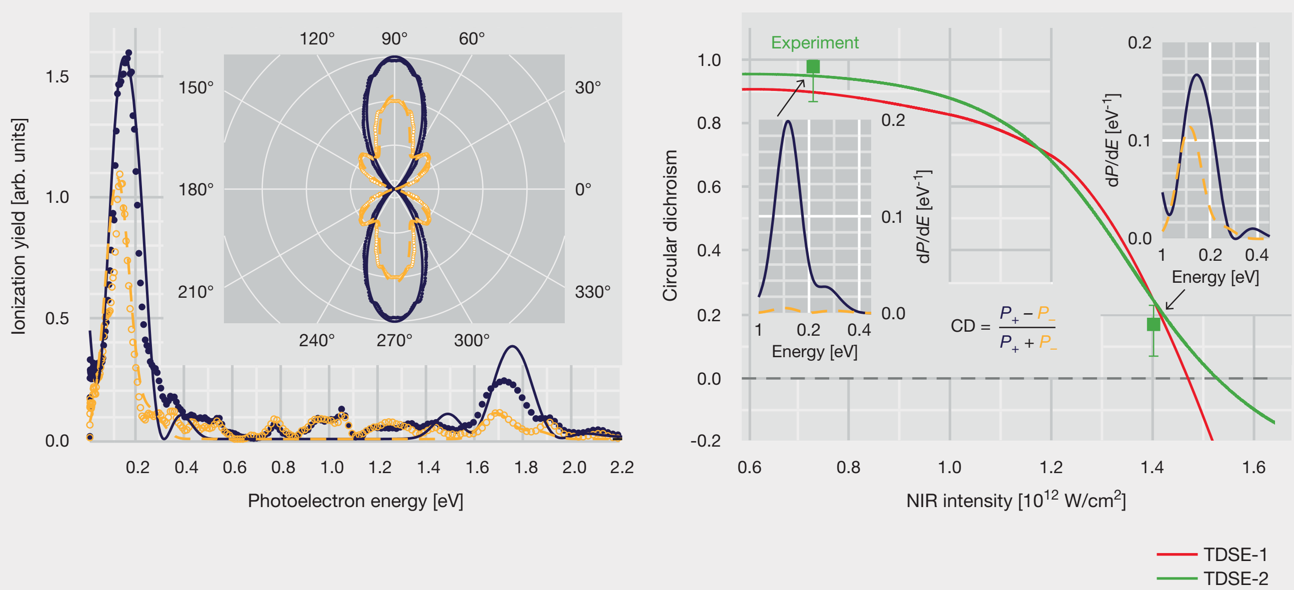

Figure 2 Circular dichroism in multiphoton ionization of resonantly excited He^{+} ions.
Left Experimental (symbols) and theoretical (lines) spectra of photoelectrons at an emission angle of 90°±5° and angular distribution (inset) of the main photoelectron line (around 150 meV) for co-rotating (blue) and counter-rotating (yellow) circular polarizations.
Right Circular dichroism (CD) in the peaks at 150 meV as a function of the NIR peak intensity for an XUV peak intensity of 1.0×10^{13} W/cm^2. The two experimental points are compared with predictions from time-dependent Schrödinger equation (TDSE) calculations. The insets show the low-energy spectra from the TDSE calculations for the two experimental cases. [2]

relative orientation of the helicity of the NIR and XUV pulses—co- or counter-rotating—the ionization pathways are quite different, leading to differences in the intensities of the ionization signal (CD) and in the angular distribution of the outgoing electrons (Figure 2, left). The surprising observation of these studies was that these differences vary as a function of the intensity of the NIR laser (Figure 2, right). This phenomenon is interpreted as a helicity-dependent shift of the 3*p* resonance position and thereby a strong change of the relative population in the resonant state.

Photoionization experiments in the presence of an intense optical laser will also be performed at the European XFEL. The observation of energy shifts for resonances in such studies points to an important effect, which is frequently neglected in the analysis of the experimental data but often essential for the correct interpretation of the experiments performed with intense FEL sources.

Outlook for 2018

The year 2018 will be marked by the installation of the SQS instrument in the first half of the year and the first commissioning experiments in the second half. The different components of the beamline and the three experiment chambers (AQS, NQS, and the reaction microscope SQS-REMI) will be installed, aligned, and characterized without beam at the beginning of the year. A similar scenario is foreseen for all electronic devices, including the integration of the electronics and control units into the European XFEL control and analysis software framework Karabo. To ensure the success of the instrument commissioning with beam, scheduled for autumn 2018, the SQS group will fully concentrate on the SQS installation tasks. The critical highlight will be the start of the first user experiments at the SQS instrument in November 2018.

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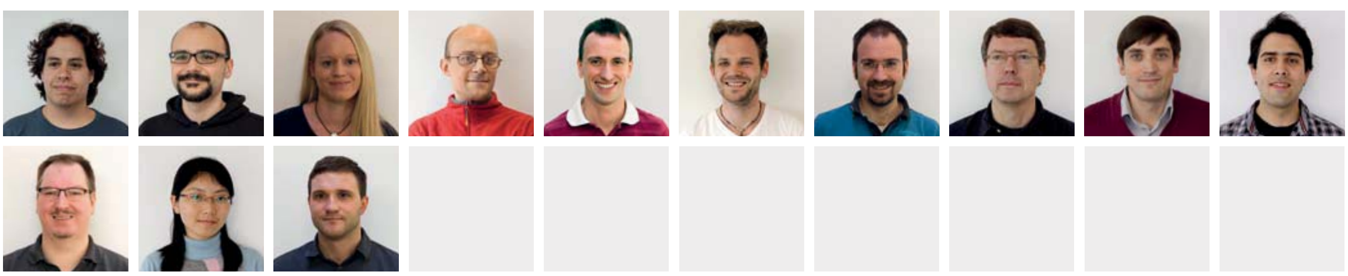
This group has received third-party funding from the **COMO** user consortium and user contributions from several universities through funding from BMBF.



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OPTICAL LASERS

The Optical Lasers group provides laser equipment for pump–probe and other experiments at the European XFEL. This equipment has been developed in house and in close collaboration with industrial partners. In 2017, the group installed the first pump–probe laser system at the SASE1 undulator beamline. The system was successfully commissioned to satisfy the laser specifications required for user experiments at the FXE and SPB/SFX instruments in November. Installations at SASE2 and SASE3 will start in 2018 as soon as the infrastructure is finalized.

Optical lasers at European XFEL

Experiments at the six scientific instruments of the European XFEL require a dedicated, synchronized optical pump–probe laser. In total, three such laser systems are being installed to serve the six instruments, one at each experiment area (SASE1, SASE2, and SASE3). The specifications for the pump–probe lasers were extracted from the science cases of the facility's instruments on the one hand and the peculiarities of the European XFEL emission patterns on the other. The scientific requirements typically result in relatively standard specifications, such as ultrashort pulse durations ranging from a few optical cycles to several 100 fs and pulse energies of a few microjoule to millijoule. Using methods of wavelength conversion, a broad spectral range should be made accessible. The European XFEL emission patterns, however, are quite specific, owing to the burst mode operation of the accelerator: up to 27 000 X-ray femtosecond pulses per second are emitted in 10 Hz bursts of at most 600 μs duration and with up to 2700 pulses per burst—that is, the repetition rate is up to 4.5 MHz within the bursts. The pump–probe laser needs to match these patterns.

Meeting these requirements in combination was clearly outside the scope of today's off-the-shelf laser technology, resulting in the need for a dedicated development effort. Major outcomes of this effort are presented in [1, 2]. They include burst average powers of more than 300 W and single-pulse energies of up to 3 mJ at the 800 nm signal wave of a multistage non-collinear optical parametric amplifier (NOPA). Other features are the capability of producing pulses between <15 fs and 300 fs duration, which are close to the Fourier transform limit. In addition, various schemes for wavelength conversion were successfully tested.

Progress in 2017

In 2017, one major achievement of the Optical Lasers group was the completion of the installation of the pump–probe laser system at the

SASE1 undulator beamline. Although the time available was insufficient for commissioning the full range of system capabilities, the group successfully provided laser service with specifications required for user experiments in November and December. The main laser parameters achieved were in good agreement with those documented during the development phase [2], as evidenced by the pulse parameters shown in Figure 1.

User experiments were performed with 30 pulses per burst, as dictated by the X-ray emission pattern of the European XFEL. The pump–probe laser consequently operated in the same mode, as shown by the oscilloscope trace in the left part of Figure 2. The pulses were synchronized to the X-ray FEL with jitter and drift values below 100 fs. The right side of Figure 2 depicts a camera image of the pump–probe laser beam transported to the experiment. The beam quality is equally excellent as that achieved during the development project.

Further activities

In addition to working on the pump–probe laser development and installation, the Optical Lasers group contributed to the laser integration at the HED instrument at SASE2. This work is a joint effort together with the HED group and the Helmholtz International Beamline for Extreme Fields (HIBEF) user consortium, which will contribute a 100 TW ultrashort-pulse laser and a 100 J–class nanosecond laser (DiPOLE 100-X) to the HED instrument. HIBEF laser scientist Toma Toncian leads all efforts related to the large laser systems on the consortium side. The HIBEF laser staff are based at European XFEL as permanent guests of the Optical Lasers group.

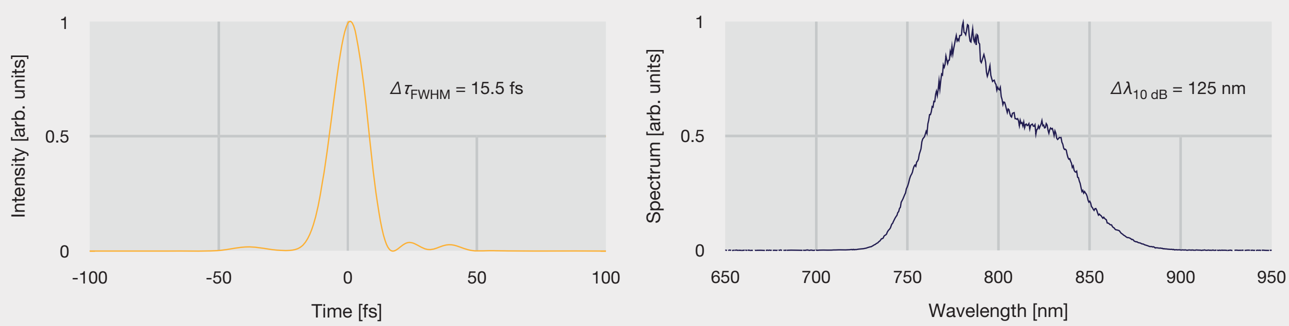

Figure 1 Characterization of amplified pulses at 1.1 MHz intra-burst repetition rate and 230 μJ single-pulse energy.
Left Short-pulse mode, reconstructed pulse shape.
Right Corresponding spectrum. ($\Delta\tau$: pulse duration; λ: wavelength; $\Delta\lambda$: spectral width; FWHM: full width at half maximum; 10 dB: at 10% of peak)

The joint European XFEL and DESY Laser Advisory Committee (LAC) convened in February 2017, explicitly endorsing the efforts and progress of the Optical Lasers group.

One major achievement of the Optical Lasers group was the completion of the installation of the pump–probe laser system at the SASE1 beamline. The main laser parameters achieved were in good agreement with those documented during the development phase.

Outlook for 2018

Major tasks and activities of the Optical Lasers group in 2018 include:

- Final commissioning of all features of the pump–probe laser at SASE1
- Start of pump–probe laser installations at SASE2 and SASE3, as soon as the respective laser rooms are available
- Continued testing of the integration of the pump–probe laser into Karabo, the European XFEL control and analysis software framework
- Continued installation of the pump–probe laser in the R&D laboratory of the headquarters building (XHQ)
- Ancillary experiments with the R&D pump–probe laser, including wavelength conversion, THz generation, and component testing
- Integration of new staff to cooperate with HIBEF in order to gain hands-on experience with the installation and operation of the lasers contributed by HIBEF

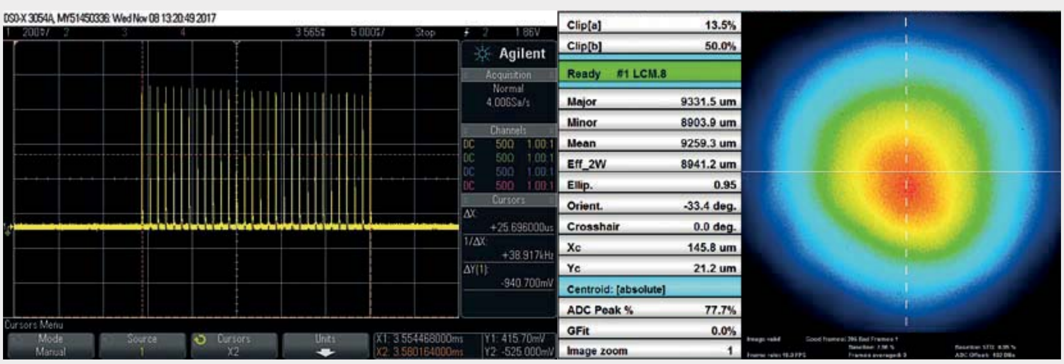

Figure 2 Pump–probe laser output during user experiments in November and December 2017.
Left Burst of 30 pulses with a pulse energy of 230 µJ at 1.1 MHz.
Right Beam profile with >95% Gaussian fit quality.

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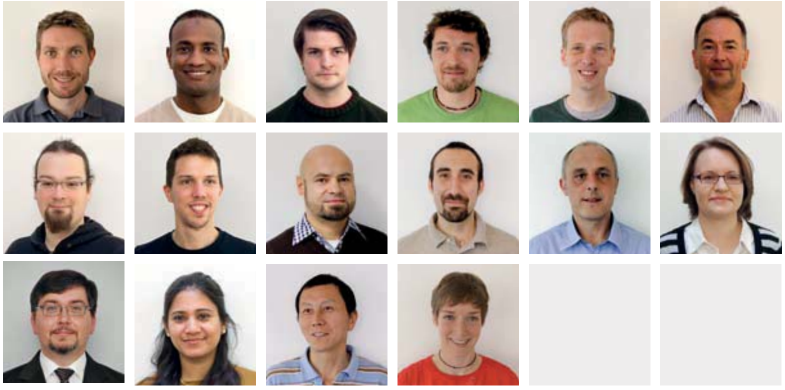


Group members
Samuele Di Dio Cafiso (permanent guest, HIBEF, not shown), Moritz Emons, Mohamed Hassan (permanent guest, HIBEF), Hauke Höppner (permanent guest, HIBEF, not shown), Tomasz Jezynski (not shown), Daniel Kane, Martin Kellert, Kai Kruse, Max Lederer (group leader), Dominik Möller (permanent guest, HIBEF), Florent Pallas, Guido Palmer, Mikhail Pergament, Gerd Priebe (†), Monika Toncian (permanent guest, HIBEF), Toma Toncian (permanent guest, HIBEF), Sandhya Venkatesan, Jinxiong Wang, and Ulrike Wegner

SAMPLE ENVIRONMENT

The Sample Environment group is responsible for delivering state-of-the-art sample environment solutions to the scientific instruments. It provides instrumentation and expert know-how in sample preparation and delivery. The group manages laboratories to assist users in preparing and delivering their samples into the European XFEL beam and coordinates the contributions of two user consortia to biological sample preparation and delivery.

Progress in 2017

In preparation for first user operation, the Sample Environment group equipped the user labs and developed procedures for safe and effective operation. In September, the group supported the first users in the labs and at the SPB/SFX instrument. In the biology lab area, the Integrated Biology Infrastructure Life-Science Facility at the European XFEL (XBI) user consortium contributed most of the budget and personnel to prepare the labs and support users. The SPB/SFX environment for liquid and aerosol sample delivery was installed commissioned, and successfully used in first experiments. Development of the fast solid-sample scanner and the magnetic sample environment for the SCS and MID instruments continued in 2017.

Changes to the group

In January 2017, Vasilii Bazhenov joined the group as lab technician. He organized lab safety and operation in the chemistry and physics user labs and supported the FXE users during experiments. Jana Makroczyova started in February as research assistant for the biology labs. Her position is funded by XBI. In addition to Kristina Lorenzen as lab manager and Makroczyova as research assistant, four more staff members were seconded by XBI member institutions. In January 2018, scientist Manuel Izquierdo will move from the SCS instrument group to the Sample Environment group to set up a lab-based photoelectron spectroscopy apparatus.

Biology user support

Led by Lorenzen, the biology lab team started full operation of the labs in August 2017 and successfully supported the first SPB/SFX user experiments. The labs enable users to prepare, purify, and analyse biological samples before delivery into the instrument. A lift connecting the Biosafety Level 1 biology labs to the SPX/SFX sample preparation hutch in the experiment hall allows direct transfer of biological samples into the experiment without leaving the biosafety area.

The Sample Environment group set up liquid-jet testing facilities in the chemistry and physics labs. These facilities include an SPB/SFX mockup chamber and a small chamber for testing the jet properties with real samples. The mockup chamber has the same flange distances as the SPB/SFX instrument chamber so that entire sample environment setups can be tested and users can be trained using the instrumentation.

Chemistry and physics user labs

The chemistry and physics user labs started operation in early 2017. In cooperation with the Sample Environment group, the SPB/SFX group used the dry sample preparation lab for commissioning components of the SPB/SFX instrument. A temporary liquid-jet test lab was set up in one of the chemistry labs. The second one was used by FXE users for sample preparation and characterization. Bazhenov supported users with the efficient and safe use of the labs.

Group member Carsten Deiter analysed the demands for an X-ray scattering device suitable for X-ray powder diffraction of powders and protein crystals in solution as well as for X-ray reflectometry and coplanar X-ray diffraction of layered samples. The device will be delivered and installed in the user labs in the first half of 2018.

Electron microscopy

In 2017, first large-scale instrumentation for the user labs was purchased. An environmental scanning electron microscope (ESEM) from the company Thermo Fisher Scientific was procured and installed. Handover of this instrument—the first electron microscope at the European XFEL—is scheduled for early 2018. The ESEM will enable users to image their samples under native wet conditions. The first SPB/SFX group members started to use it in December 2017. In 2018, it is foreseen to complement the ESEM with a transmission electron microscope in the biology labs, financed by XBI, and an ultrahigh-vacuum SEM combined with a focused ion beam column for fabrication of reference scatterers and milling of samples for scanning transmission electron microscopy.

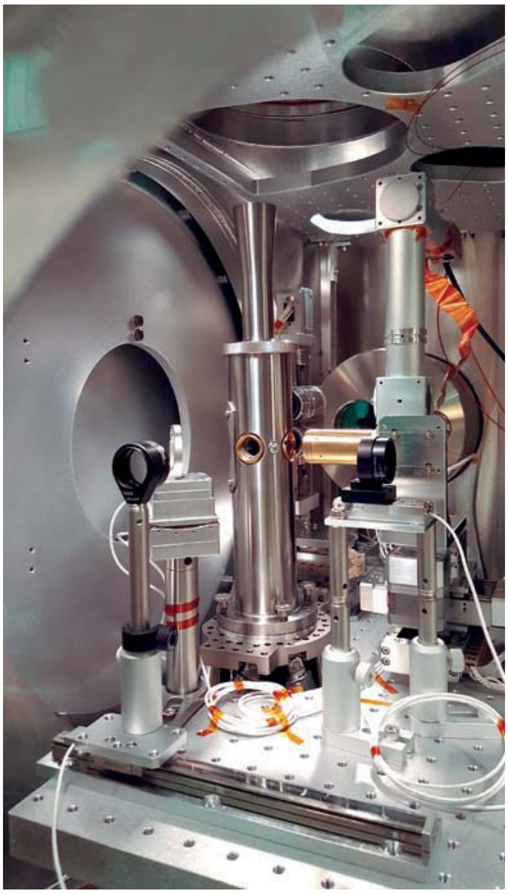


Figure 1 The SPB/SFX liquid-sample environment was set up within the SFX user consortium, in a collaborative effort coordinated by the Sample Environment group.

SPB/SFX sample environment

In cooperation with the SFX user consortium, the group delivered liquid-jet and aerosol sample environments for the SPB/SFX instrument in time for the first experiments (Figure 1). Group members Katerina Dörner, Rita Graceffa, and Johan Bielecki teamed up with the SPB/SFX group and the MPI for Medical Research in Heidelberg, Germany, to commission and operate liquid jets in the first user experiments. For the last user experiment in 2017, the aerosol injector—an in-kind contribution from Uppsala University in Sweden—was installed at the SPB/SFX instrument and successfully operated by Bielecki.

Magnetic fields

In the labs of the Sample Environment group, James Moore set up the magnets and cryogenics lab, where he continued to assemble and test the pulsed high magnetic field sample environment prototype for the MID instrument (Figure 2). He also designed and purchased a second complete prototype of this sort for the SCS instrument. Commissioning of the MID prototype is expected in June 2018 at PETRA III.

For the last user experiment in 2017, the aerosol injector for the SPB/SFX instrument—an in-kind contribution from Uppsala University in Sweden—was successfully installed.

Fast solid-sample scanners

Scanning solid-state samples or targets fixed on substrates is required at five of the six scientific instruments. In 2017, Deiter concentrated on building a fast solid-sample scanner prototype for the SCS instrument, which will start operation at the end of 2018 with the scanner as primary sample delivery device. The next versions of the scanner will be delivered to MID and HED. The specifications of these modified devices were determined in 2017. While the MID device will be a copy of the SCS prototype, major modifications will be necessary for the HED scanner.

Within the High Repetition Rate Sample Delivery (HIREP) work package of the European Cluster of Advanced Laser Light Sources (EUCALL) project, funded by the European Union, David Watts developed sample recognition and localization software to automatically find suitable samples for fixed-target experiments. The software was delivered as part of EUCALL and is in a beta version.

Outlook for 2018

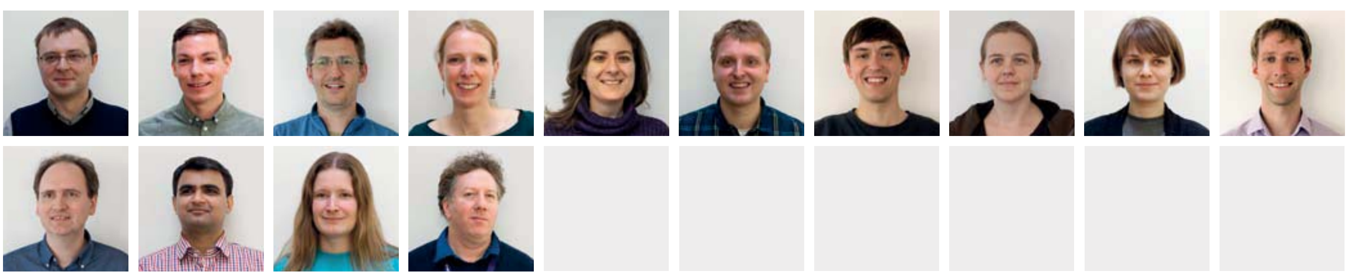
In 2018, the SASE3 and SASE2 instruments will get ready for beam. The group will deliver sample environments to SCS, SQS, MID, and HED. The fast solid-sample scanner will be installed first at SCS and then modified for MID. Development of the scanner for HED and investigations for SPB/SFX will start. The compact pulsed magnet will be delivered first to MID at the end of 2018.

Figure 2 Group member James Moore installs the sample handling device for the MID compact pulsed magnet.

The group will further optimize liquid-jet and aerosol sample delivery for SPB/SFX. In the upstream chamber, which started operating in 2017, the nozzle changing procedure will be optimized. For the downstream sample environment, liquid-sample delivery will be developed. The group will also assist MID, SCS, and SQS in providing liquid jets and aerosols for their users. With HED, a joint project for developing cryogenic liquid hydrogen jets is in preparation.

The group will also optimize support in the user labs. Instrumentation in these labs will be finalized within the first four years of operation. The group is currently launching a project to provide electron spectroscopy for users. Handing over responsibility for biology support from XBI to European XFEL will be an important task for the coming two years.

This group has received funding from the European Union’s Horizon 2020 Research and Innovation Programme for the project “**EUCALL - European Cluster of Advanced Laser Light Sources**” (Grant Agreeement No. 654220).



Group members
Vasilii Bazhenov, Johan Bielecki (seconded by Uppsala University), Carsten Deiter, Elisa Delmas (not shown), Katerina Dörner, Rita Graceffa, Yasmin Gül (XBI laboratory technician, seconded by EMBL, not shown), Huijong Han (XBI, seconded by Oulu University, Finland, not shown), Alan Kadek (guest, Heinrich Pette Institute), Matthäus Kitel, Inari Kursula (XBI coordinator, Bergen University, not shown), Kristina Lorenzen (XBI laboratory manager), Jana Makroczyova (XBI research assistant), James Moore, Ekaterina Round (XBI, seconded by EMBL, not shown), Robin Schubert (XBI, seconded by UHH, not shown), Joachim Schulz (group leader), Prasad Thute, Charlotte Uetrecht (guest, Heinrich Pette Institute), and David Watts

CENTRAL INSTRUMENTS ENGINEERING TEAM

The Central Instruments Engineering team (CIE) comprises two sub-divisions; the Electrical Engineering Team (EET) that produces electrical documentation for all six scientific instruments in terms of PLC based control, and CIE Mechanical (CIEM), responsible for instrument electrical and mechanical design projects.

The Electrical Engineering Team (EET), aims at a full electrical documentation of all six scientific instruments in terms of programmable logic controller (PLC)–based control. This documentation is required for an efficient outsourcing of hardware production through the Advanced Electronics group, for cable manufacturing and installation, as well as for firmware preparation.

Progress in 2017

In 2017, EET took part in the commissioning of the SASE1 instruments SPB/SFX and FXE, while also preparing the electrical documentation for SASE3 and partially for SASE2.

Changes to the team

To manage the workload generated by parallel commissioning and planning and to include additional functions, the team size was increased. A cable technician was hired to account for quality control of the cables laid down by external companies, lead the installation of a cable workshop, and perform on-demand cable fixing and manufacturing. A group leader was appointed to coordinate the tasks and personnel. In total, 10 people worked in EET at the end of 2017.

Electrical designs and cable planning

The core task of EET is to create documentation for the PLC modules, plan the instrument cabling up to the component connection boards, and prepare for the creation of TwinCAT control firmware using the EPLAN documentation.

The EPLAN documentation is key to successfully meeting the electrical requirements of the instruments. The EPLAN designs form the basis of production of PLC modules and inform all the other suppliers of electrical components and cables. In addition, EPLAN is used to generate the complete electrical documentation for the production of cable lists and later for maintenance of the instruments.

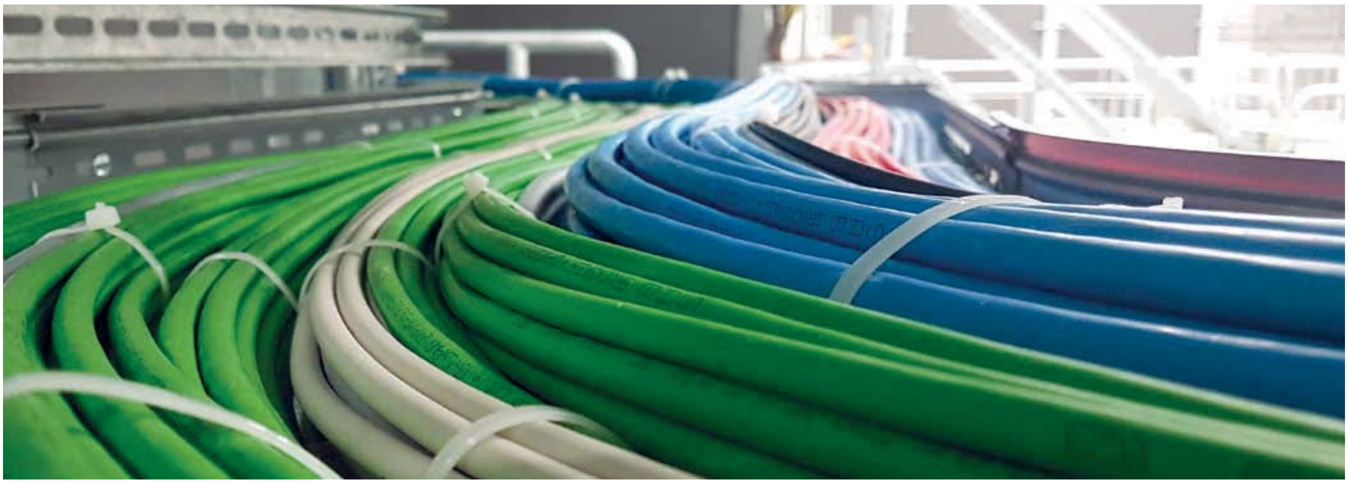


Figure 1 Artistic impression of cabling in SASE1

In 2017, the SASE1 instruments served the first users. To this end, on the infrastructure side, a total of 116 PLC modules (34 for FXE and 82 for SPB/SFX) were put into operation. The Advanced Electronics group developed and implemented a semi-automatic way to create Beckhoff firmware, which relies on the information available in the documentation provided by EET. The commissioning of the instruments thus requires a feedback to the documentation. All necessary changes were implemented, enabling the instruments to make use of the PLC-based control.

The cabling of the SASE1 instruments was completed in 2017. This infrastructure is in operation.

The production of EPLAN designs for the SASE3 instruments SCS (ca. 50 documents) and SQS (ca. 90 documents) is mostly completed, with about 2% remaining to be done. The cable planning for these instruments is ongoing, with a significant amount of cables already installed (SCS 50%, SQS 20%). For SQS, EET conducted a first EPLAN export for firmware creation. In terms of electrical infrastructure, SQS alone is about as voluminous as the SASE1 instruments taken together.

The production of documentation for the SASE2 instruments started, with an emphasis on the MID and HED tunnel components (compound refractive lenses, attenuator), the MID optics hutch, and the MID AGIPD. The cable planning for tunnel components and AGIPD is completed.

EET devoted about 25% of its working time to the implementation of 81 change requests coming mainly from the instrument groups. Change requests define deviations from the initial requests formulated in component requirement documents. This time-intensive task can interfere with all stages of the electrical documentation, module production, and cabling process. Together with the Photon Systems Project Office and the Advanced Electronics group, EET implemented a proper change request process to account for this task.

CIE mechanical projects

In 2017, the CIE group coordinated several instrumentation projects in parallel, both in-house design solutions, such as the pulse picker for the HED instrument, and subcontracted projects, such as the Danish in-kind contribution (IKC) DK02, “Components for the scientific instruments FXE, SPB, MID, and HED”. The IKC yielded three types of devices for use at each of the SASE2 instruments: beryllium compound refractive lens systems, power slits, and solid attenuators for the MID and HED instruments.

The integration of all three types of devices in the SASE2 tunnels began in 2017 and will be concluded in 2018. These components will be vital for operation of the MID and HED instruments.

Outlook for 2018

In 2018, EET will support SASE1 operation with smaller upgrades and implementation of changes where necessary. SASE3 cable installation will be completed, and the SASE3 instruments will be commissioned. EET will provide initial firmware and implement required changes into the electrical documentation. The hot phase for this task will be spring and summer. MID planning (EPLANs and cabling) will be finished in late spring, freeing up time to work on the HED EPLANs and cabling. To account for the creation of documentation for downstream components of SPB/SFX, another three people are being hired for the span of one year.

Group members
Lewis Batchelor (CIE), Oliver Bieler, Kerstin Dornack, Marco Flade, Michael Fobian, Björn Kagels, Andreas Norden, Patryk Parlicki, Wolfgang Pieper, Jörn Reifschläger, and Laurens Wißmann (group leader)

07

DETECTORS, CONTROLS, AND COMPUTING

The deployment of the detectors, controls and computing systems specially designed for the European XFEL and its massive dataflow involved different groups working in tandem. These groups also supported instrument scientists and users as the first experiments took place in the fall.

Data servers in the experiment hall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DETECTOR DEVELOPMENT

In collaboration with national and international partners, the Detector Development group develops, commissions, calibrates, and maintains high-speed large- and small-area X-ray detectors required by photon experiments for imaging, monitoring, veto, and spectroscopic applications. In 2017, with the start of the operation phase, the group focused on calibrating and commissioning detector systems for user operation.

Progress in 2017

In 2017, the group's investment in detector test infrastructure, calibration methods, and software started to pay off. In cooperation with external partners, the group members successfully tested, commissioned, and finally installed the first 4.5 MHz 2D imaging detectors—the LPD and the AGIPD—at the FXE and SPB/SFX instruments. The first users benefitted from the capabilities of these unique devices.

Changes to the group

In 2017, three new group members joined the DSSC detector integration team at the European XFEL: Student assistants Drew Lawrence and Dibin Jossey contribute to the software development and detector commissioning activities. Integration engineer Jan Engelke works on the integration of the DSSC megapixel detector system.

Ivana Klačkova successfully finished her master studies on the performance of the FastCCD detector that will be installed at the SCS instrument. She will stay in the group and continue her studies as a Ph.D. student in cooperation with Andrea Šagátová at the Institute of Nuclear and Physical Engineering, Slovak University of Technology in Bratislava, Slovakia. Detector scientist Marco Ramilli took over the responsibility for supporting the commissioning, integration, and testing of the Jungfrau detector modules provided by the detector group at PSI, which are to be used for a broad range of applications at various instruments.

From laboratory commissioning to first light

Together with partners from RAL, group member Philipp Lang performed the end-to-end test of the LPD in the HERA South laboratory after delivery of the detector to to the European XFEL in May 2017. Members of the group successfully took the first X-ray images with the fully featured 1 Mpx system and verified its interplay with the European XFEL data acquisition, control, and calibration environment at the nominal

Figure 1 First ultrafast large 2D imaging detectors, LPD and AGIPD, at the FXE and SPB/SFX instruments.
Top Preparation of the LPD at FXE for first user experiments.
Bottom View inside the AGIPD during its integration and commissioning at SPB/SFX.

operation speed of 4.5 MHz before the detector was installed and integrated into the FXE instrument in July 2017 (Figure 1, top).

In parallel, members of the group started commissioning the AGIPD in the HERA South laboratory. Detector scientist Jolanta Sztuk-Dambietz and partners from the AGIPD collaboration focused on surmounting several technological hurdles, such as the replacement of sensor modules equipped with the first-generation application-specific integrated circuit (ASIC) by the follow-up generation. After initial technical and performance testing in the HERA South laboratory, the detector was moved to the SPB/SFX hutch for integration into the instrument (Figure 1, bottom).

This very successful collaborative effort between members of the Detector Development group and their partners culminated in the detection of first X-ray laser light and diffraction patterns at the FXE and SPB/SFX instruments (Figure 2), followed by the start of user operation in mid-September 2017.

The DSSC collaboration ramped up the testing, assembly, and commissioning activities of the low-energy high-speed 2D imaging camera for the European XFEL. This first camera will be equipped with mini silicon drift detector (MiniSDD) sensors until large-format DEPFET sensors become available. The DSSC collaboration successfully demonstrated the functionality of the second-generation ASIC. The members of the Detector Development group are ready to start the camera integration and commissioning, together with their partners, as soon as the first detector components will arrive.

The cooperation between the company PNSensor in Munich and Fraunhofer IMS in Duisburg, both in Germany, continued throughout 2017 with the production of the first large-scale DEPFET active pixel sensors, the performance of which was successfully demonstrated. Further sensor production runs in 2018 will provide a sufficient number of large-scale sensor modules to build the second DEPFET-based DSSC 2D megapixel imaging camera for the European XFEL, to be installed at the SASE3 instruments in 2020.

Detectors based on CCD technology

For experiments that use single X-ray pulses per pulse train or that integrate the signal over the duration of a pulse train, “low-speed” 2D imaging detectors based on CCD technology will supplement the variety of 2D imaging detectors at the European XFEL. In April 2017, the Detector Development group started a corporation with PNSensor with the goal of providing a megapixel pnCCD camera for first user operation of the SQS and SCS instruments by the end of 2018. In cooperation with their colleagues at European XFEL and PNSensor, the members

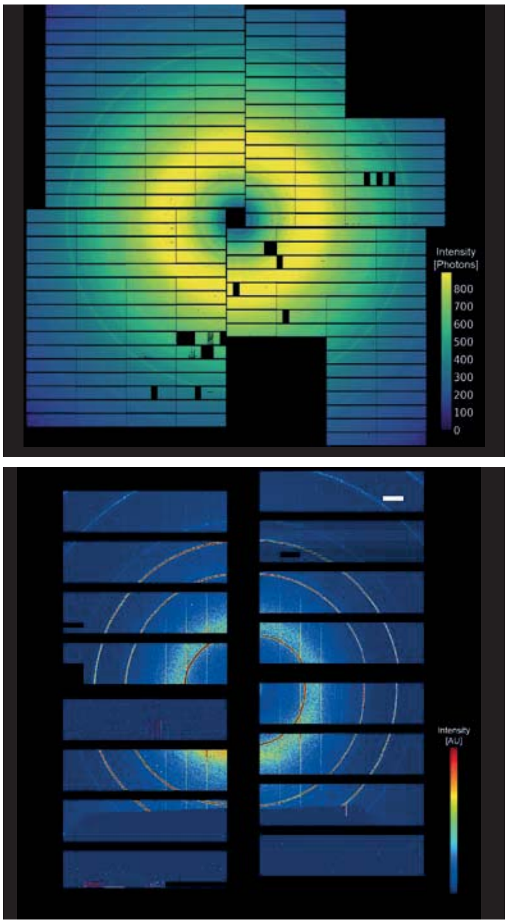


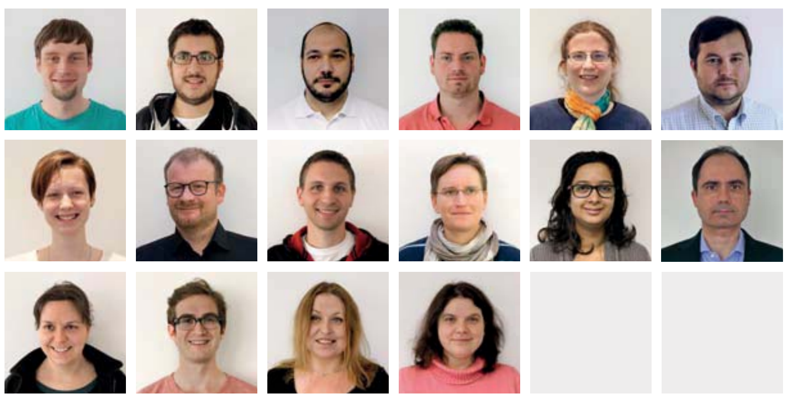
Figure 2 Some of the first diffraction images measured at the SASE1 instruments. The data was corrected for detector-specific effects using the European XFEL calibration pipeline. Darkened panels were either not operational or shielded from the beam.
Top Diffraction pattern measured with the LPD at the FXE instrument. The image shows data averaged over 100 European XFEL pulse trains.
Bottom Lithium titanate diffraction pattern acquired with the AGIPD at the SPB/SFX instrument. The data covers almost the full dynamic range of the AGIPD.

of the group started to prepare the camera design and integration. In parallel, the FastCCD camera was further integrated into the SCS instrument.

Outlook for 2018

In 2018, the SASE2 and SASE3 instruments will transition from the installation and commissioning phase to user operation. Together with its external partners, the Detector Development group will commission, test, calibrate, and perform acceptance tests of two additional 4.5 MHz large-area imaging detectors in the HERA South laboratory—the 1 Mpx AGIPD for the MID instrument and the 1 Mpx DSSC MiniSDD detector for the SCS instrument—thereby ensuring that the first scientific objectives of the MID and SCS instruments can be achieved. After installation and commissioning at MID and SCS, these two detectors will see first user operation at the end of 2018 and beginning of 2019. The group will continue to prepare the detector laboratory infrastructure in the European XFEL headquarters building (XHQ), as a preliminary step for the move of the HERA South detector laboratory to XHQ at the beginning of 2019.

Further important innovations in 2018 will be the integration, calibration, and commissioning of the “low-speed” 2D imaging detectors—the FastCCD and the pnCCD—for the soft X-ray instruments SQS and SCS. ■



Group members
Thomas Dietze (until August 2017), Mattia Donato (Ph.D. student, until August 2017), Marko Ekmedžić, Jan Engelke (not shown), Steffen Hauf, Friederike Januschek, Dibin Chungath Jossey (intern, not shown), Alexander Kaukher, Ludvig Kjellsson (student, not shown), Ivana Klačová (student), Markus Kuster (group leader), Philipp Lang, Drew Lawrence (intern, not shown), Astrid Münnich, Sneha Nidhi (DSSC project, until August 2017), Matteo Porro (DSSC project), Natascha Raab, Marco Ramilli (not shown), Tonn Rüter (Ph.D. student), Stephan Schlee (Ph.D. student, DSSC project, not shown), Rüdiger Schmitt (not shown), Jolanta Sztuk-Dambietz, Monica Turcato, and Georg Weidenspointner (DSSC project, not shown)

ADVANCED ELECTRONICS

The Advanced Electronics (AE) group is responsible for control and fast readout electronics required for automation, data acquisition, and data pre-processing at photon beamlines and instruments of the European XFEL. In 2017, the AE group focused on the installation and commissioning of electronics required for the SASE1 instruments und tunnels.

Installation and commissioning of control electronics

The scientific instruments of the European XFEL include complex systems, such as optical and laser systems as well as detectors and diagnostic devices, all of which require sophisticated vacuum setups, sensors, and motion control devices. More than 100 customized programmable logic controller (PLC) modules were installed in the electrical infrastructure rooms for the FXE and SPB/SFX instruments (Figure 1). In close collaboration with the involved groups, the AE group successfully commissioned more than 500 individual motors, 100 pumps, and 100 sensor and control channels (including in the SASE1 tunnels). Furthermore, the group integrated interlocks providing extensive low-level equipment safety functionality, which reduces the risk of collateral damage in case of human or hardware errors.

More than 100 customized programmable logic controller modules were installed in the electrical infrastructure rooms for the FXE and SPB/SFX instruments. In close collaboration with the involved groups, the AE group successfully commissioned hundreds of individual motors, pumps, and sensor and control channels.

Completion of in-kind contribution contract

The AE group’s Polish in-kind partner institute NCBJ successfully finalized the production of 200 PLC modules, which are a crucial part of the instruments’ infrastructure. Based on the very good collaboration and quality, the production was continued beyond this quantity.

High-speed data acquisition electronics

Many diagnostic and detector systems are required to carry out the experiments. Specific types of detectors—such as (avalanche) photodiodes, pin diodes, or multichannel plates—measure specific quantities at specific locations. The signals from these detectors have to be digitized with high-speed analogue-to-digital converters (ADCs) operating up to 10 billion times per second. AE group members

Figure 1 Electrical infrastructure room for the FXE instrument including complex control electronics, such as high-speed electronics (front) and PLC modules (back)

This group has received third-party funding from the European Union's Horizon 2020 Research and Innovation Programme for the project "**EUCALL - European Cluster of Advanced Laser Light Sources**" (Grant Agreement No. 654220).

Bruno Fernandes and Hamed Sotoudi Namin developed online processing algorithms and firmware for the field programmable gate arrays (FPGAs) located on the selected ADC modules that allow real-time pre-processing, feature extraction, and data reduction. In 2017, the developed systems and solutions were installed, commissioned, and used on photon diagnostic and laser systems as well as for scientific experiments at the FXE instrument.

Group members
Awais Ahmed, Frank Babies, Bernard Baranašić, Kai-Erik Ballak, Nicola Coppola, Janna Eilers, Dino Emes, Bruno Fernandes, Tobias Freyermuth, Patrick Geßler (group leader), Sylvia Huynh, Nerea Jardon, Mahadi Jidda, Marko Meyer (not shown), Hamed Sotoudi Namin, Jan Tolkiehn, and Juri Zach (student)

Changes to the group

The successful production, installation, commissioning, and support activities were only possible thanks to the tireless and devoted effort of the AE group members. To meet the expected increase of in-the-field work and support tasks, two experienced technicians (Dino Emes and Marko Meyer) as well as three PLC engineers (Bernard Baranašić, Sylvia Huynh, and Nerea Jardon) joined the group.

Outlook for 2018

In 2018, the AE group will focus on the remaining production, installation, testing, and commissioning support for control and data acquisition electronics and firmware for SASE2 and SASE3. Furthermore, the group will provide support for operation, experiments, and optimizations based on gathered experience. ■

CONTROL AND ANALYSIS SOFTWARE

The Control and Analysis Software (CAS) group is responsible for providing the experiment control and data analysis framework Karabo, which covers all scientific instruments, photon beamlines, and laboratories at the European XFEL. In 2017, the group set up the control system for the first photon beamline in operation, SASE1, and the related scientific instruments, FXE and SPB/SFX.

Summary of 2017

In 2017, CAS activities closely followed the priorities set for the facility by the Photon Systems Project Office to ensure the success of the transition to operation and of the first early user experiments at the European XFEL. The CAS group contributed to the SASE1 tunnel closure, first lasing, instrument radiation readiness, commissioning, and early user experiments at FXE and SPB/SFX by setting up and configuring the control system and providing 24/7 support for its operation. To support the experiments, CAS also started to provide help with data analysis integration. A new feature, the Karabo Bridge, was developed and used in early user experiments. It enables the experiment-specific analysis tools of the users to be directly fed acquired data in real time. In January 2017, the group presented Karabo 2 and its data analysis features to the international user community in a satellite workshop of the annual Users' Meeting.

In 2017, as CAS transitioned from development to operation, the group continued to grow to ensure the proper level of support needed for operation. The experience gained in 2017 provides a good basis for planning the activities in upcoming years, when operation and further commissioning work will need to be performed in parallel.

In 2017, the focus moved to operation, and the Agile software release cycle was adjusted to the operation schedule.

Transition to operation

After successfully developing and releasing the Karabo 2 framework in 2016, the major goal in 2017 was to finalize missing features and start using the system for commissioning and continuous operation. The focus moved from development to operation, and the Agile software release cycle was adjusted to the operation schedule. The focus change necessarily slowed development, and Karabo releases concentrated on fixes and improvements. However, as part of a development led by Hans Fangohr, the group's senior data analysis scientist, Karabo

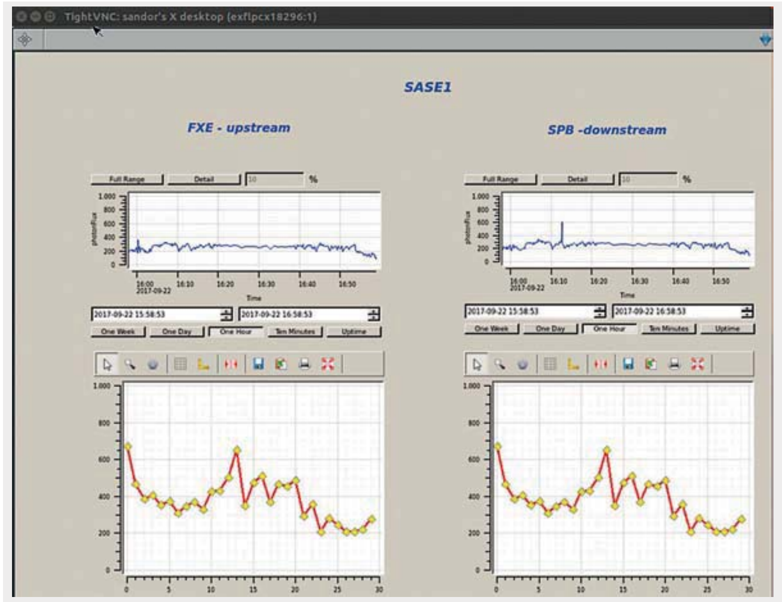


Figure 1 DOOCS-controlled X-ray diagnostic devices (in this case, X-ray gas monitors) provide pulse-resolved data via Karabo from SASE1-common upstream (left) and SPB/SFX-specific downstream (right) branches.

Bridge was introduced, which supports the integration of external user data analysis applications. Users are welcome to contact the CAS data analysis integration experts before, during, and after their experiments. In April 2017, the group established an on-call-duty system providing constant support so potential obstacles to commissioning and operation can be dealt with efficiently. Additionally, CAS members are present on a daily basis at the instruments when measurement shifts start in order to guarantee a quick intervention if errors occur.

Achievements in 2017

In 2017, the CAS group achieved the major milestone of delivering a control system for the first early user experiments. In March, CAS provided users and in-house instrument and support scientists with a virtual machine with Karabo and a hands-on tutorial pre-installed. This tool and the workshop beforehand helped the control system operators to prepare for using Karabo.

Under the respective coordination of group members Alessandro Silenzi and Christopher Youngman, the SASE1 and SASE3 photon beam transport, vacuum, and diagnostics systems were commissioned at the beginning and end of the year. In between, Dennis Göries and Alessandro Silenzi coordinated the respective efforts of setting up the control systems for FXE and SPB/SFX.

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ICALEPCS2017, Barcelona, Spain JACoW Publishing
ISBN: 978-3-95450-193-9
doi:10.18429/JACoW-ICALEPCS2017-TUCPA01

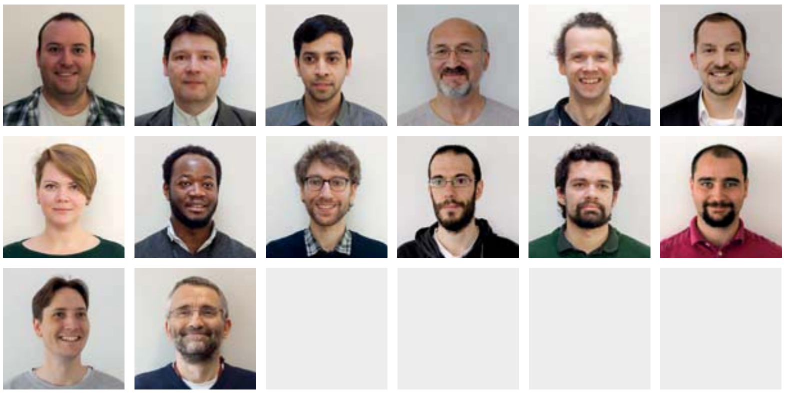
The increased group responsibilities are governed by the newly created CAS executive team, consisting of Sandor Brockhauser (group leader), Hugo Santos (agile project manager), Léonce Mekinda (chief software architect), and Hans Fangohr (senior data analysis scientist). The CAS executive team meets on a weekly basis and makes decisions on all strategic questions and unresolved issues.

The group is also participating in the European research projects OpenDreamkit, a Horizon 2020 initiative aiming to deliver an open digital research environment toolkit for the advancement of mathematics, and the European Open Science Cloud for Research Pilot Project (EOSCpilot), in which CAS contributes to the Photon-Neutron Science Demonstrator.

Outlook for 2018

In 2018, the CAS group will continue to develop Karabo, add new features, and support SASE1 operation and experiments. The group will also be involved in the commissioning of the photon beamline installations for SASE3 and SASE2 as well as the commissioning of the corresponding scientific instruments, enabling first beam and early user experiments. ■

This group has received third-party funding from the European Union's Horizon 2020 Research and Innovation Programme for the project "**EOSCpilot - The European Open Science Cloud for Research Pilot Project**" (Grant Agreement No. 739563) as well as the project "**OpenDreamKit - Open Digital Research Environment Toolkit for the Advancement of Mathematics**" (Grant Agreement No. 676541).



Group members
Marijan Beg, Valerii Bondar (not shown), Sandor Brockhauser (group leader), Cyril Danilevski (not shown), Wajid Ehsan, Sergey Esenov, Hans Fangohr (not shown), Gero Flucke, Gabriele Giovanetti (not shown), Dennis Göries (not shown), Burkhard Heisen (until March 2017), David Hickin (not shown), Tobiasz Jarosiewicz (guest, not shown), Anna Klimovskaia, Thomas Kluyver (guest, not shown), Léonce Mekinda, Thomas Michelat, Andrea Parenti, Hugo Santos, Alessandro Silenzi, Martin Teichmann (until September 2017, not shown), Kerstin Weger (until October 2017, not shown), John Wiggins, Chen Xu (guest, not shown), and Christopher Youngman

IT AND DATA MANAGEMENT

The IT and Data Management (ITDM) group is responsible for providing and maintaining IT infrastructure, a wide range of IT and data management services, and IT user support.

Progress in 2017

In 2017, several strategic decisions were made with respect to scientific data management at European XFEL. In June, the European XFEL Council approved the Scientific Data Policy document, which is the cornerstone for providing all data management services. In November, an operation agreement for ICT services (OpA4ICT), including a scientific computing annex, was signed with DESY. Another collaboration agreement was prepared and signed with NCBJ in Poland, followed by the launch of a pilot project for remote data analysis.

In 2017, IT infrastructure and data management systems for the SASE1 instruments were put into operation. Significant progress was achieved on installations in the SASE3 and SASE2 areas. The group provided further web applications and IT tools for managing experiment proposals, scheduling beamtime, and handling experiment data.

Changes to the group

In 2017, the ITDM group increased its staff by hiring an IT system administrator and a developer of data acquisition software.

IT office infrastructure and support

The IT support to European XFEL staff members and guest scientists covered all aspects of IT for everyday work in offices and laboratories as well as dedicated projects from other work packages and administrative groups. Planning and implementation of the IT infrastructure in new buildings on the campus progressed according to schedule. A dedicated IT room in the laboratory area was put into routine operation.

Data management system

The launch of the User Portal to the European XFEL (UPEX) and the first call for proposals at the beginning of 2017 set key milestones for delivering data management services. Almost 1000 users were registered in UPEX at the end of 2017. UPEX registration, including acceptance of scientific data policy and terms and conditions, is a prerequisite for external users to be granted access to the European XFEL data management services.

In September 2017, data management services were commissioned for the SASE1 instruments, enabling the first users to conduct experiments and collect and analyse experiment data at the facility or transfer the data to their home institute. Users were offered services—such as metadata catalogues and electronic logbooks—to annotate collected data, make assessment of data quality, and request migration of the data to the offline analysis facility and archive.

In 2017, the infrastructure of the DESY data centre was further extended, allowing for the installation of large-scale hardware resources for European XFEL. Half of a 10 PB raw data repository, operated using the dCache data management software, was routinely used, and the second half was delivered at the end of the year. Almost 2 PB of fast storage space, based on a high-performance clustered general parallel file system (GPFS), was used for fast data analysis. About 2000 CPU cores were available for users for the analysis of collected data, and the same amount was ordered at the end of the year in preparation for the next round of experiment data analysis.

Outlook for 2018

In 2018, the ITDM group will continue to provide IT services for internal and external users. Commissioning of the IT infrastructure required for the operation of the scientific instruments in the SASE3 and SASE2 areas will be prioritized as their full operation is expected towards the end of the year. Expansion of the IT resources in the data centre to the full design scale will continue as SASE3 and then SASE2 are brought into operation. ■

Group members
Nasser Al-Qudami (not shown), Djelloul Boukhelef, Illia Derevianko, Jorge Elizondo, Kimon Filippakopoulos, Manfred Knaack, Siriyala Devi Kujala (internship), Luis Maia, Mauricio Manetti, Bartosz Poljancewicz, Gianpietro Previtali (not shown), Eduard Stoica (not shown), Janusz Szuba, and Krzysztof Wrona (group leader)

08 OPERATIONS

In 2017, the European XFEL facility was put into operation, with both the accelerator complex and the first undulator demonstrating strong performance. The smooth startup enabled first user experiments to begin in September.

Operator screens in the Accelerator Control Room at DESY


XFEL.DIAG/CAMERA/OTRC.2615.T9/
ok
Images
Start / Stop
Print
Gain - Value
600
Auto
Frame: 224731
Rate [Hz]: 1.0
ExpGainStudies3.mov
QuickTime movie - 20,3 MB
Created Monday 1 January 2001 at 01:00
Modified Yesterday 05:31
Last opened Yesterday 05:31
Add Tags...

FACILITY

In 2017, the superconducting accelerator complex, the SASE1 undulator, and the corresponding photon beamlines of the European XFEL were successfully commissioned, with the facility generating its first X-ray laser light in May 2017. Electron and photon beam parameters were steadily improved over the summer, reaching values suitable for first user operation to begin in September. In the seven weeks of user experiments planned from mid-September to the end of the year, the facility provided X-ray laser radiation for more than 90% of the scheduled time.

Accelerator operation

The European XFEL accelerator is operated 24 hours a day, 7 days a week to provide electron beams for either photon production or further accelerator development. Operation is controlled from DESY's main accelerator control room. On-call services by vital craftspeople ensure that operation is interrupted as briefly as possible in case of malfunctions. Preventive maintenance during shutdown periods is a must to ensure the required overall availability. In June 2017, the electron beam energy was up to 14.0 GeV, with 3000 bunches accelerated per second. Lasing from the SASE1 undulator was observed at a photon energy of about 6 keV, corresponding to a wavelength of 0.2 nm. Higher photon energies became only possible after a careful alignment of the electron trajectory in the undulator. The electron beam path was straightened to within about 10 µm over a distance of 200 m. Further optimization of the electron beam properties led to lasing with up to 300 electron bunches per second generating photons with a pulse energy of up to more than 1 mJ at a photon energy of about 9.3 keV, i.e. a wavelength of 0.13 nm.

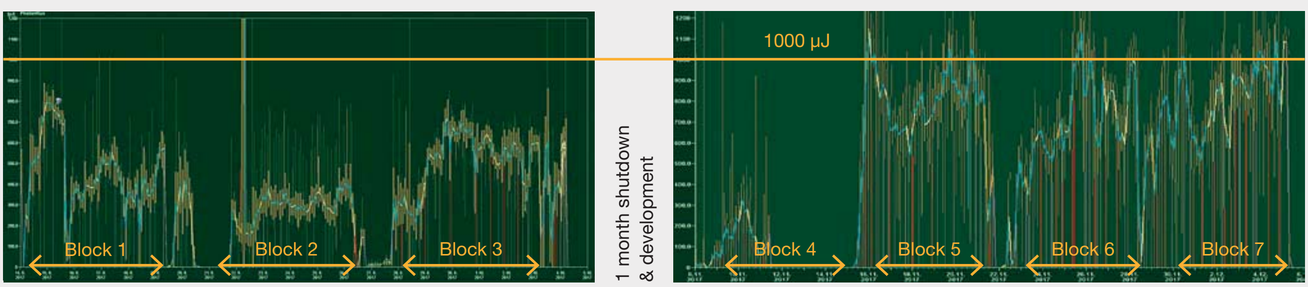


Figure 1 Recording of SASE intensity as measured in the gas monitor detector (GMD) as a function of time for the seven weeks of user operation in 2017. User blocks are marked.

Initially, photons were delivered for commissioning of the photon beam transport and the two SASE1 instruments. Eventually, the first users took beam, starting from 14 September. An operation schedule with a sequence of five days of user operation and two days for facility maintenance, setup, and tuning was established. Every 12 hours, the instrument that received beam changed, and usually it required a re-adjustment of parameters, such as the photon energy.

Figure 1 summarizes the seven weeks of user operation in 2017. As a figure of merit, the X-ray intensity as measured by a gas intensity detector behind the SASE1 undulator is plotted against time. The five-day user blocks are marked, with the weekly two-day interruptions for facility maintenance clearly visible in between. The SASE intensity fluctuates with time, partly because beam parameters have to be changed periodically when experiments change, partly also because of subtle changes of accelerator and environmental parameters. Increasing experience will allow the operators to better control or act on these changes in the future. The increase in performance from Block 5 on is due to a revised undulator trajectory alignment, which was necessary because of ground motion during the three-month period since the last alignment. In most of the weeks, X-ray radiation could be provided during well over 90% of the scheduled time.

This remarkable performance has been possible through the dedicated work of technicians, engineers, and scientists at DESY and European XFEL.

> The commissioning of the SASE1 photon beamlines started on 12 May, shortly after first lasing had been achieved. A photon commissioning team consisting of 17 European XFEL staff members and two guests was put together. With this team working in three shifts per day in the main accelerator control room at DESY, the photon beam could be used continuously for commissioning.

Operation of Photon Beamlines

The commissioning of the SASE1 photon beamlines started on 12 May 2017, shortly after first lasing had been achieved. A photon commissioning team consisting of 17 European XFEL staff members and two guests, a student at the University of Hamburg and the other a scientist from LCLS, was put together from the X-Ray Optics, X-Ray Photon Diagnostics, Undulator Systems, Simulation of Photon Fields, and the six scientific instrument groups (for more on the photon commissioning team, see Chapter 5.4, “X-Ray Optics”). With this team working in three shifts per day in the main accelerator control room at DESY, the photon beam could be used continuously for commissioning of the beam transport system, beam diagnostics, and scientific instruments until the start of SASE1 user operation on 14 September.

After the initial commissioning, the X-ray gas monitors (XGM) of SASE1 were operated 24h/7d in automatic mode with almost 100% availability, delivering absolutely calibrated photon pulse energy and beam positions at two locations in the beamline. The highly sensitive pulse-resolved detectors within the XGM were used as primary tools for SASE tuning, from the level of spontaneous radiation to full FEL lasing. In parallel, operation of the various imagers in the beamline was crucial for tune-up, to detect and optimize lasing. The imagers help to align the photon beam downstream of mirrors and other optical components, understand unexpected effects, and to characterize beam properties like position, size, and shape of the beam (Figure 2).

A particular challenge during operation was the switch between user groups at the SPB/SFX and FXE instruments every 12 h. For this purpose, the beam distribution mirror M3 about 500 m in front of the experiment hall needs to be inserted and retracted, guiding the

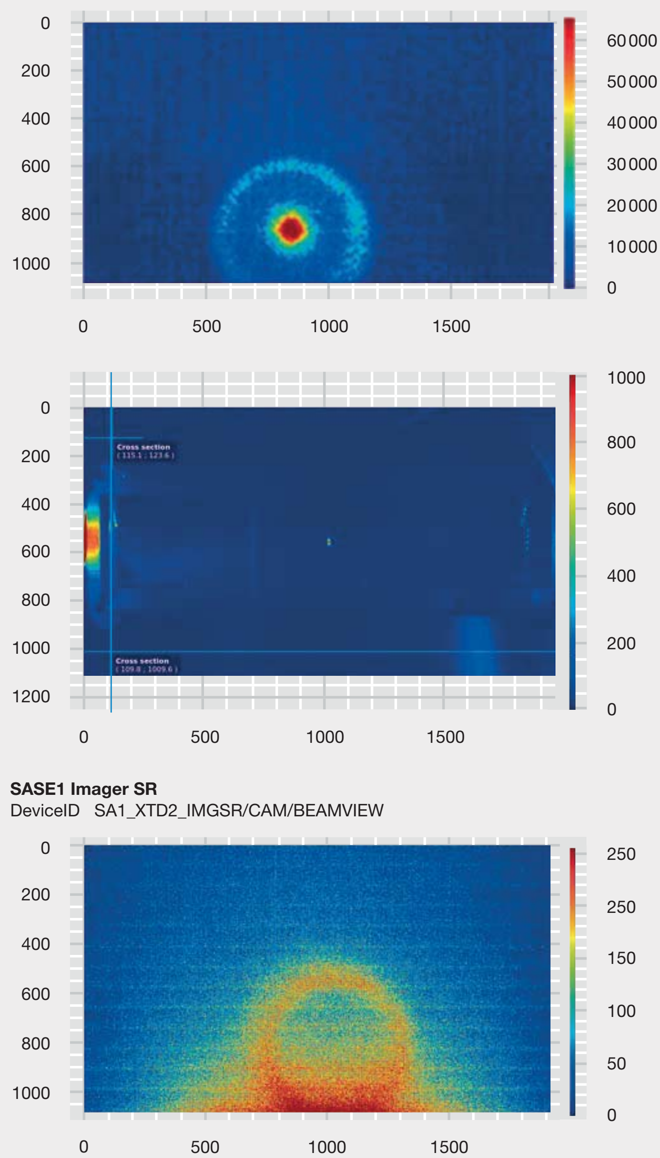


Figure 2 Examples for application of diagnostic imagers during photon beam commissioning

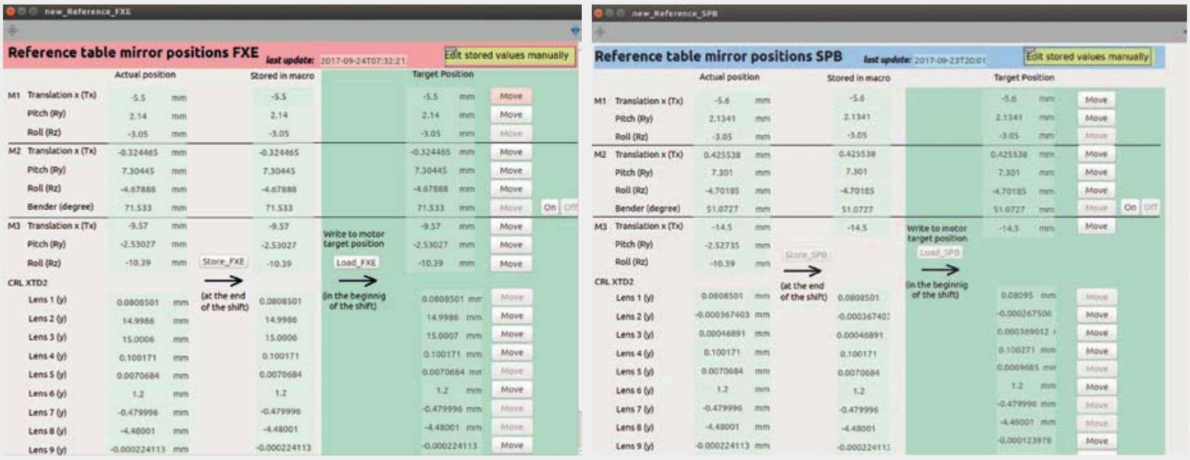


Figure 3 Beam switching macro that allows up to 19 motor positions per instrument to be stored at the end of a user shift and recovered 12 h later at the beginning of the next shift. The panels show the user interface for the FXE instrument (left) and the SPB/SFX instrument (right).

beam to either FXE or SPB/SFX. Because of the long distances, the required accuracy of the alignment is quite high, in the sub-microradian range. Moreover, due to the use of a collimating lens system for FXE, the precise beam geometries including the bending radius of the second offset mirror M2 are slightly different for the two instruments. A Karabo macro was therefore developed that allows up to 19 degrees of freedom required for the alignment of the beam transport system for each instrument to be stored and moved (Figure 3). This development significantly shortened the alignment time at the beginning of each user shift.

In November, the data acquisition system (DAQ) became available for recording diagnostics data from the tunnels into the final data repository, which enabled us to start systematic beam delivery studies. In particular this allowed for collection of statistics about the beam intensity, pointing, and determine the photon spectrum (see Chapter 5.6, “X-Ray Photon Diagnostics”).

Photons were delivered almost continuously during the first user period, with up to 30 photon pulses per pulse train and 300 pulses per second at a photon energy of 9.3 keV, corresponding to a wavelength of 0.2 nm. The individual pulse energy was typically between 0.5 and 1 mJ. Short interruptions of several hours were caused by the failure of an electrical contact on the FXE shutter and an interruption of three days by the failure of the M2 bender system due to unexpectedly high friction developing in a part of the bender mechanics.

Major challenges for 2018 are the commissioning of the SASE3 and SASE2 beam transport systems, diagnostics, and instruments. Further improvements of the SASE1 systems are required for them to reach their full capabilities, such as the availability of feedbacks, commissioning of the hard X-ray monochromator for FXE, and further automatization of diagnostic beam monitoring. The pulse rate available for users is planned to reach 3000 pulses per second in 2018.

EXPERIMENTS

The SASE1 hard X-ray undulator was the first of the three X-ray generating structures at the European XFEL to be put into operation. The two scientific instruments at the SASE1 beamline—FXE and SPB/SFX—received their first X-ray beam on 23 June 2017. After just a few weeks of commissioning, the first users were welcomed at the instruments in September 2017. User operation of this first run continued into 2018. The first publications from these experiments are expected in 2018.

First user experiments at the FXE instrument

In preparation for the first beam at the SASE1 instruments FXE and SPB/SFX, the DESY survey and alignment group had successfully aligned the 8 m stretch of various X-ray optical components (slits, focusing lenses, imagers, and so on) so that a well-shaped beam appeared on the FXE imaging screen right after the beam shutter in the XTD9 tunnel was opened (Figure 1).

The FXE group promptly performed a first X-ray diffraction experiment (Figure 2).

The Control and Analysis Software group then made it possible to resolve individual X-ray pulses within the train (containing at that time only two single pulses, separated by 880 ns), which was demonstrated using another calibration sample (lanthanum hexaboride LaB_6 powder).

The following 36 12-hour-shifts were used to commission some of the instrument components inside the FXE hutch, in order to be ready for user experiments. The FXE group

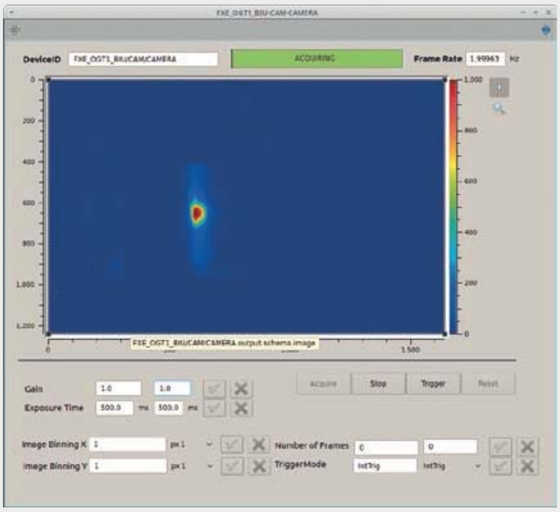


Figure 1 First X-ray beam inside the experiment hutch of the FXE instrument

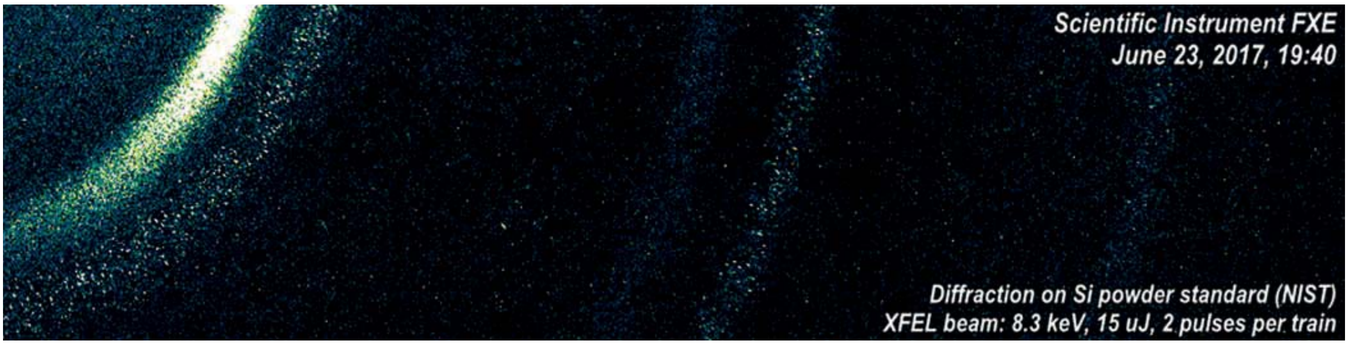


Figure 2 On 23 June 2017, shortly after receiving the very first X-ray laser beam, the FXE group recorded a first X-ray diffraction experiment.

tested the performance of the beryllium lens stack by recording caustic scans of the beam size. Finally, the X-ray emission spectrometer was commissioned by starting to fill up the von Hamos–type spectrometer with cylindrically bent crystals.

During the inauguration ceremony on 1 September 2017, European XFEL welcomed its first users of the FXE and SPB/SFX instruments by handing each of them an oversized access card to the European XFEL facility (Figure 3).

In total, seven experiments from the first call for proposals were granted beamtime. Two scheduled proposals had to be cancelled due to technical problems that were not directly related to the instruments, the users were granted additional beamtime in 2018. At the initial three user experiments, the available scanning tools were still limited. However, with each experiment performed, the capabilities of the FXE instrumentation increased, enabling the users to record a very first sub-picosecond time-resolved X-ray emission spectrum of an ongoing chemical reaction.

Figure 3 First users of the FXE instrument: Wojciech Gawelda from the FXE group and Alexander Guda of the Southern Federal University in Rostov, Russia, received their official access card to European XFEL during the inauguration ceremony on 1 September 2017.

More results were obtainable thanks to the constantly improving control software and data acquisition schemes, including pulse-resolved recording with a large 1 Mpx detector, which was successfully controlled.

First user experiments at the SPB/SFX instrument

Seven experiments from the first call for proposals were granted beamtime at the SPB/SFX instrument, including three community proposals open to all interested members of the scientific community, which emerged from the SPB/SFX Early Users Workshop held in November 2016.

All three experiments in the first block of user beamtime employed serial femtosecond crystallography to resolve the structure of proteins that were delivered as micrometre-sized crystals in a liquid jet. Additionally, the later experiments also used a laser pump/X-ray probe scheme for time-resolved studies. The final experiment performed single-particle imaging of viruses, therefore requiring major modifications to the experimental setup—most importantly, a sample-to-detector distance of several metres (Figure 4) and the installation of an aerosol injector for sample delivery. All of this was achieved from September to December.

Two scheduled proposals had to be cancelled due to technical problems that were not directly related to the instruments, the users were granted additional beamtime in 2018. Of the five experiments undertaken, all produced data and most generated tens of thousands of diffraction frames for analysis. A number of research articles are in draft, and the quantity and quality of data collected across these experiments is encouraging.

Figure 4 The SPB/SFX instrument configured for single particle imaging of single virus particles. The very long sample to detector distance was configured specifically for this experiment.

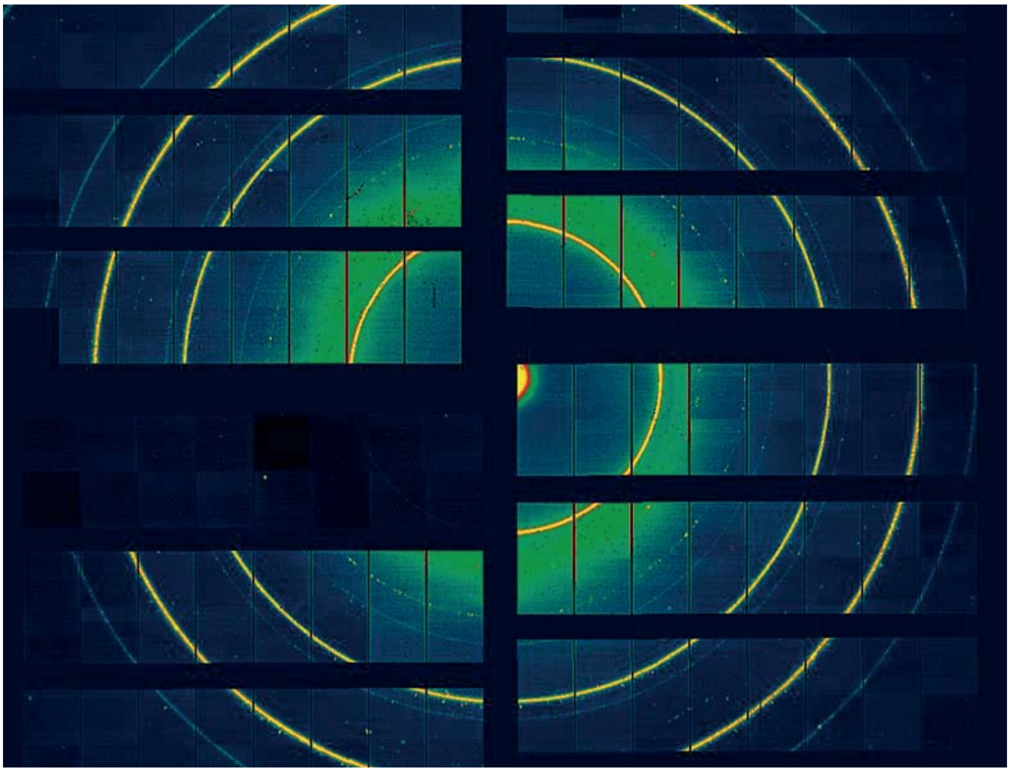


Figure 5 Powder diffraction from a single pulse of the European XFEL recorded at high dynamic range on the AGIPD (detector) at the SPB/SFX instrument

A particular highlight was the AGIPD—the 2D detector that was used in the European XFEL for the first time during the first user-assisted commissioning time. Already in its first experiments, it demonstrated a higher dynamic range than equivalent 2D detectors at other X-ray FELs (Figure 5). A collaborative effort of the AGIPD consortium, the European XFEL Detector Development group and the first user group to use the AGIPD ensured it was calibrated so well as to produce data ready for subsequent analysis.

These first measurements were made possible through the extraordinary effort of many European XFEL staff members. They were further made possible by the enthusiastic collaboration and contributions of the early user groups who understood that, while not all capabilities were perfect, results would come from working together to realize the best of the X-ray FEL source and instrumentation available at this early time. The approach was a resounding success, with each user group going home with data and the instrumentation becoming more mature with each experiment performed.

User experiments of this first beamtime allocation and commissioning continue into 2018 with further key milestones, such as the installation of the focusing mirrors to provide smaller and more intense focal spots, planned throughout the year. In 2017, the capabilities available to users already increased rapidly with each successive experiment, and the rate of progress in 2018 is expected to be almost as rapid. Simultaneously, the SPB/SFX group will work towards more standard experimental setups for the most common classes of experiment to further enhance the user experience.

OPERATION STATISTICS

Access to beamtime for non-proprietary research at European XFEL is granted on the basis of peer review of scientific proposals. More than 60 user groups answered a call for proposals issued in early 2017 for access to the FXE and SPB/SFX instruments. Proposal Review Panels (PRPs) are in charge of the evaluation of the scientific merit of these proposals.

Users at European XFEL

The first call for proposals at European XFEL in January was met with strong resonance in the scientific community: Despite experiment conditions that were still limited at the first two instruments, 63 proposals were submitted by more than 500 researchers. The large number of applicants per proposal resulted from a high interest to participate in first user experiments, and also from a series of community proposals to test and develop the new methods provided by the European XFEL. Of these, 14 proposals were selected and the respective user groups invited to carry out their research projects at the facility. Demand for beamtime remained strong following the second call for proposals, which was launched in October.

Beamtime allocation period	201701 (September–June 2018)
Proposals submitted	63
Total number of proposers	505
User shifts requested*	275
Proposals submitted to FXE	37
Proposals submitted to SPB/SFX	26
Proposals allocated beamtime	14
Proposals allocated beamtime at FXE	7
Proposals allocated beamtime at SPB/SFX	7
User visits to Schenefeld campus	463
Remote access users**	41
Individual users (on site or remote)	341

* Each shift amounts to 12 hours.
** Remote access users have access to the data generated during the experiments, but are not on site.

Table 1 Statistics of the first early user experiment allocation periods

No.	Title	Instrument
2012	Serial Femtosecond Crystallography at MHz repetition rates	SPB/SFX
2013	Internal Structure of the Melbournevirus by Flash X-ray Imaging	SPB/SFX
2016	Tracking ultrafast ligand exchange reactions using combined femtosecond X-ray solution scattering and emission spectroscopy	FXE
2017	Collaborative early experiments in time-resolved SFX: i) mix and inject methods	SPB/SFX
2026	Investigating the charge transfer excited state dynamics in mixed-ligand Cu(I) complexes using time-resolved X-ray diffuse scattering	FXE
2038	Structural dynamics induced by and studied with XFEL pulses	SPB/SFX
2042	Droplet on Demand to Massively Reduce Sample Amount for Time Resolved Serial Femtosecond Crystallography with XFELs	SPB/SFX
2045	Investigation of electronic, structural and solvation dynamics following the metal-to-ligand charge transfer in halogen containing Cu diimine complexes	FXE
2046	XFEL pump – optical probe study of ultrafast energy dissipation in semiconductors	SPB/SFX
2050	Unraveling the electronic and structural origin of intramolecular cooperativity in polynuclear transition metal complexes by combined femtosecond X-ray emission spectroscopy and X-ray solution scattering	FXE
2052	Singlet excited state of Cu-based material for Organic Light Emitting Diodes probed with pump-probe X-ray scattering and emission	FXE
2066	Time resolved fs crystallography of electron transfer reactions and the water splitting process in Photosynthesis	SPB/SFX
2072	Structural dynamics in the binding of messenger molecules to heme proteins	FXE
2073	Atomic-scale rearrangements after photon absorption in the hybrid perovskites	FXE

Table 2 Scheduled proposals in 2017

09
SERVICES

Administrative and other employees support the facility, recruit staff, communicate with the public, conduct internal audits, ensure safety, and coordinate services for the facility's external users.

Helping users get access to the experiment hall


Instruments

ADMINISTRATIVE SERVICES

The European XFEL administration fulfils an enabling role. The members of the administration provide the necessary resources for the construction and commissioning of the European XFEL facility. They recruit highly qualified staff from all over the world and purchase goods and services, from office supplies to highly sophisticated, state-of-the-art scientific equipment. They manage the company's finances, draft and implement the annual budget, run efficient cost controlling, and make sure that the company complies with all legal obligations. In 2017, the administration helped ensure a smooth transition to the operation phase.

Composition

Currently, the administration is composed of five groups: Finance and Controlling, Human Resources (see "Human Resources"), Legal, Procurement, and the User Office (see "User Office"). Furthermore, library services are part of the administration. Altogether, the administration comprises 25 staff members, some of them in part-time positions. Counted in full-time equivalents, this corresponds to 8% of the total European XFEL staff.

Finance and Controlling

The financial resources of the company are managed by the Finance group. The activities include all financial transactions, such as the payment of invoices and salaries, as well as liquidity management, based on the requirements of the project and the scheduled cash contributions by the different contracting parties funding the project. The Finance group is also in charge of bookkeeping and accounting in accordance with the applicable German accounting standards. The members of the Finance group deliver the annual financial statement of European XFEL and make sure that the company correctly fulfils all tax obligations. Members of the Finance group also serve as secretary and vice secretary of the Administrative and Finance Committee (AFC). Due to the start of facility operation, the capitalization of assets was one of the major tasks of the Finance group. As in previous years, external auditors issued an unconditional certification for the annual statement 2016.

The Controlling group issues regular cost reports and forecasts to provide the management board as well as all group leaders with up-to-date financial information.

Cost controlling of a complex project like the European XFEL with a budget of 1.25 billion euro (in 2005 value) is a big challenge. It is a joint effort involving all groups within the company and is coordinated by the Controlling group. Working at the frontier of technology means that a high level of uncertainty has to be met with high-level flexibility in project controlling. The high number of international partners, many of which contribute a large fraction of their share to the project in kind, further increases complexity. The

Controlling group issues regular cost reports and forecasts to provide the management board as well as all group leaders with up-to-date financial information, anticipating probable developments and risks. In 2017, the operation phase started with the first operation budget for the second half of the year. Controlling coordinated the execution of the budget in close collaboration with the management board, the group leaders, and the Finance group. In parallel, the spending of the remaining construction budget continued.

Legal

The Legal group supports the other administrative groups and the scientific work packages, giving legal advice and drafting legal documents (e.g. legal memos, contracts) on a wide range of subjects. In 2017, the Legal group was intensively involved in activities related to the transition from the construction to the operation phase of the European XFEL facility. As responsible operator of the facility, various contracts—in particular with DESY—and administrative procedures have to be carried out, activities that involve public authorities and considerable lead time. Members of the Legal group also serve as secretary and vice secretary of the European XFEL Council. Their task is to support the council chairman in all council matters. At the end of 2017, a member of the Legal group was re-elected as one out of two equal opportunities spokespersons.

Procurement

The Procurement and Logistics group at European XFEL guarantees the security of supply and access to new and often state-of-the-art technologies for the European XFEL campus. This is achieved by the successful and economical processing of all purchases and the performance of a variety of public tenders. Part of the group's responsibility is to ensure that all relevant European and German laws regarding public tenders are respected and kept for all procurement activities.

The year 2017 proved to be another challenging year for the Procurement and Logistics group. As the whole campus was preparing for the start of operations in September 2017, the group processed a total of 8107 purchase requests, resulting in a total of 7788 purchase orders, a significant increase of 49% compared to 2016. At the same time, the group processed a total of 12 tender procedures covering purchases above the EU tender threshold of 209 thousand euro (k€) and 25 procedures covering purchases above the national threshold of 30 k€ for goods and services. The total value of the goods and services purchased in 2017 amounted to 31.5 million euro (M€).

For civil construction, supported by seconded staff from DESY, 372 requests for civil construction were processed in 2017, an increase of 55% compared to 2016. Orders for a total value of 9.5 M€ were executed for civil construction. For the technical infrastructure of SASE2 and SASE3 (electronic installations, cabling, and so on), a total amount of 3.4 M€ was spent. For the completion of the technical building systems in the warehouse and workshop building (XHWS), orders with a total value of 1.7 M€ were placed. The remaining 4.6 M€ were placed for smaller projects in XHEP and XHQ, on the Schenefeld campus, and to start the planning and construction of the canteen building (XHC), the guest house (XHG), and the undulator building (XHU).

In April 2016, a substantial reform of the public procurement law, initiated by the EU, took place and, in the first step, affected all European-wide public tenders with a value > 209 k€. This reform changed all the pre-existing laws. The Vergabe- und Vertragsordnung für Leistungen (VOL EG) was voided and replaced by Vergabeverordnung (VgV) and a revised Gesetz gegen Wettbewerbsbeschränkungen (GWB). A new law was passed, committing all public procurement offices, starting in April 2017, to implement an electronic tendering process enabling all bidders to anonymously download and receive all tender documents electronically. Suitable software using a customized platform was tendered and set up by European XFEL just in time. In a second step, an electronic tendering management system has to be implemented by the end of October 2018 at the latest.

A joint public tender was performed successfully together with the Helmholtz procurement and logistics group, and the implementation of the system is in progress. Another European-wide public tender for the purchase of a company-wide enterprise resource planning (ERP) system proved to be a challenging task, which was successfully completed in a joint effort with the Finance department by the end of December 2017.

At the end of the year, the warehouse facility (XHWS) was still under construction and an external logistics service provider continued to take over the tasks and the processes of the goods receiving department, something that will continue until the European XFEL warehouse facility (XHWS) starts its operations. In summer 2018, the Procurement and Logistics group will start the operation of XHWS. To ensure a good start using the right concept fitted to European XFEL needs is essential. The Procurement and Logistics group is presently working together with the Fraunhofer Institute for Materials and Logistics, located in Dortmund, to develop a comprehensive concept for the new warehouse and logistics at European XFEL.

European XFEL very seldom buys off-the-shelf products. Rather, the company purchases very unique equipment or components with a limited market. It always takes considerable effort by the scientists and the Procurement and Logistics group to find the best method of introducing the demand to the market in the form of a public tender, with the goal of reaching as many potential suppliers as possible. In 2017, customs and commercial transports continued to be challenging topics. A good amount of time and effort was spent on the ratification of the customs-exempted import of scientific research technology and equipment by the German customs authorities headquartered in Munich. This continues to remain a highly sensitive topic and demands constant monitoring of all exempted goods. Furthermore, a customs audit was announced by the customs authorities and is expected to take place in the beginning of 2018.

More planned projects already waiting for procurement action in 2018 will be the tender for planning of the XUL building (formerly called HIBEF), a big tender for maintenance cleaning of the complete European XFEL campus, and tenders to procure all furniture needed for XHC and XHG. The Procurement and Logistics group is always focused on giving the best service to all European XFEL staff members, guests, and users.

Introducing an ERP system

To facilitate the smooth and efficient operation of the facility and to further increase the transparency and availability of information for stakeholders, the company will implement an enterprise resource planning (ERP) system. The main objectives are to provide an integrated real-time view of core business processes, to track business resources, to share related data across the various groups, and to facilitate the information flow between all business functions. The project will start in 2018, and the operation of the ERP system will start in the first half of 2019.

Library

Library services for European XFEL staff and guests are performed in close collaboration with the DESY Library. European XFEL is an active member of the Librarian group of EIROforum, a collaboration between eight European intergovernmental research organizations. ■

INTERNAL AUDIT

In 2017, the internal auditor conducted audits of administrative tasks and procedures and other relevant activities at European XFEL. Additionally, the internal auditor acts as the contact person for all questions related to the company anti-corruption policy.

The internal auditor verifies that employees comply with corporate rules and regulations as well as laws and decrees; that the company is making appropriate and economical use of funds; and that assets are properly safeguarded. The internal auditor thus has two core tasks. The first is to focus on the legality, propriety, and regularity of the implementation of the budget and determine whether the financial management of the company is sound and effective. The second core task is to examine the processes of the company and to advise the management board on how to best optimize processes for efficiency, practicality, and suitability. ■

HUMAN RESOURCES

The transition from the construction phase to the commissioning and early operation phase in 2017 involved a significant change in the working mode of many employees. Shift work and on-call duties were implemented and the corresponding works agreements were reached. As the chief negotiation partner of the works council, the Human Resources (HR) group strove to ensure appropriate and efficient solutions. Additionally, the diligent recording and disbursement of shift, night, Sunday, and public holiday allowances required the implementation of additional new administrative processes.

Continuing to grow

In 2017, the recruitment of staff continued to be one of the main activities of the HR group. Ninety-four new employees began work at European XFEL in the course of the year. Considering the usual fluctuation, the net growth of employees, students, and guests amounted to 60 persons. On 31 December 2017, 397 (+19%) were associated with European XFEL. During the year, the HR group processed 1781 applications.

The recruitment activities once again proved to be efficient, and all job openings could be filled. The share of women among our scientists increased to 20% (+1%). Nevertheless, the company seeks to further improve the gender balance among the scientists and engineers. The share of staff members from countries other than Germany remained at 47%, while the share of scientific staff from other countries decreased to 54% (-4%). Eleven percent of the newcomers were recruited from outside the country.

Guest scientists

Worldwide collaborations with universities, other research facilities, and user consortia resulted in a considerable amount of additional staff on the premises. At European XFEL, the support for this group is also the responsibility of HR. On 31 December, 48 guest scientists worked at the company.

Transition to the operation mode

The transition of the working time organization, which previously was mainly based on a trust-based flexible schedule, to shift work and on-call duty for a significant percentage of the staff, was—and continues to be—a challenge for the individuals and for the company. Working at night, on weekends, and on public holidays affects not only the organization but the private and social lives of employees. Through extensive consultation with the works council, working time plans were developed, which increased operational efficiency and helped safeguard the health and motivation of staff members. With the upcoming full operation mode, these issues will grow in importance. Consequently, the further development of the working time plans remains a considerable topic.

Group workshops, leadership coaching, and German classes

The still-ongoing build-up of the groups, as well as the re-orientation of objectives during operation, requires team development activities. Group workshops, usually two days in length, have been successfully implemented and are performed by the majority of the groups once a year. The feedback from the group leaders and participants is very positive.

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In particular cases, it proved very effective to support supervisors in critical team situations with individual leadership coaching. Since such development activities were implemented, some group leaders seized the opportunity to improve their leadership skills.

In 2017, we were able to continue the popular in-house German language classes for employees and their dependents. The costs of the courses were shared between the company and the employees.

Company event

On 2 September, a company event, dedicated to the partner country Russia, was held in Schenefeld. All employees and their families were invited, and more than 500 people used the opportunity to have a look at the facility and to celebrate together, playing games, listening to Russian music, and enjoying Russian food and beverages. The event was a thank-you to the families as well as an opportunity for non-German employees to build up social connections and to become better integrated.

Co-determination

According to German legislation, the works council has the right to affect personnel policy, individual personnel decisions, and organizational processes of a company. Professional and trustworthy collaboration between the works council, the HR group, and all group leaders is necessary for the efficient development of the company.

In addition to the development of shift work and on-call duty regulations, the existing works agreement on telecommuting was revised and a new works agreement to protect non-smokers was issued.

To ensure safe operation and efficient administration as well as keep data acquisition to a minimum, an access regulation system was implemented and negotiated with the works council. DESY provides the corresponding IT infrastructure and DACHS system, while the organizational setup is performed jointly by both companies. ■

PRESS AND PUBLIC RELATIONS

The Press and Public Relations (PR) group serves as an interface between the public and European XFEL. The group ensures that comprehensive and understandable information about the objectives and the progress of the European XFEL is communicated to the media, the public, and other stakeholders in science, politics, and administration. The aim is to inform the public and the scientific community about the research opportunities at the new facility and to ensure its long-term acceptance locally, nationally, and internationally. The PR group also advises the European XFEL staff on interacting with the media and the public.

Objectives

The PR group's objective is to promote European XFEL among the public and in the scientific community, in particular:

- Sustaining and improving regional, national, and international press and other media coverage of European XFEL
- Maintaining and further improving communication through the European XFEL website (www.xfel.eu), social media, flyers, brochures, posters, and the *European XFEL Annual Report*
- Communicating information about the project to the general public, specific target groups, and different stakeholder groups (such as users) through news articles, exhibitions, presentations, and special events
- Fostering neighbourhood relations
- Providing visitor services at the facility

Figure 1 Laser installation on the European XFEL research campus in Schenefeld (left) and at the Hamburg *Elbphilharmonie* (right)

The PR group also organizes events, represents European XFEL at selected external events, manages corporate identity, and develops communication concepts.

Accomplishments

The focus of the PR group's work in 2017 was to raise the profile of the facility in the lead-up to the inauguration (Figure 1 and 2) and the start of user operation in September 2017. The group successfully communicated important milestones in the commissioning of facility to a wide range of local and international audiences through press releases, news stories on the European XFEL website, and active promotion through social media channels. The media interest was unprecedented for European XFEL, and accommodating the many requests for interviews and visits was a considerable part of the group's work.

As part of its media relations work, the group organized the production of a variety of visual materials to communicate the complexity of the facility. These included an update of the "tunnel flight" movie, an animation illustrating how the FXE instrument works, and high-quality photographs of different parts of the facility. These all proved popular with the media. All visual material is maintained in the European XFEL online media database and is free for media use. The group also updated print material, which is published in several languages in collaboration with the facility's stakeholders. These flyers and brochures are useful tools in communicating with the international media, political partners, and the many visitors who come to the facility.

Figure 2 Inauguration event in Schenefeld

Figure 3 A small selection of the media reports on the inauguration of the European XFEL

In the lead-up to the inauguration, the group worked with Hamburg Marketing and the press department of the Hamburg Ministry of Science, Research, and Equality to increase interest in the facility and celebrate the official start of user operation. The main pre-opening event was a laser installation with a strong laser shining westwards from Hamburg's new concert hall, the *Elbphilharmonie*, across the sky to the European XFEL campus in Schenefeld. A message welcoming the European XFEL to the metropolitan area of Hamburg in English and the languages of the European XFEL partner countries was projected onto the base of the *Elbphilharmonie*. In addition to the *Elbphilharmonie*, four more lasers were also set off from four other science institutions in Hamburg. In Schenefeld, five lasers highlighted the underground path of the tunnel fan of the European XFEL. The lasers (Figure 1) were visible every evening from 28 August to 3 September, and the beams in Hamburg's night sky had a total length of about 72 kilometres. The laser installation was launched with a media and blogger event on a Hamburg barge and resulted in extensive media coverage on TV, radio, print, and the Internet.

Posters announcing the European XFEL inauguration were shown at locations across the city of Hamburg, on the information screens of the Hamburg Underground (*U-Bahn*), and at the airport. On 13 September, European XFEL was presented in an event in the Hamburg Planetarium, co-hosted by the Hamburg Minister of Science, Research, and Equality Katharina Fegebank.

The highlight of 2017 was the event inaugurating the facility on 1 September with ministers and other high-ranking officials from the partner countries as well as 800 invited guests. The speakers included German Minister for Education and Research Prof. Dr. Johanna Wanka, French Minister of Higher Education Prof. Dr. Frédérique Vidal, Hamburg's First Mayor Olaf Scholz, Aide to the President of the Russian Federation Prof. Dr. Andrei Fursenko, Swiss State Secretary for Education, Research, and Innovation Dr. Mauro Dell'Ambrogio, Polish Deputy Minister of Science and Education. Prof. Dr. Łukasz Szumowski, and Schleswig-Holstein Minister for Education, Science, Cultural Affairs Karin Prien.

The PR group planned and organized the event and the programme, coordinated the invitation of the representatives of the shareholder countries and other international guests, accommodated media requests, selected, briefed, and supported external partners such as catering, technical services, security, event management services, musicians, the moderator, and European XFEL staff helpers. The event programme included speeches from political representatives from the partner counties, a celebratory ribbon cutting in the experiment hall, a symbolic welcoming of several of the first users at the facility, tours of the experiment hall, and a laser show. A large number of media representatives attended the event, which received substantial national and international media coverage (Figure 3).

Outreach

In addition to the inauguration event, the group was active in a number of other outreach activities. At the end of September, the group organized the European XFEL booth at the physics festival *Highlights der Physik* in Münster, Germany, which this year focused on the topic “Structure and Symmetry”.

In November, European XFEL took part in the Hamburg *Nacht des Wissens* and the DESY Open Day on the DESY campus in Bahrenfeld. More than 20 000 visitors attended the entire event. European XFEL staff presented the facility and its research opportunities, displayed original components of the facility, and demonstrated scientific principles with hands-on activities. Visitors also enjoyed a laser show and film and photo slideshows of the facility.

Interest from different groups to visit the facility further increased, and guided tours have become an increasingly important part of the group's work. Throughout the year, the PR group organized more than 100 guided tours for 3300 visitors to European XFEL, including representatives from the diplomatic corps of different countries, scientists, journalists, politicians, PR specialists, students from universities and schools, and other stakeholders.

Together with local partners, the PR group continued to develop a concept for establishing a visitor centre at the Schenefeld site to better accommodate the increasing number of

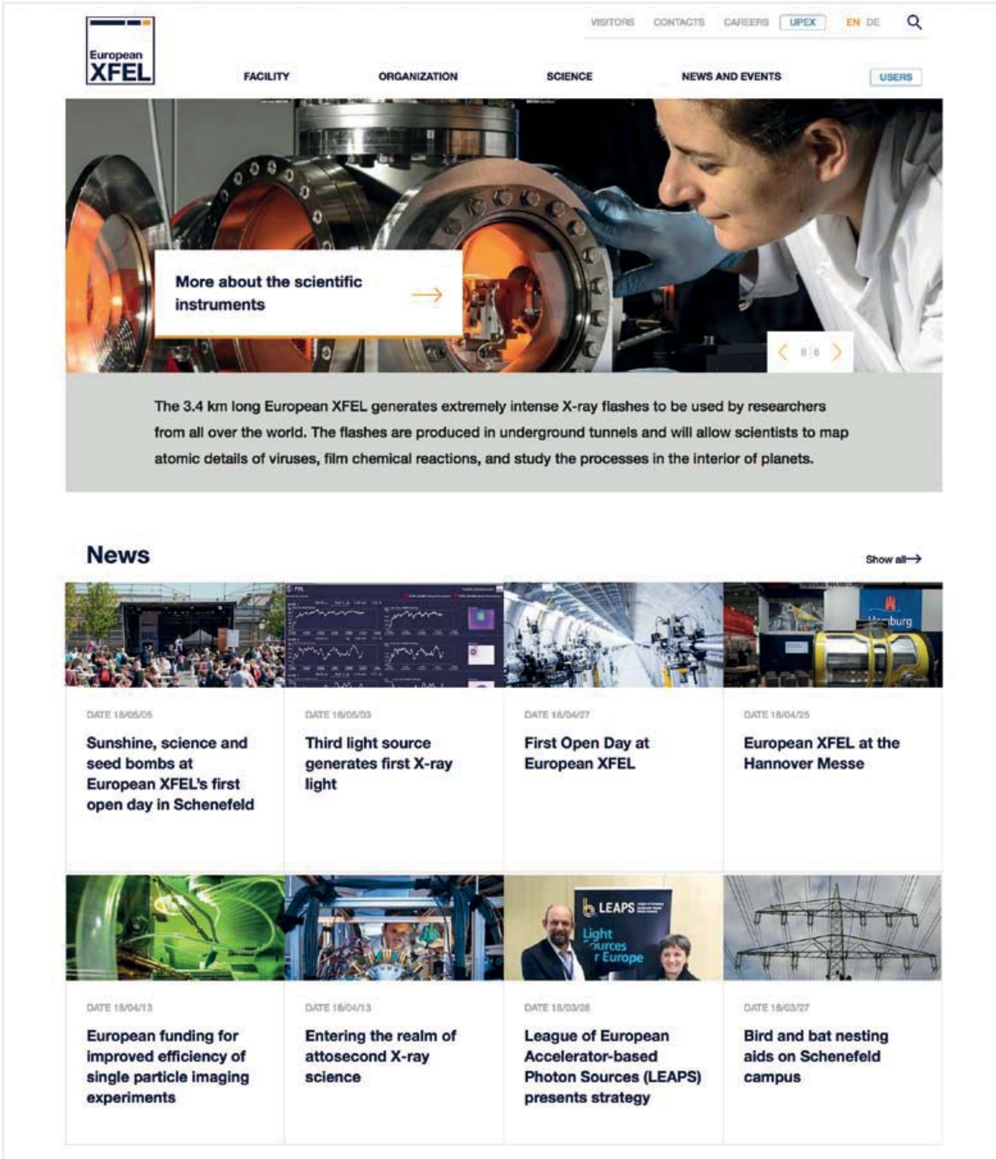


Figure 4 Relaunched European XFEL website

visitors. In 2017, the concept was updated, and meetings were prepared for and organized with different stakeholders.

Reflecting the facility's transition from the construction phase to operation, the PR group relaunched the European XFEL website at the end of August, shortly before the inauguration event. The website (Figure 4) has a new structure and layout and is optimized for use on mobile devices. The launch of the website also marked the last major step towards completing the implementation of the new corporate design.

Internal communication

The PR group supported the Human Resources group in the organization of the European XFEL staff family event on 2 September. The group provided technical and structural infrastructure that had been used for the inauguration event the day before, helped with the selection and briefing of the caterer, ran visits to the experiment hall, and coordinated children's activities. The PR group also organized the participation of the European XFEL team at the HSH Nordbank Run in Hamburg.

To keep the staff up to date with press coverage of European XFEL, the group compiles and distributes a monthly press review of articles and footage from the national and international press. European XFEL is a member of EIROforum, a collaboration of eight major international research organizations in Europe. The PR group contributes to the communications working group, coordinating communications efforts with other members. The group also contributes to the content, editing, and strategy of *Science in School*, the EIROforum journal for school teachers in Europe. In addition, European XFEL is a member of Lightsources.org, a collaboration of science communicators from major light source facilities across the globe.

Neighbourhood work

Since the facility is located in a predominantly residential area, the PR group has considered the transparent communication with local residents an extremely important part of its work throughout the civil construction of the European XFEL (since 2009). The group has taken care to establish a relationship built on trust and support within the local community, investing time in regular face-to-face meetings to keep residents informed about the current status of construction and address any concerns that may arise. In addition, local residents know they can contact the PR group's neighbourhood office at any time should they have questions or concerns. The office participated regularly in a working group focused on the Osdorfer and Schenefelder Feldmark landscape conservation areas, presenting the compensation measures implemented by European XFEL. The office maintains contacts with the local NABU nature conservationist group concerning the renaturation measures of the Düpenau river and nesting aids for birds and bats.

Outlook

With the transition from construction phase to operation, the focus of the work within the PR group has also shifted. In 2018, more instruments will come online, and more and more users will visit the facility for experiments. The group will communicate the upcoming milestones, as the additional beamlines and instruments are commissioned and start operation, and will communicate the scientific results of the user experiments. The group will communicate stories about development at the facility and take part in different outreach activities. It also plans the facility's first Open Day in May 2018 so the interested public have a chance to explore the campus and learn more about European XFEL. In all efforts, the group will show the diverse, international, and welcoming work environment of the facility. ■

USER OFFICE

The User Office coordinates user services and related administrative processes for the facility. It is in charge of administrative support, acts as the first contact for all user groups, and serves as an interface between users and other groups in the practical preparation of experiments at the European XFEL. In 2017, the User Office formally began this service for all users of the European XFEL.

First calls for proposals

The first Early User Operation call for proposals at the European XFEL for the two SASE1 instruments—FXE and SPB/SFX—was launched just before the 2017 Users' Meeting, on 23 January, with a deadline set for 20 March. Sixty-three proposals were submitted in this call, a remarkably high number for a facility just starting operation, reflecting the high expectations of the user community.

The second call for proposals opened in early October, with a deadline set for 16 November, in parallel with the Early User experiments at SASE1, and concerned access to the FXE and SPB/SFX instruments for part of 2018. The strong interest by the users was confirmed by the 61 proposals received.

First peer-reviewed proposal evaluation

The first meeting of the Proposal Review Panels (PRPs), the panel of experts in charge of the evaluation of proposals for experiments at the facility, was organized by the User Office on 11–12 May at the European XFEL headquarters. (For a list of members, see Chapter 2, "Organs and committees".)

In the present system, each PRP is in charge of evaluating the scientific merit of all proposals submitted to a specific instrument and of ranking them accordingly, although at this stage feasibility also plays a major role in defining the top proposals. The final experiment schedule is elaborated by the facility with reference to the ranking. Fourteen proposals were allocated beamtime in the second half of 2017.

The evaluation of proposals submitted in the second call will be completed during the second meeting of the PRPs on 18–19 January 2018.

First early users

Between September and December 2017, the user groups awarded beamtime in the first call for proposals conducted their Early User experiments at the FXE and SPB/SFX instruments.

Since the start of Early User Operation, an invaluable tool for practical arrangements for users was the User Portal to the European XFEL (UPEX), developed and supported by the IT and Data Management (ITDM) group. All participants in the experiments registered through

UPEX and, on this basis, the User Office could take care of many arrangements (e.g. general user access rights, assistance with accommodation in the Schenefeld area, travel arrangements and reimbursement for funded users, and specific invitations for visa purposes). Other groups, such as ITDM, used UPEX to perform other tasks (e.g. create user computing accounts). The UPEX processes will certainly evolve over time in order to increase their efficiency and user-friendliness. A development in this direction is a priority considering the size of some user groups (exceeding 80 scientists) and the planned start of operation of more instruments in the near future.

Notably, a special service offered to users affiliated with organizations based in the member countries of the European XFEL is the funding of travel expenses related to beamtime, with the aim of fostering the growth of user communities in these countries. For this purpose, the Travel Office, also part of the User Office group, compiled user travel rules comparable to the standards of other European large-scale facilities.

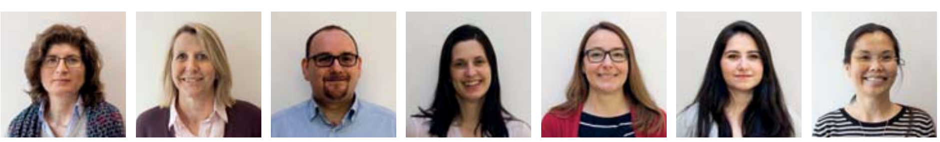
The planning phase of the User Office in the previous few years turned out to be a real asset. However, identifying any weak links in the chain of communication and operations has been one of the most important tasks at the end of the first experiments. Feedback by users was very much appreciated by the User Office. The group will use this input to improve support, which will be provided to an increasing number of users over the next few years.

Ramping up for Early Users

In 2017, a few more members of the group were recruited: Kristina Ivičić started in March as User Office administrative assistant as well as Giulia Quondam, who started in April. Tea Larsson, Travel Office assistant, joined the group in April. To prepare for the operation of the European XFEL guest house, currently in planning, Sven Heberling became a member of the group in December 2017 as guest house coordinator.

Outlook for 2018

The year 2018 will be another very busy year for the User Office. More calls are planned, involving further scientific instruments, and two more allocation periods are planned, involving the visits of about 30 user groups during the year. In addition, the organization of a number of user-related events at the facility will involve the User Office, such the 2018 Users' Meeting (in cooperation with DESY Photon Science) as well as a number of Early User workshops. ■



Group members
Silvia Bertini (group leader), Gabriela Heeßel, Sven Heberling, Tea Larsson, Giulia Quondam, Kristina Ivičić, and Halimah Shie

SAFETY AND RADIATION PROTECTION

The Safety and Radiation Protection (SRP) group supports and monitors the implementation of safety rules and regulations as well as safe working practices at European XFEL. The group reports directly to the chairman of the management board, Robert Feidenhans'l, who is responsible for occupational health and safety (OHS) and radiation protection (RP) matters at the company.

Organization

The SRP group is supervised by the group leader and consists of three teams working closely together:

- General Safety
- Experiment Safety
- Radiation Protection and Laser Safety

In November 2017, a safety review was conducted by a panel of external advisors from other European accelerator facilities. The SRP group's structure and mission as well as the follow-up of user experiments was presented and discussed. The next panel meeting will be held in May 2018.

General Safety

The General Safety team is responsible in particular for risk assessment, technical safety, fire protection, and emergency and access management. The access management system for laboratories and experiment areas was implemented with our partners at DESY. Group leaders have been trained in the use of the access control database.

Work started on a crisis and contingency plan together with the emergency service team from DESY, which began to staff the control centre located in the entrance building (XHGATE) on the Schenefeld campus.

In 2017, efforts were intensified to support staff in assessing and mitigating safety risks in their work areas. The team also did safety checks on equipment brought in by users.

Experiment Safety

The Experiment Safety team is responsible for laboratory safety and user experiment follow-up. User safety webpages and safety guidelines were published. The initial evaluation and follow-up of first user experiments and their safety training took place in close collaboration with the User Office and local contacts at the instruments. Classroom-type training was provided for biological and chemical safety. The first online safety training modules were introduced, starting with the general and experiment safety training, followed by the user safety training module for user experiments.

The Experiment Safety team established a concept for hazardous waste management. Together with the Technical Services group and the chemistry laboratory staff, the team planned for hazardous waste storage containers to be installed in early 2018.

Radiation Protection and Laser Safety

Two separate radiation protection (RP) organizations exist:

- RP organization of European XFEL run by the SRP group and supervising the use of radioactive sealed sources and equipment falling under RP regulations

- European XFEL accelerator RP organization run by DESY with three RP officers of the SRP group certified in 2017 and responsible for European XFEL staff, the experiment hall, and the photon tunnels

In June, prior to the start of first experiments, the personnel safety system (PSS) for the SASE1 experiment area was successfully certified. That same applied to the laser interlock systems of the laser rooms in SASE1 and in the lab area.

In June, prior to the start of first experiments, the personnel safety system (PSS) for the SASE1 experiment area was successfully certified. For access to RP controlled areas of the accelerator area, an electronic personnel dosimetry system was installed in autumn 2017.

For access to RP controlled areas of the accelerator area, an electronic personnel dosimetry system was installed in autumn 2017. The system is now running in test mode and will be active when European XFEL becomes responsible for radiation protection.

The team has also checked that laser or optical devices brought in by users comply with safety rules.

Outlook for 2018

- Further build-up of the SRP group: a RP and laser safety officer (January 2018) as well as a biological safety engineer (February 2018)
- PSS and laser interlock system installation in SASE2 and SASE3
- Training of the new experiment hall crew to support the SRP group in their safety tasks
- Further development of the safety organization and regulations as well as follow-up on user experiments
- Revision of existing online safety training modules and the creation of new modules (e.g. for biological safety, chemical safety, laser safety, and radiation protection)
- Further development of the crisis and contingency plan for the facility in collaboration with the DESY emergency service

Group members

- Sigrid Kozielski (group leader)
- Sabrina Scherz (assistant to SRP group)

Experiment Safety team

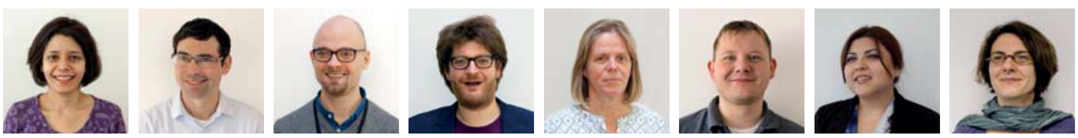
- René Gertz (safety engineer)
- Sandra Plett (safety engineer for biology, starting February 2018)

General Safety team

- Emil Dupuich (safety engineer for technical safety)
- Michael Prollius (safety engineer for general safety)

Radiation Protection and Laser Safety team

- Zunaira Ansari (starting in January 2018)
- Eric Boyd (radiation protection officer, deputy laser safety officer)
- Pouneh Saffari (senior laser safety officer) ■



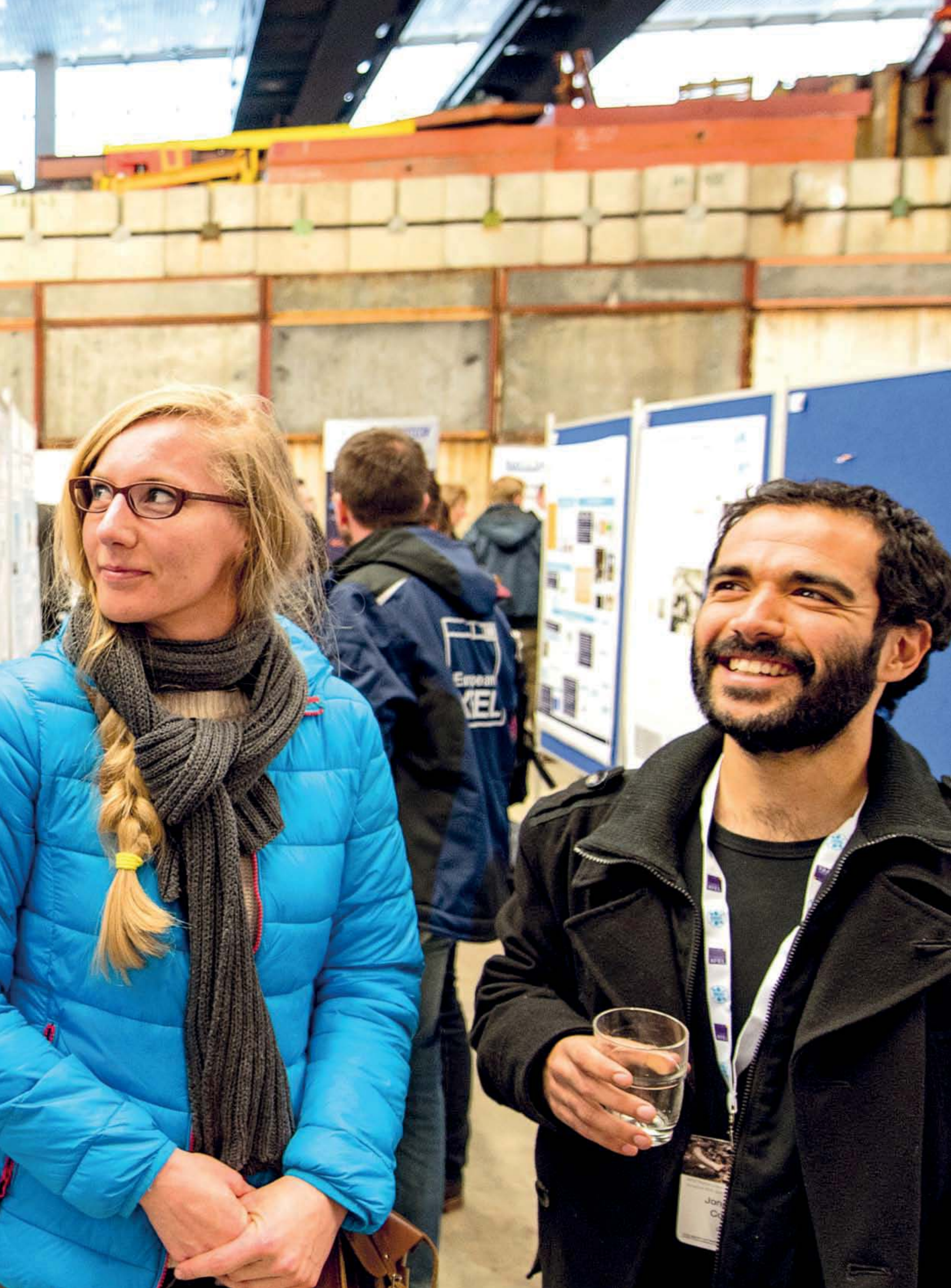
Group members
Zunaira Ansari, Eric Boyd, Emil Dupuich, René Gertz, Sigrid Kozielski (group leader), Michael Prollius, Pouneh Saffari, and Sabrina Scherz

10

SCIENTIFIC RECORD AND GLOSSARY

European XFEL regularly communicates the field's latest research and developments by way of seminars, workshops, and an annual users' meeting. European XFEL scientists also continue to contribute to the advancement of X-ray laser science with a number of publications.

Poster session at the 2017 Users' Meeting



EUROPEAN XFEL USERS' MEETING

25–27 January 2017
DESY, Hamburg, and European XFEL, Schenefeld, Germany

The joint European XFEL and DESY Photon Science Users' Meeting is an annual opportunity to strengthen the interaction between European XFEL and the scientific user community. At the eleventh meeting—the final one before the start of user operation—the number of participants broke the record from the previous year yet again: approximately 1100 scientists from around the world came to the full meeting. The programme included talks; several workshops; satellite meetings on science at the HED instrument, the release of second version of the European XFEL control and analysis framework Karabo, and the European XFEL soft X-ray instruments SCS and SQS; and a poster session with more than 300 posters. Participants discussed details of the European XFEL project, future experiments, user consortia, and recent updates within the field of photon science. Twenty-six students from around the world attended on travel grants disbursed by European XFEL.

The Users' Meeting focused on the following topics:

- Progress and status of the European XFEL
- Instrument design developments and advances
- Selected science applications
- Current developments and recent results in the field of X-ray FEL facilities

For the first time, part of the meeting programme was held on the facility's Schenefeld campus, with a special poster session inside the headquarters building that highlighted the latest developments in each of the scientific and technical groups.

Figure 1 Attendees of the 2017 European XFEL Users' Meeting

FIFTH RACIRI SUMMER SCHOOL ON GRAND CHALLENGES AND OPPORTUNITIES WITH THE BEST X-RAY AND NEUTRON SOURCES

19–26 August 2017
Ronneby and Lund, Sweden

Jointly organized by leading research organizations from Russia, Sweden, and Germany, the fifth RACIRI Summer School immersed students in the latest scientific opportunities made possible by advances at the world's leading X-ray and neutron sources. The school included lectures by representatives of the operating and upcoming X-ray and neutron sources worldwide, as well as scientists from universities and laboratories around the world. Lectures covered topics relating to the advanced studies of materials using photons and neutrons at ever shorter timescales and at increasing brightness and finer resolution, along with the potential societal implications these bring, such as the consequences of revealing the secrets of biochemical behaviour, the development of green construction materials, and the potential revolution in energy production and storage that this research could bring.

The summer school originated from a cooperation between the Roentgen-Aengstrom Cluster (RAC), a partnership between Germany and Sweden, and the Ioffe-Roentgen Institute (IRI), a partnership between Germany and Russia. Speakers included scientists from European XFEL, DESY, and the Max Planck Society in Germany; the University of Gothenburg, Uppsala University, and the European Spallation Source in Sweden; and NRC KI, JINR, and FRC "Fundamentals of Biotechnology" RAS in Russia.

WORKSHOPS

5–6 April 2017
High Intensity Laser Matter Science at the HED instrument at the European XFEL
Organized by European XFEL and the Helmholtz International Beamline for Extreme Fields (HIBEF) user consortium on the European XFEL Research Campus, Schenefeld, Germany

This workshop brought the international user community together with the HIBEF user consortium and HED instrument scientists to discuss the use of high-intensity optical lasers in pump–probe experiments involving investigations into warm dense matter, plasmas, and relativistic laser–matter interaction at the upcoming HED instrument. The event ended with a roundtable discussion, during which day-one requirements for the instrument were outlined based on feedback from the user community.

1–2 June 2017
Terahertz Science at European XFEL
Organized by European XFEL on the European XFEL Research Campus in Schenefeld, Germany

This workshop explored scientifically promising strategies for combining terahertz radiation with X-ray pulses such as those generated at the European XFEL. Attendees discussed methods for generating such radiation and ways of studying non-equilibrium states using ultrashort radiation pulses. Compatibility with the megahertz repetition rate of the European XFEL and opportunities for coherent control were key focal points at the workshop.

Figure 1 High Intensity Laser Matter Science at the HED instrument

15 June 2017

Opportunities for microfluidic devices at free-electron lasers

Organized by European XFEL on the European XFEL Research Campus, Schenefeld

Microfluidics, or micro-fabricated devices used for sample delivery, was the topic of this workshop. In presentations given over the course of this one-day workshop, developers of liquid sample delivery devices and experts in FEL experiments discussed the challenges in sample consumption and increasing repetition rates at these facilities, with a focus on the latest developments in technology and methodology.

9–10 October 2017

MooNpics Workshop

Organized by European XFEL on the European XFEL Research Campus, Schenefeld, and on the DESY campus, Hamburg, Germany

The Metrology on One-Nanometre–Precise Optics (MooNpics) work package aims to push mirror metrology and mirror fabrication techniques to a new standard of single-nanometre figure errors as well as a high slope error precision, while making this know-how available to user facilities and optics companies around the world. The workshop reviewed current metrology capabilities and the latest advancements in measurements of ultrahigh-precision mirrors.

Figure 2 Microfluidics Workshop

29 November – 1 December 2017
New trends in theory for experiments at advanced light sources
Organized by European XFEL, CFEL, and UHH on the European XFEL Research Campus, Schenefeld, and the CFEL campus, Hamburg, Germany

This workshop focused on recent developments in theoretical methods used for interpreting and designing experiments at novel large-scale facilities, including FELs and synchrotrons. Topics discussed included valence-band photoemission spectroscopy; core-level spectroscopy; advanced theories; spectroscopy of strongly correlated systems out of equilibrium; dynamics of topological materials; atomic, molecular, and optical physics; and ultrafast structural dynamics.

30 November – 1 December 2017
Biology at Advanced Laser Light Sources
Organized by the European Cluster of Advanced Laser Light Sources (EUCALL) at the European XFEL Research Campus, Schenefeld, Germany

Among the main objectives of the EUCALL project is to bring together researchers from laser-based and accelerator-based X-ray sources in order to develop new techniques and research opportunities. This workshop aimed to help these scientific communities collaborate on biology applications, with a focus on imaging, serial crystallography, biological X-ray cross-sectional techniques, spectroscopy, radio-biological experiments, sample delivery, industrial use, and data handling.

Figure 3 Biology at Advanced Laser Light Sources

SEMINARS

10 Janurary 2017
Nanoscale plasmas meet X-ray imaging
Thomas Fennel, University of Rostock, Germany

19 January 2017
Plans for a helical afterburner at LCLS-II
Zachary Wolf, SLAC, Menlo Park, California, USA

14 February 2017
Time-resolved studies of small molecules employing coincidence detection techniques
Till Jahnke, University of Frankfurt, Frankfurt am Main, Germany

17 February 2017
Efficient generation of fast particles and attosecond pulses from relativistic laser plasmas
Alexander Andreev, ELI-ALPS, Szeged, Hungary, and MBI, Berlin, Germany

21 February 2017
Laser-plasma accelerators and radiation sources
Dino Jaroszynski, University of Strathclyde, Glasgow, UK

1 March 2017
Coupling microfluidics and small-angle X-ray scattering to study the whole crystallization process of proteins in solution
Sébastien Teychené, Laboratoire de Génie Chimique, Toulouse, France

7 March 2017
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AGIPD
Adaptive Gain Integrating Pixel Detector [European XFEL detector]

ANKA
Angströmquelle Karlsruhe at the Karlsruhe Institute of Technology, Germany

ANL
Argonne National Laboratory in Argonne, Illinois, USA

BINP
Budker Institute of Nuclear Physics of the Siberian Branch of the Russian Academy of Sciences (SB RAS) in Novosibirsk, Russia

BMBF
German Federal Ministry of Education and Research

CAD
computer-aided design

CAEP
China Academy of Engineering Physics in China

CEA in Saclay
Commissariat à l'Énergie Atomique et aux Énergies Alternatives in Saclay, France

CELLS
Consorcio para la Construcción, Equipamiento y Explotación del Laboratorio de Luz de Sincrotrón in Cerdanyola del Vallès, Spain

CFEL
Center for Free-Electron Laser Science in Hamburg, Germany

CIEMAT
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas in Madrid, Spain

CNRS
Centre National de la Recherche Scientifique in Orsay, France

CUI
Centre for Ultrafast Imaging in Hamburg, Germany

DASTI
Danish Agency for Science, Technology, and Innovation

DESY
Deutsches Elektronen-Synchrotron in Hamburg and Zeuthen, Germany

DFG
Deutsche Forschungsgemeinschaft

DOOCS
Distributed Object Oriented Control System

DPG
German Physical Society

DSSC
Depleted P-Channel Field Effect Transistor Sensor with Signal Compression [European XFEL detector]

DTU
Technical University of Denmark

Elettra
Elettra Sincrotrone Trieste in Italy

ELI
Extreme Light Infrastructure in the Czech Republic, Hungary, and Romania

EMBL
European Molecular Biology Laboratory in Germany, France, Italy, Spain, and the UK

ESRF
European Synchrotron Radiation Facility in Grenoble, France

ESS
European Spallation Source in Lund, Sweden

FEL
free-electron laser

FERMI
Free Electron Laser for Multidisciplinary Investigations at Elettra Sincrotrone Trieste in Italy

Fermilab
Fermi National Accelerator Laboratory in Batavia, Illinois, USA

FLASH
Free-Electron Laser in Hamburg at Deutsches Elektronen-Synchrotron (DESY) in Hamburg, Germany

FSBI TISNCM
Technological Institute for Superhard and Novel Carbon Materials in Troitsk, Moscow, Russia

FXE
Femtosecond X-Ray Experiments [European XFEL instrument]

GUI
graphical user interface

HED
High Energy Density Science [European XFEL instrument]

HZB
Helmholtz-Zentrum Berlin (HZB) in Germany

HZDR
Helmholtz-Zentrum Dresden-Rossendorf in Germany

HZG
Helmholtz-Zentrum Geesthacht in Germany

IFJ-PAN
Henryk Niewodniczański Institute of Nuclear Physics of the Polish Academy of Sciences in Kraków, Poland

IHEP
1. Institute of High Energy Physics in Protvino, Russia
2. Institute of High Energy Physics at the Chinese Academy of Sciences in Beijing, China

IKC
in-kind contribution

IMPMC
Institut de Minéralogie, de Physique des Matériaux et de Cosmochimie in Paris, France

IMPRS-UFAST
International Max Planck Research School for Ultrafast Imaging and Structural Dynamics

INFN
Istituto Nazionale di Fisica Nucleare in Italy

INR
Institute for Nuclear Research of the Russian Academy of Sciences (RAS) in Troitsk, Russia

IRFU
Institut de Recherche sur les lois Fondamentales de l'Univers in Saclay, France

JINR
Joint Institute for Nuclear Research in Dubna, Russia

KTH
Royal Institute of Technology in Stockholm, Sweden

LAL in Orsay
Laboratoire de l'Accélérateur Linéaire in Orsay, France

LASA
Laboratorio Acceleratori e Superconduttività Applicata in Milano, Italy

LBNL
Lawrence Berkeley National Laboratory in Berkeley, California, USA

LCLS
Linac Coherent Light Source at SLAC National Accelerator Laboratory in Menlo Park, California, USA

LPD
Large Pixel Detector [European XFEL detector]

MBI
Max Born Institute for Nonlinear Optics and Short Pulse Spectroscopy in Berlin, Germany

MID
Materials Imaging and Dynamics [European XFEL instrument]

MPI
Max Planck Institute

MSL
Manne Siegbahn Laboratory in Stockholm, Sweden

NCBJ
National Centre for Nuclear Research in Świerk, Poland

NIIEFA
D.V. Efremov Institute of Electrophysical Apparatus in St. Petersburg, Russia

NRC KI
National Research Centre Kurchatov Institute in Moscow, Russia

NRDI Office
National Research, Development, and Innovation Office in Budapest, Hungary

PAL
Pohang Accelerator Laboratory in South Korea

PETRA III
PETRA III at DESY in Hamburg, Germany

PSI
Paul Scherrer Institut in Villigen, Switzerland

RAL
Rutherford Appleton Laboratory in the UK

RF
radiofrequency

SACLA
SPring-8 Angstrom Compact Free Electron Laser in Hyogo, Japan

SAS
Slovak Academy of Sciences

SASE
self-amplified spontaneous emission

SCS
Spectroscopy and Coherent Scattering [European XFEL instrument]

SINAP
Shanghai Institute for Nuclear and Atomic Physics

SLAC
SLAC National Accelerator Laboratory in Menlo Park, California, USA

SOLEIL
SOLEIL Synchrotron in Saint-Aubin, France

SPB/SFX
Single Particles, Clusters, and Biomolecules and Serial Femtosecond Crystallography [European XFEL instrument]

SQS
Small Quantum Systems [European XFEL instrument]

STFC
Science and Technology Facilities Council in Swindon, UK

SU
Stockholm University in Sweden

SwissFEL
Swiss Free-Electron Laser at the Paul Scherrer Institut in Villigen, Switzerland

TUHH
Technische Universität Hamburg-Harburg

UHH
University of Hamburg in Germany

UPM
Universidad Politécnica de Madrid, Spain

UU
Uppsala University in Sweden

VUV
Vacuum ultraviolet radiation

WUT
Wrocław University of Technology in Poland

XUV
extreme ultraviolet radiation

YAG
Yttrium aluminium garnet

ACKNOWLEDGEMENT

We would like to thank everyone who contributed to the creation of this annual report.
European X-Ray Free-Electron Laser Facility GmbH, May 2018

European XFEL Annual Report 2017

Published by
European XFEL GmbH

Editor in chief
Robert Feidenhans'l

Managing editor
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Joseph W. Piergrossi
Frank Poppe

Layout and graphics
blum design und kommunikation GmbH, Hamburg

Photos and graphs
BINP, Novosibirsk (p. 87); Michael Björnson (p. 6); DESY (pp. 14, 53-55, 61, 62, 86, 88, 93, 176); Patrick Dumas/CEA, Saclay (p. 87); European XFEL / Blunck+Morgen Architekten (p. 69); European XFEL / DESY (p. 183); European XFEL / Heiner Müller-Elsner (pp. 15, 86); European XFEL / Jan Hosan (pp. 89, 94-95, 126-128, 158, 162-163); FHH, Landesbetrieb Geoinf. und Vermessung (aerial views pp. 20–21); Jessica Mancuso (pp. 15, 145); NASA/JPL (p. 14); NCBJ, Otwock-Świerk (p. 87); Michael Schmidt (p. 63)
All others: European XFEL

Printing
Druckerei Siepmann GmbH, Hamburg

Available from
European XFEL GmbH
Holzkoppel 4
22869 Schenefeld
Germany
+49 (0)40 8998-6006
contact@xfel.eu
doi:10.22003/XFEL.EU-AR-2017
http://www.xfel.eu/documents

Copy deadline
31 December 2017

www.xfel.eu

European XFEL GmbH ■ ANNUAL REPORT 2017