European XFEL

ANNUAL REPORT

European X-Ray Free-Electron Laser Facility GmbH

2015

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

European XFEL

2015

ANNUAL REPORT

European X-Ray Free-Electron Laser Facility GmbH

CONTENTS


X069 – K029
CELL 03
SASE1

Left to right Andreas S. Schwarz, Serguei Molodtsov, Massimo Altarelli, Claudia Burger, and Thomas Tschentscher

Opposite Installed undulator segments in photon tunnel

Dear Readers,

With this annual report, we are very pleased to deliver a record of the progress we made in 2015 towards completing the European XFEL facility.

The past year was an exciting one, culminating in an important milestone on 18 December: The first acceleration of electrons in the injector, albeit over a small fraction of the future linear accelerator, marks the beginning of commissioning and inaugurates a new phase of the project. The fast and relatively smooth achievement of this important step by our DESY partners is a good sign. Although substantial work is still ahead of us, the final milestones are now in sight, and the fruits of our efforts are within reach.

While 2014 had seen a remarkable acceleration of the series production of accelerator components and modules, in 2015 there was similar progress in streamlining the complex set of operations necessary to test, prepare, and finally install the accelerator modules in the tunnel. By the end of 2015, 59 modules were installed, out of a total of 100. The exact date of completion of the remaining installation will be determined by the continuing timely supply of high-quality components required for the assembly of the modules and other accelerator parts.

Over the course of 2015, the Undulator group received the 91 segments as well as additional components for the three undulators that will make up the baseline configuration of the facility. A second campaign of magnetic measurements verified their stability after storage for some months. In the very last weeks of the year, the installation of the first undulator started in the tunnel. We are confident that all three undulators will be in place when the accelerator is fully operational and producing high-energy electron beams.

The X-ray pulses generated in the undulators must be characterized and transported over several hundred metres to the experiment hall. The X-Ray Optics, X-Ray Diagnostics, and Vacuum groups made great progress over the year and started hardware installations in the tunnels. The production of extremely high-quality X-ray mirrors, which are to be polished to the very limits of feasibility, is a precondition for delivering high-quality X-ray pulses to the scientific instruments. We were pleased to see steady progress of the industrial supplier towards meeting the specifications, which were nearly achieved by the end of the year. Diagnostic equipment was tested in the lab and, in some cases, at LCLS in the USA and at FLASH at DESY for commissioning with FEL pulses before being installed in the tunnels.

In Schenefeld, the construction of the new headquarters building made great progress, the external appearance being essentially final and remaining work concentrating on the equipment inside. At the same time, the entrance gate building started to take shape.

Underneath the headquarters building, the experiment hall was the site of very intense activity. The construction of the hutches for the first two instruments, Femtosecond X-Ray Experiments (FXE) and Single Particles, Clusters, and Biomolecules and Serial Femtosecond Crystallography (SPB/SFX)—the latter of which involves a user consortium with wide international participation—went into full swing. In the meantime, construction of the next set of hutches for the two instruments Small Quantum Systems (SQS) and Spectroscopy and Coherent Scattering (SCS) also started. The simultaneous and contiguous activities of several different contractors in the hall require close follow-up and coordination by the Photon Systems Project Office, which is responsible for setting up and maintaining the master schedule of all installations in the hall, including the instrument installations, which will soon begin.

Users of the six scientific instruments foreseen in the baseline version of the facility—those mentioned above, plus the Materials Imaging and Dynamics (MID) and the High Energy Density Science (HED) instruments—will benefit from novel developments in optical lasers, detectors, controls, and data acquisition. The Optical Lasers group successfully developed lasers for pump–probe experiments with a time structure matching the burst mode structure of the European XFEL and performed all proof-of-principle experiments required to validate the concept, before proceeding to fabrication and, in 2016, to installation. In 2015, the Detector Development group was primarily engaged in testing and calibration activities of small prototype detector systems and in the production and integration of the final detector components. The Control and Analysis Software group continued the development of the supervisory control and data acquisition system, Karabo, identifying remaining instabilities and shortcomings; the group successfully demonstrated control of an imager—a diagnostic device—installed in the tunnel.

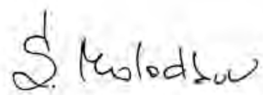
With the year drawing to a close and the promising results from the injector commissioning, setup of the Early User Programme, which will provide a framework for the first call for user proposals by the recently formed User Office, began.

The remarkable achievements summarized here and those that will become more apparent in the coming year are the result of the hard work, dedication, and ingenuity of the whole staff: the six instrument groups that will soon start to assemble their instruments, the scientific and technical groups mentioned above, and also the Sample Environment group, the Advanced Electronics group, and the theory and simulation groups; the sometimes less visible but essential contributions of the Technical Services, IT, and administrative groups are also gratefully acknowledged.

We would like to thank our staff and the staff of DESY and all partner laboratories for their hard work and dedication to the European XFEL and to its success. We also thank the scientific community at large for the interest and support, especially through the provision of important additional resources within the user consortia programme. We are grateful to the shareholders and to their delegates in our council and committees for their constructive and helpful attitude in addressing the issues facing a large and technically very complex project and in providing the necessary resources.

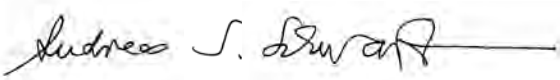
We hope you will find this annual report informative and interesting.

Massimo Altarelli



Serguei Molodtsov

Claudia Burger



Andreas S. Schwarz

Managing Directors

Thomas Tschentscher

Scientific Directors

Martin Meedom Nielsen

Dear Readers,

As you will read in more detail elsewhere in this report, the first part of the European XFEL facility, the electron injector, accelerated its first electron bunches just before the end of 2015. This achievement is one of the signs that the construction phase of the European XFEL is entering its final stages. Also, the new headquarters building in Schenefeld is rapidly taking shape, and, in the vast underground tunnels, the accelerator modules are being installed at a swift pace along with undulators and other photon systems, while hutches in the experiment hall are being readied for the installation of the scientific instruments. The contours of what will become the world's best facility for X-ray science are becoming clearer and clearer—a visible testimony of the significant steps forward for the project in 2015.

In last year's annual report, I wrote that, due to the enormous complexity of the project, some technical challenges were encountered that could not have been foreseen in the original planning. This resulted in a one-year shift of the project milestones and hence also a shift in the start of operation to 2017. Together with the European XFEL Management Board, the Council has been heavily engaged in establishing a framework for handling the shift in the start of the operation phase, in ensuring the financial and legal platform for extending the construction for a further year, and in setting up initiatives to minimize further risks to the new milestone dates. These initiatives have been very efficiently coupled with the efforts of the Accelerator Consortium, which is constructing the superconducting linear accelerator of the facility. The Accelerator Consortium has been working hard to implement new measures to overcome risks to the project milestones and has managed to increase the rate of production and installation of critical components. I am happy to say that these measures are working very well, and our primary objective is to maintain this momentum, ensuring that 2017 will remain the start of operation.

The European XFEL Council met three times in 2015, taking note of the reports by the European XFEL Council Chairman, Management Board, Administrative and Finance Committee (AFC), Machine Advisory Committee (MAC), and Scientific Advisory Committee (SAC). The council discussed and decided on the issues related to these reports, along with a number of other important issues concerning staff, legal matters, in-kind contributions, and project management as well as financial and organizational matters. As we are approaching the end of the construction phase, we are also nearing the financial limit, or “cap”, for construction. I am pleased to say that we are coming out of 2015 in good shape, due to the efforts of the shareholders and partners to ensure timely financial contributions to the company, and I am confident that the European XFEL has the staff, management, council, and project partners needed to get the world’s best facility for X-ray science ready to start operation in 2017.

The facility is being built for science, and significant contributions to the advancement of science are expected from the users of the facility. Hence, a close involvement of the scientific community is essential to the success of the project. Therefore, I am particularly happy about the large attendance at the 2015 Users’ Meeting with more than 800 participants. The first user operation is foreseen for mid-2017, so it is not too early to start thinking about proposals for experiments!

Martin Meedom Nielsen

Chairman of the European XFEL Council

01

NEWS AND EVENTS

European XFEL reached many milestones in 2015, including topping out of its headquarters and startup of the injector. Several outreach events brought thousands of visitors to the facility.

Topping-out ceremony of the headquarters building


voss

January 2015

30 January
2015 Users' Meeting attendance climbs higher

The European XFEL Users' Meeting 2015, held jointly with the DESY Photon Science Users' Meeting on 28–30 January, yet again breaks its attendance record from the previous year. Over 800 scientists from around the world come to Hamburg to participate, with more than 600 attending the first day's sessions regarding the European XFEL.

In the packed DESY Auditorium, European XFEL Managing Director Massimo Altarelli presents the facility's current status and progress. Other talks detail the specific electron beam parameters of the first user operation run, the Karabo control and data analysis framework, beamline installations in the photon tunnels, and continuing research and design work on the six initial scientific instruments. Attendees express excitement over learning about initial plans for first users, instrumentation, and experimental parameters. Scientific Director Andreas Schwarz states that he is overwhelmed by the number of users interested in the project's status, which bodes well for the future operation phase of the facility.

February 2015

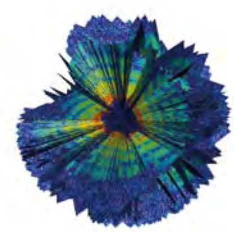
18 February
Topping out of headquarters building

The topping out of the future headquarters building marks a milestone in the construction of the European XFEL. More than 350 guests, including representatives from the German federal government, the states of Schleswig-Holstein and Hamburg, the consular corps, politics and administration, the European XFEL Council, and European XFEL and DESY employees attend the event. In his speech, European XFEL Managing Director Massimo Altarelli thanks everybody who took part in the construction of the building. After the programme, which includes remarks from dignitaries and a short film about the construction progress, the attendees tour the underground experiment hall.

March 2015

4 March
Researchers snap giant virus in 3D

Using the X-ray laser LCLS at SLAC, an international team of researchers, including scientists from DESY and European XFEL, have produced a 3D image of an intact Mimivirus. The study demonstrates how the 3D structure of biological samples can be reconstructed from a series of X-ray laser snapshots, a technique holding great potential for the European XFEL. In February, an affiliated team had announced the imaging of living bacteria with an X-ray laser for the first time.



26 March
Major Chinese research centre signs collaboration agreement

Representatives of the China Academy of Engineering Physics (CAEP) sign a framework collaboration agreement with European XFEL. The agreement formalizes CAEP's future involvement in the facility and is intended to provide the basis for future exchange of staff and students and the development of instrumentation for the European XFEL.

April 2015

13 April
Minister Alheit visits European XFEL

The Minister for Social Affairs, Health, Science, and Equality of the German federal state of Schleswig-Holstein, Kristin Alheit, visits the Schenefeld site of European XFEL. Managing Directors Massimo Altarelli and Claudia Burger, as well as DESY Director Helmut Dosch, inform Minister Alheit about the scientific goals and planned operation of the facility as well as about ideas for building a visitor or science centre on the site.

23 April
Girls' Day 2015

Seven girls and one boy of age 10–13 years visit European XFEL as part of the annual Girls' Day. Throughout the day, they learn about the working environment of various scientific and technical jobs.

May 2015

5 May
Feasibility study: good prospects for visitor centre

A visitor centre or science centre on the European XFEL campus would be well received within the region, and its site would be a favourable location. This is the conclusion of a feasibility study by external experts from the consulting groups dwif-Consulting GmbH and fwi, who researched the possible visitor turnout, cost, concept, and financing estimates.

European XFEL Administrative Director Claudia Burger stresses the high demand to offer schools the experience of science at a location where it takes place and the importance of getting young people interested in science. She says that European XFEL, together with partners in Schleswig-Holstein and Hamburg, will figure out how the financial requirements spelled out in the study can be met.

June 2015

30 June
Helmholtz International User Consortia at European XFEL funded with 30 million euro

The Helmholtz Senate is giving the green light for the Association's involvement in a new kind of experiment station at the European XFEL: the Helmholtz International User Consortia at the European XFEL will be funded with 30 million euro. The largest portion of the funding goes to the Helmholtz International Beamline for Extreme Fields (HIBEF), which will contribute essential components to the High Energy Density Science (HED) instrument. Other funds go to the Serial Femtosecond Crystallography (SFX) and Heisenberg Resonant Inelastic X-Ray Scattering (h-RIXS) user consortia. The research centres HZDR and DESY applied for the funding for the international user consortia.

July 2015

1 July

European XFEL takes over EIROforum chairmanship

European XFEL begins its one-year term as chair of the EIROforum collaboration, which is composed of eight major international European research facilities.

13 July

Two Nobel laureates visit

American-born Australian astronomer Brian Schmidt, who won the Nobel Prize in Physics in 2011 for his work on the expansion of the universe, visits the European XFEL sites. For Egyptian-born US-based chemist Ahmed Zewail, his visit a few days later is a chance to see one of the next steps of his most celebrated work. Zewail won the Nobel Prize in Chemistry in 1999 for his foundational work on femtochemistry.

Top Brian Schmidt
Bottom Ahmed Zewail

July/August 2015

17 July

UK contributes high-energy optical laser to HED instrument

The STFC in the UK will contribute to the European XFEL an optical laser that will generate conditions similar to the interior of Earth-like exoplanets. The £8 million (approximately 11 million euro) development and construction of the laser will be funded by STFC and the Engineering and Physical Sciences Research Council.

25 August

First scientific instrument component installed

A 3 t, almost 4 m tall support tower for a high-precision robot, which will hold a sensitive detector for the Femtosecond X-Ray Experiments (FXE) instrument, is delivered and erected in its final position in its hutch.

The tower and the robot are in-kind contributions from Denmark developed in collaboration with the Danish company JJ X-Ray.

September 2015

26 September

European XFEL presents free-electron laser science in Jena

From 22 to 26 September, European XFEL participates in the Highlights of Physics (*Highlights der Physik*) science festival in Jena, Germany, which was attended by a record 53 000 people. European XFEL's exhibition comprises facility components, including a niobium accelerator cavity and a strong neodymium undulator magnet, as well as informative materials about the research opportunities made available by the facility. Employees and Ph.D. students are on hand to answer questions from the public. The festival is organized and sponsored by the German Federal Ministry of Education and Research (BMBF), Deutsche Physikalische Gesellschaft (DPG), and the University of Jena. It presents developments in physics research to the general public with the theme of "*Lichtspiele*" ("Light Games") and a focus on the physics of light.

October 2015

5 October

New EU project EUCALL supports collaboration of X-ray research infrastructures

The EU is funding a 7 million euro effort to bring research centres together through the European Cluster of Advanced Laser Light Sources (EUCALL) project. The project, which is managed by European XFEL, aims to help both accelerator-driven and laser-driven X-ray facilities to even better serve the scientific community.

Within the EUCALL project, the two types of large-scale X-ray research infrastructures (RIs) in Europe collaborate for the first time in a comprehensive way on technical, scientific, and strategic issues. One of the project's main goals is to make substantial scientific and technological contributions through new synergies between laser-driven and accelerator-driven X-ray RIs. The EUCALL partners will work together on strategic and technological developments that can be used at all facilities, along with better protocols to enable scientists to make the best possible use of limited experiment time.

EUCALL

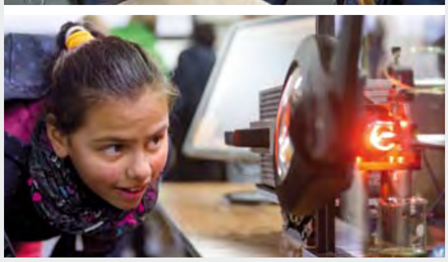
November 2015

7 November

Open House event attracts thousands to European XFEL

European XFEL attracts thousands of visitors for its Open House, as part of the DESY Day and the Hamburg Night of Science (*Nacht des Wissens*). The entrance hall for the facility's injector complex on the DESY campus, the starting point of the X-ray laser's electrons, serves as an exhibition hall for scientists and engineers to present interactive activities and information for the general public.

More than 18 000 people come to the DESY site, which hosts, in addition to DESY's own facilities, part of the European XFEL as well as several other laboratories and research centres. The European XFEL entrance hall is constantly full of people of all ages who are curious about the work going on at the facility.



December 2015

5 December

Science day reaches out to more than 300 guests of Turkish origin

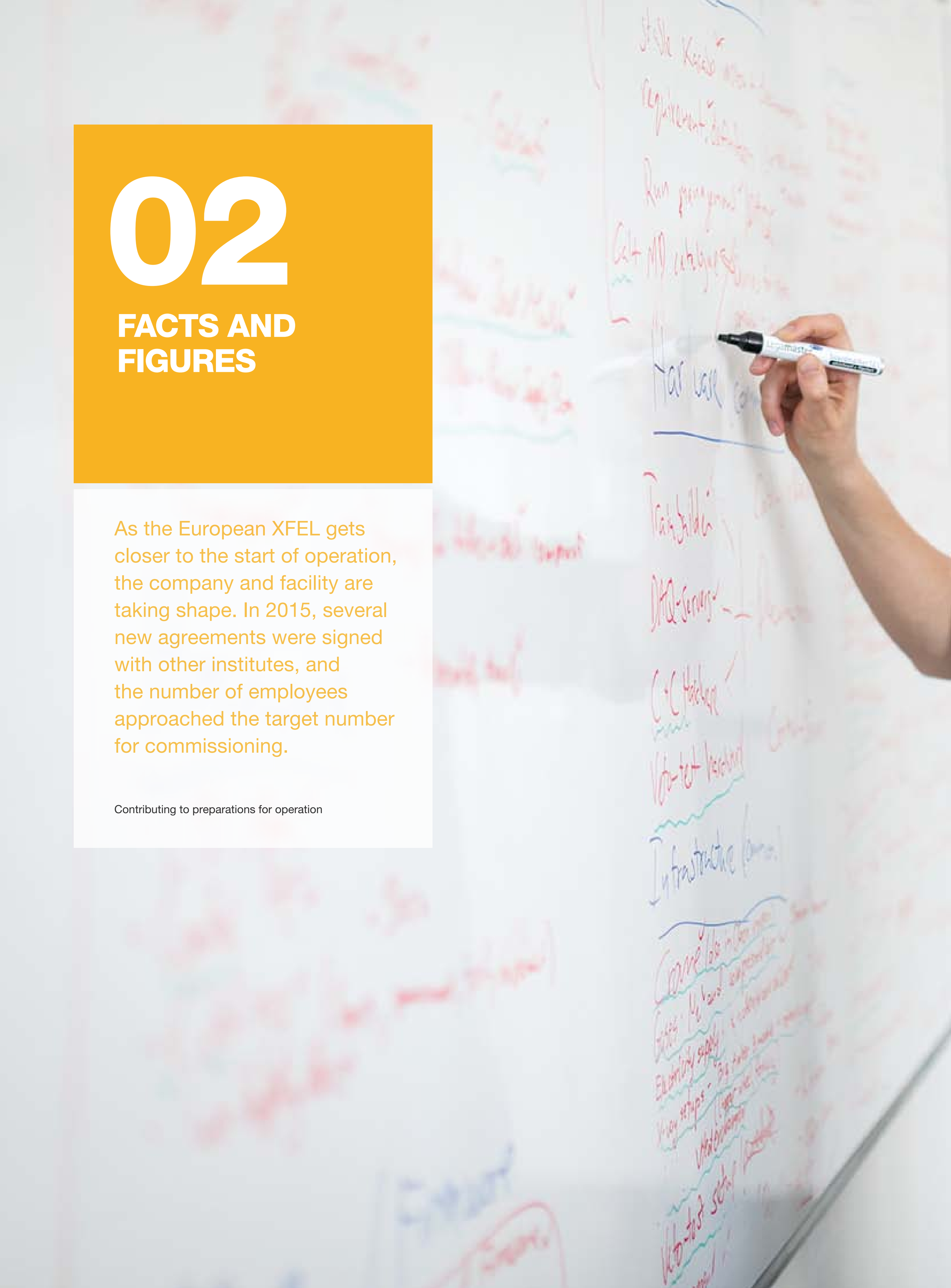
More than 300 people take part in a science day jointly organized by DESY, European XFEL, and the Consulate-General of Turkey in Hamburg, demonstrating the longstanding research cooperation between Germany and Turkey.

21 December

First electrons accelerated in the European XFEL

The injector, the first part of the superconducting particle accelerator, accelerates its first electrons to nearly the speed of light. This is the first beam ever accelerated at the European XFEL.

The assembly of the 100 modules for the main accelerator is also progressing rapidly: At the end of 2015, 59 of them are installed in the tunnel.



02 FACTS AND FIGURES

As the European XFEL gets closer to the start of operation, the company and facility are taking shape. In 2015, several new agreements were signed with other institutes, and the number of employees approached the target number for commissioning.

Contributing to preparations for operation

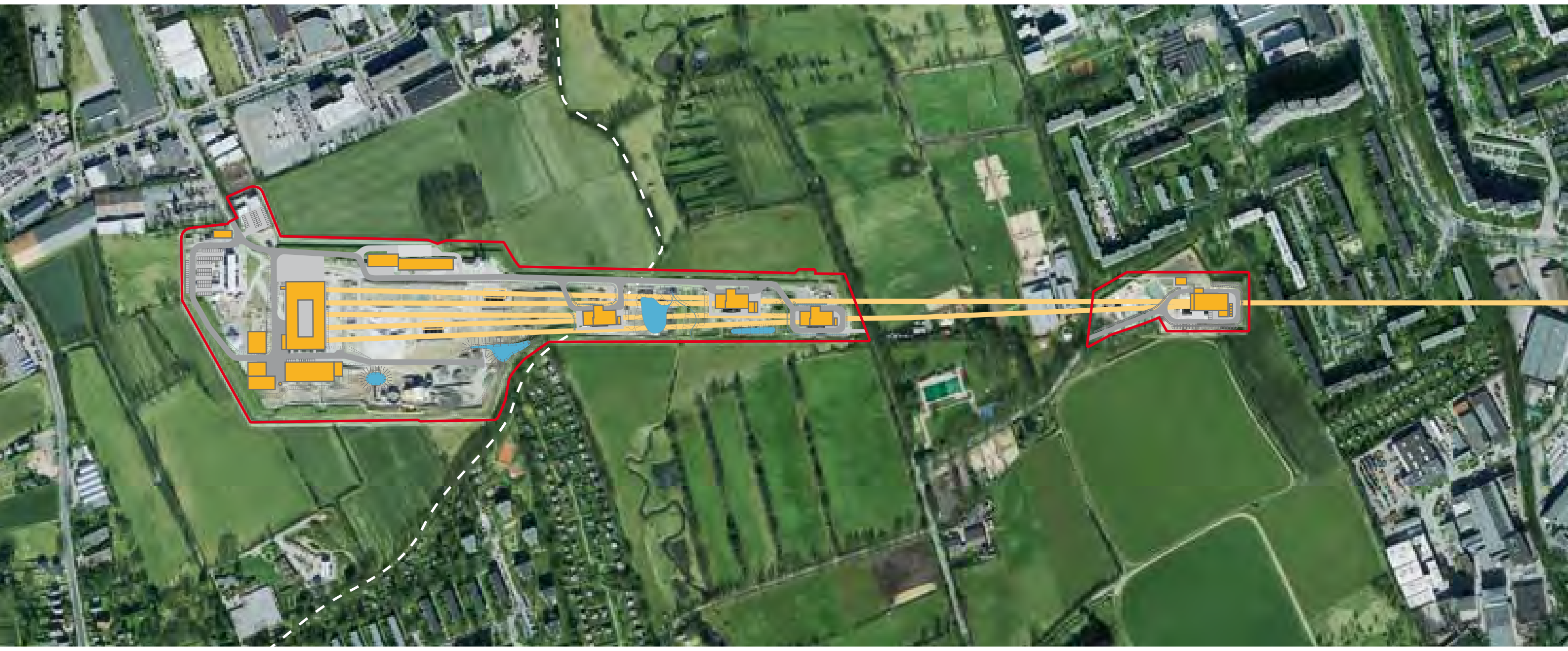


Figure 1 Aerial view of the European XFEL facility. **Left to right** Schenefeld, Osdorfer Born, and DESY-Bahrenfeld sites.

AT A GLANCE

The European XFEL is a research facility that will open up new research opportunities for science and industry. Currently under construction in Hamburg and Schleswig-Holstein in northern Germany, the 3.4 km long X-ray FEL will generate ultrashort X-ray flashes for photon science experiments with a peak brilliance that is a billion times higher than that of the best X-ray synchrotron radiation sources.

Brilliant X-ray flashes for new research opportunities

With a repetition rate of 27 000 pulses per second and an outstanding peak brilliance, the European XFEL facility will produce ultrashort X-ray flashes that will 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 will be located mainly in tunnels 6 to 38 m underground with inner diameters of up to 5.3 m, roughly the diameter of a subway tunnel. The 3.4 km long facility will run 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 will comprise three sites: the DESY-Bahrenfeld site with the injector complex, the Osdorfer Born site with one distribution shaft, and the Schenefeld campus site, which will host the underground experiment hall with a large laboratory and office building on top. The latter will serve as the company headquarters.

European XFEL GmbH

As of December 2015, 11 countries are participating in the European XFEL project: Denmark, France, Germany, Hungary, Italy, Poland, Russia, Slovakia, Spain, Sweden, and Switzerland. In December 2014, the United Kingdom stated its intention to join the European XFEL as the twelfth member state. 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. When user operation starts in 2017, European XFEL will employ about 280 people.

Construction costs

Construction of the European XFEL facility started in early 2009. The beginning of commissioning is planned for 2016. User operation with three beamlines and six instruments will start in 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 will be realized by means of in-kind contributions by shareholders and partners.

STAFF

In 2015, the European XFEL workforce of employees, students, and guests grew from 233 to 278 (+19%).

The number of employees increased as follows:
- Scientists: 123 (+19)
- Engineers: 83 (+17)
- Technical staff: 31 (+9)
- Administrative staff: 41 (±0)

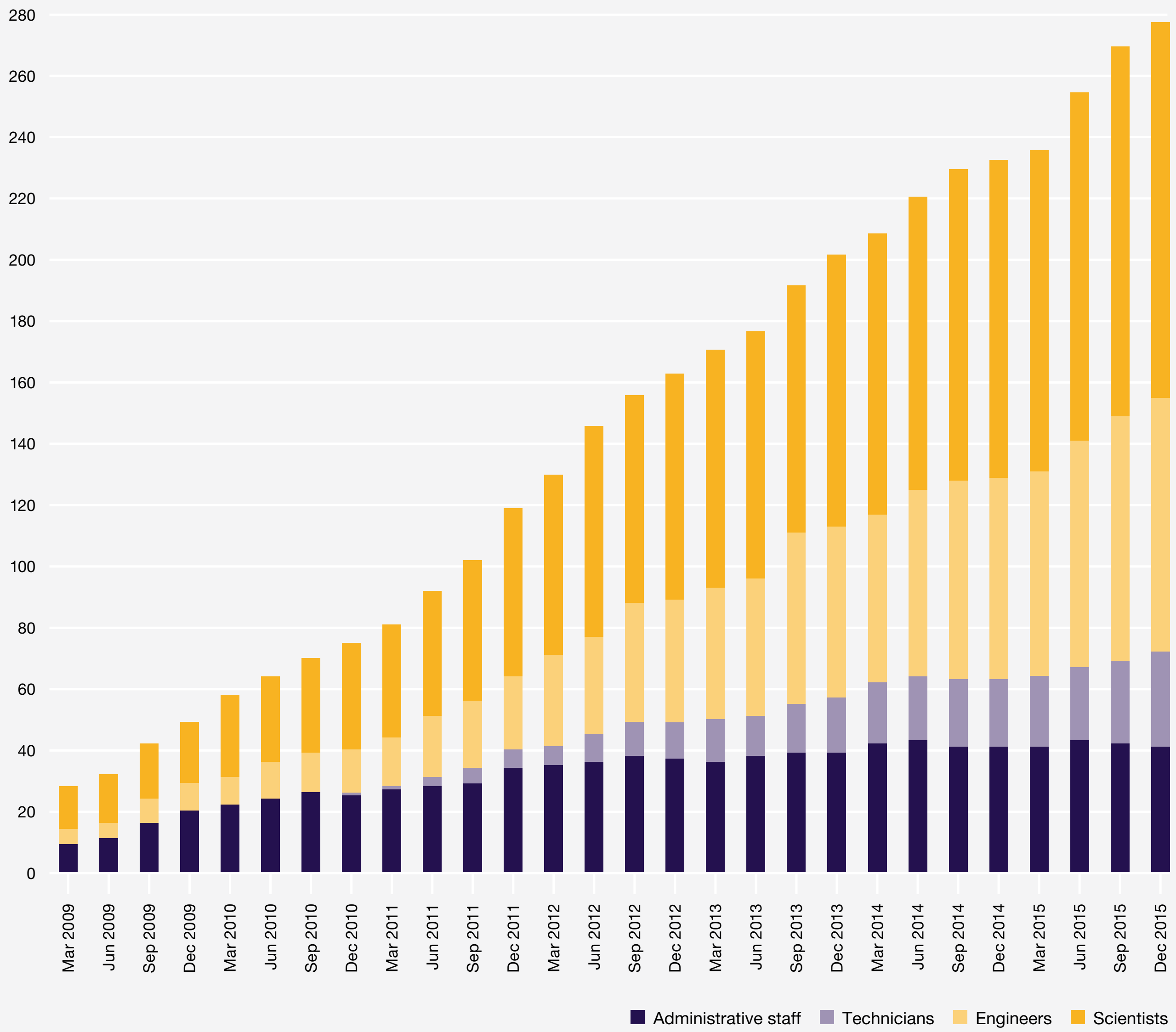


Figure 1 Overall growth in the number of employees, students, and guests (2009–2015)

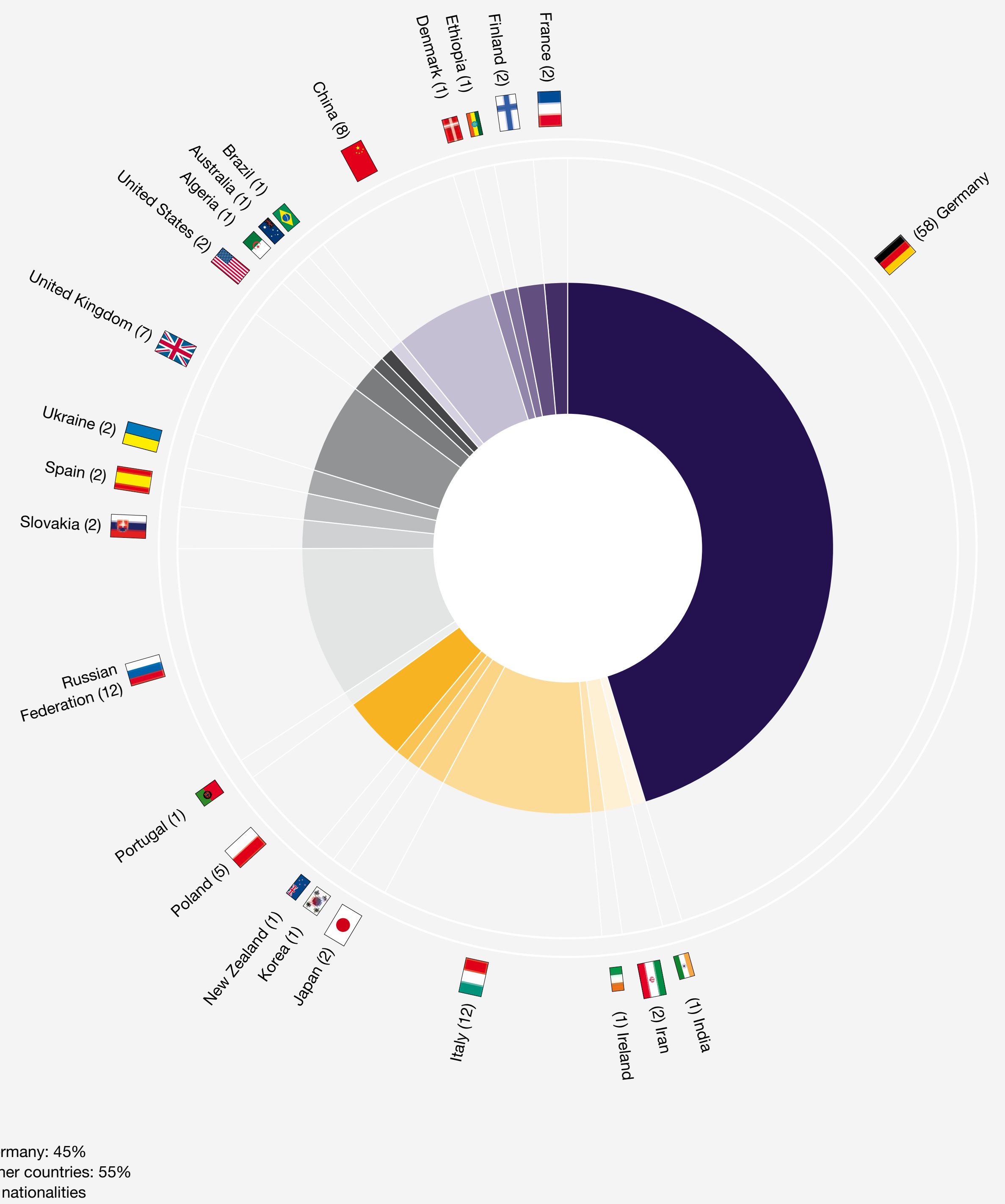
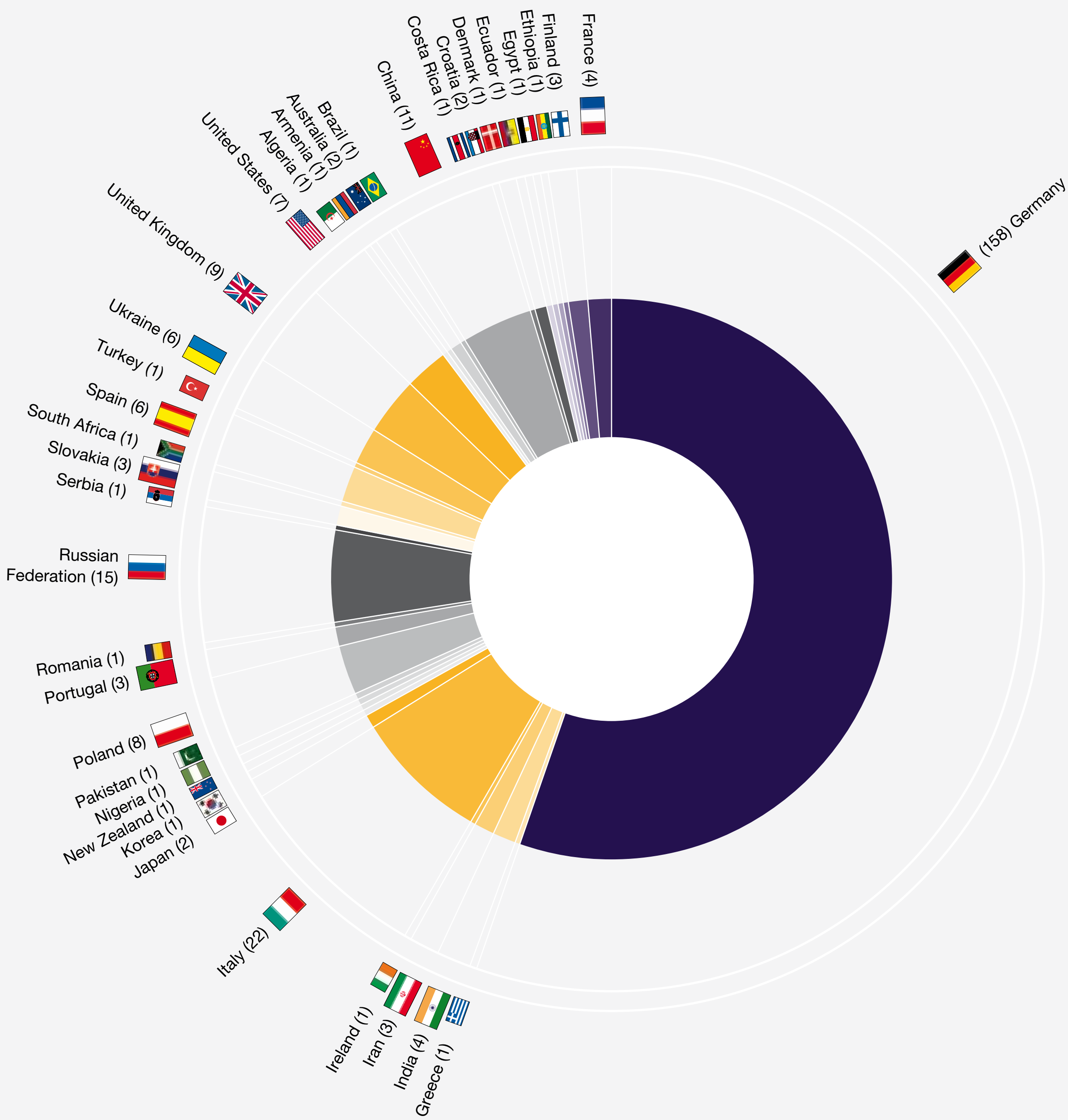


Figure 2 Nationalities of scientific staff (2015)



Germany: 55%
Other countries: 45%
36 nationalities

Figure 3 Nationalities of all (scientific and non-scientific) staff (2015)

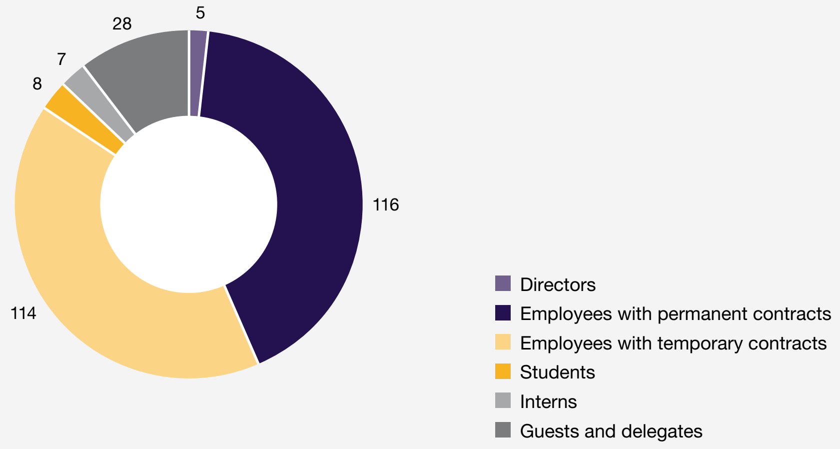


Figure 4 Contractual status of staff (2015)

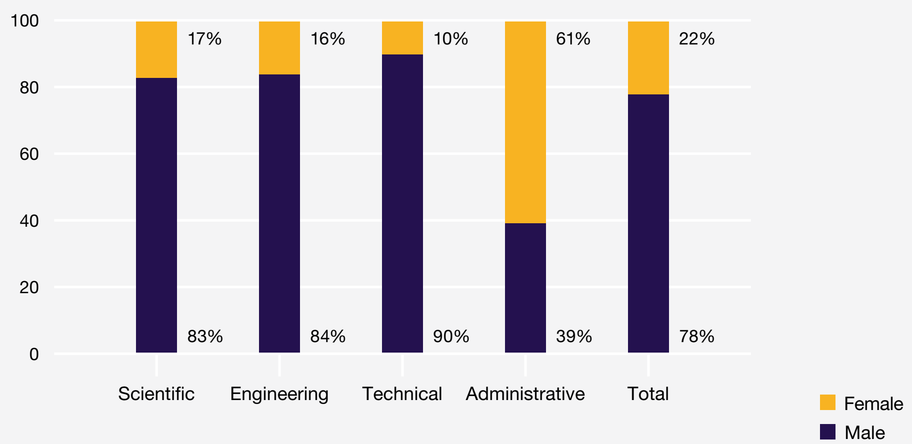


Figure 5 Gender of staff by work area (2015)

The share of staff from outside Germany among all European XFEL employees remained constant:

- Total staff: 55% (±0 from 2014) from Germany, 45% from other countries
- Scientific staff: 45% (+1% from 2014) from Germany, 55% from other countries

A total of 36 (+5 from 2014) nationalities are now represented within the company.

At the end of 2015, 22% (±0) of all employees and 17% (+3%) of scientists employed at European XFEL were female.

The average employee age remained unchanged from the previous year, at 39 years.

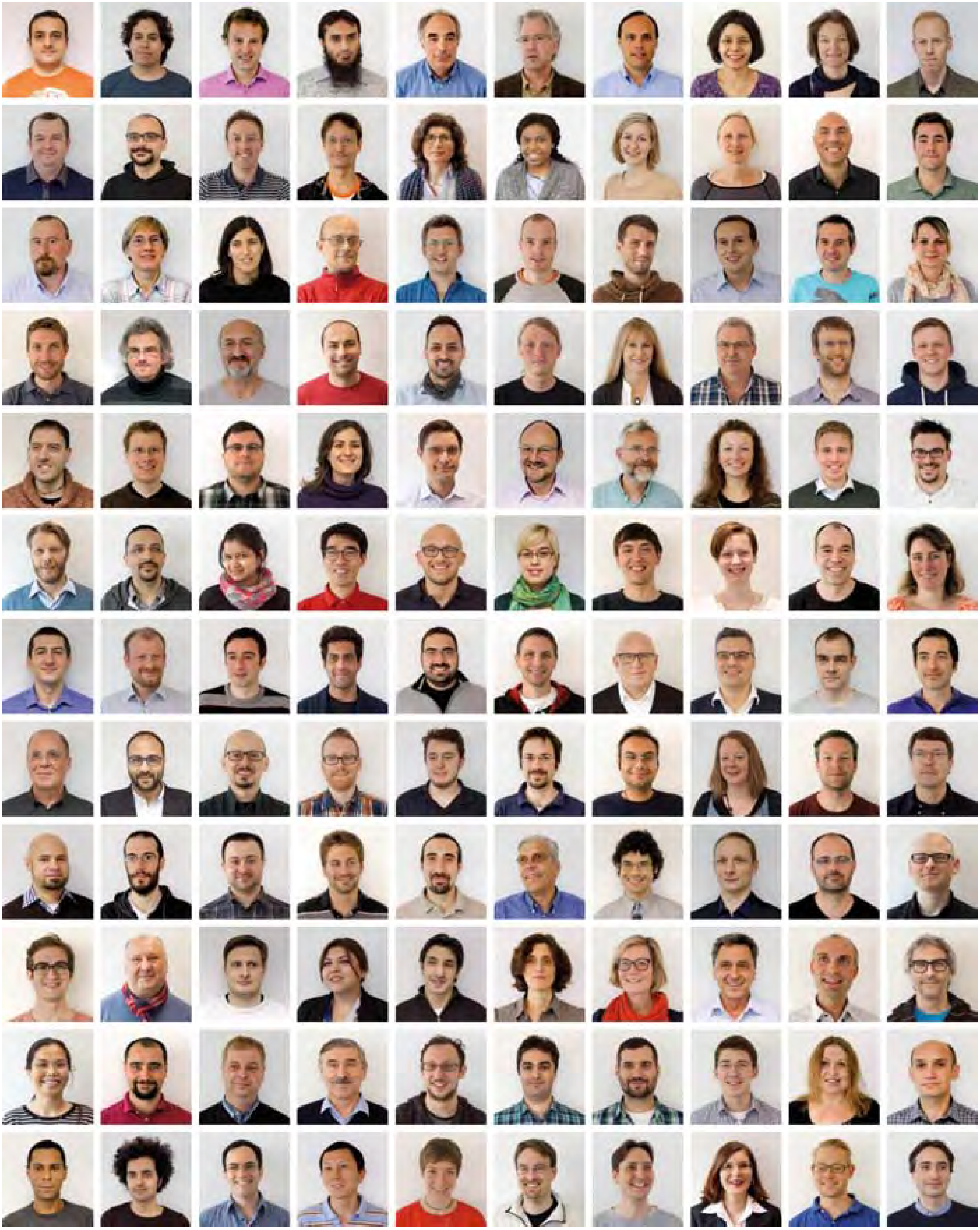
Staff of European XFEL as of 31 December 2015

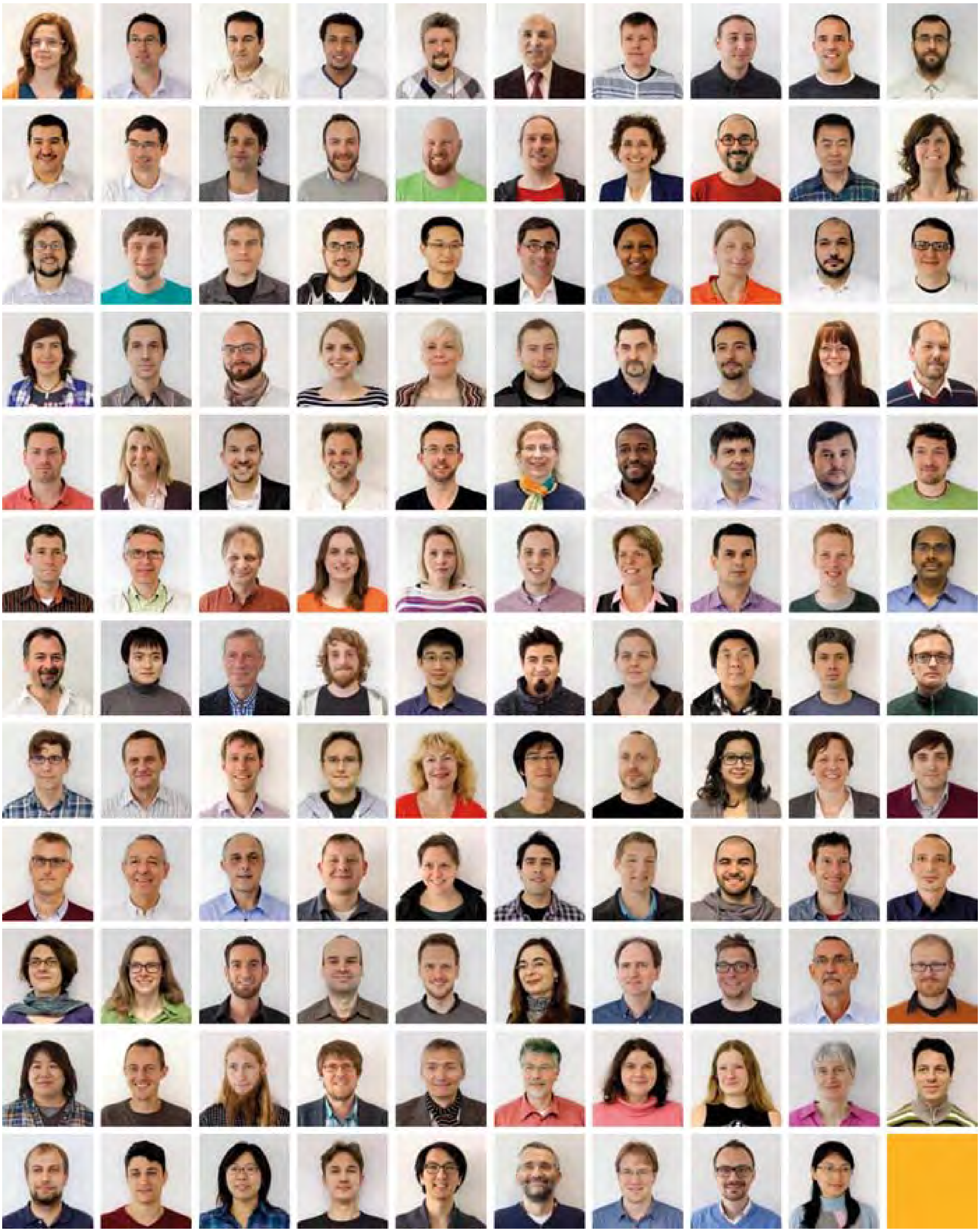
Abeghyan, Suren
Agapov, Ilya
Ahmed, Awais
Altarelli, Massimo
Ament, Kurt
Ansaldi, Gabriele
Ansari, Zunaira
Appel, Karen
Appleby, Graham
Aresté, Mónica
Arnold, Mathias
Arslan, Süleyman
Babies, Frank
Bagha-Shanjani, Majid
Ballak, Kai-Erik
Baranašić, Bernard
Bartmann, Alexander
Bartsch, Tobias
Batchelor, Lewis
Baumann, Thomas
Bean, Richard
Beckmann, Andreas
Berndgen, Karl-Heinz
Bertini, Silvia
Biedermann, Nicole
Boehme, Elizabeth
Bonucci, Antonio
Borchers, Gannon
Bösenberg, Ulrike
Boukhelef, Djelloul
Boyd, Eric
Bressler, Christian
Britz, Alexander
Broers, Carsten
Buck, Jens
Burger, Claudia
Carley, Robert
Conta, Uschi
Coppola, Nicola
Cunis, Sabine
Da Costa Pereira, Maria Helena
De Fanis, Alberto
Deiter, Carsten
Delitz, Jan Torben
Delmas, Elisa
Derevianko, Illia
Deron, Georg Christian
Di Felice, Massimiliano
Dickert, Bianca
Dietrich, Florian
Dietze, Thomas
Dommach, Martin
Donato, Mattia
Dong, Xiaohao
Ebeling, Bernd
Eder, Catherine Ann
Eggers, Kara
Eidam, Janni
Ekmedzic, Marko
Elizondo, Jorge
Emmerich, Ralf
Emons, Moritz
Englisch, Uwe
Esenov, Sergey
Ferreira Maia, Luís Goncalo
Fijalkowski, Dominik
Filippakopoulos, Kimon
Flammer, Meike
Flucke, Gero
Fortmann-Grote, Carsten
Frankenberger, Paul
Freijo Martín, Idoia
Freund, Wolfgang
Freyermuth, Tobias
Fritz, Mareike
Fritz-Nielen, Kitty
Galler, Andreas
Gawelda, Wojciech
Geloni, Gianluca
Gembalies, Imke
Gerasimova, Natalia
Geßler, Patrick
Giambartolomei, Gabriele
Giewekemeyer, Klaus
Göde, Sebastian
Gorelov, Evgeny
Göries, Dennis
Graceffa, Rita
Grünert, Jan
Guhlmann, Florian
Haas, Tobias
Hagitte, Magdalena
Hagitte, Martin C.
Hallmann, Jörg
Hauf, Steffen
Heeßel, Gabriela
Heisen, Burkhard
Holz, Christian
Ilchen, Markus
Ivanov, Alexandru
Izquierdo, Manuel
Januschek, Friederike
Jidda, Mahadi Umar
Kane, Daniel
Karabekyan, Suren
Kaukher, Alexander
Kellert, Martin
Kelsey, Oliver
Kersting, Lorenz
Khakhulin, Dmitry
Khandelwal, Komal
Kim, Chan
Kirsch, Jan Oliver
Kist, Birthe
Kitel, Matthäus
Klačková, Ivana
Knaack, Manfred
Kniehl, Sandra
Knoll, Martin
Koch, Andreas
Köhler, Martin
Kohlstrunk, Nicole
Kondraschew, Alexander
Konôpková, Zuzana
Korsch, Timo
Kozielski, Sigrid Susanne
Kristic, Hrvoje
Krüger, Lennart
Kruse, Kai
Kujala, Naresh
Kunz, Marc
Kurta, Ruslan
Kuster, Markus
La Civita, Daniele
Lang, Philipp-Michael
Lange, Torsten
Laub, Malte
Le Guyader, Loïc
Le Pimpec, Frédéric
Lederer, Maximilian Josef
Li, Yuhui
Liebel, Henrik
Liu, Jia
López Morillo, Luis
Lorenzen, Kristina
Lu, Wei
Lyamayev, Viktor
Madsen, Anders
Malso, Michael
Mancuso, Adrian
Manetti, Maurizio
Manning, Bradley Jacob
Martens, Eike-Christian
Mau, Daniel
Mazza, Tommaso
McBride, Emma Elizabeth
Meger-Farshad, Danuta
Mergen, Julia
Meyer, Michael
Meyn, Frederik
Molodtsov, Serguei
Moore, James
Mulá Mathews, Gabriella
Münnich, Astrid
Nakatsutsumi, Motoaki
Neumann, Maik
Nidhi, Sneha
Osterland, Christiane
Ovcharenko, Yevheniy

Pahl, Deike
Palmer, Guido
Parenti, Andrea
Parlicki, Patryk
Pergament, Mikhail
Pflüger, Joachim
Piergrossi, Joseph W.
Piórecki, Konrad
Planas Carbonell, Marc
Poljancewicz, Bartosz
Poppe, Frank
Porro, Matteo
Priebe, Gerd
Prollius, Michael
Raab, Natascha
Reifschläger, Jörn
Reimers, Nadja
Rodrigues Fernandes, Bruno Jesus
Roth, Thomas
Rüscher, Jan Christoph
Rüter, Tonn
Rychev, Mikhail
Saaristo, Niko
Salem, Osama Ahmed
Samoylova, Liubov
Sander, Marieke
Sauermann, Wolf-Ulrich
Schaper, Jörg
Scherz, Andreas
Scherz, Sabrina
Schlappa, Justine
Schlee, Stephan A.
Schmidt, Andreas
Schmitt, Rüdiger
Schön, Torsten
Schrage, Marco
Schulz, Carola
Schulz, Joachim
Schulz, Sebastian
Schwarz, Andreas S.
Shevchuk, Ivan
Shie, Halimah
Silenzi, Alessandro
Sinn, Harald
Sorin, Alexander
Sotoudi Namin, Hamed
Sprenger, Uta
Sztuk-Dambietz, Jolanta
Szuba, Janusz
Teichmann, Martin
Thorpe, Ian
Thute, Prasad
Tolkiehn, Jan
Tomin, Sergey
Trapp, Antje
Tschentscher, Thomas
Tscheu, Wolfgang
Turcato, Monica
van Hees, Brunhilde
Vannoni, Maurizio
Viehweger, Marc Simon
Villanueva Guerrero, José
Violante, Adriano
Wang, Jinxiong
Weger, Kerstin
Wegner, Ulrike
Weidenspointner, Georg
Wellenreuther, Gerd
Wiggins, John
Winterhoff, Gundel
Wißmann, Laurens
Wolff-Fabris, Frederik
Wrona, Krzysztof
Wünschel, Mark
Yakopov, Mikhail
Yang, Fan
Yaroslavtsev, Alexander
Youngman, Christopher
Zach, Juri
Zastrau, Ulf
Zhang, Haiou

Guests of European XFEL as of 31 December 2015

Achner, Alexander
Assefa, Tadesse Abebaw
Bähtz, Carsten
Bömer, Christina
Chen, Bolun
Diez, Michael
Fobian, Michael
Kabachnik, Nikolay
Kallio, Juha
Kursula, Inari
Li, Peng
Mehrjoo, Masoud
Messerschmidt, Marc
Nawrath, Günther
Pelka, Alexander
Prat, Serge
Raabe, Steffen
Rafipoor, Amir Jones
Sato, Tokushi
Serkez, Svitozar
Smirnov, Petr
Stäps, Christoph
Stern, Stephan
Uetrecht, Charlotte
Vagovič, Patrik
Wei, Tao
Zalden, Peter





MANAGEMENT BOARD

- **Chairman, Managing Director** Massimo Altarelli
- **Managing Director** Claudia Burger
- **Scientific Director** Serguei Molodtsov
- **Scientific Director** Andreas S. Schwarz
- **Scientific Director** Thomas Tschentscher

MANAGEMENT BOARD OFFICE

- **MB Assistant** Frédéric Le Pimpec
- **Secretariat**

ADMINISTRATION
Claudia Burger

- **Distinguished Advisor** Mikhail Rychev
- **Finance and Controlling** Uta Sprenger ▪
- **Human Resources** Wolf-Ulrich Sauermann ▪
- **Legal** Malte Laub ▪
- **Procurement** Kitty Fritz-Nielen ▪
- **User Office** Silvia Bertini ▪
- **Library** Martin Köhler

SCIENTIFIC UNIT
Serguei Molodtsov

- **Simulation of Photon Fields** (WP72) Gianluca Geloni ▪
- **X-Ray Photon Diagnostics** (WP74) Jan Grünert ▪
- **Sample Environment** (WP79) Joachim Schulz ▪
- **Scientific Instrument SQS** (WP85) Michael Meyer ▪
- **Scientific Instrument SCS** (WP86) Andreas Scherz ▪
- **Theory** ▪▪ Alexander Lichtenstein ▪/ Serguei Molodtsov
- **Central Instruments Engineering** Wolfgang Tscheu

SCIENTIFIC UNIT
Andreas S. Schwarz

- **Accelerator Liaison**
- **Technical Services** Lorenz Kersting ▪
- **Civil Construction** (WP31, WP41–WP45, WP47, WP48) Hubert Weissgerber
- **Undulator Systems** (WP71) Joachim Pflüger ▪
- **Detector Development** (WP75) Markus Kuster ▪
- **Control and Analysis Software** (WP90) Burkhard Heisen ▪
- **Advanced Electronics** (WP91) Patrick Geßler ▪
- **IT and Data Management** (WP92) Krzysztof Wrona ▪

SCIENTIFIC UNIT
Thomas Tschentscher

- **X-Ray Optics** (WP73) Harald Sinn ▪
- **Optical Lasers** (WP78) Maximilian Lederer ▪
- **Scientific Instrument FXE** (WP81) Christian Bressler ▪
- **Scientific Instrument HED** (WP82) Ulf Zastrau ▪
- **Scientific Instrument MID** (WP83) Anders Madsen ▪
- **Scientific Instrument SPB/SFX** (WP84) Adrian Mancuso ▪
- **Vacuum** Martin Dommach ▪

EUCALL
Graham Appleby

- **In-Kind Contributions / Quality Assurance** Antonio Bonucci ▪
- **Internal Audit** Jörg Schaper
- **Photon Systems Project Office** Tobias Haas ▪
- **Press and Public Relations** Bernd Ebeling ▪
- **Safety and Radiation Protection** Sigrid Kozielski ▪

Company Doctor
Katharina Bünz

- **Data Protection** Carsten Porthun

—— Director
– – External staff
▪ Work package/ group leader
▪▪ Joint group with University of Hamburg

All in alphabetic / WP number order

European X-Ray Free-Electron Laser Facility GmbH (December 2015)

BUDGET

The overall budget for the construction phase of the European XFEL project amounts to around 1.22 billion euro (2005 value). This amount includes a budget increase of 74 million euro (M€) to accommodate a one-year extension of the construction phase until 2017, which was agreed to in 2015 by the company's shareholder assembly, the European XFEL Council. Forty-five 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 2015, as the construction of the European XFEL progresses, more than 60% 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 2015 amounted to 117.8 M€.

Major activities

One major activity in 2015 was "Machine and technical infrastructure", with a budget of 55.8 M€ (47%). Within this activity, 20 M€ was devoted to civil construction, mainly the construction of the headquarters building in Schenefeld, and another 20 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 55.8 M€ (47%). Of this, the largest fraction, 36.6 M€, was spent on capital investment.

In 2015, the main activities were "machine and technical infrastructure" and "beamlines and experiments", each representing 47% of the year's total budget.

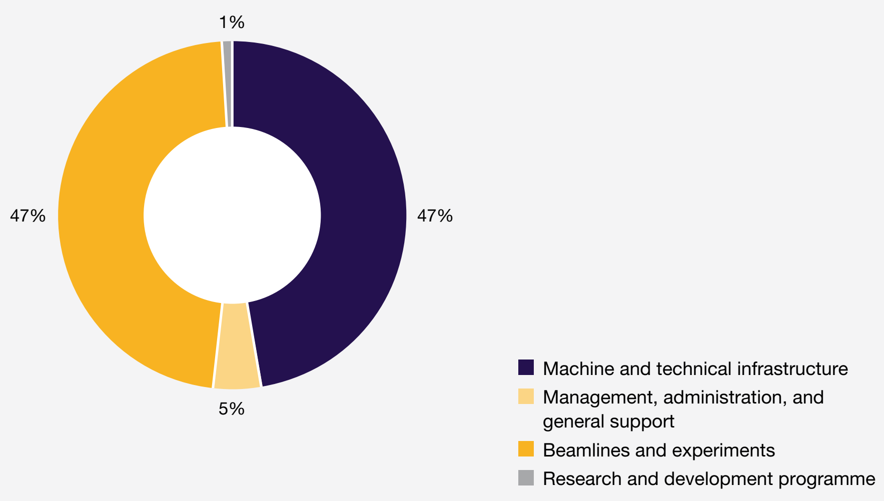


Figure 1 Payments by major activity in 2015

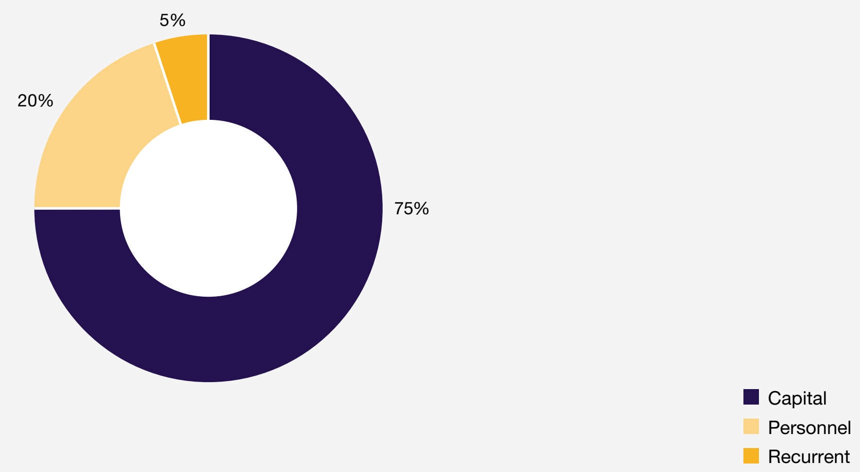


Figure 2 Payments by budget items in 2015

Budget items

The overwhelming portion (75%) of the 2015 payment budget was related to capital investment. This trend will continue during the construction phase of the facility, as the biggest share of the project expenses are related to capital investment, with personnel and recurrent cost being of only subordinate importance.

Outlook for 2016

For the budget year 2016, an annual payment budget of 90.2 M€ was approved. This is lower than the 2015 budget because most above-ground construction will end in the first half of 2016.

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 2015)	
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	Open Joint Stock Company RUSNANO
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 Richerche)
Spain	Kingdom of Spain

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, Denmark)
Vice Chairman	Lars Börjesson (Chalmers University of Technology, Gothenburg, Sweden)
Delegates	
Denmark	Robert K. Feidenhans'l (University of Copenhagen) and Anders Kjær (DASTI, Copenhagen)
France	Maria Faury (CEA, Paris), Alex Mueller (CNRS, Paris) until 30 June 2015, and Amina Taleb-Ibrahimi (CNRS, Paris) since 1 July 2015
Germany	Helmut Dosch (DESY, Hamburg) and Beatrix Vierkorn-Rudolph (BMBF, Bonn)
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) and Andrey Svinarenko (OJSC RUSNANO, Moscow)
Slovakia	Karel Saksl (Institute of Materials Research, SAS, Košice) and Pavol Sovák (P.J. Šafárik University, Košice)
Sweden	Johan Holmberg (Swedish Research Council, Stockholm)
Switzerland	Bruno Moor (State Secretariat for Education, Research and Innovation, Bern) and Gabriel Aeppli (PSI, Villigen) since 18 September 2015
Secretary	
	Malte Laub (European XFEL, Hamburg)
Vice Secretary	
	Meike Flammer (European XFEL, Hamburg)

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.

European XFEL Management Board	
Chairman	Massimo Altarelli
Administrative Director	Claudia Burger
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,
and Laser Advisory Committee.

Administrative and Finance Committee (AFC)	
Chairman	Leif Eriksson (Swedish Research Council, Stockholm, Sweden)
Delegates	
Denmark	Anders Kjær (DASTI, Copenhagen) and Troels Rasmussen (DASTI, Copenhagen)
France	Bertrand Franel (CEA, Paris) until October 2015, Salah Dib (CEA, Paris) since December 2015, and Laurent Pinon (CNRS, Paris)
Germany	Michael Budke (BMBF, Bonn), Christian Scherf (DESY, Hamburg) until October 2015, and Christian Harringa (interim, DESY, Hamburg) since December 2015
Hungary	Barbara Tóth-Vizkelety (NRDI Office, Budapest)
Poland	Zbigniew Gołębiewski (NCBJ, Otwock-Świerk)
Russia	Aleksandr Lvovskii (OJSC RUSNANO, Moscow) and Valeriy Nosik (NRC KI, Moscow)
Slovakia	Pavol Sovák (P.J. Šafárik University, Košice)
Sweden	Inger Andersson (Swedish University of Agricultural Sciences, Uppsala), Elin Swedenborg (Swedish Research Council, Stockholm) until October 2015, and Katrin Brandt (Swedish Research Council, Stockholm) since December 2015
Switzerland	Peter Allenspach (PSI, Villigen) and Xavier Reymond (State Secretariat for Education, Research and Innovation, Bern)
Secretary	
	Uta Sprenger (European XFEL, Hamburg)
Vice Secretary	
	Deike Pahl (European XFEL, Hamburg)

In-Kind Review Committee (IKRC)	
Chairman & Russian Delegate	Leonid V. Kravchuk (INR, Moscow)
Vice Chairman & Swiss Delegate	Volker Schlott (PSI, Villigen)
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, Hamburg, Germany)
Lawyer	
	Malte Laub (European XFEL, Hamburg, Germany)

Machine Advisory Committee (MAC)	
Chairperson	Richard Walker (Diamond Synchrotron, Oxfordshire, UK) until 23 October 2015, Camille Ginsburg (Fermilab, Batavia, Illinois, USA) since 24 October 2015
Members	
	Caterina Biscari (CELLS–ALBA, Cerdanyola del Vallès, Spain)
	Hans-Heinrich Braun (PSI, Villigen, Switzerland) until 23 October 2015
	Ángeles Faus-Golfe (LAL, Orsay, France) since 24 October 2015
	Camille Ginsburg (Fermilab, Batavia, Illinois, USA) until 23 October 2015
	Zhirong Huang (SLAC, Menlo Park, California, USA)
	Andreas Jankowiak (HZB, Berlin, Germany)
	Heung-Sik Kang (PAL, Pohang, Korea) since 24 October 2015
	Leonid V. Kravchuk (INR, Moscow, Russia)
	John Mammosser (Jefferson Lab, Newport News, Virginia, USA) until 23 October 2015
	Pantaleo Raimondi (ESRF, Grenoble, France)
	Felix Rodriguez Mateos (CERN, Geneva, Switzerland) until 23 October 2015
	Richard Walker (Diamond Synchrotron, Oxfordshire, UK) since 24 October 2015
	Andrzej Wolski (University of Liverpool, UK) since 24 October 2015

Scientific Advisory Committee (SAC)

Chairman	Rafael Abela (PSI, Villigen, Switzerland) until 23 October 2015, Stefan Eisebitt (MBI, Berlin, Germany) since 24 October 2015
Members	
	Rafael Abela (PSI, Villigen, Switzerland) since 24 October 2015
	Patrick Audebert (LULI, École Polytechnique, Palaiseau, France)
	Mike Dunne (SLAC, Menlo Park, California, USA) since 1 March 2015
	Stefan Eisebitt (MBI, Berlin, Germany) until 23 October 2015
	Gyula Faigel (Wigner Research Centre for Physics, Hungarian Academy of Sciences, Budapest) until 23 October 2015
	Gerhard Grübel (DESY, Hamburg, Germany)
	Jerome Hastings (SLAC, Menlo Park, California, USA) until 23 October 2015
	Ursula Keller (ETH Zürich, Switzerland) until 28 February 2015
	Maya Kiskinova (Elettra Sincrotrone Trieste, Italy)
	Inari Kursula (University of Oulu, Finland; CSSB, Hamburg, Germany)
	Anders Nilsson (Stockholm University, Sweden)
	Natalia Novikova (IC RAS, Moscow, Russia)
	Keith Nugent (La Trobe University, Melbourne, Australia) since 24 October 2015
	Christoph Quitmann (MAX-lab, Lund, Sweden) since 24 October 2015
	Ian Robinson (UCL, London, UK) since 24 October 2015
	Ilme Schlichting (MPI for Medical Research, Heidelberg, Germany)
	Francesco Sette (ESRF, Grenoble, France) until 23 October 2015

Scientific Advisory Committee (SAC) (continued)	
	David Stuart (University of Oxford and Diamond Synchrotron, Oxfordshire, UK)
	Linda Young (ANL, Argonne, Illinois, USA)
Secretary	
	Gianluca Geloni (European XFEL, Hamburg, Germany)

Detector Advisory Committee (DAC)	
Chairman	Jörn Wilms (University of Erlangen, Germany)
Members	
	John Arthur (SLAC, Menlo Park, California, USA)
	Eric Eikenberry (DECTRIS Ltd. (retired), Baden, Switzerland)
	Roland Horisberger (PSI, Villigen, Switzerland)
	Christopher J. Kenney (SLAC, Menlo Park, California, USA)
	Jörg Klora (ITER, St. Paul-lez-Durance, France) until 10 December 2015
	Jens Meyer (ESRF, Grenoble, France)
	David Quarrie (LBNL, Berkeley, California, USA)
	Kay Rehlich (DESY, Hamburg, Germany) since 8 December 2015

Laser Advisory Committee (LAC)	
Chairman	Uwe Morgner (Laser Zentrum Hannover, Germany)
Members	
	Giulio Cerullo (Politecnico di Milano, Italy)
	Mike Dunne (SLAC, Menlo Park, California, USA)
	Patrick Georges (Institut d’Optique, Paris, France)
	Alfred Leitenstorfer (University Konstanz, Germany)
	Robert Schoenlein (LBNL, Berkeley, California, USA)
	William E. White (SLAC, Menlo Park, California, USA)
Secretaries	
	Oliver Mücke (CFEL and DESY, Hamburg, Germany) and Andreas Galler (European XFEL, 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 2015, European XFEL signed collaboration agreements with institutes in China, Germany, Italy, and Japan, and a Memorandum of Understanding (MoU) with RIKEN SPring-8 Center. Additionally, an MoU was signed with several European research infrastructures regarding a plan to generate unique, trans-facility identifiers for users, and two new EU programmes were launched, one of which is coordinated by European XFEL.

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.

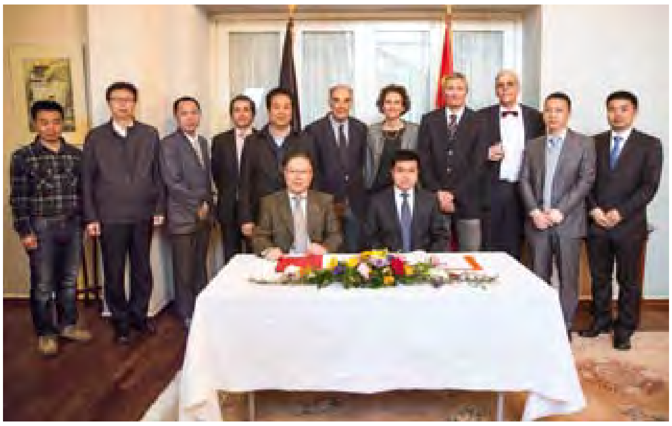


Figure 1
Signing of framework collaboration agreement at the Consulate of the People's Republic of China in Hamburg on 26 March 2015

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.

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.

EMBL
European XFEL cooperates with European Molecular Biology Laboratory (EMBL), Europe's top address for biological research on the molecular level. An MoU was signed on 12 September 2011.

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, made a “Work for Others” agreement regarding detector development, with the aim of creating detectors for a possible future light source at LBNL.
An MoU was signed in Hamburg on 16 April 2013.

LNLS
DESY, European XFEL, and the Brazilian synchrotron radiation laboratory (LNLS) in Campinas signed a cooperation agreement in Brasília on 5 May 2011.

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”.

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) for the European XFEL 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, establishes 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.

UCL
The clock and control hardware for the European XFEL detectors is being developed at University College London (UCL) in the UK.

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.

Uppsala University
European XFEL and Uppsala University in Sweden cooperate in the field of X-ray science with a focus on structural biology. Professor Janos Hajdu acts as a senior advisor to the scientific directors of European XFEL and contributes his expertise to the realization of measuring stations and experiments. An agreement was signed on 15 October 2010.

Participation in EU programmes

BioStruct-X

BioStruct-X is a consortium of 19 institutions from 11 EU member and associated states. Within a broader research programme, European XFEL scientists work with colleagues from leading international research centres to improve the structure determination of biomolecules. The EU project was started in 2011 and a consortium agreement specifying the relationship between the parties was signed in 2012. BioStruct-X receives funding from the EU Seventh Framework Programme (FP7/2007-2013) under grant agreement No. 283570.

CALIPSO

CALIPSO is an EU consortium that coordinates the European synchrotrons and FELs, including the three European Strategy Forum on Research Infrastructures (ESFRI) roadmap projects—European XFEL, EuroFEL, and the ESRF Upgrade Programme—with the aim of creating a fully integrated network. CALIPSO receives funding from the EU FP7 under grant agreement No. 312284. The project began in June 2012 and continued through December 2015. European XFEL contributes to scientific cooperation, workshops, and joint trainings as an observer within the High-Z sensors for Pixel Array Detectors (HIZPAD2) project to improve exchange among accelerator physicists and FEL users on diagnostics techniques.

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.

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.

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, the future SwissFEL in Switzerland, the future 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.

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 are contributing to the construction of scientific instruments, to the ancillary instrumentation, and to the technical infrastructure of the European XFEL:

- The **Integrated Biology Infrastructure Life-Science Facility at the European XFEL (XBI)** is a proposal for an integrated structural biology infrastructure—including laboratory space, sample characterization technique, and operation staff—in the headquarters building (XHQ). XBI already provided the infrastructure for the corresponding area in the XHQ laboratory floor and recently acquired sufficient funding to proceed to the first phase of instrument acquisitions. Current members 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 **Serial Femtosecond Crystallography (SFX)** user consortium proposes to build a second interaction chamber for nanocrystallography and sample screening in the Single Particles, Clusters, and Biomolecules and Serial Femtosecond Crystallography (SPB/SFX) instrument hutch, re-using the transmitted X-ray FEL beam. 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 proposes to contribute two high-energy optical lasers (one of them by the UK), a high-field pulsed magnet instrument, and a number of scattering diagnostics to be integrated into the High Energy Density Science (HED) instrument. A laser building could house future upgrades of the optical lasers and offices for the staff to build and operate the systems. HIBEF 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 intends to build an additional chamber that can be attached to the European XFEL instruments, in particular Small Quantum Systems (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 Spectroscopy and Coherent Scattering (SCS) instrument and facilitate RIXS-type experiments. Current members are the University of Potsdam, DESY, and the University of Milan.

The CircPol user consortium that was seeking to build afterburner undulators to create X-ray pulses with controllable polarization states is no longer active due to lack of adequate financial support.

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.

Figure 4 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 5 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.

Figure 7 On 25 July 2006, representatives of European XFEL and DESY hand over the European XFEL TDR to the chairman of the International Steering Committee (ISC). **Left to right** Jochen R. Schneider, Albrecht Wagner, Hermann Schunck (BMBF), Massimo Altarelli, Karl Witte, Andreas S. Schwarz, Reinhard Brinkmann, and Thomas Delissen

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. Other Pre-XFEL activities include recruiting international staff, informing potential users about the European XFEL, and facilitating the specification, research and development, prototyping, and industrialization required to build the technical infrastructure and components for the facility

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

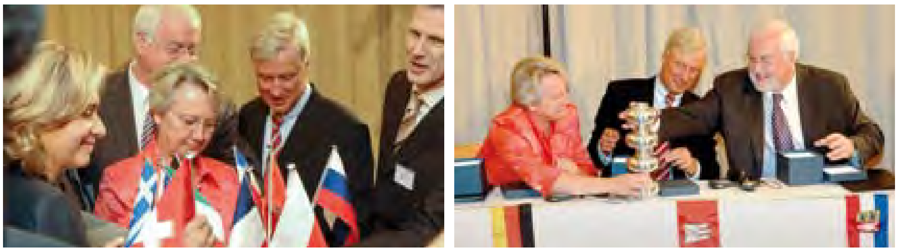


Figure 8 The European XFEL is officially launched on 5 June 2007.
Left Valérie Pécresse, French Minister of Higher Education and Research; Peter Harry Carstensen, Minister President of Schleswig-Holstein; Annette Schavan, German Federal Minister of Education and Research; Ole von Beust, Mayor of the 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 9 Signing of the building contracts for the three underground construction lots for the European XFEL facility on 12 December 2008

Figure 10 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 11 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 has played an important role in fostering the X-ray laser project. It advanced the funding for the preparatory work and hosted the European XFEL project team. 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 12 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 13 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 14 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 has been 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.

Figure 15 Celebration of the end of underground construction at the Schenefeld site on 6 June 2013

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

Figure 17 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 is also progressing rapidly. At the end of the year, 59 of them are installed in the tunnel.

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

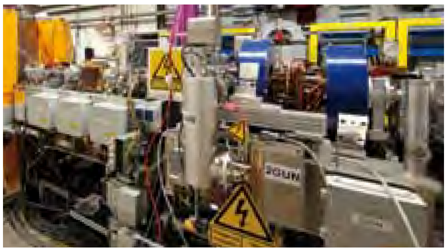
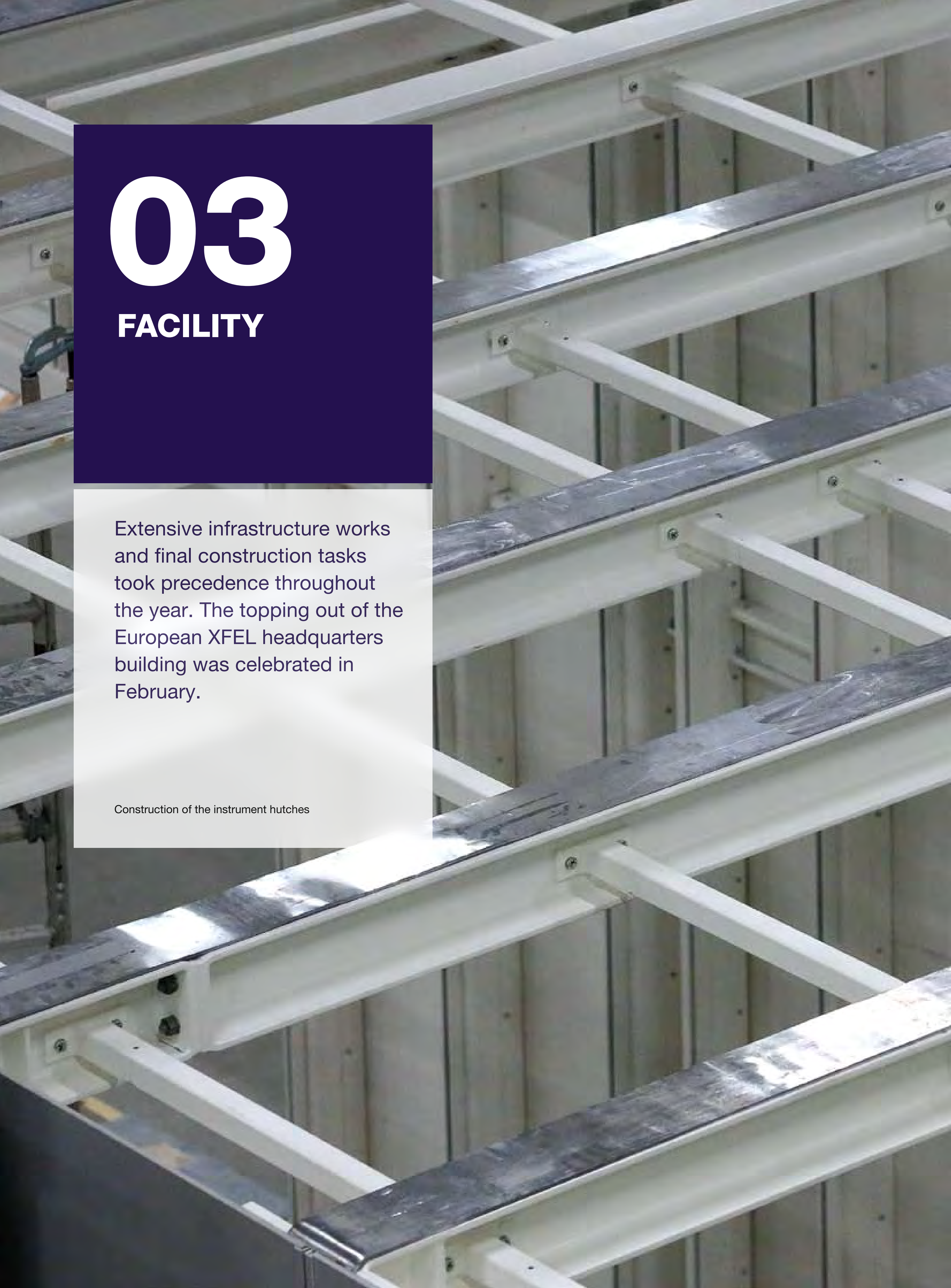


Figure 19 The European XFEL electron injector in December 2015



03 FACILITY

Extensive infrastructure works and final construction tasks took precedence throughout the year. The topping out of the European XFEL headquarters building was celebrated in February.

Construction of the instrument hutches

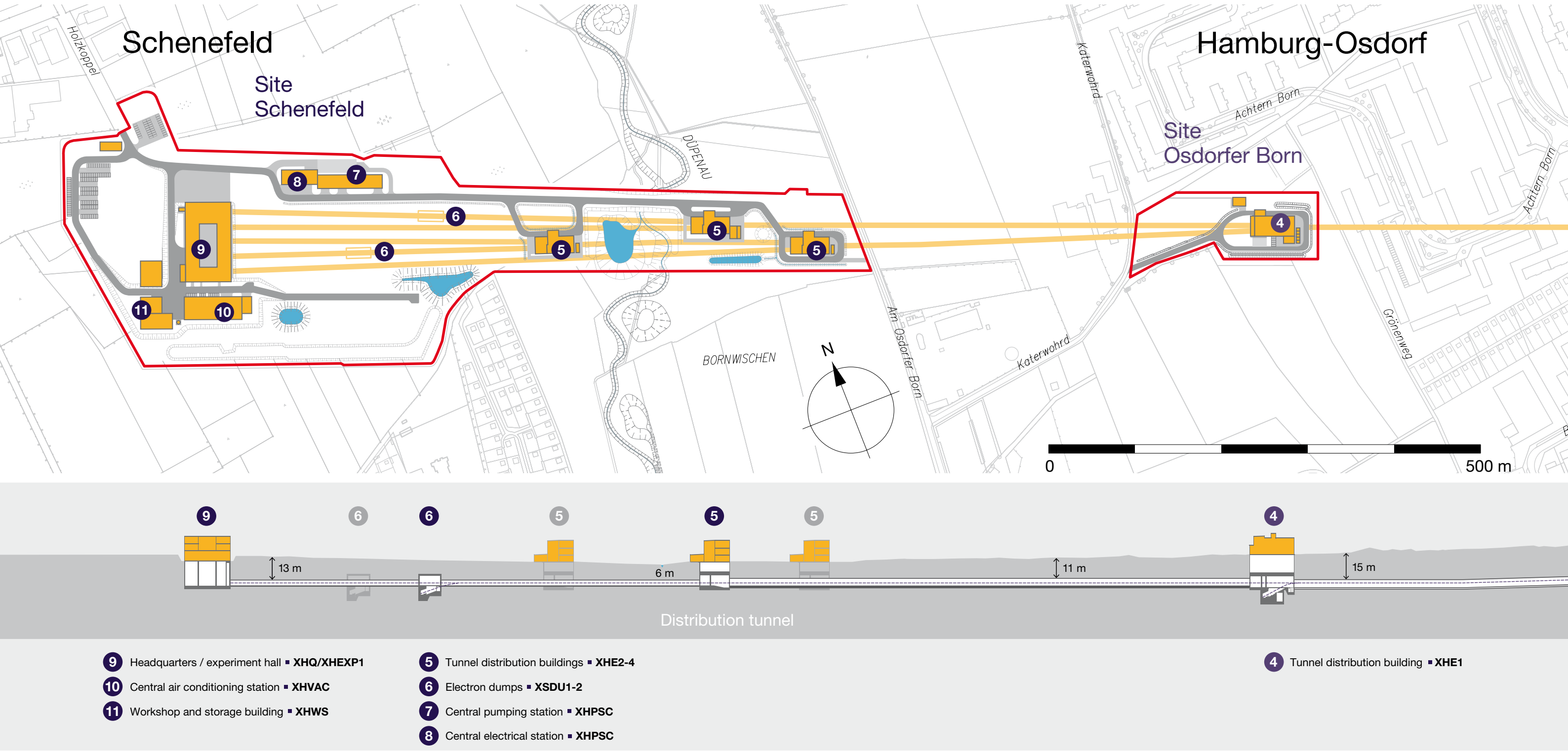


Figure 1 Layout of the European XFEL facility

CIVIL CONSTRUCTION

In 2015, most civil construction work took place on the Schenefeld site, with a particular focus on the facility's headquarters building, which houses laboratories and offices atop the underground experiment hall. Installation of infrastructure on the three sites has been completed, and planning for environmental compensation measures and landscaping is nearing completion.

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 cross-sectional side 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.

At the start of user operation, scientists from around the world will come to the Schenefeld site to carry out their experiments in a large underground experiment hall situated under the laboratories and offices of the European XFEL headquarters building. Figure 2 shows a schematic of all the underground and surface buildings of the European XFEL facility.

Status—December 2015

On the Bahrenfeld and Osdorfer Born sites, the activities in 2015 focused on completing the access halls and finishing the site infrastructure (water management, layout of piping for water, distribution of electricity, and district heating) as well as on the overall landscaping. The civil construction work on these two sites is finished.

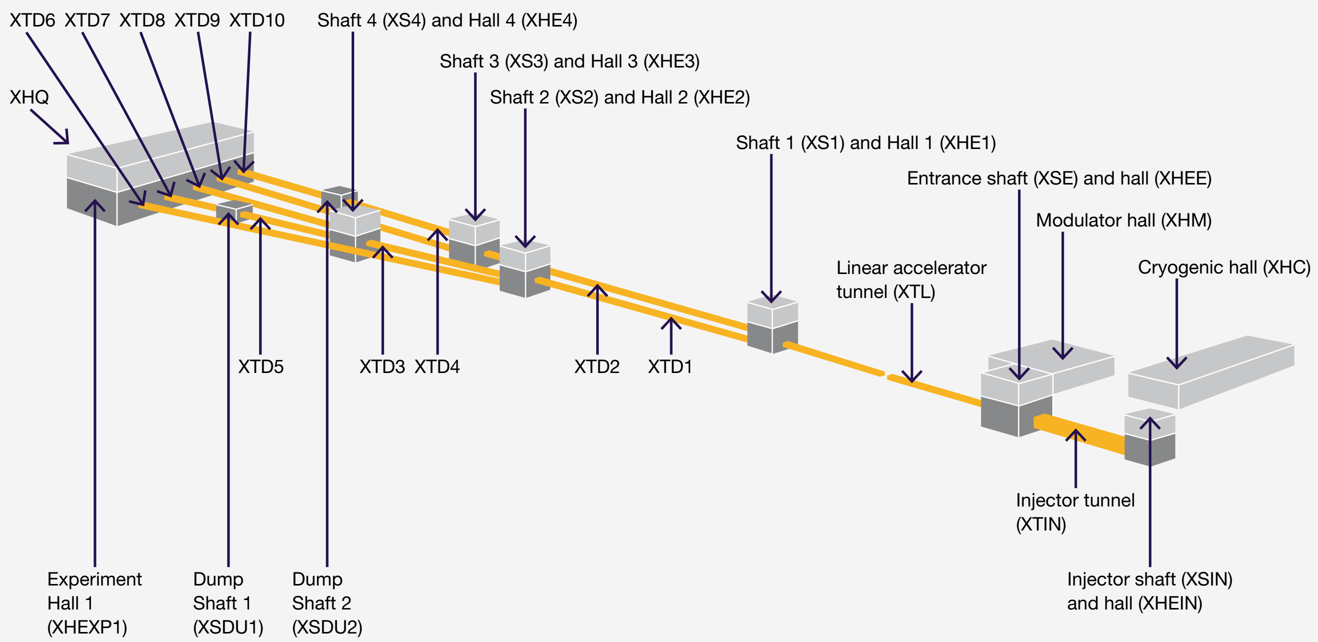
Most activities concentrated on the Schenefeld site. Moving from east to west, the landscaping and infrastructure work was pushed forward and the road connecting the entrance halls (XHE2–XHE4) and the power building XHPSC with the office and laboratory building (XHQ) was completed. The civil construction and technical installation work in XHQ is in full swing. The planning of the entrance building (XHGATE) was finalized and construction started. Planning of the workshop and storage building (XHWS) continues.

The planning of the environmental compensation measures on the Schenefeld site was discussed with the authorities in Hamburg and Schleswig-Holstein, and work on the realization of these plans (for example, the planting of trees) will commence in 2016.

DESY-Bahrenfeld site

The civil construction work on the DESY-Bahrenfeld site is finished. Figure 3 shows an aerial view of the site in September 2015. The access halls XHEIN and XHEE are now being used to install the technical infrastructure and components needed for the operation of the linear accelerator.

Work on the realization of environmental compensation measures will commence in 2016.



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

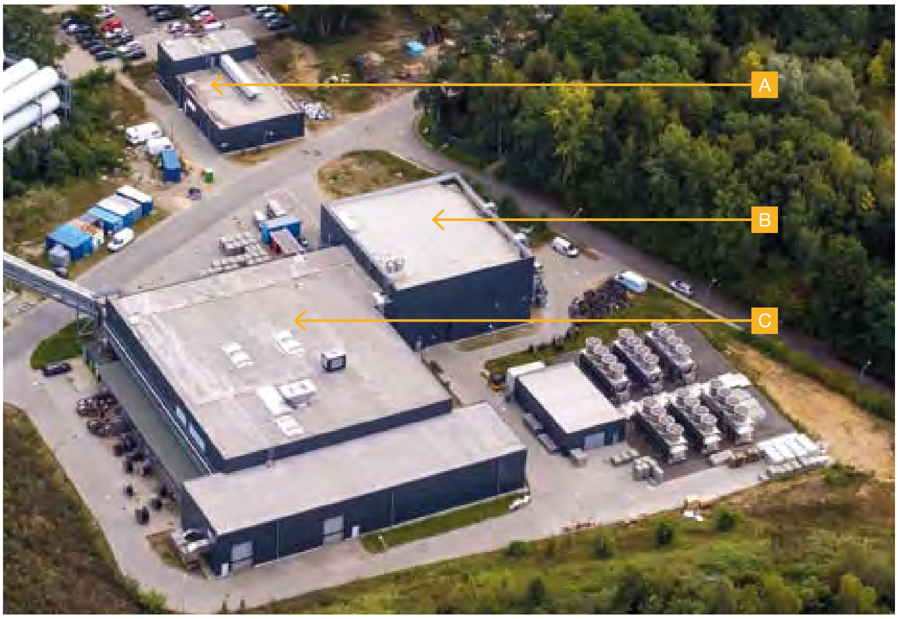


Figure 3 Aerial view of the DESY-Bahrenfeld site (September 2015)
(A) Injector hall (XHEIN)
(B) Entrance hall (XHEE)
(C) Modulator hall (XHM)

Figure 4 Aerial view of the Osdorfer Born site (September 2015)
(A) Hall 1 (XHE1)

Osdorfer Born site

The civil construction work on the Osdorfer Born site is finished. Figure 4 shows an aerial view of the site in September 2015.

Schenefeld campus

Figure 5 shows an aerial view of the Schenefeld site in September 2015. XHE2–XHE4 can be seen in the back, towards the Osdorfer Born site.

The large building in the foreground (XHQ) will contain the laboratory complex for the facility on the ground floor and the offices on the first and second floor. XHPSC is visible on the left side of Figure 5 in the centre, and the building providing the air conditioning for the entire facility (XHVAC) is to the right of XHQ.

XHE2–XHE4 and XHPSC are finished, and technical installation is proceeding at full speed. XHPSC and XHVAC are connected to the underground experiment hall (XHEXP1, situated below XHQ) by large underground concrete media channels.

The infrastructure work (water pipes, power lines, and district heating) has continued, and the road connecting XHE2–XHE4 and XHPSC with XHQ is now complete. The transformer that provides power to XHEXP1 was installed on the west side of XHQ, and the access road to XHVAC is now complete.

Figure 5 Aerial view of the Schenefeld site (September 2015)
(A) Hall 2 (XHE2)
(B) Hall 3 (XHE3)
(C) Hall 4 (XHE4)
(D) Headquarters building (XHQ)

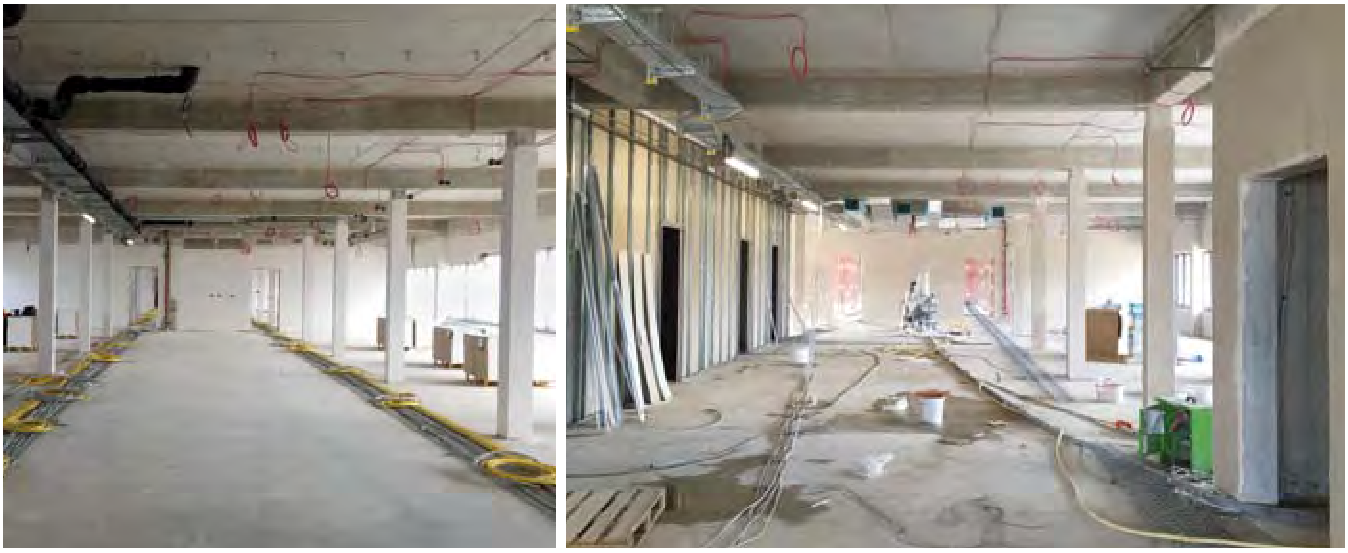


Figure 6 Views of the second floor of XHQ (September 2015)

A large part of the activities on the Schenefeld campus focused on XHQ. After the completion of the concrete shell, the windows were installed to ensure a dry interior for further work during the winter season. The façade was completed and the roof was sealed. Many trades are working in parallel in the interior of the building (for electricity, networks, piping, wall preparation, laboratory air conditioning, heating, double floors, and so on). Figure 6 shows snapshots of the work on the second floor of XHQ in September 2015.

Summary and forecast

In 2015, all essential civil construction milestones were met. Costs for civil construction overall remained within the budget foreseen for the year. Final discussions are under way with the contractors for the large underground Lots 1 and 2 (tunnel and shaft construction) in order to complete and agree on the final bill, with the goal of mitigating the remaining associated cost risks.

In 2016, most of the civil construction work will focus on finalizing the construction of XHQ. The entire staff of European XFEL will move to the new office and laboratory building in June 2016.

XHGATE is scheduled to be completed in the summer of 2016 as well. The civil construction for XHWS should begin in June 2016, with completion scheduled for late spring 2017. Finally, implementation of the environmental compensation measures will continue along with the groundwork for finalizing roads, associated infrastructure, and 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 currently used facilities in Hamburg-Bahrenfeld, including Albert-Einstein-Ring 17 and 19, HERA South, and various buildings on the DESY campus.

Activities in 2015

In 2015, the TS group focused on planning and preparing the call-for-tender documentation for the technical infrastructure of all instrument hutches in the experiment hall (XHEXP1), as well as on supervising the construction and installation of technical equipment and machinery in the European XFEL headquarters building (XHQ), which comprises laboratories and offices. In a joint effort with the Safety and Radiation Protection group at European XFEL and the Accelerator Physics, Emergency Services, Personnel Safety Systems, and Safety and Environmental Protection groups at DESY, the access and emergency response concept for the campus was developed and approved.

District heating in Schenefeld started

By the end of the year, the piping infrastructure for the heating network on the Schenefeld site was completed, enabling heating of the shaft buildings, tunnels, experiment hall, and XHQ. The final commissioning of the complete district heating system for the Osdorfer Born and Schenefeld sites (XDH) is planned for the first quarter of the year 2016.

The team also supervised the installation of the first precision climate control unit for the SASE1 undulator section in the XTD2 tunnel (see Chapter 3, “Civil Construction”).

Building infrastructure installations and planning

The plan of the central workshop and storage building (XHWS), a rendering of which is shown in Figure 1, was improved during the year, and the legal procedure for financing and constructing public-sector infrastructures (*Zuwendungsverfahren Bau*) will be initiated in January 2016.

Thanks to the mild winter in late 2015, the structural works of the entrance building (XHGATE), shown in Figure 2, have already been completed. The building has to be operational in June 2016 in order to house the fire detection system for the facility.

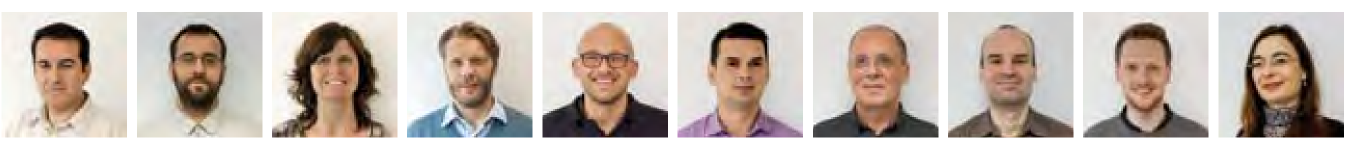
Figure 1 Three-dimensional rendering of the planned XHWS building

Figure 2 Three-dimensional model of the XHGATE building

Outlook for 2016

In the first half of 2016, a major challenge for the group will be moving the European XFEL staff from the offices at Albert Einstein Ring 17 and 19 to the new offices in XHQ in Schenefeld. The move is planned to take place in summer 2016. Calls for tender have to be prepared for the move and for the operation and maintenance of all buildings, including building sanitation, landscape management, and waste management. The TS group will also be involved in the planning of the canteen and the guest house for the European XFEL research campus.

The main task for the group in 2016 will be the commissioning of the majority of the technical installations in the XHQ, XHEXP1, and XHGATE buildings. Installation work at XHGATE will be finished by the beginning of June 2016, and the construction of the XHWS building will start in summer 2016. Investments for hall crew equipment—such as machinery for indoor and outdoor cleaning as well as a special forklift—will be made at the beginning of 2016. Three additional group members were hired in the fourth quarter of 2015 and will start working in 2016. Another two group members will have to be hired to complete the team by the end of 2016.



Group members

Süleyman Arslan, Tobias Bartsch, Uschi Conta, Lorenz Kersting (group leader), Jan Oliver Kirsch, Hrvoje Kristic, Henrike Lunau (from September until December 2015, not shown), Michael Malso, Friedericke Müller (from August until October 2015, not shown), Yana Ogrodowski (until May 2015, not shown), Torsten Schön, Marco Schrage, Carola Schulz (Facility Management team leader), and Christoph Stäps (guest from RMN Ingenieure GmbH, not shown)

04
IN-KIND CONTRIBUTIONS

Contributions from many institutions are helping bring the facility to fruition. In December, the first electrons were accelerated in the injector complex. Many other major components are making good progress to completion.

The transverse deflecting structure, contributed by Russia

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, secondment of staff, or both. To date, 79 IKCs by 22 institutes from 9 different countries are under way for a total of 584 million euro (M€), while a few other proposals are in preparation.

Summary of 2015

Thirty-eight milestones were reached in 2015. Many milestones were related to the installation, cool-down, and commissioning of the injector, the first part of the facility. Accomplishments included the installation of the 3.9 GHz accelerator module in the injector and of the transverse deflecting structure for the beam diagnostics, as well as the first electron beam acceleration as an important test of the injector (for details, see Chapter 4, “Accelerator Consortium”). Also remarkable is the delivery of 76 assembled cryomodules, 60 of which are already installed in the injector and linear accelerator tunnels, after characterization in the Accelerator Module Test Facility (AMTF), which is a Polish contribution. Also of importance is the successful completion of testing of all cold magnets.

Overall contributions

In 2015, adjustments were made in the relative amounts of some IKCs. The total value of IKCs under way was approximately 584 M€, including contracts to Russian institutes (Table 1).

Abbreviation	Country	Number of IKCs	IKC value (k€)
DK	Denmark	2	4 087
FR	France	4	36 000
DE	Germany	36	429 447
IT	Italy	3	33 000
PL	Poland	5	18 390
RU	Russia	13	42 043
ES	Spain	4	7 811
SE	Sweden	10	4 948
CH	Switzerland	2	8 835
Total		**79**	**584 563**

Table 1 Projected IKC amounts by country (in 2005 prices) in thousands of euro (k€) as of December 2015

Countries contributing in kind

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

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.

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	Milano	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
	GU	Gothenburg University	Gothenburg	85
CH	PSI	Paul Scherrer Institut	Villigen	16, 17

Table 2 Institutes contributing in kind to the European XFEL facility (DECO = European XFEL Commissioning)

Contributing institutes

As of December 2015, a total of 22 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 2015, the IKRC recommended to allocate the contribution:

- “European XFEL Commissioning” by DESY at the 2005 value of 21 265 k€
- “Production of Programmable Logic Controller (PLC) crates for six instruments” by NCBJ at the 2005 value of 741 k€.

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

Abbreviation	Institute	IKC No.	Work package	Title	2005 values (k€) (2015)
DESY	Deutsches Elektronen-Synchrotron, Germany	DECO	CO	European XFEL Commissioning	21 265
UU	Uppsala University, Sweden	SE10	85	1D imaging SXES/RIXS spectrometer	270
GU	Gothenburg University, Sweden	SE11	85	Magnetic Bottle Electron Spectrometer	65
NCBJ	National Center for Nuclear Research, Poland	PL08	91	Production of PLC (Programmable Logic Controller) crates for six instruments	741
CNRS/IN2P3	Institut national de physique nucleaire et de physique des particules, France	FR01	05	Production of 670 Power Couplers and RF conditioning of 812 Power Couplers	18 000

Table 3 IKCs allocated in 2015 by the European XFEL Council (in 2005 prices)

recommendation by the European XFEL Administrative and Finance Committee (AFC).

In 2015, five contributions with a total value of 40 341 M€ were allocated to the respective institutes. 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 in case of contracts with Russian institutes. The validation of milestones follows a specific procedure established in 2011.

Thirty-eight milestones were completed and validated in 2015. In total, 254 milestones have been completed since the start of the project. As of December 2015, a total of 22 institutes are contributing in kind to the European XFEL facility.

Thirty-eight milestones were completed and validated in 2015. 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, 254 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 2015, the series production of IKC components for the accelerator complex progressed at full speed.

In particular, the following items were completely delivered:
- Superconducting cavities: 800
- Cryostats: 100
- Warm magnets: 715
- Cold magnets: 100

Cumulatively, 76 modules have been delivered to DESY for final characterization and installation. Sixty-five modules have been completely characterized at AMTF thanks to the IKC Polish contribution PL05, and 60 modules are already installed in the tunnel.

However, some critical difficulties arose in the manufacturing processes of two IKCs for the accelerator complex: the production of power couplers and the warm vacuum components and chambers. Countermeasures to mitigate schedule problems were successfully implemented.

In 2015, three IKCs were successfully completed:

- **IT02, "Production of 25 cryostats (pressure vessels and cold masses) and payment of cost for 17 additional cryostats" for Work Package 3, by INFN – Sezione di Milano (LASA)**
  A total of 103 cryostats custom-built for the European XFEL by the Italian company ZANON S.p.A and IHEP in China arrived in Hamburg for the 1.7 km long European XFEL linear accelerator. This accomplishment is part of Work Package 3, "Accelerator Modules", which includes the contribution DE03 from DESY, FR03 from CEA, and IT02 from INFN. Some of the cryostats (42 pressure vessels and cold masses) were provided through the Italian IKC IT02. A cryostat is a major component of each 12 m long module. It has the main function to isolate the cold interior from the warm environment and is composed of a yellow outer cylinder, a vacuum vessel, two additional shields cooled with helium gas, various helium processing pipes, the suspension for the string of eight niobium resonators, and one magnet unit. After completion, each accelerator module is tested at AMTF at -271°C.

  INFN (LASA) delivered 42 cryostats, consisting of pressure vessels and cold masses for the cryomodules, including:
  - Qualification of cryostat vendor, the Italian company ZANON S.p.A
  - Supervision of the production of 42 cryostats and auxiliaries
  - Supervision of quality control of 42 cryostats
  - Shipping to CEA in Saclay, France

- **PL07, "Tests of the cold magnets" for Work Package 11, by IFJ-PAN, on behalf of the Polish shareholder NCBJ, the legal successor of IPJ**
  A total of 103 cold magnets have been fully characterized by the highly skilled personnel that IFJ-PAN made available to perform the acceptance tests. The contribution was carried out by preparing the test procedures and instructions, setting up and managing the ORACLE database, training dedicated staff and, as the most relevant activity, performing the tests. The tests were mainly one of four kinds: current lead tests, feed-through tests, magnet tests at room temperature, and magnet tests at cryogenic temperature.

Figure 1 Cryostat delivery (42 from IKC IT02/WP03 by INFN) and installation (IKC DE33 by DESY).
The delivery of the remaining cryostats will be managed by WP03 and in particular through IKC DE03 by DESY.

- **ES04, "Undulator intersections: 95 quadrupole movers, 95 intersection control racks, and 2 phase shifters" for Work Package 71, by CIEMAT**
  CIEMAT delivered several components of the so-called intersections, which are 1.1 m long assemblies placed between two undulator segments:
  - Ninety-five quadrupole movers, with a motion accuracy of less than 1 µm and a speed of 0.5 mm/s, which allow control of the quadrupole position by a closed-loop system with direct measurement.
  - Ninety-five intersection control racks, compatible with the European XFEL undulator control system and the tunnel requirements. Prototyping and production of the racks involved design drawings (in ePlan format), documentation, quality management, and reception tests at European XFEL.
  - Two phase shifters, which are needed in undulator systems with adjustable gaps to exactly control the phase retardation between the electrons and the radiation field over the entire length of an undulator system. Long undulator systems cannot be built as one contiguous device and need to be segmented. A phase shifter is made using a chicane consisting of three electromagnets in between the segments.

Photos of activities going on in 2015 at the collaborating institutes are shown in Figures 1–6.

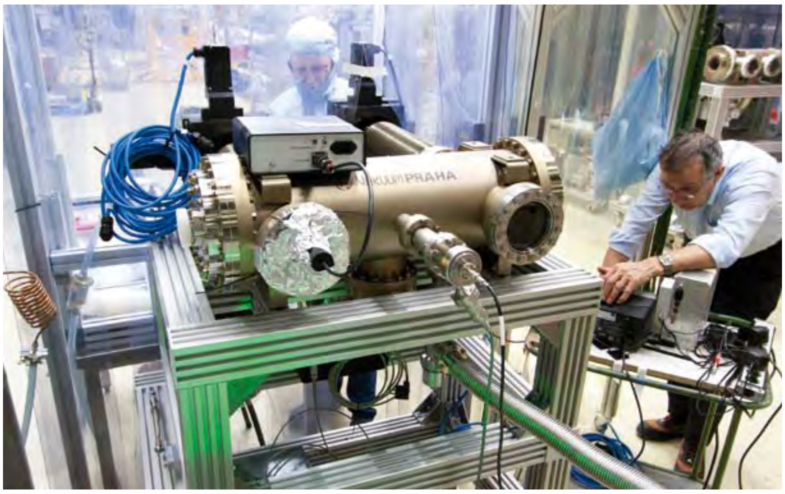


Figure 2 SASE3 microchannel plate–based detector after assembly at European XFEL (IKC RU03/WP74 by JINR)

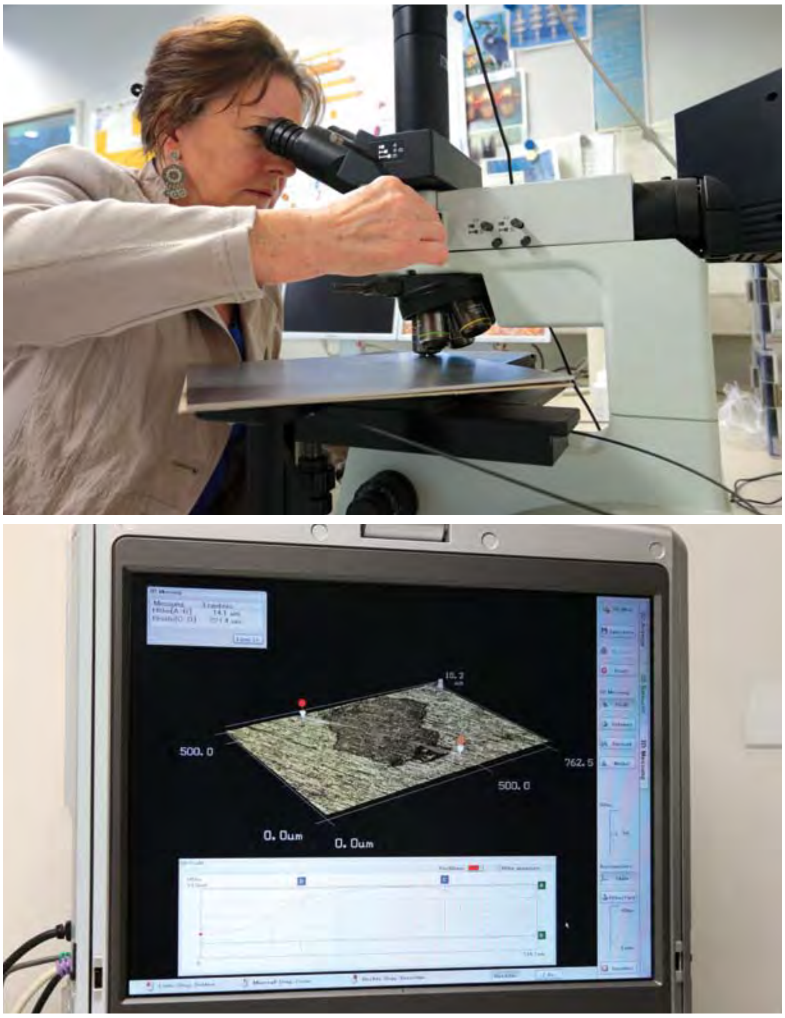


Figure 3 Niobium quality control (IKC DE04 by DESY)

Figure 4 Cryomodules assembled (IKC FR03 by CEA) and installed in the tunnel (IKC DE33 by DESY)

Figure 5 Test of a cryomodule at AMTF (IKC PL05/WP10 by NCBJ)

Figure 6 Re-entrant beam position monitor (BPM) assembly to the cold quadrupole (IKC DE17 by DESY)

Outlook for 2016

In 2016, a large number of milestones should be achieved in the ongoing IKCs. The remaining serial components of the accelerator complex will be delivered and installed, the commissioning of the injector system will be completed, and the commissioning of the linear accelerator will start.

Group member
Antonio Bonucci

ACCELERATOR CONSORTIUM

The linear accelerator complex of the European XFEL and its comprehensive infrastructure are being constructed by an international Accelerator Consortium of 17 European research institutes under the leadership of DESY. In 2015, series production was finished for many components, accelerator module assembly was continued at a high rate, and installation was carried out in all tunnel sections. By the end of the year, the European XFEL injector accelerated the first electron beam.

Building up the accelerator

The accelerator complex of the European XFEL consists of the injector, the main linear accelerator with altogether 100 superconducting accelerator modules, and so-called warm (that is, not cryogenically cooled) beamlines used to transport the electron beam either between successive linear accelerator sections or to the undulators. In 2015, the injector was complemented by its two accelerator sections. Commissioning of the injector started in the fourth quarter of the year.

Tunnel installation

Tunnel installation of the accelerator components is carried out by a large team coordinated by DESY. The installation work is proceeding at a quick pace, and remarkable progress is visible in all accelerator sections. Figure 1 shows the cold (that is, cryogenically cooled) linear accelerator section L3.

All 800 superconducting cavities have been delivered. A team from Poland successfully tested the cavities and demonstrated their high performance.

The accelerator modules are assembled at IRFU of CEA in Saclay, France, in a strong collaborative effort. All components need to be delivered at a sufficient rate and quality so the assembly team can concentrate on the procedures and especially on the throughput of the different workstations.

Meanwhile, all 800 superconducting cavities—an in-kind contribution of DESY and INFN in Milano, Italy—have been delivered. A team from IFJ-PAN in Poland successfully tested the cavities and demonstrated their high performance. The high-power radio frequency couplers are still among the most challenging components needed for the accelerator modules, requiring care and excellent quality control in

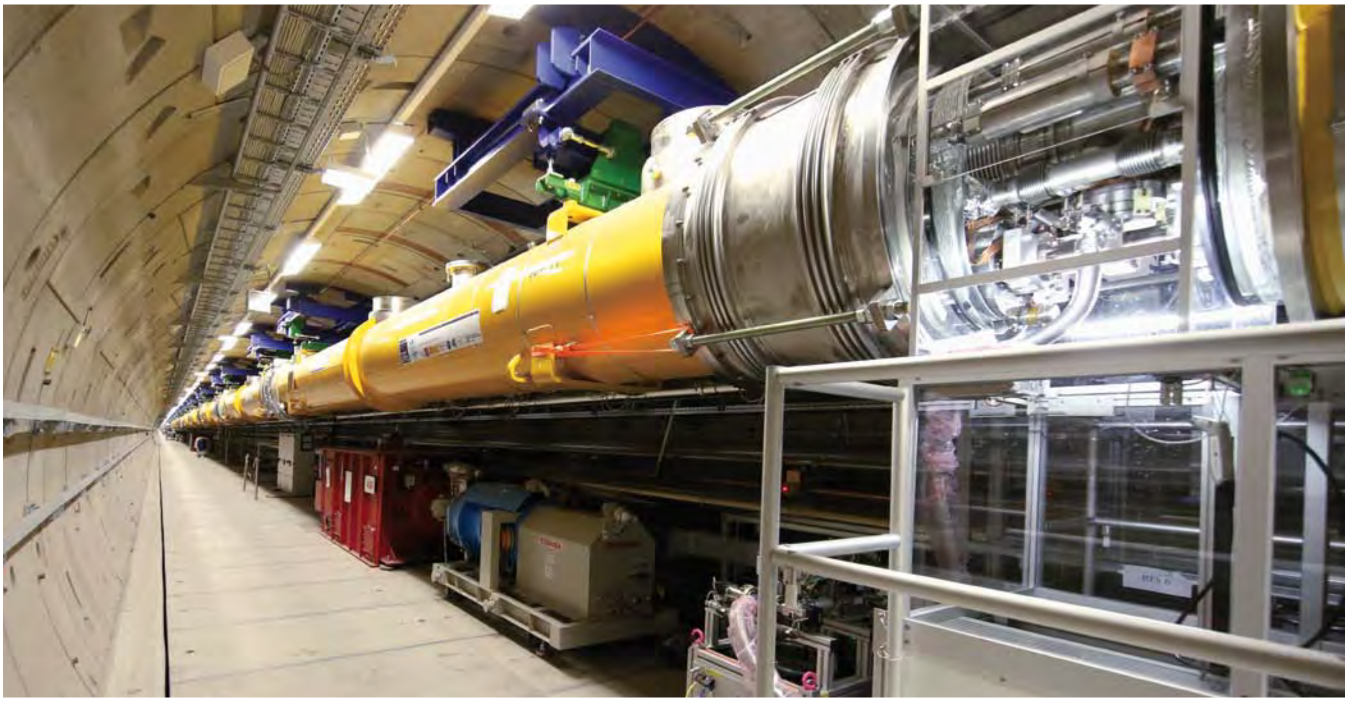


Figure 1 Accelerator modules installed in the linear accelerator section L3. Only some of the 59 modules that were put in place by the end of 2015 are visible. The continuous string of modules at the end of 2015 exceeded 400 m.

all production steps. The in-kind contributor, LAL in France, continued to supervise the coupler vendors. During most of 2015, couplers were regularly delivered from LAL to IRFU after successful conditioning. However, a buffer to cushion irregularity in the delivery rate could not yet be established.

All other components of the accelerator modules were available for module integration. The superconducting quadrupole packages were built in a collaboration between CIEMAT in Spain, IRFU, and DESY, with magnet tests performed by IFJ-PAN. The frequency tuners were provided by DESY in collaboration with INFN. IRFU took care of assembly material like magnetic shielding. The cryostats, with the cold mass and the outer vessel, were produced under supervision of DESY together with INFN. Cold vacuum components are provided by BINP in Russia.

All accelerator modules of the European XFEL are tested at the Accelerator Module Test Facility (AMTF) at DESY. In spring 2015, a dedicated effort by IFJ-PAN and DESY helped to drastically shorten the testing time, ensuring that newly arriving modules could be installed in one of the test benches almost immediately after their delivery to DESY. By the end of 2015, nearly 75 modules had been tested. For most of them, the average usable accelerating gradient was found to clearly exceed the European XFEL specification.

An average of 27.4 MV/m was reached, which is 16% above the design value and ensures a wide margin for the final electron energy. The last 14 measured modules even showed an average gradient of 29.3 MV/m. The variation of the maximum usable accelerating gradients of the individual cavities and modules was within acceptable limits. Right after the cold module test in the AMTF at DESY, an individually tailored waveguide distribution system is assembled for each module, with the help of a team from Sofia University in Bulgaria.

Beamline magnets, vacuum chambers, and a variety of beam diagnostic elements, such as cold beam position monitors (BPMs), warm BPMs, current transformers, dark-current monitors, scintillator-based screen stations, and wire scanners, were delivered by consortium partners. For the bunch compressor sections, pre-assembled girders are used, and chicane vacuum systems from BINP complement the installation. After finishing the cryogenic transfer line, which is located above the electron beamline, installation in these sections now continues. Beam distribution systems downstream of the cold linear accelerator are currently being put in place. In 2015, the focus was on the construction and installation of the steel suspension system for about 400 m of electron beamline. In the undulator areas SASE1 and SASE3, all beam transport magnets were installed, and the SASE1 electron vacuum system was completed.

First electron beam accelerated in injector

The injector is the first section of the accelerator. It is about 40 m long and located on the seventh underground floor of the injector building on the DESY-Bahrenfeld site. Here, the electrons are extracted from a photoelectric cathode exposed to an ultraviolet laser. After acceleration to relativistic energies in a normal-conducting 1.6 cell cavity, the electrons enter the first two superconducting accelerator modules: a standard 1.3 GHz module similar to the other 100 modules that are being installed in the accelerator tunnel and a 3.9 GHz higher-harmonic module used to manipulate the longitudinal beam shape. At a beam energy of about 130 MeV, the electron bunches pass through the laser heater, where the longitudinal bunch properties are altered again. The beam properties can afterwards be measured with various devices in an extensive diagnostic section.

All the members of the Accelerator Consortium contributed to the construction of the injector, which was completed with the insertion of the 3.9 GHz module in November 2015. After the final approval of the personnel safety measures by the authorities, commissioning started. For the first time, the complete cryogenic installation in the injector was cooled down to 2 K, and the modules were ready to be operated with radio frequency. Thanks to the careful preparation of all the subsystems and a thorough technical commissioning, it was possible, within five

Figure 2 First electron beam acceleration in injector.
Top Scientists observing the first beam in the accelerator control room at DESY.
Bottom The dump area in the injector tunnel.

hours on 18 December, to accelerate and steer the electron beam all the way to the injector beam dump (Figure 2).

In early 2016, a comprehensive beam commissioning will follow, with the aim to investigate the complete electron beam parameter space that is needed to serve the various user needs. In addition, an R&D programme has been launched to improve the reliability of some crucial injector components that showed early fatigue during high-power operation. DESY and European XFEL have also decided to prepare a second photocathode laser system to eliminate this single point of failure and improve the overall availability of the accelerator during commissioning and operation.

Full accelerator commissioning to start in 2016

In 2016, installation of all the sections of the accelerator complex will be finished. Depending on the availability of the required subcomponents, the last module (XM100) should be at DESY before the end of the second quarter. AMTF tests and tunnel installation will follow immediately. In order to concentrate on the final module installation, the tunnel installation team aims to finish all the beam transport sections before the summer.

All the members of the Accelerator Consortium contributed to the construction of the injector, which was completed with the insertion of the 3.9 GHz module in November 2015. After the final approval of the personnel safety measures by the authorities, commissioning started.

The beam-based commissioning of all the injector systems that began in 2015 will continue in 2016. About 12 months are foreseen to reach all the injector commissioning goals and be well prepared for the full accelerator commissioning, which should start in the second half of 2016, marking the transition from construction to operation phase. DESY will be responsible for the operation of the accelerator and has begun to prepare for this new and exciting task.

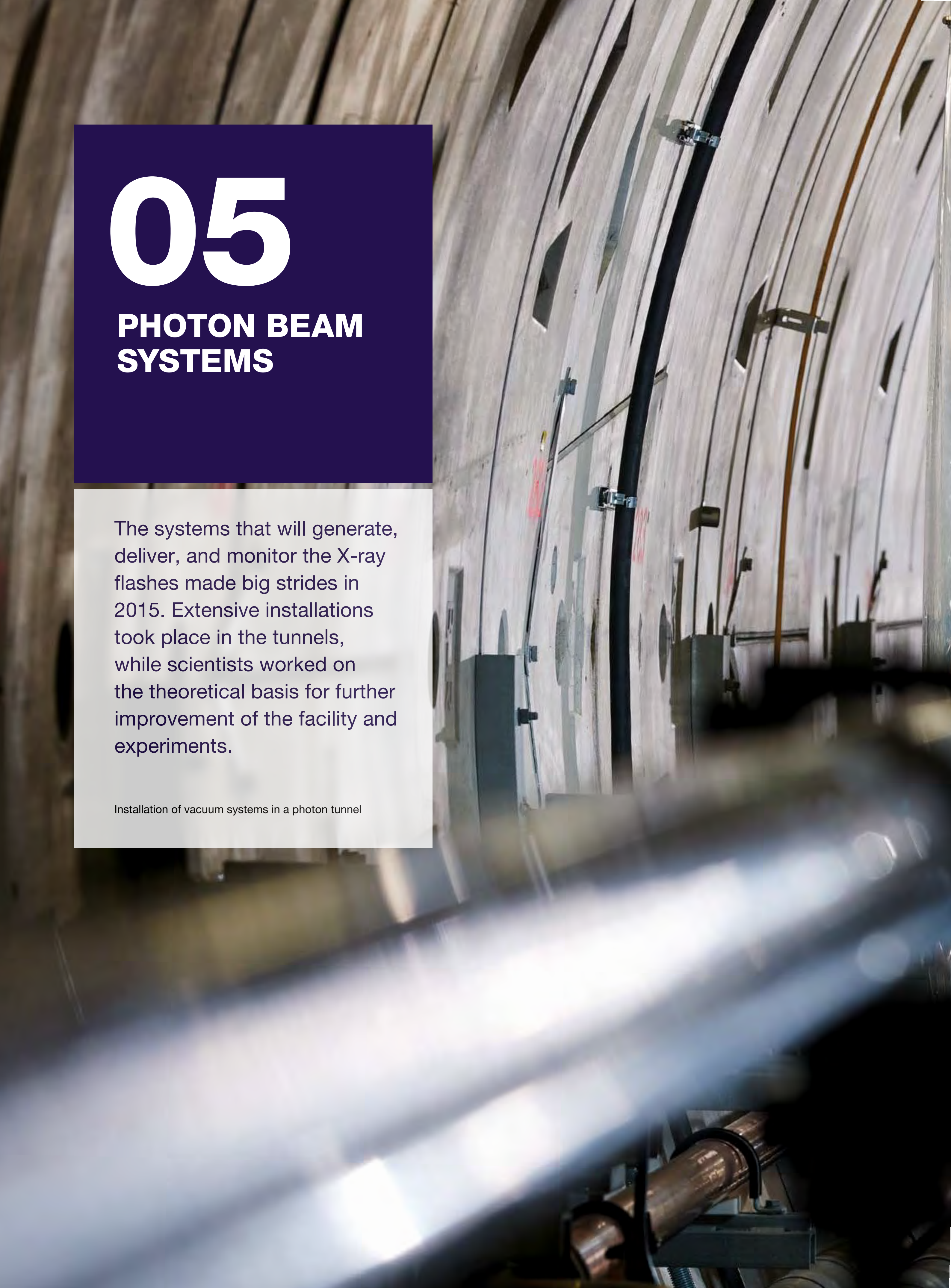
European XFEL accelerator technology sets benchmark

The successful implementation of superconducting accelerator technology at DESY's FLASH facility, and now in much larger scale at the European XFEL, led to the decision to realize the LCLS upgrade at SLAC as a superconducting continuous-wave facility—a choice of technology that underlines the world-leading position of the European XFEL project. Essentially all the basic technology used for FLASH and the European XFEL is going to be reproduced for the LCLS upgrade, and corresponding collaborations between SLAC and DESY have been established.

05

PHOTON BEAM SYSTEMS

The systems that will generate, deliver, and monitor the X-ray flashes made big strides in 2015. Extensive installations took place in the tunnels, while scientists worked on the theoretical basis for further improvement of the facility and experiments.



Installation of vacuum systems in a photon tunnel


VARIABOX

UNDULATOR SYSTEMS

The European XFEL will include three undulator systems—periodic magnetic structures in which the electrons will generate ultrabrilliant pulses of X-ray radiation. Each of the hard X-ray systems, SASE1 and SASE2, will be more than 200 m long and comprise 35 undulator segments with a period length of 40 mm. The soft X-ray system, SASE3, will be about 120 m long and contain 21 segments with a period length of 68 mm. Also required are phase shifters, quadrupole movers, control systems, and various auxiliaries. The Undulator Systems group is responsible for producing, installing, and commissioning these systems. Another important task is the coordination with the Accelerator Consortium, which supplies the undulator vacuum system, electron beam diagnostics, quadrupoles, and tunnel infrastructure and carries out most of the installation work in the tunnels.

Summary of 2015

In 2015, the Undulator Systems group completed all activities related to serial manufacturing and production as scheduled. The group measured and tuned all undulator segments. All phase shifters successfully passed the acceptance tests and complied with specifications. All quadrupole movers were delivered, validated, and found to be within specifications as well. Other components, such as air coils, base plates, and intersection control racks, arrived at European XFEL on time, and most were installed in 2015. Tunnel installation continued: The installation of SASE1 in the XTD2 tunnel (see Chapter 3, “Civil Construction”) is the most advanced, with the first undulator segments installed on 14 December. The installation of SASE3 in XTD4 continued. The installation of SASE2 in XTD1 began and made good progress.

Undulator segments

In 2015, serial production of the undulator segments, in-house magnetic measurements, and tuning in the three magnetic labs were finished. To further improve the quality of the undulator segments, the group initiated a second magnetic check directly before installation. The additional time required for these measurements had no impact on the overall project schedule.

These re-measurements were made for the following reasons:

- The undulator hall in DESY Building 36 did not provide sufficient storage space for the large amount of required hardware components. Therefore, starting in late 2012, about 60% of the undulator segments were transported by truck to an offsite storage hall after the magnetic measurements and tuning of each segment were finished.

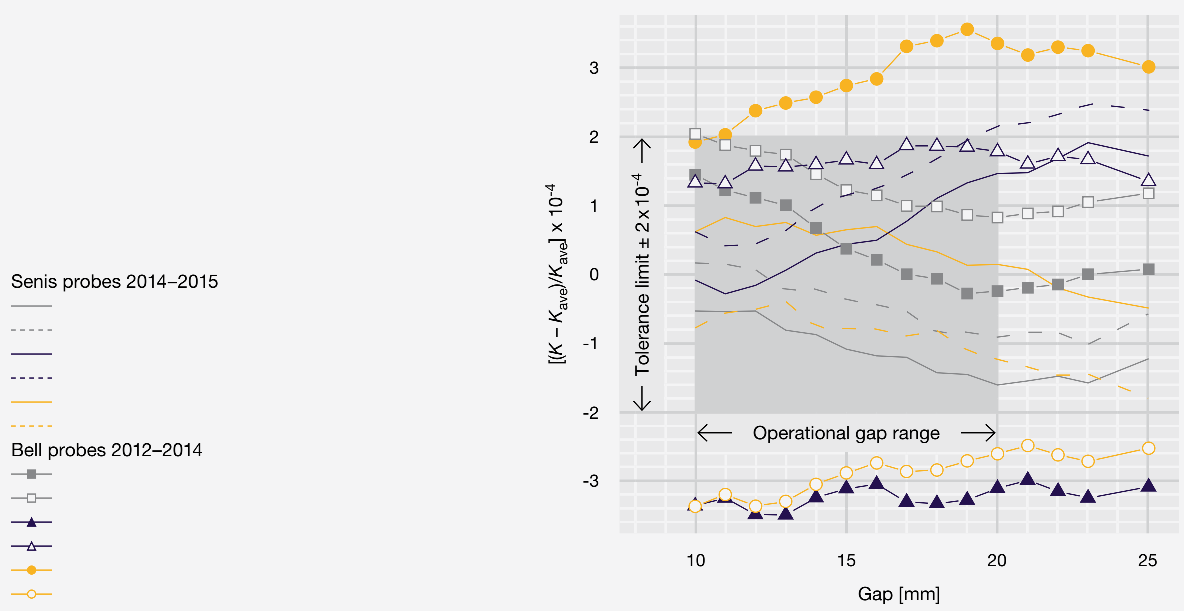


Figure 1 Comparison of the achievable accuracy of magnetic measurements using the old (Bell) and new (Senis) sensors: *ΔK/K* measurements on reference undulator U40-X057 on magnetic benches 1 to 3

The conditions in the hall, changing temperatures, long storage times, and additional transports pose risks to the performance of the undulator segments, which can be eliminated only by final checks prior to installation.

- Over the production period of 2.5 years, some procedures, tests, specifications, and quality criteria were refined and optimized. For example, there were slight differences on the order of 10–20 μm in the definition of motion limits of the motors and hard stops between the undulator segments produced earlier and those produced later. Ultimately, all segments need to comply with the same criteria.
- In the course of the magnetic measurements, new and better Hall probes became available, offering lower noise, better drift stability, and higher long-term accuracy. Such probes are now being used for the re-measurements. Figure 1 shows long-term accuracy tests of the *K* parameter of the old (Bell) and new (Senis) sensors using the reference undulator U40-X057. *ΔK/K* is plotted as a function of the undulator gap for the different old and new probes. Data were taken on all three magnetic benches over an extended period of time. As Figure 1 shows, in the operational gap range of 10–20 mm, the Senis probes allow for $\Delta K/K \leq 2 \times 10^{-4}$. In contrast, the accuracy of the old Bell system is lower by almost a factor of 2. The improved accuracy will facilitate the precise tuning of all segments of a given undulator system to the same *K* parameter based on magnetic data.

Figure 2 Transport of an undulator segment in the XTD2 tunnel using a specially developed undulator transport vehicle

Re-measurements started in the summer of 2015. It was observed that, in general, magnetic properties such as phase errors and beam wander are well preserved, and no re-tuning of poles was needed. Only occasionally did an end pole have to be re-adjusted. Under optimum conditions, using the three magnetic benches, three to four undulator segments can be re-measured per week. By the end of 2015, all 35 segments for SASE1 and about 20% of the 21 segments for SASE3 had been re-measured and stored in the undulator hall in Building 36, ready for installation.

Phase shifters

In the course of 2015, all phase shifters were delivered to European XFEL and underwent acceptance tests. The tests were performed at European XFEL using a short moving wire stand and one of the magnetic benches. They included measurements of the first field integrals and magnetic maps as a function of the phase shifter gap. All the phase shifters needed for SASE1 and SASE3 are now ready for installation.

Installation in the tunnels

The installation of SASE1 in the XTD2 tunnel was continued and is the most advanced. The intersections, base plates, quadrupole movers, and quadrupoles were assembled and aligned. In October 2015, the undulator air conditioning system was mounted. In parallel, the installation and alignment of the 220 m long vacuum system—including the 6 m long undulator vacuum chambers, the intersection vacuum system, and the beam position monitors—were started in close collaboration with DESY. Work on the vacuum system was finished at the beginning of December. A major step forward was made on 14 December, when the first undulator segments were rolled into XTD2 and installed in their final positions. The segments were transported using an undulator transport vehicle developed by the DESY Tunnel Installation group. Figure 2 shows the transport of an undulator segment.

By the end of December 2015, seven undulator segments had been installed. Figure 3 shows an upstream view of three segments after installation in XTD2.

The installation of SASE2 and SASE3 made good progress as well. Work on SASE3 is scheduled to follow the SASE1 scheme with a time difference of about four to five months, SASE2 with a difference of about one year.

Figure 3 Undulator segments installed in the XTD2 tunnel

Outlook for 2016

In 2016, the group will complete and commission all three undulator systems:

- XTD2/SASE1
  After installation of the undulator segments, the local control system of each cell will be connected with the corresponding undulator segment, phase shifter, and quadrupole mover so the local control systems can be commissioned. In the next step, the global control system will be put into operation. By the summer of 2016, SASE1 will be completed.

- XTD4/SASE3
  The next steps are the installation of the quadrupole movers, the quadrupoles, and the vacuum system. In April and May, the undulator segments will be rolled in, followed by the same steps used for SASE1.

- XTD1/SASE2
  The installation schedule will follow that of SASE1 and SASE3, but it will take advantage of the experience gained with the other two systems so the roll-in of the undulator systems can start in September 2016. Commissioning will end in late 2016.

All three undulator systems will be ready for beam at the beginning of 2017. ■

Group members
Suren Abeghyan, Majid Bagha-Shanjani, Karl-Heinz Berndgen (not shown), Georg Deron, Uwe Englisch, Suren Karabekyan, Bora Ketenoglu (guest, until June 2015), Martin Knoll (until May 2015), Peng Li (guest, not shown), Yuhui Li, Joachim Pflüger (group leader), Marc Viehweger, Tao Wei (guest, not shown), Frederik Wolff-Fabris, and Mikhail Yakopov

SIMULATION OF PHOTON FIELDS

The Simulation of Photon Fields (SPF) group studies developments beyond the baseline concept of the European XFEL in order to improve the performance of the facility, assists other groups with simulations of radiation properties, and develops software tools needed for these tasks.

Summary of 2015

In 2015, the SPF group, in close collaboration with partners, answered theoretical FEL physics questions on polarization properties of FEL pulses. The group also studied schemes for producing FEL pulses with high spectral density based on hard X-ray self-seeding (HXRSS) for inelastic X-ray scattering (IXS), pulses suitable for single-particle imaging, and short-wavelength HXRSS pulses. The SPF group assisted the Materials Imaging and Dynamics (MID) group with split and delay line simulations and collaborated with the Small Quantum Systems (SQS) group on two-colour schemes. The group also helped in the efforts towards the construction of a HXRSS setup for the SASE2 beamline. Finally, the OCELOT simulation software was further developed and used for FEL performance optimization.

In close collaboration with partners, the group answered theoretical physics questions on polarization properties of FEL pulses. The group also helped in the efforts towards construction of a self-seeding setup setup for the SASE2 beamline.

The SPF group greatly benefited from collaborations with members of external institutions: Vitali Kocharyan, Evgeni Saldin, and Igor Zagorodnov at DESY; Kartik Ayyer and Oleksandr Yefanov at CFEL; Nikolay Smolyakov, Boris Krasnopolskiy, and Evgeny Fomin at the NRC KI synchrotron; Oleg Chubar at BNL; Yury Shvydko at ANL; and John Sutter at Diamond Light Source.

Changes to the group

Ilya Agapov left the SPF group in December 2015, but he will continue to collaborate with SPF from his new position at DESY. Sergey Tomin (previously at NRC KI) joined the SPF group in the framework of a project, jointly funded by the German Federal Ministry of Education and Research (BMBF) and the Russian Ministry of Science and Education, aiming at further development of the OCELOT software. Svitozar Serkez (previously at DESY) was hired as a consultant in December 2015.

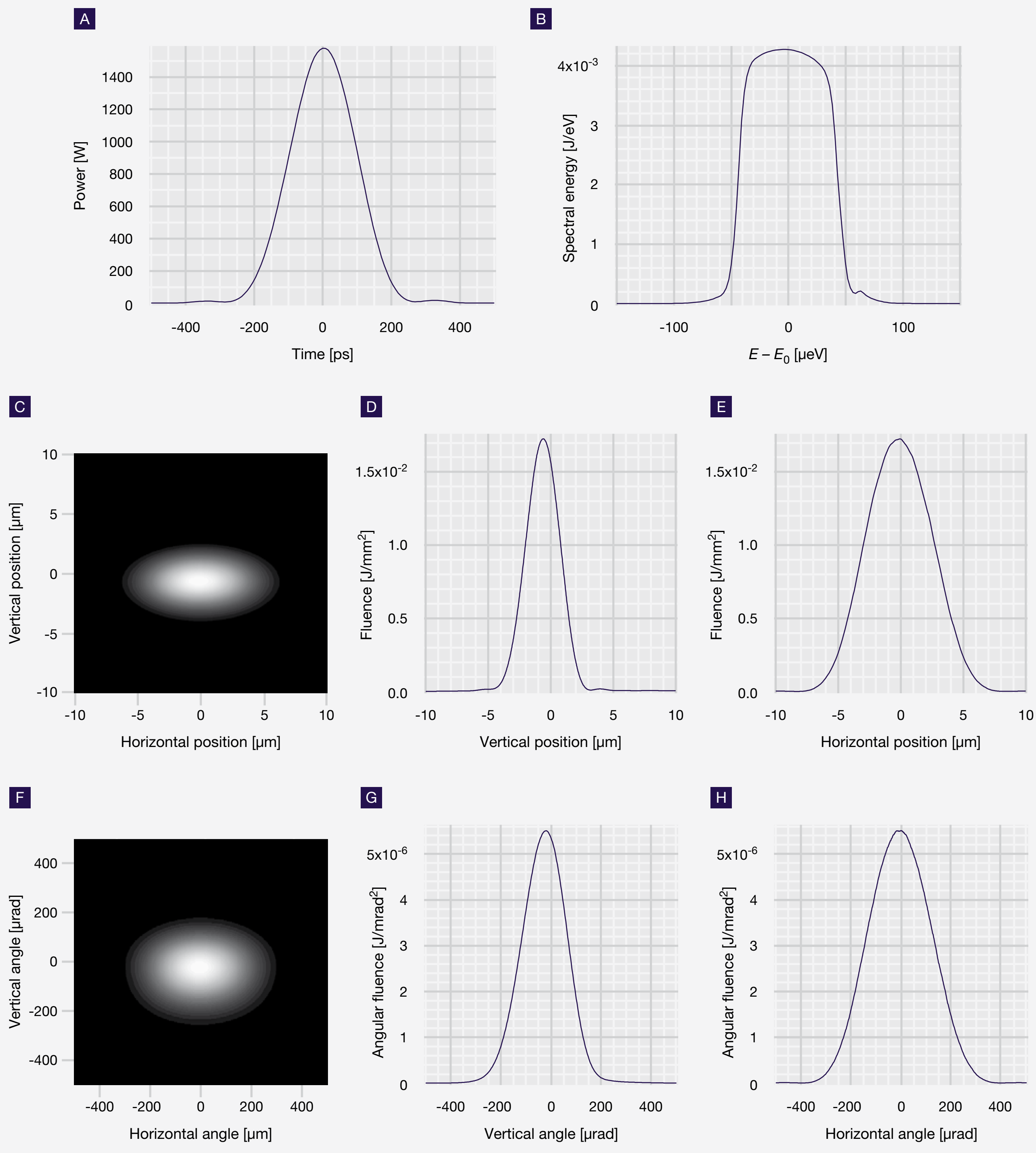


Figure 1 Radiation pulse on the sample.
A pulse power, **B** spectrum, **C** 2D spatial distribution, **D** vertical cut through the maximum of the fluence distribution, **E** horizontal cut, **F** 2D angular distribution, **G** vertical cut through the maximum of the angular fluence distribution, and **H** horizontal cut.
When the full repetition rate of the European XFEL (27 000 pulses/s) is exploited, it will be possible to obtain 7 x 10^{12} photons/s in a 90 μeV bandwidth at the sample position.

Theoretical developments

X-ray FEL radiation is highly polarized. Kocharyan and Saldin, together with SPF group member Gianluca Geloni, studied this polarization from a quantitative viewpoint and showed [1] that, in an undulator with the electron motion on the horizontal plane, the horizontally polarized component of the radiation greatly dominates, and less than one part in a million of the total intensity is polarized in the vertical plane.

One of the group's collaborations studied options for performing ultrahigh resolution inelastic X-ray scattering, making use of self-seeding and the high repetition rate of the European XFEL.

Lasing schemes and collaborations

Together with Chubar, Kocharyan, Saldin, Shvydko, Sutter, and MID group member Anders Madsen, SPF group members Geloni and Serkez studied a scheme for producing FEL pulses around 9 keV with very high average spectral flux density for IXS applications. This technique should make use of HXRSS, the high repetition rate of the European XFEL, and a novel spectrometer for ultrahigh-resolution IXS (UHRIX) to reach about 7×10^{12} photons/s in a 90 µeV bandwidth of the sample, opening new possibilities for IXS dynamics studies [2] (Figure 1).

Together with Ayyer, Kocharyan, Saldin, Yefanov, and Zagorodnov, Geloni and Serkez continued to study options for imaging single protein molecules using a combination of HXRSS and a special mode of operation of the accelerator complex. The collaboration produced simulations for the 15 nm size RNA polymerase II molecule by generating noisy diffraction patterns and obtaining back the 3D intensity distribution. They also discussed requirements for the signal-to-background ratio needed to obtain correct pattern orientation.

Kocharyan, Saldin, and Geloni studied an option for generating HXRSS pulses at high photon energies. Taking 14.4 keV as an example, they proposed to exploit HXRSS at 7.2 keV in a first part of the undulator setup and then to amplify the bunching at the second harmonic in the last undulator part by tuning the fundamental at 14.4 keV. Proper undulator tapering promises a maximum flux on the order of 1×10^{12} photons/s in a meV bandwidth, an increase of about two orders of magnitude compared to the average spectral flux for the nominal, untapered SASE regime at saturation.

Finally, in 2015, the SPF group collaborated with the MID group, supporting their simulation efforts towards the design of a split and delay line, and with the SQS group, researching possible options for two-colour operation at the SASE3 beamline.

Software developments

In 2015, developments of OCELOT—the synchrotron light source and FEL simulation package developed in collaboration with DESY and NRC KI—gained further momentum, receiving additional support from the EDYN EMRAD project funded by the Ioffe-Röntgen-Institute (IRI), a partnership between Germany and the Russian Federation, which allowed Tomin to be hired as a postdoctoral researcher.

An application of particular interest is the use of OCELOT for automatic empirical online optimization of FEL performance, which is important for reducing the FEL tuning time.

The SPF group developed OCELOT-based tuning software and experimentally demonstrated it at FLASH in collaboration with DESY. Results indicate a substantial reduction of the tuning time. OCELOT has also been adapted to the control system of LCLS, where it has been successfully used for FEL tuning.

Outlook for 2016

In 2016, the SPF group members will advance their studies on theoretical developments and novel schemes for the production of X-ray pulses with special characteristics. They will further maintain their collaborations with external partners and other European XFEL groups. Moreover, they expect to pursue software development within the EDYN EMRAD project. In particular, a continuation of the experimental programme exploiting OCELOT for online optimization of FEL performance has been approved at FLASH, and the software is expected to be used in the upcoming commissioning of the European XFEL facility. ■

Group members
Ilya Agapov (until December 2015), Gianluca Geloni (group leader), Svitozar Serkez (guest, since December 2015), and Sergey Tomin (postdoc)

References

[1] Theoretical computation of the polarization characteristics of an X-ray Free-Electron Laser with planar undulator
G. Geloni, V. Kocharyan, E. Saldin
Opt. Comm. **356**, 435 (2015)
DESY 15-021
doi:10.1016/j.optcom.2015.07.048

[2] Novel opportunities for sub-meV inelastic X-ray scattering at high-repetition rate self-seeded X-ray free-electron lasers
O. Chubar, G. Geloni, V. Kocharyan, A. Madsen, E. Saldin, S. Serkez, Y. Shvydko, J. Sutter
Proceedings of FEL2015: Seeded FELs
37th International Free Electron Laser Conference, FEL 2015, Daejon, South Korea, 23 Aug 2015 – 28 Aug 2015
MOP086 (2015)
DESY 15-140
arXiv:1508.02632

THEORY

The task of the Theory group is to generate ideas for novel time-dependent FEL applications and develop efficient tools to extract and analyse information from data acquired at the European XFEL. The group's research involves program developments and simulations ranging from the electronic spectrum of correlated materials to the nanoscale structure of complex objects. Close cooperation with the instrument groups ensures that the cutting-edge experiments at the European XFEL will be supported by a solid theoretical basis. Part of the Theory group is based at the University of Hamburg in Germany.

Activities in 2015

In 2015, the Theory group continued to work on existing projects and established new collaborations.

Group member Evgeny Gorelov carried on his extensive collaboration with the Spectroscopy and Coherent Scattering (SCS) group. Motivated by SCS experimental results, Gorelov and group member Igor Krivenko are developing a new method to interpret the spectroscopic data of strongly correlated systems; together with group member Viktor Valmispild, Gorelov is working on computational methods to describe strongly correlated materials in strong electromagnetic fields.

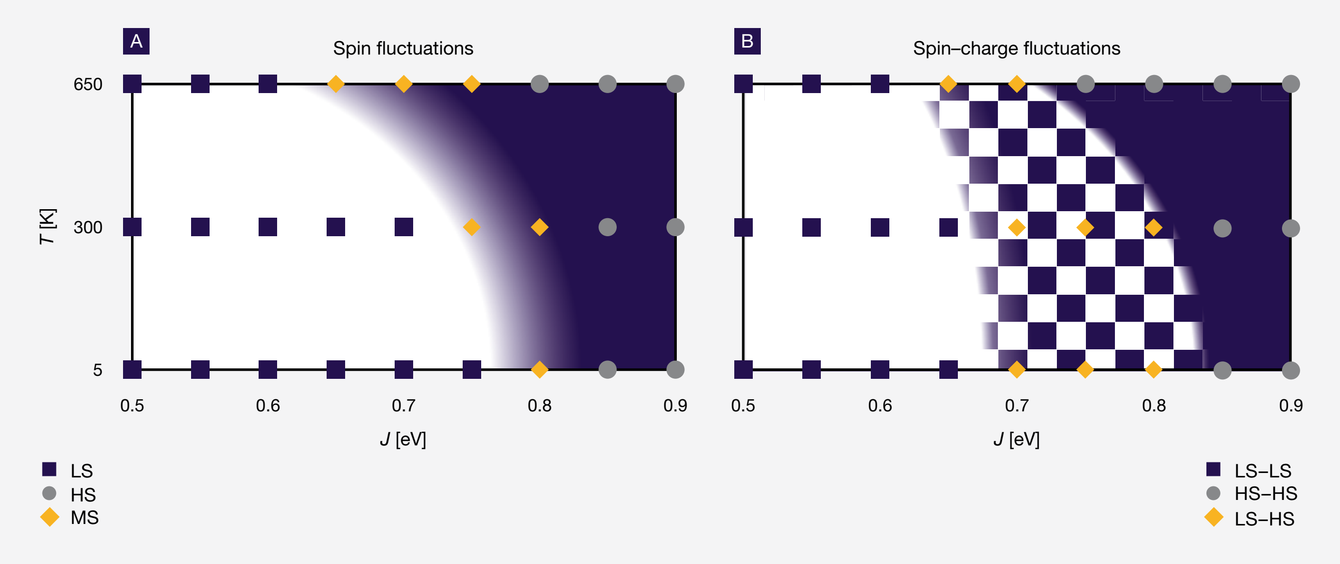


Figure 1 Phase diagram of $LaCoO_3$ as a function of lattice temperature *T* and Hund's rule coupling *J*.
The coloured parts illustrate different regions, with white indicating low spin (LS) and blue high spin (HS), with mixed spin (MS) in between.
A Homogeneous phase exhibiting the LS, MS, and HS states as indicated by the data points.
B Data points and possible phase regions for the calculation with inequivalent Co atoms. The checkerboard pattern marks the LS–HS phase where strong charge fluctuations are present.

In cooperation with Alexander Yaroslavtsev of SCS, Gorelov is performing spectroscopic calculations of pnictides and related compounds. In addition, he has started to collaborate with Andrei Rogalev of ESRF on data interpretation of X-ray magnetic circular dichroism experiments.

Group member Ruslan Kurta joined a project devoted to ultrafast magnetization studies, led by Andreas Scherz of SCS, within which he is performing magnetic resonant X-ray diffraction calculations. Within the Single Particle Imaging (SPI) initiative at LCLS, Kurta is working on novel techniques required for single-particle structure determination together with Adrian Mancuso of the Single Particles, Clusters, and Biomolecules and Serial Femtosecond Crystallography (SPB/SFX) group, Peter Zwart of LBNL, and Andrew Aquila of LCLS. In collaboration with Ivan Vartanyants of DESY and Sergey Bobkov and Anton Teslyuk of NRC KI, Kurta is developing algorithms for the classification of scattering data measured at X-ray FELs [1].

The group performed further studies of $LaCoO_3$ in the framework of cluster calculations, including full on-site Coulomb interaction and metal-to-ligand charge transfer.

Spectroscopy of strongly correlated materials

Stimulated by experimental results in $LaCoO_3$ published in 2014 by Manuel Izquierdo of SCS, the Theory group performed density functional theory plus dynamical mean-field theory (DFT+DMFT) calculations in collaboration with Michael Karolak of the University of Würzburg, Germany [2]. The results show that strong charge fluctuations and disproportionation induced by electronic correlations are relevant to understanding the spin transition in $LaCoO_3$ (Figure 1). The group performed further studies of this compound in the framework of cluster calculations, including full on-site Coulomb interaction and metal-to-ligand charge transfer. The spectroscopic imprints of lattice thermal expansion, change in electron temperature, and low-spin to high-spin transition were disentangled.

Non-equilibrium correlated systems in strong electric fields

Using the recently developed microscopic Green's function approach within the Keldysh formalism to describe the non-equilibrium many-body dynamics of the single-band Hubbard model—a mathematically simplified model of correlated materials—the Theory group investigated the response of correlated materials to a strong electric field pulse and analysed the change in total energy of the electronic system as a function of the laser pulse shape.

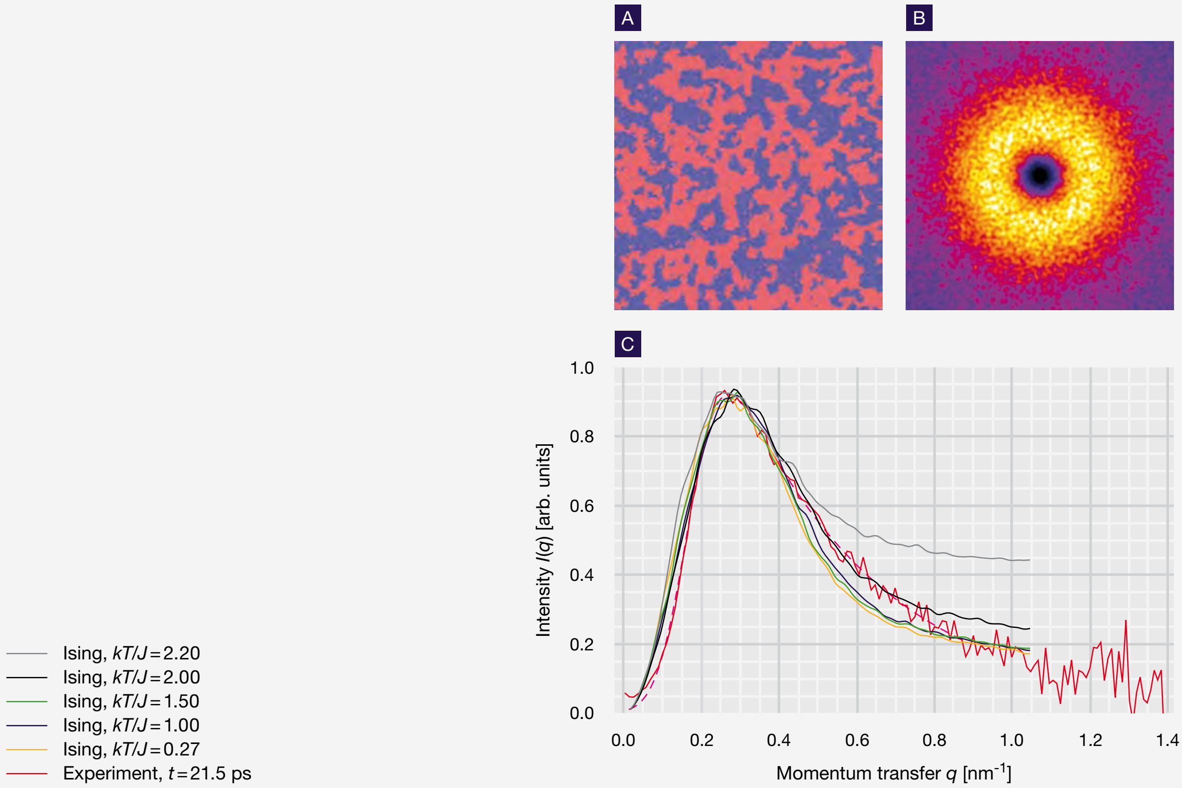


Figure 2 Simulating ultrafast laser-driven magnetization in FeRh.
A Two-dimensional Ising model of the sample. **B** Corresponding simulated magnetic resonant diffraction pattern.
C Radial intensity profiles simulated at different values of *kT/J* (*k* is the Boltzmann constant, *T* is the temperature, and *J* is the exchange constant) in the 2D Ising model and experimental data measured at *t* = 21.5 ps delay after the pump laser pulse.

Single-particle structure determination with an X-ray FEL

One of the important challenges facing the X-ray FEL diffraction community is to image an individual object, such as a small virus, eventually at atomic resolution. In 2015, the SPI initiative was formed with the aim of establishing single-particle imaging at X-ray FELs. While conventional SPI techniques rely on data sets consisting of single-particle hits, most of the measured data contains multiple-particle hits that cannot be utilized for such techniques. In collaboration with Zwart, the Theory group is developing an approach suitable for processing both types of data by combining novel iterative phasing techniques with X-ray cross-correlation analysis (XCCA). XCCA of LCLS data measured on the rice dwarf virus (RDV) shows good agreement between the experimental cross-correlation functions (CCFs) and the ones simulated for a solid icosahedral object, indicating that XCCA has substantial potential as a technique for single-particle structure recovery.

Ultrafast phase transitions in magnetic materials

Changes in the atomic, electronic, and spin structure that happen in materials on ultrashort time scales are indispensable elements of research at X-ray FELs. Together with the SCS group, the Theory group aims to understand the ultrafast processes occurring in FeRh films that undergo antiferromagnetic to ferromagnetic phase transitions. Motivated by ultrafast laser-driven magnetization studies in FeRh using magnetic resonant X-ray diffraction, the Theory group is performing simulations of nucleation and coarsening of magnetic domains based on several theoretical models. The group is also calculating magnetic resonant X-ray diffraction from the simulated samples to extract basic parameters that characterize the samples' magnetic state and to test the feasibility of different models (Figure 2).

Outlook for 2016

In 2016, the Theory group will further the projects outlined above. Within the collaboration with the SCS group, Gorelov will improve theoretical techniques for interpreting spectroscopic data and develop methods for describing the interaction of correlated systems under the influence of strong laser fields. He will also continue to develop and apply up-to-date methods for spectroscopic calculations. Kurta will work on the development and application of novel techniques for single-particle structure recovery in the framework of the SPI initiative and carry on developing classification algorithms for SPI data together with Bobkov, Teslyuk, and Vartanyants. He will also model ultrafast structural changes in magnetic systems in collaboration with the SCS group. ■

Group members
Evgeny Gorelov, Daniel Hirschmeier (student, University of Hamburg, not shown), Alexander Joura (guest, not shown), Nikolay Kabachnik (guest, not shown), Jindrich Kolorenc (guest, not shown), Igor Krivenko (University of Hamburg, not shown), Ruslan Kurta, Alexander Lichtenstein (group leader), Maria Valentyuk (student, University of Hamburg, not shown), and Viktor Valmispild (student, University of Hamburg, not shown)

References

[1] Sorting algorithms for single particle imaging experiments at x-ray free electron lasers
S.A. Bobkov, A.B. Teslyuk, R.P. Kurta, O.Yu. Gorobtsov, O.M. Yefanov, V.A. Ilyin, R.A. Senin, I.A. Vartanyants,
J. Synchrotron Rad. **22**, 1345–1352 (2015)
doi:10.1107/S1600577515017348

[2] Correlation-Driven Charge and Spin Fluctuations in $LaCoO_3$
M. Karolak, M. Izquierdo, S.L. Molodtsov, A.I. Lichtenstein
Phys. Rev. Lett. **115**, 046401 (2015)
doi:10.1103/PhysRevLett.115.046401

X-RAY OPTICS

The X-Ray Optics group is responsible for the X-ray beam transport in the tunnels and shaft buildings of the facility upstream of the experiment hall. This task includes the design and procurement of mirrors, monochromators, beam loss monitors, collimators, and shutters, which are needed to ensure the safe and efficient use of X-ray beams at the experiments. The X-Ray Optics group also supports the scientific instrument groups in the conceptual design and implementation of X-ray optics around the experiments.

Changes to the group in 2015

In 2015, the former X-Ray Optics and Beam Transport group was split into two groups: X-Ray Optics and Vacuum. While the X-Ray Optics group is mainly responsible for developing X-ray optical components, the Vacuum group concentrates on the facility-wide vacuum system, cleanroom techniques, and installation. Three students joined the X-Ray Optics group in 2015: Ann-Kristin Meyer, who is working on wavefront propagation calculations; Valerija Music, who is writing her bachelor thesis on X-ray metrology; and Mahadi Umar Jidda, who started his master thesis on hardware controls for mirror systems.

Progress in 2015

Together with the Vacuum group and the X-Ray Photon Diagnostics group, the X-Ray Optics group installed and nearly finished the photon transport systems for the SASE1 instruments in the tunnels XTD2 and XTD9 (see Chapter 3, “Civil Construction”). First tests with the control system were done in collaboration with the Advanced Electronics group and the Control and Analysis Software group. Some hardware components are still missing due to delayed delivery from manufacturers or to environmental conditions unsuitable to installation in the tunnels in 2015. The detailed design of the photon transport system for the SASE3 beamline was finished and installation in the XTD10 tunnel started.

Significant progress was made on the hard X-ray monochromators. All six vacuum vessels were received, and the assembly of the first monochromator pair for the FXE instrument started. A particular problem was the ultrahigh-vacuum compatibility of the pulse tube cryocoolers, which required a special cleaning protocol. The soft X-ray monochromator for the SASE3 beamline is currently being tested at the vendor’s site (FMB Feinwerk- und Meßtechnik in Germany) and will be ready for installation in early 2016. The photon beam loss monitors will allow the beam to be switched off instantaneously whenever a mis-steering occurs. The electronics were developed and produced in collaboration with the DESY Standard e-Beam Diagnostics group.

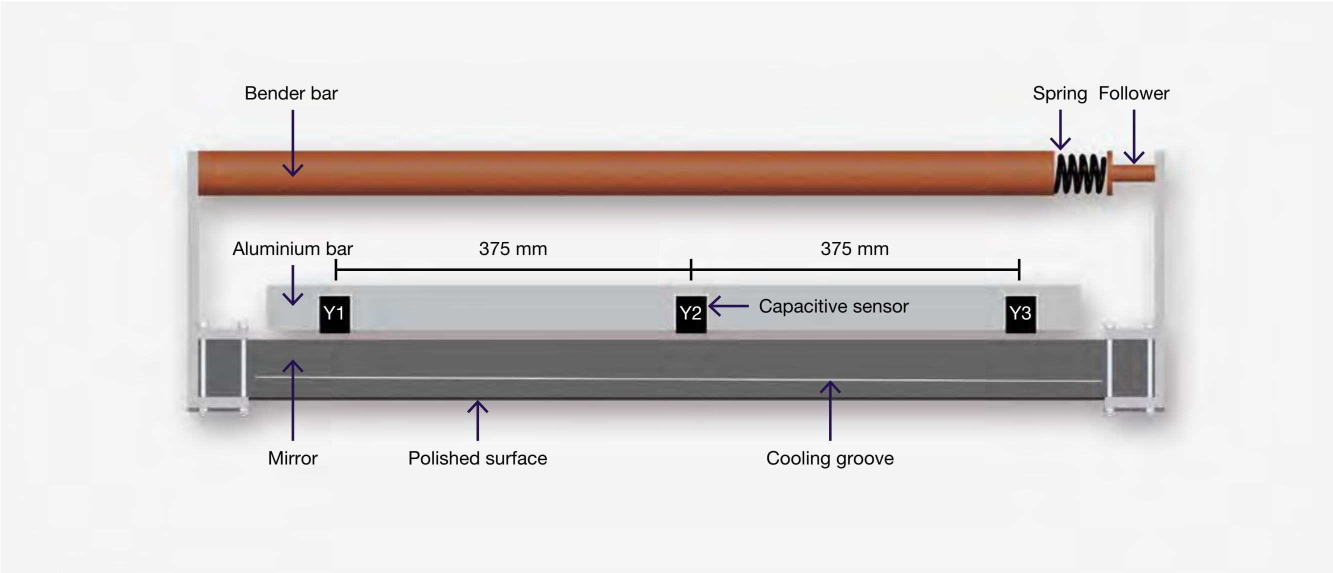


Figure 1 Bender mechanism for mirrors at the European XFEL

The most challenging elements of the X-ray beam transport are the X-ray mirrors. Over a length of up to 1 m, the deviation from the idealized shape should typically not exceed 1 nm in order to maintain the high quality of the X-ray laser beam.

The vacuum hardware is currently in production and will be ready for tunnel installation in the second quarter of 2016. The serial production of the large mirror chambers for the offset and distribution mirrors is under way. The vendor (CINEL Strumenti Scientifici in Italy) and the X-Ray Optics group made significant efforts to fulfil the stringent specification needed to keep the X-ray mirrors free from contamination during operation.

All the ray tracings, the dimensions of static collimators, and—in collaboration with the Safety and Radiation Protection group—the radiation shielding requirements for the experiment hall were updated and finalized.

X-ray mirrors

The most challenging elements of the X-ray beam transport at the European XFEL are the X-ray mirrors. Over a length of up to 1 m, the deviation from the idealized shape should typically not exceed 1 nm in order to maintain the high quality of the X-ray laser beam. For the X-ray beam transport in the tunnel and in two instruments, 10 flat and 8 profiled high-quality mirrors are in production at the companies

JTEC Corporation in Japan and Carl Zeiss SMT in Germany. In-house metrology is being prepared and cross-calibrations with metrology laboratories at HZB and JTEC are being performed.

Besides perfect polishing, these mirrors require a perfect mounting scheme. This is particularly challenging, as some of the flat mirrors have to be bent during operation to different radii in the range of 12–50 km. In collaboration with FMB Oxford in the UK, a suitable bender mechanism was designed, based on a friction-free motion principle (Figure 1).

Using a Fizeau interferometer, group members Maurizio Vannoni and Idoia Freijo Martín were able to demonstrate reproducible control of the mirror shape. However, a weak dependence on temperature was detected: a change of 0.1°C led to a deflection of about 100 nm in the centre of the mirror. Because this is too much for reliable operation, Valerija Music developed a system based on three capacitive sensors (Y1, Y2, and Y3 in Figure 1). Using this system, the bending of the mirror can be detected over the entire required range and drifts can be corrected (Figure 2).

The group was able to demonstrate reproducible control of the X-ray mirror shape. Using a system of three capacitive sensors, the bending of the mirror can be detected over the entire required range and drifts can be corrected.

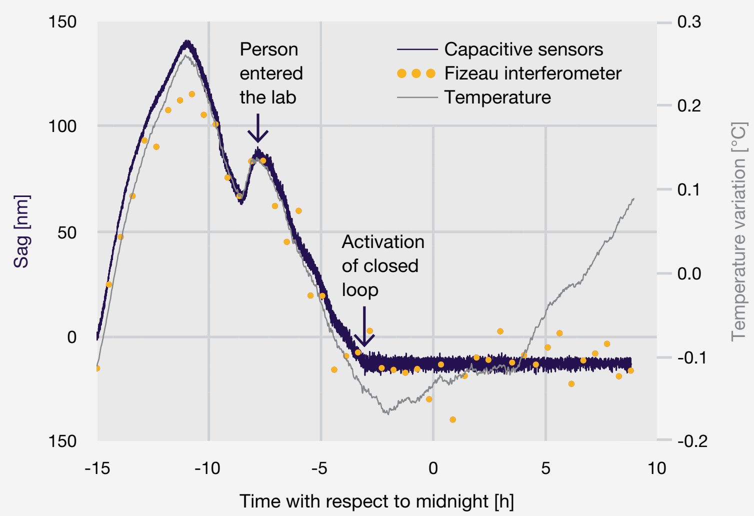


Figure 2 Deflection of the mirror centre as a function of time. A feedback loop based on the signal from three capacitive sensors is activated in the middle of the measurement period and keeps the mirror radius stable.

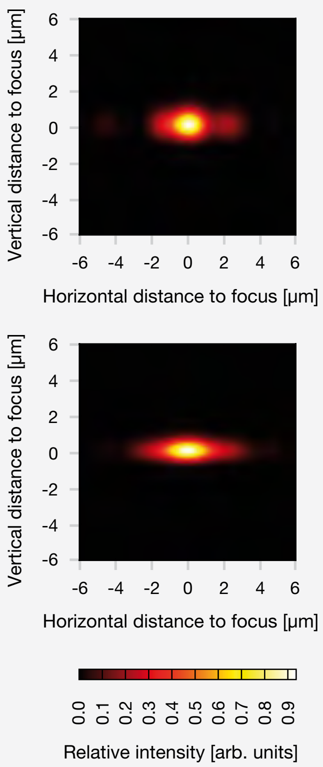


Figure 3 Calculated intensity distribution at the focus position of the SCS instrument.
Top The clean-up slits in the vertical and horizontal focus are fully open.
Bottom Both clean-up slits are closed to a gap of 50 µm.

Such capacitive sensor arrangements will now be used on all bendable mirrors currently planned at the European XFEL.

Wavefront propagation

To diagnose potential problems in the beam transport, it is important to analyse and understand the complicated patterns arising from interferences of the X-ray laser beam at the optical elements. Group member Liubov Samoylova and co-workers developed the software WavePropaGator (WPG) [2], which allows coherent beam patterns to be simulated throughout an entire X-ray FEL beamline.

Examples of such wave patterns were calculated by Ann-Kristin Meyer. The top panel of Figure 3 shows the calculated beam intensity around the focus position of the SCS instrument with clean-up slits in the intermediate foci fully open. Asymmetric wings of the focus are visible in the horizontal plane, while the focus size is slightly enlarged in the vertical plane. These distortions arise in the calculation from assumed inflated profile errors of some of the mirrors. When closing the clean-up slits (bottom panel), the focus becomes more homogeneous and smaller in the vertical plane. As demonstrated in this example, clean-up slits can be used to reduce the effect of profile distortions from upstream mirrors without losing much intensity. However, damage effects on these slits have to be carefully monitored and will limit this method to moderate intensities.

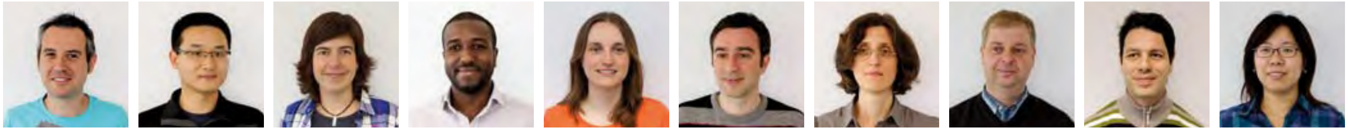
Outlook for 2016

The detailed installation drawings for the SASE2 beamline will be finalized, and the remaining required short lead time items will be ordered. Installation of X-ray beam transport components will continue in XTD10 for the SASE3 beamline and later in XTD1 and XTD6 for the SASE2 beamlines. By the third quarter of 2016, the beamlines in SASE1 and SASE3 have to be ready for the first X-ray beam of the facility, which is expected at the end of 2016. ■

References

[1] Optimisation and characterisation of a mechanical bender for X-ray mirrors
V. Music, Bachelor Thesis, University of Hamburg (2015)

[2] WavePropaGator (WPG)
L. Samoylova, A. Buzmakov, O. Chubar
https://github.com/samoylv/WPG



Group members
Massimiliano Di Felice, Xiaohao Dong, Idoia Freijo Martín, Natalia Gerasimova (not shown), Mahadi Umar Jidda (student, since October 2015), Nicole Kohlstrunk, Daniele La Civita, Ann-Kristin Meyer (student, from April to November 2015, not shown), Valerija Music (student, from August to December 2015, not shown), Liubov Samoylova, Harald Sinn (group leader), Antje Trapp (not shown), Maurizio Vannoni, and Fan Yang

VACUUM

The Vacuum group is in charge of designing, installing, and operating the photon vacuum system at the European XFEL. To ensure reliable operation, the group sets standards and guidelines for the design and handling of vacuum components.

Progress in 2015

The Vacuum group was established on 1 August 2015 as a spin-off from the former X-Ray Optics and Beam Transport group (now called the X-Ray Optics group). It is responsible for the photon beam transport vacuum systems located in the XTD tunnels between the Osdorfer Born and Schenefeld sites (see Chapter 3, “Civil construction”) and supports the scientific instrument groups and the users of the facility with vacuum-related tasks. The main activity of the group in 2015 was the installation, in the tunnels XTD2 and XTD9, of the photon transport system for the X-ray beam generated in the SASE1 undulator. Many components were received, tested, and installed in 2015. After the electronic racks in XTD2 were operational, the Vacuum group started to set up the SASE1 control system.

Figure 1 Differential pumping unit upstream of the gas-based diagnostic system, mounted on a custom-made support adapted to the beam height of 2.7 m above the floor at this location in the XTD2 tunnel

Installation of SASE1 beam transport in XTD2 and XTD9

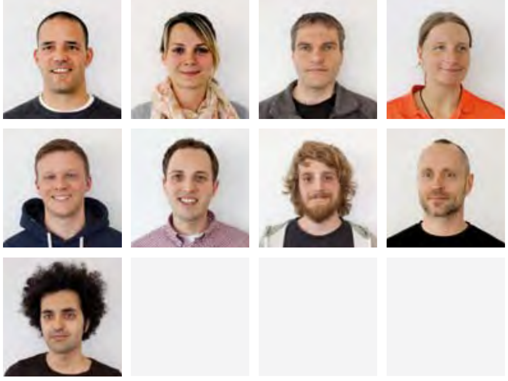
In 2015, the Vacuum group began installing ultrahigh-vacuum (UHV) components for the photon beam transport inside XTD9. More than 800 m of DN100 vacuum beam pipe were delivered from the company Trinos Vakuum-Systeme in Germany as pre-fabricated segments of 6 m length. They were joined together into 18 m long pipes inside XTD9 under cleanroom conditions by orbital welding, carried out by Trinos staff. The pipes were brought to their final position, placed in aligned pipe holders, equipped with ion pumps, valves, and so on, and connected.

The specially designed electronic racks for SASE1 were delivered in 2015, brought to their intended position in XTD2 and XTD9, and connected to the IT network, electrical power, and cooling water by the responsible groups. Afterwards, the Vacuum group began equipping the racks with programmable logic controllers and related components and connecting the installed X-ray optics and vacuum components to the different control loops. Commissioning of the system and implementation within Karabo, the European XFEL control and analysis software framework, is ongoing.

Figure 2 Installation work in the XTD9 tunnel. To avoid particle contamination of the sensitive X-ray mirrors, the beam pipes and vacuum chambers are being connected using mobile cleanrooms.

Differential pumping units

To connect the gas-based diagnostic beam intensity and position monitors to the windowless UHV beam transport system, members of the Vacuum group have developed a differential pumping unit. A prototype was assembled in the HERA South vacuum lab. It consists of a modular set of long narrow pipes—which act as flow-limiting elements although they have a relatively large optical clear aperture of 25 mm—and two intermediate chambers equipped with turbomolecular pumps. After thorough and successful testing with different gases like nitrogen, neon, argon, xenon, and krypton in the lab, the series production of pre-assembled supports and vacuum chamber modules started. Subsequently, two of these units were installed and commissioned in XTD2 and in the beam transport branch leading to the Single Particles, Clusters, and Biomolecules and Serial Femtosecond Crystallography (SPB/SFX) instrument in XTD9.



Group members
Alexander Bartmann, Bianca Dickert, Martin Dommach (group leader), Janni Eidam, Paul Frankenberger, Timo Korsch, Henrik Liebel (student assistant), Maik Neumann, and Raúl Villanueva Guerrero

Outlook for 2016

In 2016, the Vacuum group will focus on finalizing the SASE1 and SASE3 beam transport systems in the tunnels and on commissioning the corresponding control systems in close collaboration with the X-Ray Optics group, the Advanced Electronics group, and the Control and Analysis Software group. At the same time, the first components for the scientific instruments and the SASE2 beam transport system will be assembled, tested, and installed. The R&D effort on gas-based diagnostic devices will concentrate on the SASE3 gas attenuator, the installation of which is foreseen for spring. In mid-2016, after moving into the new European XFEL headquarters building on the Schenefeld campus, the group will look forward to the challenging task of equipping the vacuum lab and the cleanroom. ■

X-RAY PHOTON DIAGNOSTICS

The X-Ray Photon Diagnostics group is responsible for designing, constructing, and operating the diagnostic devices that will monitor the X-ray photon pulses generated by the European XFEL. In 2015, installation of sensitive equipment in the tunnels started, and assembly and testing of many devices were completed.

Overall progress

In 2015, XTD2 was the first photon tunnel section (see Chapter 3, “Civil Construction”) to become available for the installation of sensitive equipment, so the X-Ray Photon Diagnostics group was able to install most of the photon diagnostics [1] required in this tunnel. All six X-ray gas monitors (XGMs) were assembled, some of them were calibrated and delivered to the facility, and one of them was installed. The designs of new devices, such as the spontaneous-radiation (SR) imager and the high-resolution hard X-ray (HIREX) diagnostic spectrometer, were completed and production started. The photoelectron spectrometer (PES) was used in the first half of 2015 in several experiments at LCLS with technical and scientific objectives. The group also made good progress in the realization of vital infrastructure, such as the rare-gas supply, differential pumping, and control electronics.

Figure 1 First tunnel installation of an XGM (November 2015)

Gas-based intensity and position monitors

The XGMs for the European XFEL are provided by DESY. In January 2015, an XGM was tested with X-ray FEL radiation at LCLS. After calibration with synchrotron radiation at PTB in Berlin, Germany, the first XGM was delivered to European XFEL in May, with two more units following later in the year. By December 2015, all remaining units were produced, assembled at DESY, and calibrated at PTB. In November 2015, the first XGM was installed in the tunnel XTD2 (Figure 1).

Online photoelectron spectrometer

After the first PES made for the European XFEL was assembled in Hamburg in late 2014, it was used in spring 2015 in several measurement campaigns at LCLS. Through direct FEL polarization measurements, the PES enabled the LCLS beam polarization to be tuned to an arbitrary state in a controlled manner using a Delta-type undulator. A proof-of-principle experiment demonstrated the feasibility of arrival time monitoring using the “streaking” technique, for which circularly polarized optical laser pulses are superposed onto the FEL pulses. Finally, in a scientific experiment, a novel approach to data mining with multiple sources of diagnostic input was used. In all these projects, the PES was an essential piece of instrumentation, providing enormous benefit thanks to its single-shot and multichannel information.

Operating gas-based devices requires a rare-gas supply for the tunnels, which was designed and tendered in 2015. There will be four gas cabinets, located at the experiment hall and at the access shafts XS2 and XS3. From each of them, four parallel gas pipes will lead to remote-controlled gas selection panels at the devices in the tunnels. The use of different gases will enable diagnostics over a broad range of photon energies.

Another essential prerequisite for gas-based devices is differential pumping. A test stand was set up to validate the efficiency with only three pumps while injecting two different gases from opposite ends. Single-sided injection tests were successful, and tests with two gases have started.

Figure 2 View into the *K* monochromator for the SASE3 beamline

HIREX

The HIREX single-shot spectrometer is a diagnostic tool based on a transmissive diamond diffraction grating that splits off a small fraction of the photon beam. This beam fraction is then sent onto a bent crystal, which spectrally disperses the beam onto a fast detector [2]. The HIREX spectrometer consists of three main parts: grating, crystal, and detector unit. The final design by AXILON in Germany was finished, and fabrication began.

Undulator commissioning spectrometer system

The undulator commissioning spectrometer (*K* monochromator) for the SASE1 beamline is now installed in the XTD2 tunnel, waiting for vacuum connection to the corresponding SR imager. Assembly of the SASE3 *K* monochromator unit is nearly finished (Figure 2), and pre-assembly of the SASE2 unit has started.

The SR imager is located directly downstream of the *K* monochromator and serves as its detection system. All SR imager units are currently in final testing.

For energy calibration purposes, it is necessary to filter or attenuate the incoming beam. The filter insertion device is designed to be used for SR pulses or low-intensity FEL pulses together with the *K* monochromator and the SR imager. The first filter chamber is ready for installation, and pre-assembly of the other two units has started.

Figure 3 Pop-in monitor Type II-45 in XTD2

Diagnostic imagers

The first diagnostic imagers were installed in XTD2 (Figure 3). Further units will be installed in XTD9 as soon as air quality conditions in the tunnel allow.

Out of 26 diagnostic imagers for the photon tunnels, 7 devices passed the ready for installation milestone; others are being designed, fabricated, assembled, and tested: transmissive imagers, 2D-imagers-FEL, 2D-imagers-SR, exit slit imagers, and pop-in monitors. Activities on data acquisition, control, and image processing became more important in 2015. Some smaller studies investigated special scintillating screens to optimize the imagers.

Temporal diagnostics

Focusing on THz streaking–based pulse length monitoring (TPLM) and photon arrival time monitoring (PAM), the group participated in angular-streaking experiments using the European XFEL PES at the AMO instrument at LCLS and in X-ray chirped-pulse amplification at FLASH. Optical laser–based THz generation was achieved, diagnosed, and optimized (Figure 4).

A new design enables TPLM and PAM to be united in a joint prototype chamber. A technical note on diagnostics of temporal photon beam properties at the Small Quantum Systems (SQS) instrument is under final review. Considering the unique temporal structure of the European XFEL facility, the X-Ray Photon Diagnostics group proposed experiments on hard X-ray–induced carrier dynamics of electron cascading, relaxation, and target damage.

MCP-based detectors

JINR contributes the microchannel plate (MCP)–based detectors, which will be most important during initial lasing attempts. All three MCP units required for SASE1, SASE2, and SASE3 were produced and tested. The SASE1 unit was installed in XTD2.

Outlook for 2016

In 2016, many remaining diagnostic devices will be assembled, installed, and technically commissioned in the tunnels. Installation of the rare-gas supply for the tunnels will start in January 2016. The SR imager units are scheduled to be set up starting in early 2016. Experiments are planned at X-ray sources in 2016 to investigate the radiation hardness of new scintillator materials for scintillating screens.

References

[1] **Photon Diagnostics and Photon Beamlines Installations at the European XFEL**
J. Grünert, A. Koch, N. Kujala, W. Freund, M. Planas, F. Dietrich, J. Buck, J. Liu, H. Sinn, M. Dommach, S. Molodtsov
Proceedings of FEL2015, Daejeon, Korea, WED03 (2015)
ISBN 978-3-95450-134-2

[2] **High-resolution single-shot spectral monitoring of hard x-ray free-electron laser radiation**
M. Makita, P. Karvinen, D. Zhu, P.N. Juranic, J. Grünert, S. Cartier, J.H. Jungmann-Smith, H.T. Lemke, A. Mozzanica, S. Nelson, L. Patthey, M. Sikorski, S. Song, Y. Feng, C. David
Optica **2**, 10, 912–916 (2015)
doi:10.1364/OPTICA.2.000912

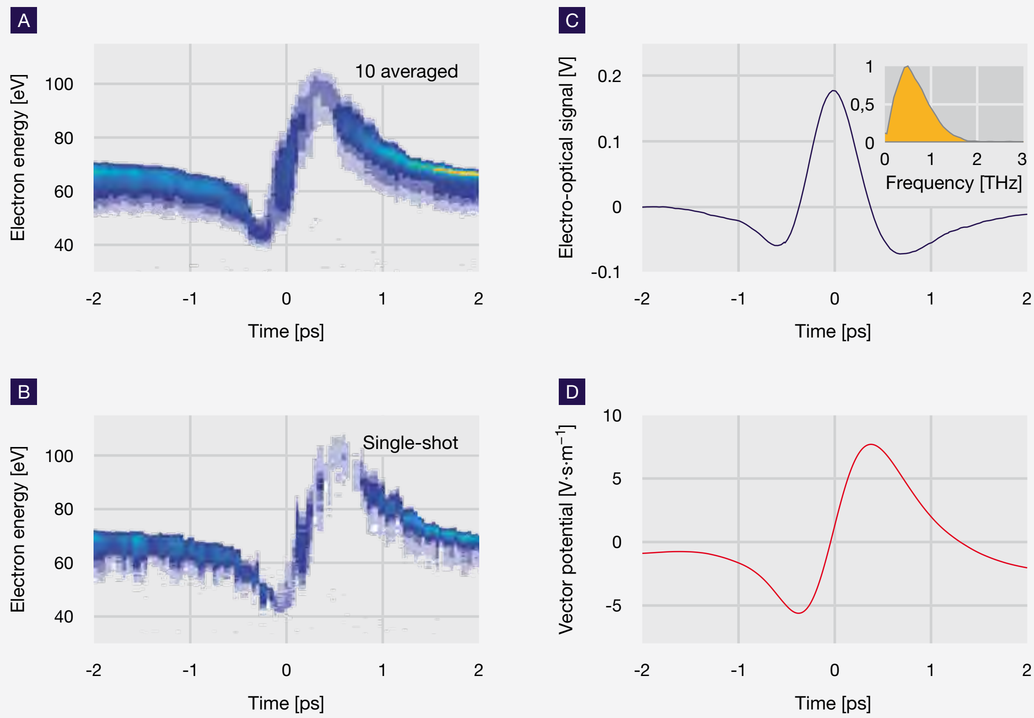


Figure 4 Experimental THz streaking signal (A) averaged over 10 shots and (B) single-shot. Typical single-cycle THz (C) temporal waveform, (D) vector potential, and (C, insert) frequency spectrum from the THz generation prototype, with a period of approximately 4 ps, centred at 0.5 THz and with a vector potential rise time of 700 fs.

The HIREX spectrometer will be installed in the SASE1 branch in mid-2016. Towards the end of the year, commissioning with the European XFEL beam will start, enabled by the various photon diagnostic devices, on the way to the first lasing of the facility. ■

Group members
Bernard Baranašić, Jens Buck, Florian Dietrich, Dominik Fijalkowski (student, since August 2015), Wolfgang Freund, Jan Grünert (group leader), Andreas Koch, Naresh Kujala, Jia Liu, Sascha Lübbe (student, April to September 2015, not shown), and Marc Planas

PHOTON SYSTEMS PROJECT OFFICE

The Photon Systems Project Office (PSPO) group is coordinating the installation of beamline components in the photon tunnels as well as the installation 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.

Expansion of the PSPO group

The PSPO group acts as the primary interface between the scientific and technical work packages within European XFEL. In 2015, with the project entering the the busiest time of the installation phase, the group's tasks increased in magnitude and complexity. To support this effort, an engineer for experiment hall infrastructure joined PSPO in May. In November, a project-planning assistant, who will join the group at the beginning of 2016, was hired. She will interface with the software and electronics groups. Finally, the group hosted one intern with a civil engineering background. For most of 2015, the group had eight members; this will increase to nine in 2016.

Planning and installation in the photon tunnels

In 2015, component installations, such as those in Figure 1, made great progress in the northern part of the photon beam distribution tunnels (XTD2, XTD4, XTD9, and XTD10; see Chapter 3, "Civil Construction"). These installations, which normally would have been completed on schedule, were impeded by the lack of infrastructure services, such as air conditioning, cooling water, and power. At the end of 2015, these services were working, albeit in a provisional mode without regulation, which nonetheless allowed installation activities to proceed and further delays to be avoided.

Component installations made great progress in the northern part of the photon tunnels. By the end of 2015, all contracts had been awarded for the hutches and infrastructure of SASE1. The hutches of SASE1 are almost complete and infrastructure installation is in full swing.

Infrastructure installations in the southern tunnels were further delayed. Component installations started in the last quarter of 2015 in the XTD1 tunnel. Further downstream, in tunnels XTD3, XTD5, and XTD6, installation of components was not yet possible. As a result,

Figure 1 View of the XTD2 tunnel with photon and electron beamlines installed

Figure 2 View of the experiment hall with completed SASE1 hutches

the SASE2 beamline schedule had to be adjusted, and operation is now expected in December 2017 at the earliest. Despite these problems, the first devices in the SASE1 photon beamline were integrated into and operated by the full control and readout chain in Karabo, the European XFEL control and analysis software framework.

Planning of hutches and infrastructure in the experiment hall

Accommodating the complex space, access, stability, practicability, and cost requirements of the scientific instruments in the experiment hall in Schenefeld constitutes a major challenge. Difficulties also arise from the need for large independent optical laser and electronics installations in each instrument area.

In 2015, planning for hutches and infrastructure in the experiment hall took up a large part of the resources of the PSPO group, as many activities had to be carried out simultaneously. Construction started in the SASE1 instrument area, planning and tendering was in full swing for the SASE3 area, and planning for the SASE2 area continued for civil construction and infrastructure. Due to limited resources to handle all these demands, clear priorities were established in the order SASE1, SASE3, and SASE2. The primary goal was to maintain the key milestone of delivering the hutches and infrastructure ready for instrument installation in SASE1 at the end of April 2016. Despite setbacks in procurement processes and difficulties with contracting construction companies, this milestone still appears to be achievable by optimizing installation schedules. SASE3 and SASE2 operation are now expected for September 2017 and December 2017, respectively.

By the end of 2015, all contracts had been awarded for the hutches and infrastructure of SASE1. The hutches of SASE1 are almost complete (Figure 2), and infrastructure installation is in full swing. For SASE3, all construction contracts have been awarded and most of the tenders for the infrastructure are running. Results are expected in early 2016. Brick and concrete construction for the SASE3 laser hutches has been completed. The radiation protection hutches will be installed next, in January 2016. For SASE2, contracts for hutch construction are about to be awarded and infrastructure planning is nearly complete, with tendering expected in February 2016.

CAD integration

One of the tasks of the PSPO group is CAD integration, which helps assure the compatibility of all interfaces and forms the basis for identifying spatial conflicts of components within the facility. Following the overall philosophy of the project, CAD integration relies on all project partners providing workable computer models of their respective components. Due to the size and complexity of the facility, strict standards for these models have been defined and must be strictly followed if the resulting integrated models are to remain manageable. The guidelines developed earlier by the PSPO group for the integration models to be used during the engineering design phase for the photon tunnels and for the experiment hall have proven practicable and successful. Hence, a complete CAD model of the experiment hall now exists. This model incorporates contributions from many internal and external planning groups. It constitutes the basis for all installation activities, in particular where high installation density is required and where the hutches and infrastructure need to be precisely aligned with respect to the beams.

In 2016, the peak of installation activities in the photon tunnels and in the experiment hall will be reached. All three photon beamlines in the tunnels should be completed and the tunnels closed for operation with beam.

Instrument installation planning

Instrument installation planning is especially challenging. First, the scientific instruments at the European XFEL are complex and tightly integrated. Second, European XFEL has few technical resources of its own and therefore relies on contractors for most hands-on installations, such as vacuum, electronics, and cabling. PSPO provides extensive support to the instrument groups with vacuum and electronics installations and has set up installation schedules for all six instruments as well as the lasers. These schedules properly account for all required resources. PSPO also maintains an infrastructure master schedule that accounts for civil construction and infrastructure installations. The instrument installation schedules, the infrastructure master schedule, and the schedules of supporting groups, such as electronics, IT, detectors, and sample environment, form the integrated master plan. Using this master plan, resource allocation, schedule optimization, and critical path analysis are performed to keep the project on track.

Risk management

The European XFEL Management Board introduced in 2013 a risk management system to identify and monitor risks that might threaten the company’s existence and the timely and economical completion of the European XFEL facility. To implement the risk management system, the management board set up a risk committee and appointed the PSPO group leader as risk coordinator. Hence, risk management is one of the tasks of PSPO.

Currently, the PSPO group is tracking several hundred risks in its catalogue. Two risk reports with the most salient entries were prepared in 2015 and submitted to the European XFEL Management Board, Administrative and Finance Committee (AFC), and Council. To reduce the administrative effort associated with risk management and maintenance and to involve more project members directly in the risk collection process, PSPO is currently investigating different software systems to support this activity.

Outlook for 2016

In 2016, the peak of installation activities in the photon tunnels and in the experiment hall will be reached. All three photon beamlines in the tunnels should be completed and the tunnels closed for operation with beam. In the experiment hall, construction of hutches and their infrastructure will be completed for the SASE1 and SASE3 areas. For SASE2, these activities will extend into 2017. At the same time, the instruments will be installed in the SASE1 and SASE3 areas. The rapid succession of complex interdependent activities, in particular for the installation of the scientific instruments, requires careful monitoring and controlling of the installation schedules so any deviations and problems can be caught early and remedial measures taken. ■

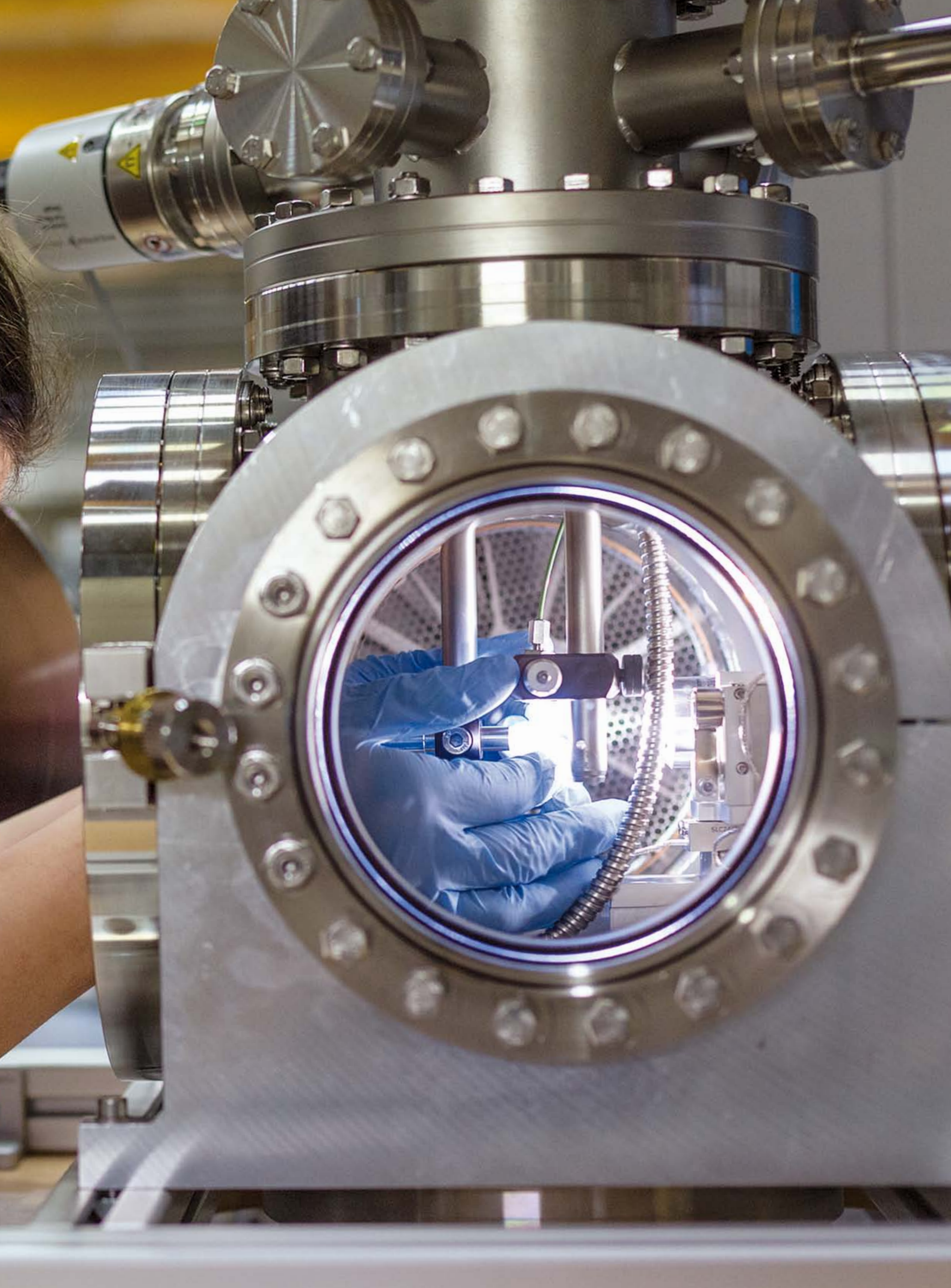
Group members
Uschi Conta, Sabine Cunis, Tobias Haas (group leader), Alexandru Ivanov (intern, not shown), Konrad Piórecki, Niko Saaristo, Adriano Violante, and Gerd Wellenreuther

06

SCIENTIFIC INSTRUMENTS AND EQUIPMENT

In 2015, construction began on the instrument hutches in the experiment hall. The first instrument component was set up, and sample and optical laser systems made major progress towards user operation in 2017.

Sample scientist adjusts a liquid jet setup



SCIENTIFIC INSTRUMENT FXE

The Femtosecond X-Ray Experiments (FXE) instrument will enable ultrafast pump–probe experiments on extremely short time scales—100 fs and below—for a broad scientific community. While the first components have already been delivered, the FXE group is furthering the design of the remaining 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.

Strengthening the FXE group

Martin Knoll, previously an engineer in the Undulator Systems group, joined FXE in early 2015, significantly strengthening the group's ability to perform installation work. He is also involved in FXE project planning. Dmitry Khakhulin, formerly an FXE group member from CUI, joined the group as an instrument scientist, and Peter Zalden, formerly at SLAC, joined the group through CUI. Khakhulin initiated test runs of the Large Pixel Detector (LPD) to determine its current specifications, delivering important feedback for the fabrication of the final version. Zalden commenced THz studies of liquid water. Two students, Michael Diez and Christina Bömer, started their doctoral projects at FXE. Sebastian Schulz was hired within the framework of the European Cluster of Advanced Laser Light Sources (EUCALL) project funded by the European Union.

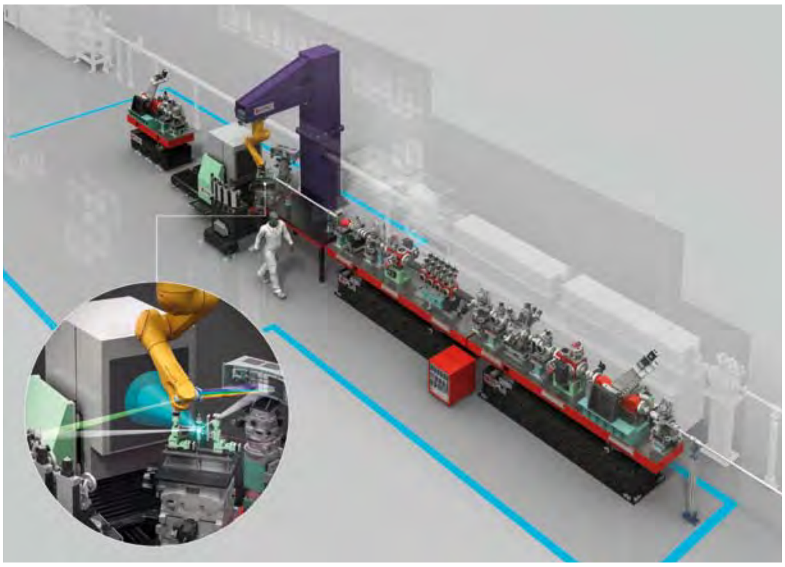


Figure 1 FXE instrument in its present design stage

Figure 2 FXE robot tower installed inside the experiment hutch

Construction and installation in the experiment hall

The first FXE installations took place concurrently with the construction of the hutch that will house the instrument. The FXE group grouted four alignment metal plates to the ground floor of the experiment hall, supervised by Idoia Freijo Martín of the X-Ray Optics group and supported by Lewis Batchelor of the Central Instruments Engineering team. The tower that will hold the FXE robot with the X-ray emission detectors (Figure 2) was then installed on one of the plates, supervised by Süleyman Arslan of the Technical Services group and Martin Knoll of FXE. Definition of cabling is nearly complete. In September, Knoll verified the fabrication progress of FXE components at the premises of IKC subcontractor JJ X-Ray at the Technical University of Denmark in Lyngby.

External funding

The FXE group is collaborating with research groups at the University of Duisburg-Essen and TU Dortmund University, both in Germany, on proposals they submitted to the German Federal Ministry of Education and Research (BMBF), aiming to deliver new capabilities to the FXE instrument not foreseen in its baseline equipment. The renewal of the project “SFB925: Light induced dynamics and control of strongly correlated quantum systems” at the University of Hamburg in Germany, funded by Deutsche Forschungsgemeinschaft (DFG), provides important funding for experiments of the FXE group at leading X-ray facilities.

Research activities

In several beamtimes at PETRA III between July and September 2015, the FXE group implemented a novel gated integrator device for the European XFEL multi-MHz data acquisition (DAQ) scheme, capable of recording X-ray pulse intensities at repetition rates up to 7.8 MHz (corresponding to the 60 bunch mode of PETRA III). The device was conceived, designed, and built by members of the Advanced Electronics (AE) group. With the dedicated help of the AE group, the FXE group managed to acquire time-resolved data with unprecedented sensitivity, making multi-MHz pump–probe experiments with extreme signal-to-noise ratios feasible for the first time. Figure 3 shows a schematic layout of the entire setup. Figure 4 shows some preliminary results, which demonstrate the achieved sensitivity.

As in previous years, the FXE group remained scientifically very active throughout 2015, carrying out experiments at several synchrotron and X-ray FEL sources. In particular, Tadesse Assefa and Alexander Britz led two campaigns together at the 7ID-D beamline at APS. In May and

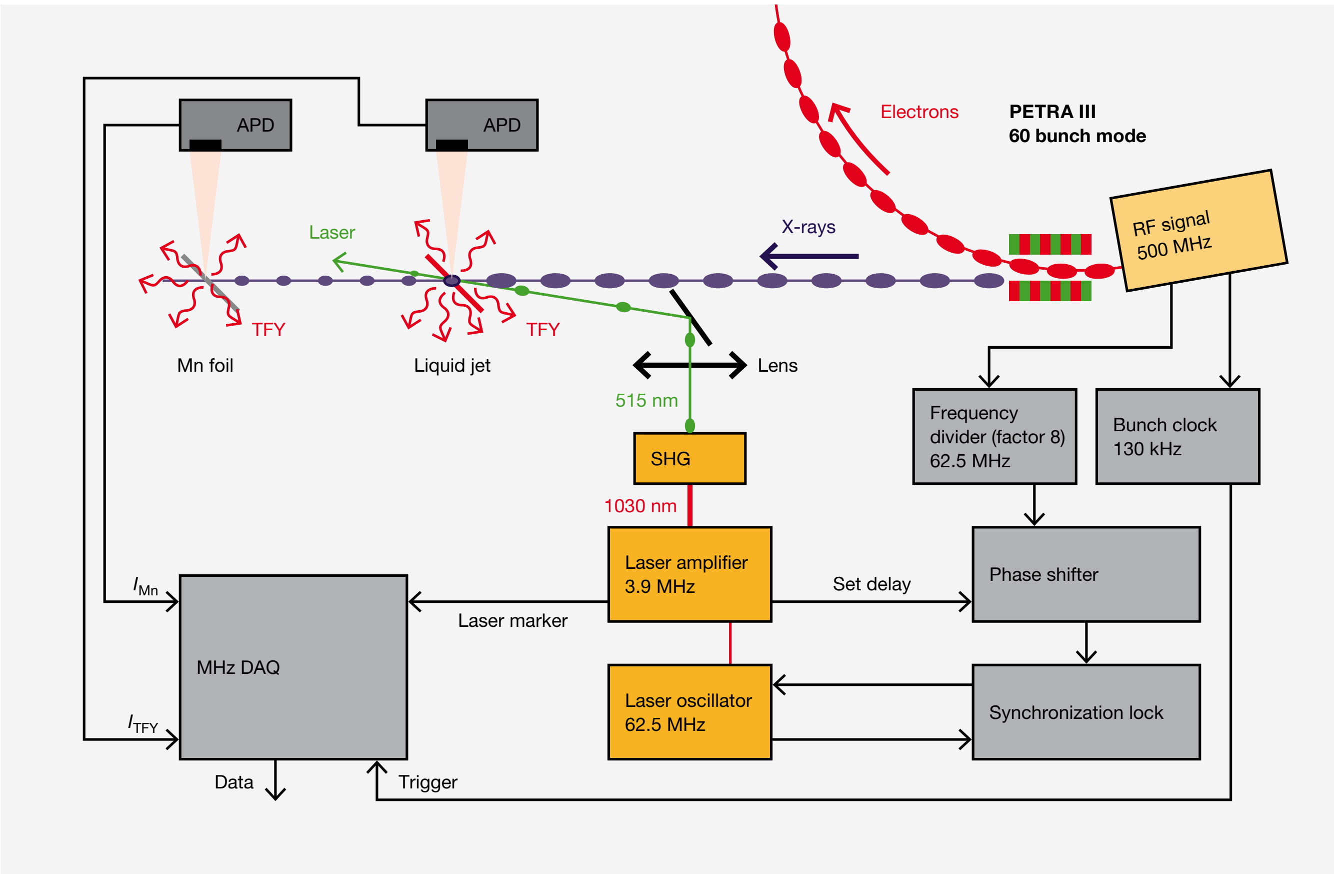


Figure 3 MHz DAQ setup at PETRA III
ADC analogue-to-digital converter; **APD** avalanche photodiode; ***I*** intensity; **Mn** manganese; **RF** radio frequency;
SHG second-harmonic generation; **TFY** total fluorescence yield

November, Wojciech Gawelda coordinated and carried out experiments at SACLA exploiting the group's established scheme of using a combination of X-ray spectroscopic and X-ray scattering tools. In addition, the group collaborated in an LCLS experiment in August.

Teaching and educational activities

During the summer semester 2015, Andreas Galler and Christian Bressler taught the course "Light–Matter Interactions: Atoms, Molecules, and (Non)Linear Optics" at the University of Hamburg, with the support of guest lecturer Michael Meyer of the Small Quantum Systems (SQS) instrument group. Gawelda held invited lectures at the 4th EIROforum School on Instrumentation (ESI2015) in Garching, Germany, and at the Warsaw School on Science with FELs in Poland. He was appointed assistant professor at Jan Kochanowski University in Kielce, Poland.

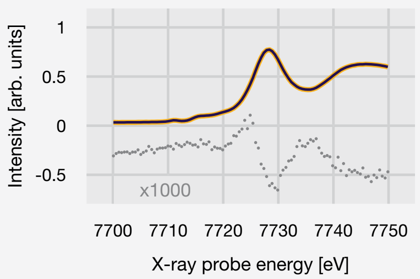


Figure 4 First results obtained using the MHz DAQ setup in Figure 3 for photo-excited aqueous $[Co^{III}(CN)_6]^{3-}$, showing the extremely good signal quality obtainable now at PETRA III. The visible transient signal (grey) is generated from the small differencebetween the static (blue) and the laser-excited spectrum (orange, lying almost exactly underneath the blue curve).

Workshops and conferences

The FXE workshop with 40 participants at the 2015 European XFEL Users' Meeting, co-organized by Federico Boscherini from the University of Bologna in Italy, presented design studies towards implementing a solid-state vacuum chamber. During the 16th International Conference on X-ray Absorption Fine Structure (XAFS16), held in August 2015 at KIT, the FXE group organized a symposium entitled "Current and Future Opportunities for X-ray Spectroscopies at XFELs", which was attended by about 150 participants.

Outlook for 2016

In 2016, the FXE group will finish the design details of the few remaining instrument parts and commence hardware installation in the experiment hall in early summer. Nearly all components will have been delivered by then, and the remaining few parts will arrive a few months later. By the end of the year, the group will have completed installation and technical commissioning to get ready for the first experiments. The group's teaching activities will resume at the University of Hamburg during the summer semester, with the support of SQS scientists Michael Meyer and Tommaso Mazza. Within the EUCALL project, the FXE group will study the capabilities of both circular and flat-sheet liquid jets at high speed for pump–probe studies at the European XFEL. Experimental campaigns at APS, ESRF, LCLS, and SACLA will be carried out, besides pursuing the long-term FXE proposal at PETRA III on MHz pump–probe experiments with extreme signal quality, where the soon-to-be-upgraded FXE MHz laser system will play a major role together with the MHz DAQ scheme. R&D of femtosecond timing tools will be pursued within the framework of EUCALL, starting with a novel high-speed liquid flat sheet jet, which can refresh the sample at the European XFEL's high repetition rate of 4.5 MHz.

Group members
Tadesse Assefa (student), Christina Bömer (student, supported by SFB925), Christian Bressler (group leader), Alexander Britz (student), Michael Diez (student, CUI, not shown), Andreas Galler, Wojciech Gawelda, Dmitry Khakhulin (not shown), Martin Knoll, Sebastian Schulz (supported by EUCALL), and Peter Zalden (guest, from CUI)

References

[1] Detailed Characterization of a Nanosecond-lived Excited State: X-ray and Theoretical Investigation of the Quintet State in Photoexcited $[Fe(terpy)_2]^{2+}$
G. Vankó, A. Bordage, M. Pápai, K. Haldrup, P. Glatzel, A.M. March, G. Doumy, A. Britz, A. Galler, T.A. Assefa, D. Cabaret, A. Juhin, T.B. van Driel, K.S. Kjaer, A.O. Dohn, K.B. Moller, H.T. Lemke, E. Gallo, M. Rovezzi, Z. Németh, E. Rozsàlyi, T. Rozgonyi, J. Uhlig, V. Sundström, M.M. Nielsen, L. Young, S.H. Southworth, C. Bressler, W. Gawelda
J. Phys. Chem. C **119** (11), 5888-5902 (2015)
doi:10.1021/acs.jpcc.5b00557

[2] Visualizing the non-equilibrium dynamics of photoinduced intramolecular electron transfer with femtosecond X-ray pulses
S. Canton, K. Kjaer, G. Vankó, T. van Driel, S. Adachi, A. Bordage, C. Bressler, P. Chabera, M. Christensen, A. Dohn, A. Galler, W. Gawelda, D. Gosztola, K. Haldrup, T. Harlang, Y. Liu, K. Moller, Z. Németh, S. Nozawa, M. Pápai, T. Sato, Ta. Sato, K. Suarez-Alcantara, T. Togashi, K. Tono, J. Uhlig, D. Vithanage, K. Wärnmark, M. Yabashi, J. Zhang, V. Sundström, M. Nielsen
Nature Communications **6**, 6539 (2015)
doi:10.1038/ncomms7359

SCIENTIFIC INSTRUMENT HED

The High Energy Density Science (HED) group is responsible for the design, installation, and operation of the HED scientific instrument—a unique platform for experiments combining hard X-ray FEL radiation and the capability to generate extreme states of matter. In 2015, the group finalized the hutch and infrastructure planning of the SASE2 experiment area as well as the mechanical design of the majority of the beamline components required for the HED instrument.

Summary of 2015

In 2015, a new group leader, an engineer, a scientist, a postdoc, and a Ph.D. student were appointed. The group finished the design of the large interaction chamber, published the corresponding call for tender, and defined the baseline detector suite. The group also conducted a plasma experiment at FLASH and published scientific and instrumentation work.

Changes to the group

In January 2015, mechanical engineer Andreas Schmidt was appointed for both SASE2 instruments, HED and Materials Imaging and Dynamics (MID). His role is to plan the SASE2 hutch and infrastructure. Since April, the HED group has been led by Ulf Zastrau, who took over from interim group leader Thomas Tschentscher, scientific director at European XFEL. In November 2015, Sebastian Göde from the HED group at SLAC joined HED as an instrument scientist focusing on detector implementation. He is also an expert in cryogenic jets and high-power laser experiments. Emma McBride, a Peter Paul Ewald Fellow funded by Volkswagen Stiftung, started her postdoc work at LCLS, with European XFEL as her home institute. Nicole Biedermann joined the group as a Ph.D. student funded through Deutsche Forschungsgemeinschaft (DFG) in November. Since May, guest scientist Bolun Chen from the China Academy of Engineering Physics has been designing a single-shot spectrometer.

Since the summer, former ESRF scientist Carsten Bähtz is permanently present at European XFEL as coordinator of the Helmholtz International Beamline for Extreme Fields at the European XFEL (HIBEF) user consortium at the HED instrument, which is led by HZDR. The role of the HIBEF coordinator is to ensure that the various HIBEF activities fit the overall HED time planning and establish close communication with the HED group.

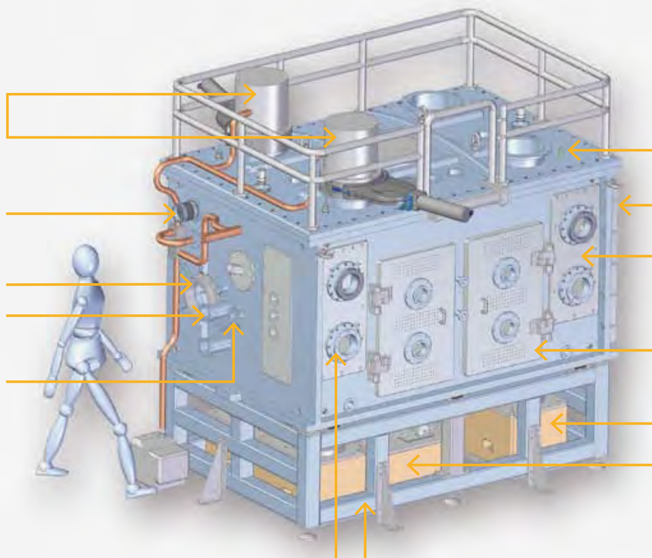


Figure 1 Model of the large vacuum chamber for the HED instrument

Interaction chamber, baseline detectors, and further activities

The HED group worked out a specification document, including a 3D mechanical model, for the first interaction chamber (IC1), the main vacuum chamber at HED where the majority of experiments will be carried out. Group members visited various potential manufacturers to ensure the feasibility of the HED requirements. The decision was taken to build the chamber entirely from aluminium, and the design was positively reviewed by external referees and in an internal project readiness review. The call for tender was published in November.

The group also selected the X-ray detector suite for the first experiments. For this purpose, Göde and Zastrau prepared a Statement of Work document to be agreed on between SLAC and European XFEL. Collaborations with SACLA and PSI regarding X-ray detectors and potential laser-induced electromagnetic pulse noise effects on the detector were launched.

Instrument scientist Karen Appel was awarded funding in a German research unit on the high-pressure and high-temperature behaviour of carbonates, and the HED group hired Biedermann as a Ph.D. student for this project. A collaboration agreement was established between European XFEL and Osaka University in Japan with special emphasis on HED science using X-ray FEL and high-power lasers.

In cooperation with the PR group, the HED group devised a new webpage providing important information for future users. The HED webpage is expected to go online before the European XFEL Users' Meeting in January 2016.

XUV pump–probe experiment on dense hydrogen

The HED group played a major role in an experiment at FLASH in December 2015, tracking phase transition and dissociation–recombination dynamics in Jovian planetary atmosphere analogues, that is, in astrophysically relevant hydrogen plasmas. This XUV pump–probe experiment utilized the split and delay line at FLASH, which was built by a group from the University of Münster in Germany. The same group provides an X-ray split and delay line with a similar concept for the HED instrument. Furthermore, the FLASH experiment included a high-repetition-rate target provided by means of a cryogenic jet, a technique that is also foreseen for implementation at HED. Hence, apart from the science case, this FLASH experiment allowed the HED group to gain significant practical experience with HED-relevant instrumentation.

HED publications

Within an international collaboration, members of the HED group published results on ultrafast electron kinetics in short-pulse laser-driven dense hydrogen in a special issue of *Journal of Physics B*, dedicated to the spectroscopy of transient plasmas [1]. All the HED instrument scientists co-authored many other publications related to the MEC instrument at LCLS and to other laser facilities. These publications include a reference paper for the MEC beamline as well as results on ultrabright X-ray laser scattering for dynamic warm dense matter physics and X-ray absorption spectroscopy of iron and molybdenum under high pressure [2].

Outlook for 2016

In 2016, the construction of hutches and infrastructure will be largely completed. The kick-off meeting with the awarded supplier of the HED target chamber will initiate the final chamber design and production process. Key components, such as attenuators, beryllium lenses, and slit assemblies, will be delivered and tested for acceptance. The detector implementation collaboration with SLAC will continue. Furthermore, the completion of the design and the ordering of large and complex components will ensure that these components are ready for installation in 2017. HZDR will deliver the beam transport system for the optical lasers as part of the contributions of the HIBEF collaboration, and the University of Münster will install and commission the split and delay line system in the XTD6 tunnel (see Chapter 3, “Civil Construction”).

HED group members will participate in several experiments at LCLS and SACLA, focusing on X-ray absorption near edge structure (XANES) spectroscopy, timing tool developments, inelastic scattering from ion-acoustic modes, and X-ray diffraction under high pressure—all key techniques and science cases for the HED instrument. The HED group will also analyse and publish first results obtained in the FLASH experiment on hydrogen plasma.

References

[1] Ultrafast electron kinetics in short pulse laser-driven dense hydrogen
U. Zastrau, P. Sperling, C. Fortmann-Grote, A. Becker, T. Bornath, R. Bredow, T. Döppner, T. Fennel, L.B. Fletcher, E. Förster, S. Göde, G. Gregori, M. Harmand, V. Hilbert, T. Laarmann, H.J. Lee, T. Ma, K.H. Meiwes-Broer, J.P. Mithen, C.D. Murphy, M. Nakatsutsumi, P. Neumayer, A. Przystawik, S. Skruszewicz, J. Tiggesbäumker, S. Toleikis, T.G. White, S.H. Glenzer, R. Redmer
J. Phys. B **48** (22), 224004 (2015)
doi:10.1088/0953-4075/48/22/224004

[2] Time evolution of electron structure in femtosecond heated warm dense molybdenum
F. Dorchies, V. Recoules, J. Bouchet, C. Fourment, P.M. Leguay, B.I. Cho, K. Engelhorn, M. Nakatsutsumi, C. Ozkan, T. Tschentscher, M. Harmand, S. Toleikis, M. Störmer, E. Galtier, H.J. Lee, B. Nagler, P.A. Heimann, J. Gaudin
Phys. Rev. B **92**, 144201 (2015)
doi:10.1103/PhysRevB.92.144201

Group members
Karen Appel, Carsten Bähtz (guest, from HIBEF, not shown), Nicole Biedermann (Ph.D. student, jointly with the University of Potsdam, not shown), Bolun Chen (guest), Sebastian Göde (not shown), Emma McBride (postdoc at LCLS, not shown), Motoaki Nakatsutsumi, Alexander Pelka (guest, from HIBEF), Andreas Schmidt (jointly with MID instrument), Ian Thorpe, and Ulf Zastrau (group leader)

SCIENTIFIC INSTRUMENT MID

The Materials Imaging and Dynamics (MID) group is responsible for building one of the scientific instruments in the experiment hall. The MID instrument will enable studies of structure and dynamics in condensed matter by means of X-ray scattering and imaging experiments on the nanoscale. Further areas of application are materials science and nanomaterials. In 2015, the group finalized the design of the various devices to be used at the MID instrument. All major components are now in production.

Progress in 2015

In 2015, the MID group concluded the technical designs of all major instrument components. The first footprint of the MID instrument became visible in the experiment hall when a high-quality floor made of carefully aligned and polished granite tiles was installed, covering more than 70 m^2. The first prototype parts of the hard X-ray split and delay line (SDL) were manufactured and tested. The SDL features a high-precision optical interferometer, first tests of which were performed at PSI. The MID group was also involved in measurements at LCLS, ESRF, and PETRA III.

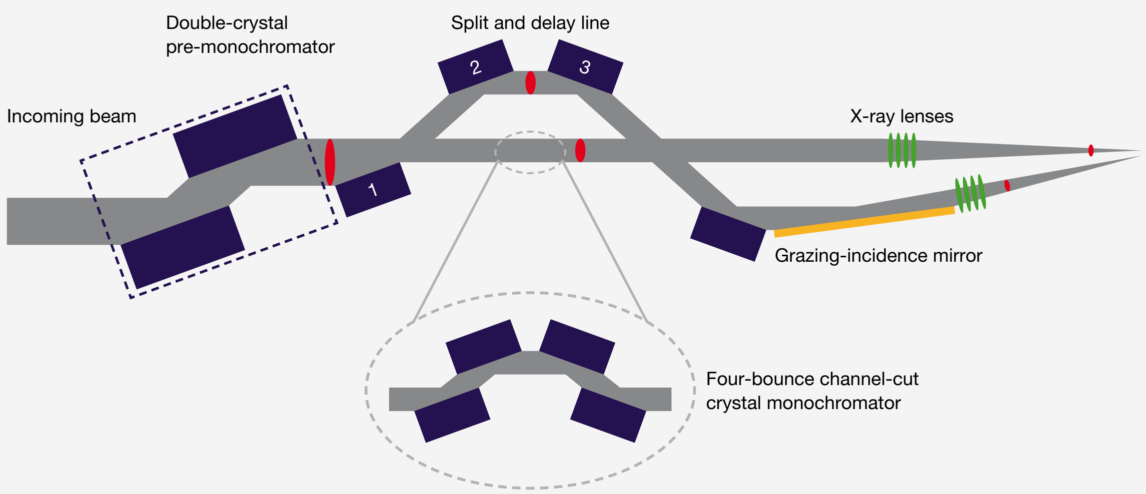


Figure 1 MID split and delay line. Sketch of the split and delay line, which separates one X-ray pulse into two equal parts. The pulses hit the sample at different incidence angles and with time delays Δ_t = 0–800 ps.

The MID group in 2015

In conjunction with the European XFEL Users' Meeting in January 2015, a workshop on "Early Science at MID" was organized. More than 90 participants contributed to lively discussions about which experiments would be allowed by the initial beam parameters, instruments, and detectors. Two new scientists, Ulrike Bösenberg and Chan Kim, joined the group in 2015, further broadening its competence in imaging experiments and instrumentation. Birthe Kist defended her bachelor thesis at TU Hamburg-Harburg in Germany. Wei Lu, who has been employed since 2014 on the project Split-X–MID—a project funded by the German Federal Ministry of Education and Research (BMBF) through a "Verbundforschung" grant—will transfer to a scientist position in the MID group at the beginning of 2016. Bertram Friedrich, a design engineer located at HZB to work on instrumentation design for the Split-X–MID project, has been collaborating with MID since October 2015.

In 2015, the group concluded the technical designs of all major instrument components. Additionally, the first prototype parts of the hard X-ray split and delay line were manufactured and tested.

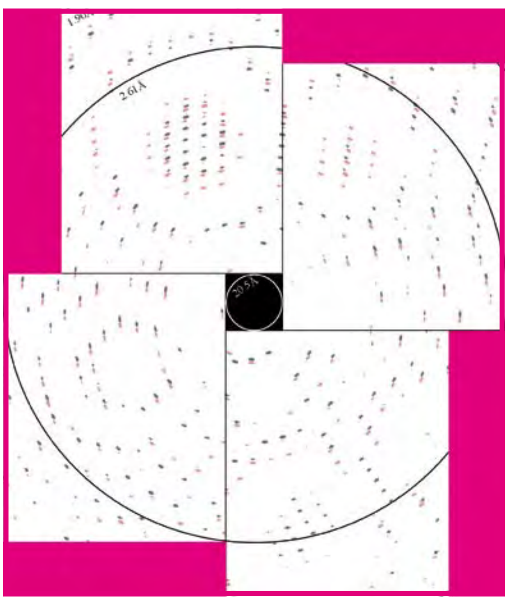


Figure 2 Simulation of the scattering by a photoactive yellow protein (PYP) crystal captured by an AGIPD from the first pulse (black spots) and the second pulse (red spots) if the crystal is photoexcited using an optical laser pump between the two pulses. This probe–pump–probe scheme is further developed in [1].

Instrument design and construction

In 2015, the MID group was busy tendering and procuring equipment for the instrument. The differential pumping section, which separates the ultrahigh-vacuum side (10^{-9} mbar) of the beamline from the downstream section with high vacuum (10^{-3}–10^{-1} mbar), is currently being assembled by CINEL Strumenti Scientifici in Italy. Likewise, slits, attenuators, and lens transfocators are being manufactured by JJ X-Ray in Denmark. In 2015, the MID group awarded the contract for the cryocooled X-ray mirror to AXILON in Germany. This device will allow the beam to be directed either downwards—for studying liquid surfaces—or upwards in combination with the SDL if a beam separation on the detector is required, for instance in probe–pump–probe experiments [1] (Figures 1 and 2).

In October 2015, the MID group published a large combined call for tender for an X-ray instrumentation setup called the X-Ray Scattering and Imaging Setup (XSIS, Figure 3), designed in collaboration with ESRF and comprising a sample chamber, a telescopic flight tube, and a stand for an Adaptive Gain Integrating Pixel Detector (AGIPD). The telescopic arm and the detector can be moved by high-pressurized air flowing into air pads, which lift the heavy assembly (>5 t) a few tens of micrometres above the floor. A special high-quality granite floor was

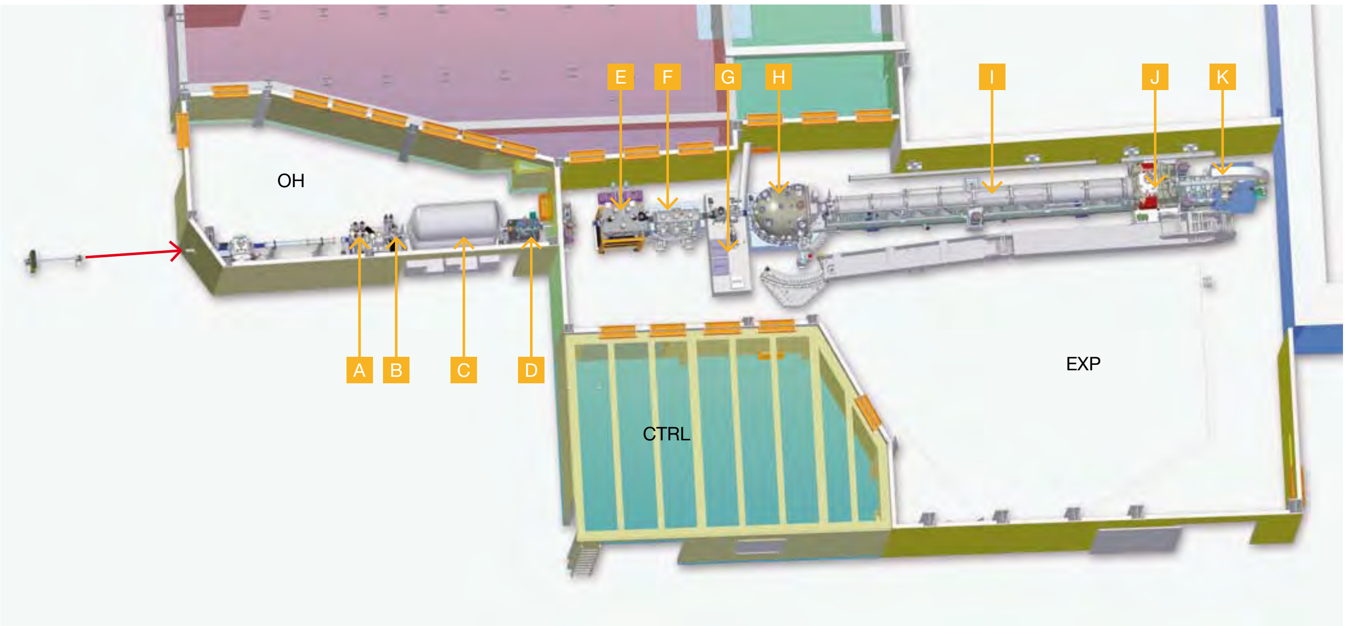


Figure 3 MID optics hutch (OH) and experiment hutch (EXP). The X-ray beam enters from the left (red arrow). The control hutch (CTRL) and optical laser hutches (truncated, in red and green) are also indicated. (A) Si (220) monochromator, (B) slit, imager, and attenuator unit, (C) SDL, (D) safety shutter, (E) cryocooled mirror, (F) differential pumping section, (G) optical laser table and diagnostics, (H) sample chamber, (I) telescopic flight tube, (J) AGIPD and detector stand, and (K) diagnostic station. The sample chamber, the telescopic flight tube, and the detector stand constitute the XSIS setup.

installed for this purpose. Bids to manufacture XSIS have been received and the contract will be awarded in early 2016. This marks the end of the design phase of essential beamline components required to operate the MID instrument.

Research and development

The MID group is collaborating with Stefan Eisebitt (TU Berlin and MBI) to build the hard X-ray SDL. The BMBF Verbundforschung project Split-X–MID involves a great deal of prototype developments. Wei Lu presented the mechanical design of the SDL, as well as simulations of its performance in SASE and self-seeded modes, at the Synchrotron Radiation Instrumentation conference in New York, USA, in July 2015 [2].

The MID group is participating in a Röntgen-Ångstrom-Cluster collaboration with the University of Gothenburg and the Chalmers University of Technology, both in Gothenburg, Sweden, and the universities of Rostock and Siegen in Germany with the aim of developing a new scheme to perform X-ray photon correlation spectroscopy (XPCS) experiments at an FEL. First experiments were performed at PETRA III. This technique will allow dynamics experiments in the femtosecond to picosecond range using the SDL.

The MID group also continued its digital computed laminography experiments at ESRF to image the structure and morphology of beryllium lenses with the aim of optimizing refractive lens optics. In July 2015, the MID group went on testing sequential 120 Hz XPCS at LCLS using the Cornell-SLAC Pixel Array Detector (CS-PAD) together with collaborators from France, Germany, Italy, and the USA. The continued pixel detector developments at LCLS are of huge benefit for demanding techniques like XPCS.

Outlook for 2016

In 2016, activities at MID will focus on manufacturing, acceptance testing, and technical commissioning of instrument components. To this end, the group will hire a mechatronics technician. The staff ramp-up towards the operation phase will continue with the recruitment of an additional scientist for the group. Construction of the hutches and infrastructure for the MID instrument will begin in the experiment hall, and the MID equipment currently located in the HERA South hall at DESY will be moved to the new headquarters building in Schenefeld. Depending on the outcome of several grant applications, additional instrumentation and detectors will be planned.

Scientific work will continue with the analysis and publication of results from experiments and simulations, together with the group's collaborators. Experiments at ESRF (ptychographic imaging) as well as at PETRA III and LCLS (for example, tests of a dispersive diamond analyser) are foreseen in 2016. A Ph.D. project will be initiated on the analysis of summed speckle images in collaboration with Christian Gutt from the University of Siegen.

References

[1] **A split-beam probe-pump-probe scheme for femtosecond time resolved protein X-ray crystallography**
J.J. van Thor, A. Madsen: Structural Dynamics **2**, 014102 (2015)
doi:10.1063/1.4906354

[2] **Design and Throughput Simulations of a Hard X-Ray Split and Delay Line for the MID Station at the European XFEL**
W. Lu, T. Noll, T. Roth et al.: Conference Proceedings of the 12th International Conference on Synchrotron Radiation Instrumentation (SRI 2015), New York, 6–10 July 2015 (2015)

Group members
Gabriele Ansaldi, Ulrike Bösenberg, Jörg Hallmann, Chan Kim, Birthe Kist (student), Wei Lu, Anders Madsen (group leader), Thomas Roth, Andreas Schmidt (jointly with HED), and Hong Xu (student, not shown)

SCIENTIFIC INSTRUMENT SCS

The Spectroscopy and Coherent Scattering (SCS) instrument will enable time-resolved experiments to unravel the electronic and structural properties of condensed-matter systems in the smallest space–time dimensions. In 2015, the SCS group started construction of the instrument components, some of which were completed and tested. The scientific activities of the group included an experimental campaign on ultrafast magnetization dynamics.

Progress in 2015

In 2015, the SCS group completed the final design of permanent beamline components, and procurement of device components is under way. In March, the construction and testing of critical beamline devices started in the SCS assembly lab in the HERA South hall. The Kirkpatrick–Baez (KB) focusing mirror system was contracted to an external company and passed the final design review in December, clearing the way for manufacture in 2016. The execution planning of the SCS hutches and infrastructure was accomplished, and hutch construction started with the installation of the SASE3 and instrument optical laser hutches.

Changes to the group

The SCS group hired five new members in 2015. Mechanical engineering student assistant Alexander Sorin assembled the first instrument components and furthered the mechanical design of the SCS alignment laser. Student assistant Komal Khandelwal is a master student in mechatronics with expertise in programmable logic controllers. Mechatronics technician Carsten Broers takes care of media and cabling layout, and will also assemble and test instrument device controls. Justine Schlappa began to design X-ray resonant diffraction (XRD) instrumentation and will support the integration of resonant inelastic X-ray scattering (RIXS) instrumentation provided by the Heisenberg RIXS (h-RIXS) user consortium. Peter Paul Ewald Fellow Loïc Le Guyader is seconded to LCLS, where he works on a Volkswagen Stiftung–funded project to explore new methods “Towards Ultrafast and Nanoscale control of Exchange” (TUNE) in collaboration with the group of Hermann Dürr.

In 2015, the group completed the final design of permanent beamline components, and procurement of device components is under way. In March, the construction and testing of critical beamline devices started.

First instrument components ready

Figure 1 The DPS comprises three sequential vacuum sections

The high-planarity floor in the SCS experiment hutch, made of marble stone slabs recessed into the concrete hall floor, was completed in October. It has an average height variation of just 54 μm/m^2 and a planarity better than 250 μm over a total area of 37 m^2. The floor enables precise movements of instrumentation, such as the planned RIXS spectrometer of the h-RIXS user consortium, which will hover on air pads only tens of micrometres above the floor.

The differential pumping system (Figure 1) was the first component to be assembled and tested in the SCS assembly lab in 2015. It is a compact, three-stage differential pumping unit designed to keep the X-ray beamline pressure in the 10^{-9} mbar range while operating an X-ray gas monitor for pulse-to-pulse intensity recording at 10^{-4}–10^{-5} mbar. The differential pumping system served as a testbed for vacuum and interlock controls that can be conceptually transferred to other SCS components. It was successfully tested and controlled using the Karabo GUI framework developed by the Control and Analysis Software group.

Optical laser interfaces designed

The design of the beamline components for the laser in-coupling (LIN) and the alignment laser (ALAS) (Figure 2) was finalized in 2015, and procurement is under way.

The LIN, which is located right upstream of the instrument, will direct the pump–probe (PP) laser beams to the samples nearly collinearly with the X-ray beam. Its key element is a vertical stack of four mirrors for different wavelengths that can be exchanged and positioned precisely in vacuum, thus allowing good vacuum conditions to be maintained for the KB mirrors. Angular adjustment of the mirrors is performed using in-vacuum piezo motors. Linear movement and mirror selection are implemented by a translation system fixed directly to a solid granite base for vibrational stability. Breadboards for optical components outside the vacuum are attached to the same granite base. These features will minimize additional timing jitter between the PP and X-ray laser pulses.

As the first beamline component in the SCS experiment hutch, the ALAS will facilitate the alignment of all subsequent beamline elements. It will introduce a visible laser beam exactly collinearly into the X-ray beam path. The beam size and divergence can be adjusted to match those of the X-rays as closely as possible. The ALAS can then be used to align downstream beamline components and implement a preliminary bending of the KB mirrors without the need for X-rays. The ALAS subcomponents—including the optical breadboard for the laser—

Figure 2 SCS optical laser interfaces.
Left SCS laser in-coupling (LIN)
Right SCS alignment laser (ALAS)

are mounted on a single granite pillar for stability. The ALAS includes an in-vacuum mirror of proven DESY design that can be reproducibly placed into and removed from the X-ray path.

Ultrafast magnetization dynamics in rare earths

SCS group member Robert Carley led a beamtime at the ARTEMIS facility at RAL, aiming to use femtosecond time-resolved photoemission spectroscopy (PES) to address questions arising from previous work on ultrafast magnetization dynamics in rare-earth metals. A new sample environment was prepared collaboratively by RAL, Freie Universität Berlin in Germany, and European XFEL, and was successfully used in the experiment. Static and time-resolved PES measurements were made using the ARTEMIS time-of-flight instrument, resolving the magnetically significant spectroscopic details of gadolinium.

Publications in 2015

Joachim Stöhr of SLAC—a former LCLS director—and Andreas Scherz of the SCS group proposed a resonant core–valence two-level model that describes the modification and control of X-ray transmission by stimulated X-ray scattering [1]. It is predicted that the onset of the optical analogue of “self-induced transparency” is several orders of magnitude lower than observed before in stimulated X-ray experiments using non-resonant excitations and broad-bandwidth SASE pulses. The results have important implications not only for X-ray absorption measurements but also for coherent X-ray imaging and inelastic X-ray scattering in the vicinity of core-level resonances.

Calculations within a density-functional theory formalism in combination with dynamical mean-field theory were performed in collaboration with Alexander Lichtenstein, from the University of Hamburg and the European XFEL Theory group, and Michael Karolak, from the University of Würzburg in Germany. The work was stimulated by experimental results in $LaCoO_3$ published in 2014 by lead author Manuel Izquierdo of SCS. The results show that strong charge fluctuations induced by electronic correlations are relevant to understanding the spin transition in this compound [2].

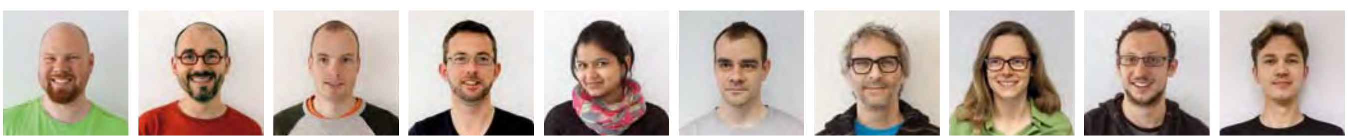
Outlook for 2016

In 2016, construction of the SCS instrument hutch will continue in the experiment hall. In parallel, further instrument components will be procured and built in the SCS assembly lab. The instrument components will be transferred to Schenefeld and installed in the experiment hutch after hutch infrastructure installation is done. The first phase of the instrument installation will be completed when the KB vacuum chamber will be delivered at the end of 2016.

References

[1] Creation of X-ray transparency of matter by stimulated elastic forward scattering
J. Stöhr, A. Scherz
Phys. Rev. Lett. **115**, 107402 (2015)
doi:10.1103/PhysRevLett.115.107402

[2] Correlation-Driven Charge and Spin Fluctuations in $LaCoO_3$
M. Karolak, M. Izquierdo, S.L. Molodtsov, A.I. Lichtenstein
Phys. Rev. Lett. **115**, 046401 (2015)
doi:10.1103/PhysRevLett.115.046401



Group members
Carsten Broers, Robert Carley, Jan Torben Delitz, Manuel Izquierdo, Komal Khandelwal (student), Loïc Le Guyader (at LCLS), Andreas Scherz (group leader), Justine Schlappa, Alexander Sorin (student), and Alexander Yaroslavtsev

SCIENTIFIC INSTRUMENT SPB/SFX

The Single Particles, Clusters, and Biomolecules and Serial Femtosecond Crystallography (SPB/SFX) group is responsible for building a scientific instrument for structural investigations of crystalline and non-crystalline matter—in particular for understanding the structure of biological molecules. The group's activities focus on two goals: to provide users with a state-of-the-art instrument for determining the structure of samples with crystallographic and imaging techniques; and to perform research into imaging and optics that supports the application of structure determination at X-ray FELs.

Summary of 2015

The SPB/SFX group has been working diligently to ensure that users can perform their first experiments in 2017. In 2015, the group expanded significantly to support the remaining construction tasks and meet the requirements for the upcoming user operation. The last major pieces of instrumentation required for first user experiments were ordered, and the group continued to carry out research enabling the realization of imaging experiments at X-ray FELs.

Expanding the group

The SPB/SFX group continued to grow in 2015. Carsten Fortmann-Grote, who joined the group through the European Cluster of Advanced Laser Light Sources (EUCALL) project funded by the European Union, heads the group's efforts to model entire X-ray FEL experiments. Project funding through the SFX user consortium allowed the group to appoint Luis López Morillo as SPB/SFX instrument integration engineer, who will ensure that the many and varied components form a seamless scientific instrument both mechanically and conceptually. López Morillo's previous experience in large-scale scientific projects is proving invaluable to the group's engineering coordination. Zunaira Ansari, who is also supported by SFX project funding, is the group's new project planner and administrator. Her scientific background in both academia and industry gives her valuable insights into coordinating the various funding streams and stakeholders of the SPB/SFX instrument.

Installing hutches, completing instrumentation designs

The realization of the SPB/SFX instrument reached major milestones in 2015 with the construction of the experiment and optics hutches as well as the optical laser hutches for the instrument in the experiment hall (Figure 1). The designs for core instrumentation that is constructed

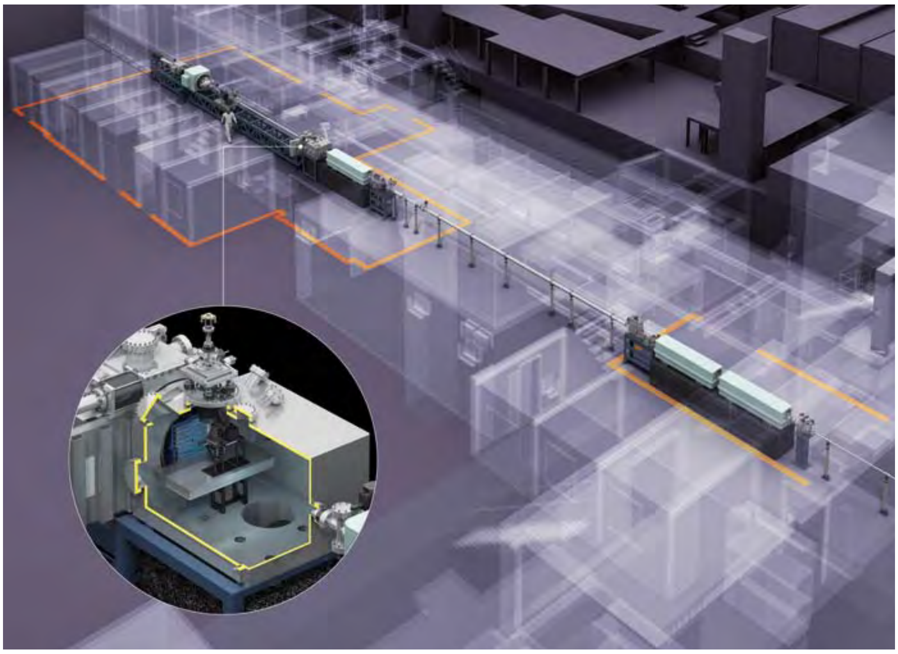


Figure 1 Illustration of the SPB/SFX instrument as it will appear in the experiment hall

in house, such as diagnostic screens, were finalized and manufacturing started. In addition, contracts were awarded for most of the larger components that are sourced externally, including attenuators, slits, supports for the detector, and diagnostics.

Optimizing X-ray FEL mirror focusing

The SPB/SFX instrument uses focusing mirrors as the primary method to create both micrometre-scale and 100 nm–scale focal spots, mainly because of the high transmission of these optical systems and their potential for preserving a neat wave field after the optics. Before being able to use such an optical system at the European XFEL, however, it must be examined whether the facility's high-intensity X-ray beam will damage the surface of the mirrors. Former group member Andrew Aquila and others studied the issue by placing test mirrors with coatings identical to those on the SPB/SFX mirrors into an X-ray FEL beam at SACLA. The determined damage thresholds indicated that the SPB/SFX mirrors should survive their expected operating conditions, and the collaboration proposed a mechanism that explains the observations [1].

Exploring methods of single-particle imaging

Another key result of the SPB/SFX group involved exploring the 3D structure of a cryo-immobilized yeast cell. Klaus Giewekemeyer and colleagues performed the first cryo-ptychographic tomography of a biological specimen at PETRA III [2]. Figure 2 shows the structure

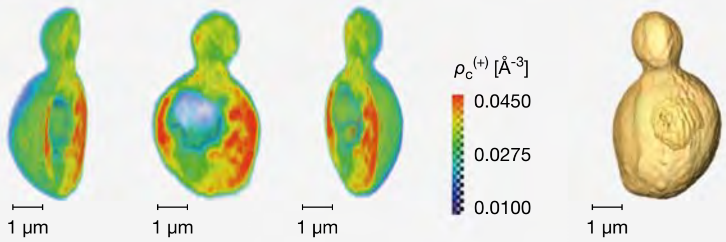


Figure 2 Three-dimensional renderings of the reconstructed electron density of a single, cryo-immobilized yeast cell. **Left** Three-dimensional electron density distribution. The colour scale, which also indicates corresponding levels of transparency, was clipped to values between 0.010 and 0.045 excess electrons per Å^{-3}. **Right** Isosurface representation of the cell. Image originally published in [2].

of the yeast cell, and, more importantly, the kind of information that can be measured using synchrotron sources, which complement the future opportunities at the European XFEL.

Modelling entire X-ray FEL experiments

Beamtime at X-ray FEL sources is a valuable commodity. One way to ensure that the allocated time is best used is to perform computational modelling of experiments beforehand, to identify optimal parameter spaces for measurements, to help refine subsequent signal analysis, or simply to better understand the tricky parts of the experiment. In 2015, group member Chunhong Yoon and collaborators finalized a modelling pipeline that enables a detailed simulation of single-particle imaging experiments at X-ray FELs (in particular at SPB/SFX).

At first sight, the experiment seems simple: insert single biomolecules into the X-ray FEL beam, which is scattered onto a 2D detector; the scattered X-rays encode the sample's structure and can be interpreted after the measurement, during which they destroy the biomolecules. In reality, however, each phase of the experiment involves sophisticated physics. The modelling pipeline developed by Yoon and collaborators comprises realistic models from the start to the end of the experiment, including: models of the X-ray FEL source pulses, models of their transport over free space and their focusing by mirror optics, a sophisticated model of the radiation damage in the biomolecule, and software to interpret the scattered signal registered by the 2D detector and reconstruct the 3D structure of the biomolecule. This flexible and powerful pipeline allows the effects of different pulse durations or photon energies to be explored without necessarily having to carry out an entire, complicated preliminary experiment in order to gain insight into the best way to perform such a single-particle imaging experiment. A publication detailing the modelling pipeline was submitted.

Exploring the limits of single-particle imaging

In 2015, many SPB/SFX group members contributed to the Single Particle Imaging (SPI) initiative at LCLS. Led by former group member Aquila, the SPI initiative systematically investigates the experimental and physical limits of single-particle imaging experiments at X-ray FELs. Group members Richard Bean and Klaus Giewekemeyer have been instrumental in demonstrating reduced background in imaging experiments, investigating optimal photon energies, and optimizing experimental geometries for SPI-type experiments. Within the SPB/SFX group, Masoud Mehrjoo, Patrik Vagovič, and others continue to explore how to measure wavefronts of X-ray FEL pulses, which have an impact on the fidelity of imaging experiments.

Outlook for 2016

Starting in mid-2016, the SPB/SFX instrument will be installed in the experiment hall. It will be pre-commissioned prior to the first arrival of the X-ray beam at the instrument in early 2017. The focusing optics required for first operation—compound refractive lenses—are expected to be delivered in 2016 and will immediately be installed in the tunnel right upstream of the experiment hall. Other key instrumentation for basic experiments, such as the sample chamber, the sample delivery apparatus, and the 2D detector, are scheduled for delivery and commissioning before the end of 2016.

References

[1] Fluence thresholds for grazing incidence hard x-ray mirrors
A. Aquila, R. Sobierajski, C. Ozkan, V. Hajkova, T. Burian, J. Chalupský, L. Juha, M. Störmer, S. Bajt, M.T. Klepka, P. Dłuzewski, K. Morawiec, H. Ohashi, T. Koyama, K. Tono, Y. Inubushi, M. Yabashi, H. Sinn, T. Tschentscher, A.P. Mancuso, J. Gaudin
Applied Physics Letters, **106** (24), 241905 (2015)
doi:10.1063/1.4922380

[2] Tomography of a Cryo-immobilized Yeast Cell Using Ptychographic Coherent X-Ray Diffractive Imaging
K. Giewekemeyer, C. Hackenberg, A. Aquila, R.N. Wilke, M.R. Groves, R. Jordanova, V. Lamzin, G. Borchers, K. Sakls, A.V. Zozulya, M. Sprung, A.P. Mancuso
Biophysjcal Journal, **109** (9), 1986–1995 (2015)
doi:10.1016/j.bpj.2015.08.047

Group members
Zunaira Ansari (supported by SFX project, Wellcome Trust UK), Richard Bean, Gannon Borchers, Carsten Fortmann-Grote (supported by EUCALL project), Klaus Giewekemeyer, Oliver Kelsey (not shown), Masoud Mehrjoo (student, supported by CUI), Luis López Morillo (supported by SFX project, Wellcome Trust UK), Adrian Mancuso (group leader), Steffen Raabe (supported by SFX project, DESY, not shown), Nadja Reimers (not shown), Tokushi Sato (supported by SFX project, DESY, not shown), Stephan Stern (supported by SFX project, DESY, not shown), Patrik Vagovič (supported by SFX project, DESY, not shown), and Chunhong Yoon (until February 2015)

SCIENTIFIC INSTRUMENT SQS

In 2015, the Small Quantum Systems (SQS) instrument group finalized the infrastructure planning for the experiment area and developed the detailed layout of the optical laser beam transport and of various components for the two experiment chambers, dedicated to the study of atomic-like quantum systems (AQS) and nano-size quantum systems (NQS). The research activities of the group at other FEL sources focused on investigations of non-linear processes and applications of two-colour experiments in atomic and molecular photoionization.

Construction of the SQS instrument

In 2015, the SQS group was strongly involved in the final definition of the experiment area, including the layout for the rooms hosting the SQS instrument, the instrument laser, the experiment control, and the electronic racks. In addition, the requirements for media supply and instrument cabling were elaborated and finalized. Construction activities started in October, and the installation of the infrastructure will follow in spring 2016.

Specific production steps were undertaken for the following components:

- **KB focusing optics**
  The specialized SQS focusing optics, which consists of a pair of about 80 cm long, bendable high-quality mirrors mounted in a Kirkpatrick–Baez (KB) configuration, will ensure a tight focusing (1 µm) at the three interaction points of the SQS instrument. The concept of using mechanical benders enables the focus to be shifted and the beam size on the sample to be varied. The surface of the mirrors will be polished for optimal focus at the first interaction point (F1) and pre-shaped to enable the optimization of the focus at the second interaction point (F1’) after bending of the mirrors.
- **In-coupling unit for the optical laser**
  The SQS group developed the beam transport system for the optical laser in the experiment area and the setup enabling the overlap between the optical laser and the X-ray beam. Special attention was paid to assure a high stability and precise spatial alignment of the optical laser beam and to realize a collinear and quasi-collinear geometry for all two-colour experiments at SQS.
- **VMI prototype**
  One of the main components of the SQS instrument is a newly designed velocity map imaging (VMI) spectrometer, which enables the angular distribution of electrons to be measured up to kinetic energies of 500 eV. A prototype spectrometer was built in 2015 and successfully tested at PETRA III (Figure 1). The first results show that all individual parts operate well within specification. In particular,

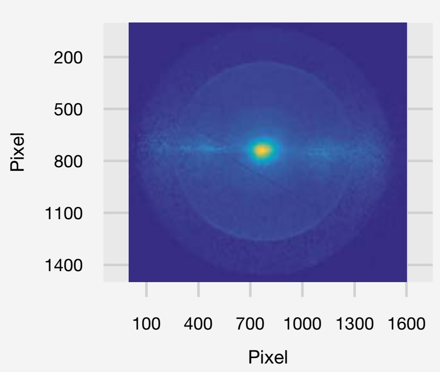


Figure 1
Top VMI prototype spectrometer for the SQS instrument.
Bottom Two-dimensional image (raw data) of the electron distribution produced upon ionization of atomic argon with photons of 350 eV. The clearly visible ring represents the emission of photoelectrons from the $2p$ shell at kinetic energies of about 100 eV.

the spectrometer can analyse electrons of high kinetic energy with high spectral resolution ($E/\Delta E = 10^2$).

- **XUV 1D imaging spectrometer**
  A high-resolution XUV 1D imaging spectrometer developed by Uppsala University in Sweden will be used to analyse the radiative emission produced by gas targets at the SQS instrument. A special optical design together with a new 2D detector will enable a spectral analysis of the XUV fluorescence and provide a spatial map of the interaction of the intense FEL beam with a dense gas target. Special care was taken to ensure that the unique performances of the spectrometer can be exploited without severe constraints for the operation of other components.
- **NQS chamber**
  The design and layout of the NQS chamber was reviewed during a one-day workshop in June involving most of the potential SQS user groups. In particular, the integration of various cluster sources and specific equipment was discussed, and the compatibility of different electron and ion spectrometers with the large imaging detector provided by the Depleted P-Channel Field Effect Transistor (DEPFET) Sensor with Signal Compression (DSSC) collaboration was reconsidered. The resulting layout concepts will be taken into account for the final design of the NQS chamber.

Research activities

In July 2015, the SQS group organized the third international workshop on “Intense field, Short Wavelength Atomic and Molecular Processes” (ISWAMP-3). The main contributions covered the scientific scope of the SQS instrument to a large extent, relating to non-linear processes in XUV and X-ray fields, ionization and fragmentation in intense X-ray fields, as well as developments and instrumentation for short-wavelength FELs.

The research activities of the SQS group in 2015 took advantage of the specific characteristics of two FELs, FLASH in Hamburg and FERMI in Italy.

The high pulse energy and short pulse duration of FLASH enable studies of multiphoton processes, such as the above-threshold ionization (ATI) of $4d$ electrons in xenon (Figure 2). Using electron spectroscopy, one- and two-photon processes can be easily disentangled with respect to their different kinetic energies and intensity dependences. Carried out in close collaboration with the theory group of Robin Santra at CFEL, this study of xenon $4d$ ATI demonstrated for the first time that new and unique insights into one-photon ionization dynamics can be obtained by observing the non-linear process [1]. In the present case, resonant substructures that were unresolved in the broad one-photon xenon $4d$ giant

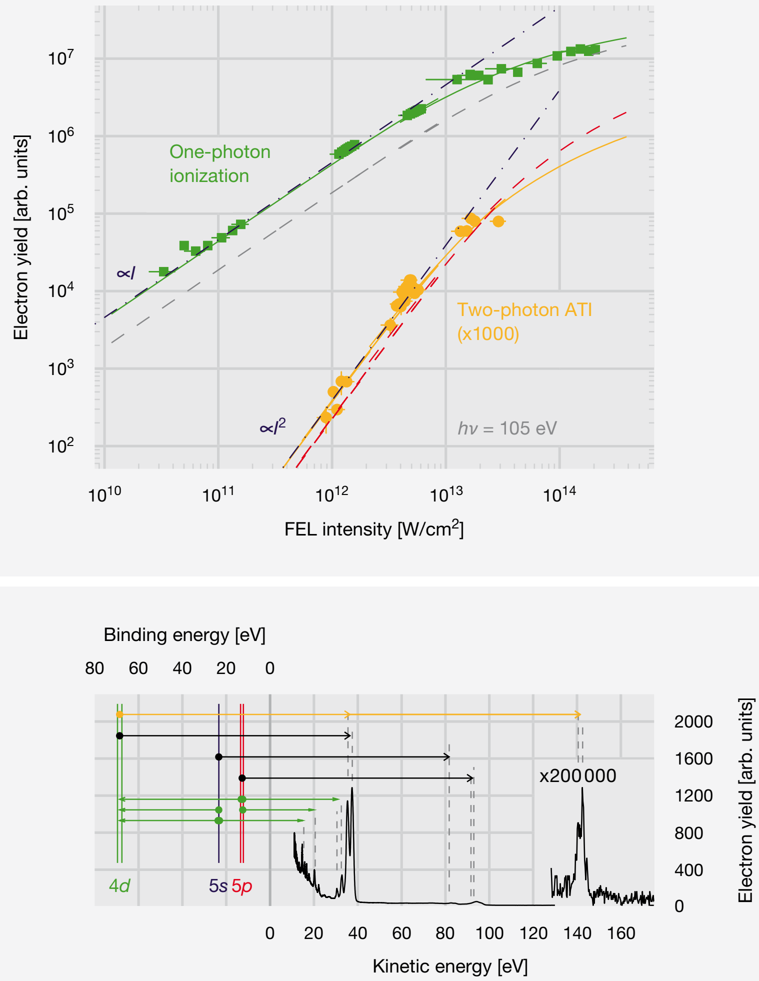


Figure 2 Above-threshold ionization (ATI) of *4d* electrons in xenon.
Top Intensity dependence of the xenon *4d* ionization following one-photon and two-photon absorption at photon energies of 105 eV. Full dots: experiment. Full and broken line: results of calculations [1] with and without inclusion of intra-channel coupling.
Bottom Electron spectrum and energy diagram of atomic xenon upon ionization at 105 eV. The *4d* ATI signal is observed around 140 eV.

resonance were identified in the energy dependence of the *4d* ATI signal, underlining the importance of collective phenomena for the *4d* ionization of atomic xenon.

The wavelength tunability and high stability of the seeded FEL FERMI were exploited to measure electron angular distributions combined with the application of a variable polarization—linear and circular—of the optical and XUV radiation in order to provide insight into the dynamics of atomic photoionization in the presence of an intense optical field [2]. The novel experiment was realized in a large collaboration involving teams from Italy, Japan, the USA, Russia, and Germany. Based on the possibility at FERMI to control the spectral phase of the FEL emission, coherent control of the atomic photoionization process was achieved. The success of this experiment opens up a wide range of investigations that were previously possible only using optical lasers.

Outlook for 2016

With installation of major instrument components in the experiment hall ready to start, 2016 will mark a particular milestone for the SQS experiment. At the beginning of the year, the SQS group will continue to test and characterize further components for the instrument, especially the integration of the electronics and control units into the European XFEL control and analysis software framework, Karabo. The data acquisition system will be tested as closely as possible to the experimental conditions foreseen for the SQS instrument. In autumn 2016, the AQS and NQS experiment chambers and the reaction microscope (SQS-REMI) will be assembled and installed in the experiment hall. Research activities will continue on specific topics related to molecular fragmentation dynamics and non-linear and dichroic phenomena in one- and two-photon ionization.

References

[1] Sensitivity of nonlinear photoionization to resonance substructure in collective excitation
T. Mazza, A. Karamatskou, M. Ilchen, S. Bakhtiarzadeh, A.J. Rafipoor, P. O'Keeffe, T.J. Kelly, N. Walsh, J.T. Costello, M. Meyer and R. Santra
Nature Communications **6**, 6799 (2015)
doi:10.1038/ncomms7799

[2] Dichroism in the photoionization of atoms at XUV Free Electron Lasers
T. Mazza, E.V. Gryzlova, A.N. Grum-Grzhimailo, A.K. Kazansky, N.M. Kabachnik and M. Meyer
J. Electr. Spectr. Rel. Phenom. **204B**, 313 (2015)
doi:10.1016/j.elspec.2015.08.011

Group members
Alexander Achner (student), Thomas Baumann, Alberto De Fanis, Markus Ilchen (postdoc at LCLS), Nikolay Kabachnik (guest scientist, not shown), Tommaso Mazza, Michael Meyer (group leader), Yevheniy Ovcharenko, Amir Jones Rafipoor (student), Ivan Shevchuk (not shown), and Haiou Zhang

OPTICAL LASERS

The Optical Lasers group will provide laser equipment for pump–probe and other experiments at the European XFEL. This equipment is being developed in house and in close collaboration with industrial partners. In 2015, the group completed all proof-of-principle experiments for the high-power burst mode pump–probe laser, advanced the final engineering of the laser systems, and initiated the procurement of all components and subsystems for three complete pump–probe lasers.

Optical lasers at European XFEL

With the experimental R&D of the pump–probe laser nearing completion, the Optical Lasers group began to finalize the engineering designs of the three laser systems for the experiment hall. Procurement for these systems and other laser-related applications, including those of other scientific groups and the R&D labs in the European XFEL headquarters building, progressed substantially during the year, demanding steady and concerted efforts from all group members. Similarly, the planning and construction of laser hutches advanced well under the group's continuous input and supervision. For the installation of the pump–probe lasers in 2016 and 2017, a detailed installation plan was devised for all the SASE beamlines, taking into account logistics and resources. Together with the High Energy Density Science (HED) instrument group, the Optical Lasers group continued to plan the integration of a 100 TW laser and a 100 J laser, which will be contributed by the Helmholtz International Beamline for Extreme Fields at the European XFEL (HIBEF) user consortium.

The joint European XFEL and DESY Laser Advisory Committee (LAC) convened in June 2015, explicitly endorsing the efforts and progress of the Optical Lasers group.

Pump–probe laser development status

In 2015, the Optical Lasers group completed all proof-of-principle experiments required for the development of the burst mode pump–probe laser. In particular, the energy and the power extraction from the multistage non-collinear optical parametric amplifier (NOPA), pumped by the second harmonic of a 5 kW InnoSlab amplifier [1], were confirmed to be as expected. At a wavelength of 800 nm, more than 2 mJ of pulse energy were achieved conservatively at a repetition rate of 100 kHz. The pulses were compressible to below 15 fs, which was the target value. For higher repetition rates, the pulse energy scaled roughly inversely with the frequency, while the burst average power increased slightly from 250 W to 360 W at 1 MHz and above [2].

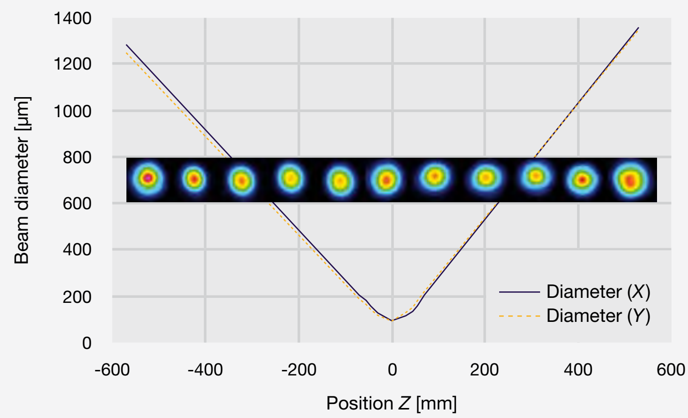


Figure 1 Caustic of the NOPA output beam, revealing close-to-ideal focusing conditions. The deduced beam quality parameter M^2 is around 1.1. The inset shows beam profile measurements at different positions along the caustic. NOPA working point: 1.1 MHz intra-burst frequency, 330 µJ single-pulse energy, 360 W burst average power, and sub-15 fs pulse duration.

These are unprecedentedly high power levels for ultrashort-pulse lasers, in particular considering the close-to-perfect beam quality of the NOPA output.

Figure 1 shows an example of a caustic—the measured evolution of the beam diameter through a focus—of the NOPA output together with the associated beam shapes along the caustic (inset). The operating conditions correspond to an intra-burst repetition rate of 1.1 MHz, a corresponding average power of 360 W, and a single-pulse energy of 330 µJ with compressibility down to 15 fs. From an evaluation of the caustic, a Gaussian beam quality close to the diffraction limit can be deduced, resulting in nearly ideal focusing conditions for experiments.

The group completed all proof-of-principle experiments required for the development of the burst mode pump–probe laser.

Figure 2 depicts examples of a typical optical spectrum and temporal intensity of the NOPA output pulses. The pulse intensity was reconstructed using spectral phase interferometry for direct electric-field reconstruction (SPIDER), which reveals a full width at half maximum of below 15 fs. During these measurements, the NOPA was operated at an intra-burst repetition rate of 188 kHz, where the single-pulse energy of 1.7 mJ was extracted with a corresponding intra-burst average power of 320 W.

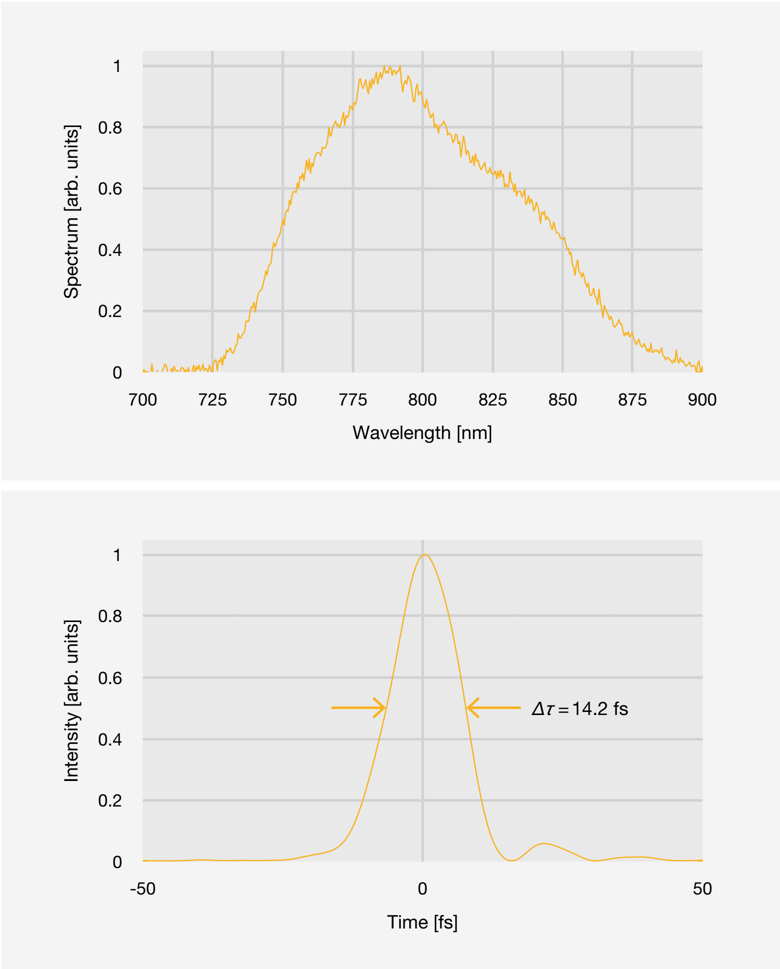


Figure 2 NOPA pulse characteristics for 188 kHz intra-burst repetition rate and 1.7 mJ single-pulse output energy (320 W average power during the 600 μs long burst).
Top Optical spectrum.
Bottom Temporal intensity after compression (measured with SPIDER).

The pulse conditions shown in Figure 2 are an example of possible NOPA settings. Given appropriate tooling time, however, different conditions can be adjusted. For instance, as was shown experimentally in 2015, it is possible to arrange for even shorter pulses (10 fs) as well as nearly Fourier transform–limited pulses with a length of up to several hundred femtoseconds. In the latter case, wavelength tuning over a range of ca. 100 nm is possible. Together with wavelength conversion, arbitrary pulse selection, and the use of compressed and uncompressed NOPA pump pulses at 1030 nm, the burst mode pump–probe laser promises to become a versatile and indispensable tool for experiments at the European XFEL.

Further activities

In addition to working on the pump–probe laser development, the Optical Lasers group continued to plan the laser integration at the HED instrument at SASE2. The proposed lasers for the instrument will be contributed by the HIBEF user consortium and include a 100 TW ultrashort-pulse laser and a 100 J–class nanosecond laser (DiPOLE 100-X). In collaboration with the HED group, HIBEF, and facility planners, the layout and infrastructure planning for the rooms housing the large lasers was finalized in 2015.

Outlook for 2016

Major tasks for the Optical Lasers group in 2016 include:

- Ancillary experiments with the R&D pump–probe laser, including galvo-operation, wavelength conversion, and component testing
- Continued testing of the integration of the pump–probe laser into Karabo, the European XFEL control and analysis software framework
- Finalization of the CAD integration of the pump–probe laser systems
- Integration of staff contributed by HIBEF to gain hands-on experience with the installation and operation of 100 TW and 100 J lasers at various sites (HZDR in Germany and CLF at Rutherford Appleton Laboratory in the UK)
- Finalization of procurement of all components and subsystems for three pump–probe laser systems to be installed in the experiment hall
- Start of hutch accession and installation of equipment and lasers at SASE1 and SASE3

Group members
Moritz Emons, Daniel Kane (not shown), Martin Kellert, Kai Kruse, Max Lederer (group leader), Guido Palmer, Mikhail Pergament, Gerd Priebe, Jinxiong Wang, Ulrike Wegner, and Laurens Wißmann

References

[1] **5kW burst-mode femtosecond amplifier system for the European XFEL pump-probe laser development**
M. Kellert, M. Pergament, K. Kruse, J. Wang, G. Palmer, G. Priebe, L. Wissmann, U. Wegner, M. Emons, J. Morgenweg, T. Mans, M.J. Lederer
The European Conference on Lasers and Electro-Optics, 21–25 June 2015, Munich, Germany, CA_3_5
ISBN 978-1-4673-7475-0

[2] **340W Femtosecond Burst-mode Non-collinear Optical Parametric Amplifier for the European XFEL Pump-probe-laser**
M. Pergament, M. Kellert, K. Kruse, J. Wang, G. Palmer, L. Wissmann, U. Wegner, M. Emons, M.J. Lederer
Advanced Solid State Lasers, 04-09. October 2015, Berlin, Germany, ATu4A.4
doi:10.1364/ASSL.2015.ATu4A.4

SAMPLE ENVIRONMENT

The Sample Environment group is responsible for delivering state-of-the-art sample environment solutions for the scientific instruments. It provides instrumentation and expert know-how in four domains: biological samples, liquid and gaseous samples, solid samples, and magnetic and cryogenic sample environments. The group manages the construction and preparation of laboratories to assist users in delivering their samples into the beam and coordinates the contributions of two user consortia to biological sample preparation and delivery.

Summary of 2015

In 2015, the group focused on developing the sample environment technologies required for the first user experiments. In particular, it developed dedicated prototypes for a fast solid-sample scanner and a compact pulsed magnet for use at the scientific instruments.

Sadia Bari, expert for liquid- and gas-phase sample delivery, left the Sample Environment group in June 2015 to start a junior research group at DESY. Rita Graceffa, expert for biological sample preparation using microfluidic devices, joined the group in September. In October, Prasad Thute rounded out the group with engineering expertise. Thute's position is funded by the Serial Femtosecond Crystallography (SFX) user consortium, and he will help to integrate the sample environments into the Single Particles, Clusters, and Biomolecules and Serial Femtosecond Crystallography (SPB/SFX) instrument.

Biological samples

Together with the Safety and Radiation Protection group, the User Office, and the Integrated Biology Infrastructure Life-Science Facility at the European XFEL (XBI) user consortium, the Sample Environment group developed a biology safety and support concept. This concept will ensure a seamless integration of the laboratory infrastructure provided by the XBI user consortium with the user laboratories financed by European XFEL. The Sample Environment group collaborated with the user consortium to ensure that all the equipment necessary for user operation will be in place for early experiments. The laboratory infrastructure for the European XFEL headquarters building was developed and built, and it will be ready for installation in early 2016. A list of equipment required for the first biological experiments at the scientific instruments was agreed on with the user consortium, and a consortium contract was drafted.

Figure 1 Scientist at the liquid-jet test chamber setup with high-performance liquid chromatography pump system and high-speed camera

Liquid jets

In 2015, the Sample Environment group set up a system to fabricate gas dynamic virtual nozzles. With the help of Ilme Schlichting's group at Max Planck Institute for Medical Research in Heidelberg, Germany, the group installed a grinding machine to manufacture nozzles from fused-silica capillaries. These nozzles have been established as a standard technology for serial femtosecond crystallography at other FEL sources. Setting up independent fabrication facilities is an important step to ensure optimal user support.

In the provisional laboratory in the HERA South hall, the group installed a compact test chamber for liquid-jet development. Combined with a high-speed camera, this system can be used to test liquid-jet systems for stability (Figures 1 and 2).

SPB/SFX sample environment

In 2015, the group began coordinating the sample environment of the SFX user consortium's contributions to the SPB/SFX instrument. After presenting a concept for sample environment integration at the SFX consortium board meeting in October, the group agreed with consortium members and in-house contributors on the deliverables for the sample environment. These discussions revealed synergies between the different contributors that will lead to a more economic use of labour and investments.

Together with Schlichting's group at Max Planck Institute for Medical Research, the Sample Environment group began developing a liquid-jet holder for serial femtosecond crystallography. Other important contributions to the European XFEL sample environment come from CFEL in Hamburg, Germany, and, as an in-kind contribution, from Uppsala University in Sweden.

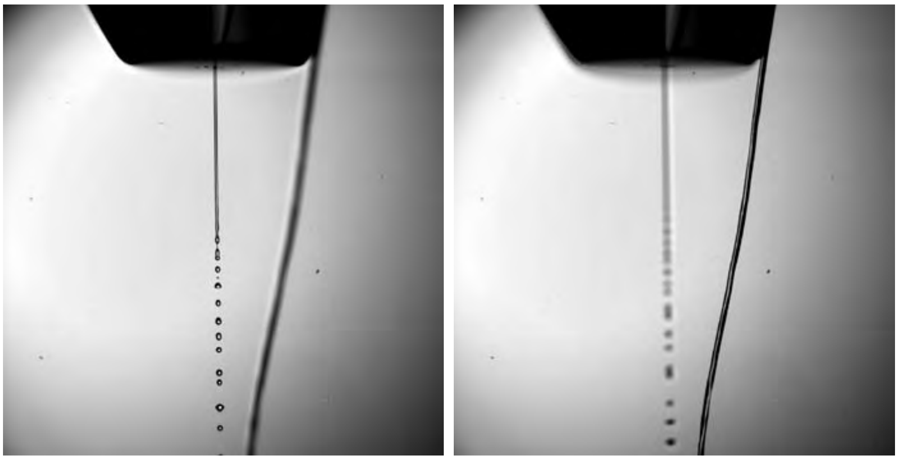


Figure 1 Investigating the stability of liquid jets with a high-speed camera. With an exposure time of a microsecond, the split-up of the jet into droplets can be made visible.
Left Droplets in focus.
Right Human hair in focus.

Fast solid-sample scanner

The development of a fast solid-sample scanner for the Spectroscopy and Coherent Scattering (SCS) instrument was finalized, and first parts for setting up a prototype in the laboratory were delivered. A compact direct-current magnet was designed to deliver fields of about 1 T.

The project for supplying pulsed magnetic field and cryogenic sample environments is well on track. In 2015, a prototype device was designed and construction started.

The Sample Environment group plays a leading role in 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. This project aims to develop a standard workflow for bringing solid targets in sampled or fixed form into the beam of high-power optical lasers, synchrotron radiation sources, and FELs. Within the project, specifications for commonly used sample holders and a roadmap for developing common sample finding and positioning software have been defined.

Magnets and cryogenics

Figure 3 Group members setting up a test vacuum chamber for housing pulsed-coil sample environments

The project for supplying pulsed magnetic field and cryogenic sample environments is well on track. In 2015, a prototype device was designed and construction started. The first instrument to receive this device will be Materials Imaging and Dynamics (MID), for use in its multipurpose chamber, by the end of 2016. Later, the SCS instrument will be provided with a similar model for its resonant X-ray diffraction chamber.

A collaboration contract was established between the sample environment groups at European XFEL and ESRF to jointly develop coils for pulsed magnetic fields, and this has resulted in a split-pair coil design being used for the European XFEL prototype. The device consists of two cryostats: a liquid-nitrogen cryostat for housing the coil and a liquid-helium cryostat for cooling samples in ultrahigh vacuum. In addition, there is a provision for quick changing of samples and four-axes sample manipulation. Facilities were also set up for in-house coil winding and testing at 77 K using a dipper dewar (Figure 3).

Outlook for 2016

In 2016, the Sample Environment group will move into the new laboratories of the European XFEL headquarters in Schenefeld. The laboratories will be equipped to support early experiments and test sample environment components for the future user experiments. Laboratory tests of liquid jets, of the fast solid-sample scanner, and of compact pulsed magnets will be performed.

To demonstrate the usefulness of mass spectrometry systems for delivering large biomolecules into FEL sources, the Sample Environment group has been granted beamtime in May 2016 at FLASH together with Heinrich Pette Institute at the University of Hamburg and HZDR, both in Germany. This experiment will not only help to understand the dissociation of biological molecules under soft X-ray radiation but also provide valuable experience for developing similar biomolecular sample sources for the European XFEL.

Together with in-house and external collaboration partners, the Sample Environment group will set up and test the sample environment required for first experiments in the SPB/SFX upstream interaction chamber by the end of 2016.

Group members
Sadia Bari (until June 2015, not shown), Carsten Deiter, Elisa Delmas (not shown), Rita Graceffa, Juha Kallio (student, not shown), Matthäus Kitel, Inari Kursula (guest, not shown), Kristina Lorenzen, James Moore, Joachim Schulz (group leader), Prasad Thute (not shown), and Charlotte Uetrecht (guest)

CENTRAL INSTRUMENTS ENGINEERING

The Central Instruments Engineering (CIE) team aims to coordinate, standardize, and implement common engineering projects of the six scientific instruments. In 2015, the team finalized the designs, initiated the procurement, and began the installation of components, and promoted effective communication between the groups responsible for building the instruments.

Main activities

In 2015, CIE finalized the designs for a variety of projects. Significant developments were made in the definition and design of standard processes for electrical connections and cabling, paving the way for calls for tender and installation in 2016.

In 2015, CIE undertook multiple projects with diverse scope: electrical design of components and cabling, in-house development of X-ray optics, coordination of in-kind contribution (IKC) projects with external vendors, development of differential pumping stages, X-ray–induced heat load simulation, and procurement of vacuum pump carts.

Changes to the team

After establishing the ePlan software as a key tool for electrical design and planning, and creating a team of ePlan experts, CIE team member Antonios Lalechos left European XFEL in June 2015. Michael Fobian was then hired as an interim consultant to continue the planning of the complex cabling required to make the instruments ready for first lasing.

In 2015, the ePlan team was consolidated and integrated into CIE. Jörn Reifschläger of the Advanced Electronics group and Bernard Baranašić of the X-Ray Photon Diagnostics group joined the CIE team, together with a new recruit, Patryk Parlicki.

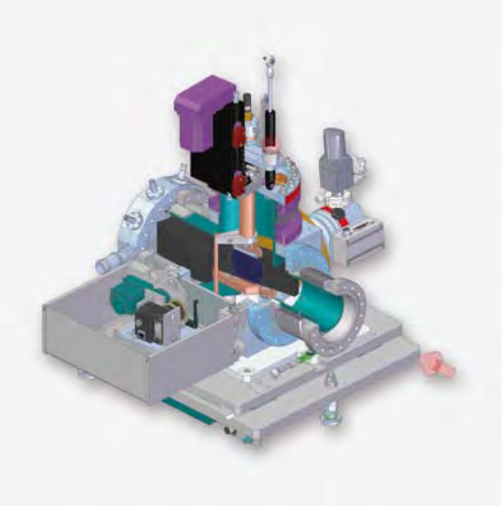


Figure 1 Beam stop for the SPB/SFX instrument

Final design for installation

In 2015, CIE developed several key X-ray components, such as fast shutters and beam stops for the SASE1 instruments (Figure 1), for manufacturing. Procurement of these components, together with vacuum pump carts and other supporting equipment, is well under way.

The team also started instrument installation activities: grouting a granite base for the beryllium compound refractive lens (CRL) system of the Femtosecond X-Ray Experiments (FXE) instrument and installing

Figure 2 Danish IKC prototype CRL system for the FXE instrument in factory acceptance tests

the baseplates for the large granite tables for X-ray optics in the FXE hutch in the experiment hall.

Test stands were constructed to commission and operate a prototype attenuator and power slit from the Danish IKC DK02, “Components for the scientific instruments FXE, SPB, MID, and HED”. The first CRL system, built for the FXE instrument, is due for delivery in March 2016 (Figure 2).

Electrical designs produced by CIE using ePlan have been essential to defining and documenting the requirements needed to initiate the Polish IKC production of crates. Furthermore, these designs are proving critical in defining the framework of the challenging cable design in the experiment hall.

In 2015, a regular engineers meeting was established, which led to more effective communication between the instrument engineers, helping to solve problems and share ideas.

Outlook for 2016

In 2016, the CIE team will conclude critical projects for the SASE1 beamline, while continuing in parallel to develop designs and plans for SASE2 and SASE3. Many components will be procured, delivered, assembled, and integrated into the beamlines. The CIE team will also support the commissioning of these systems, endeavouring to apply the experience and expertise gained with SASE1 to the development of the SASE2 and SASE3 beamlines.

At the end of the first quarter of 2016, Wolfgang Tscheu will retire and the CIE team will be supervised by Scientific Director Serguei Molodtsov.

Group members
Bernard Baranašić (jointly with X-Ray Photon Diagnostics), Lewis Batchelor, Michael Fobian (since July 2015), Antonios Lalechos (until June 2015), Viktor Lyamayev, Patryk Parlicki, Jörn Reifschläger (since August 2015), Osama Salem, and Wolfgang Tscheu (team leader)

07
DETECTORS AND DATA ACQUISITION

In 2015, manufacturing began on European XFEL control hardware, data infrastructure installations in the experiment hall went into high gear, performance tests of the detectors were done, and the user interface for the control and analysis framework was developed.

Setting up wiring for prototype detector

DETECTOR DEVELOPMENT

In collaboration with national and international partners, the Detector Development group at European XFEL develops high-speed large- and small-area X-ray detectors required by photon experiments for imaging, monitoring, veto, and spectroscopic applications. In 2015, the group mainly concentrated on testing and calibrating detector prototypes.

Summary of 2015

Following a comprehensive development phase in previous years, 2015 was predominantly distinguished by the testing and calibration of small prototype detector systems as well as the production and integration of final detector components. In collaboration with external partners, the Detector Development group supported and promoted detector calibration activities at various synchrotron and FEL X-ray sources and in the European XFEL detector laboratories in the HERA South hall.

Preparing for the operation phase

While the previous years were mainly dedicated to detector prototype development, tests, and optimization, in 2015, the group and its collaborators began production of detector components for the final

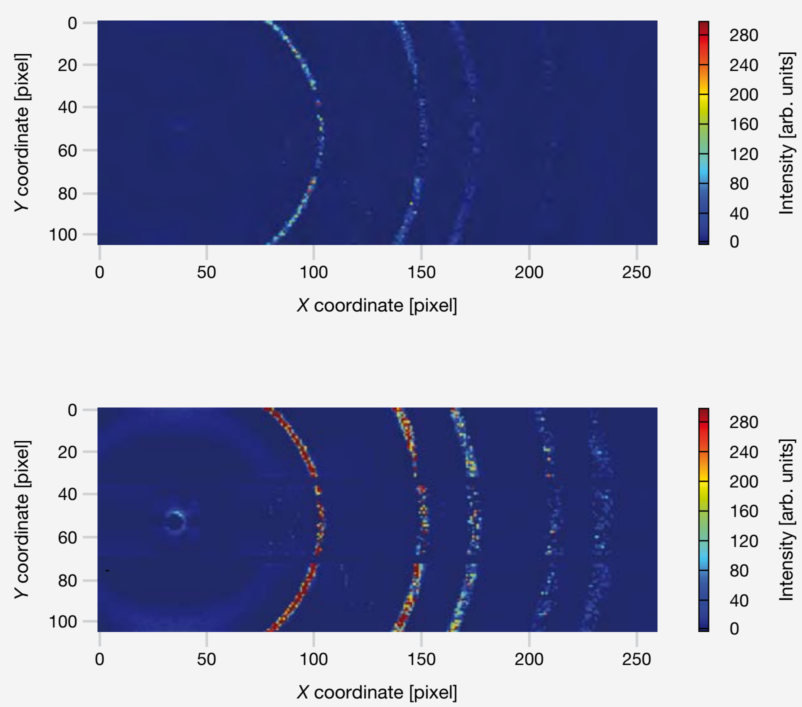


Figure 1 X-ray diffraction pattern of a silicon oxide powder sample acquired at ESRF with an LPD prototype operating in low gain (top) and medium gain (bottom).

megapixel detectors. The Large Pixel Detector (LPD) and Adaptive Gain Integrating Pixel Detector (AGIPD) collaborations ramped up manufacturing of the main detector components.

Together with collaborators from RAL, members of the Detector Development group successfully performed a range of test measurements at ESRF in France using a partially populated LPD super-module. The collaboration demonstrated the capabilities of the LPD technology at its full operation speed of 4.5 MHz by imaging an X-ray diffraction pattern of a silicon oxide powder sample (Figure 1). During the subsequent experiment at APS in the USA, the Detector Development group acquired high-quality calibration data. This experiment was an important milestone towards the calibration of the fully integrated 1 Mpx LPD, which is to be delivered to the European XFEL in 2016. Finally, the LPD collaboration exemplarily demonstrated single-photon imaging capabilities of a complete super-module through radiography of a rose blossom (Figure 2).

Together with collaborators from Rutherford Appleton Laboratory, the group successfully performed a range of test measurements at ESRF using a partially populated Large Pixel Detector super-module.

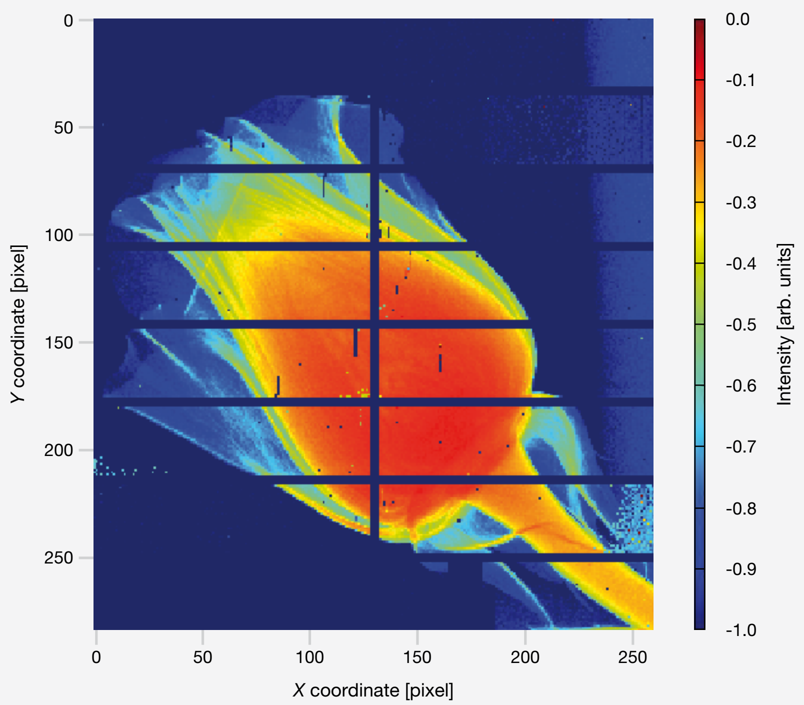


Figure 2 Radiography image of a rose blossom acquired with a fully equipped prototype LPD super-module at RAL. The image is averaged over 2000 individual images and subsequently corrected for dark current and flat-field inhomogeneity.

Figure 3
AGIPD single-module prototype installed in an X-ray test stand at European XFEL

After restructuring measures within the collaboration for the development of the Depleted P-Channel Field Effect Transistor (DEPFET) Sensor with Signal Compression (DSSC) were successfully completed at the beginning of 2015, the Detector Development group focused on preparatory measures for commissioning, calibrating, and integrating the DSSC 1 Mpx camera. At European XFEL, members of the group put two test systems into operation: the vacuum and thermal qualification test chamber RHEA and the DSSC ladder camera test system FENICE. At the same time, the DSSC collaboration made a big step towards a fully functional system by successfully demonstrating the functionality and performance of their application-specific integrated circuit (ASIC) including all subunits of the detector front-end electronics. The first sensor modules will be available in 2016, which will enable the DSSC collaboration to demonstrate the performance of a full prototype detector system.

In autumn 2015, the AGIPD collaboration delivered a small prototype detector system to European XFEL (Figure 3). After acceptance of the prototype, the Detector Development group started first in-depth performance tests, integration of the prototype into the European XFEL control and analysis software framework Karabo, and implementation of user control and data processing software. The AGIPD collaboration successfully continued the production of final components for the megapixel camera and the integration of these components into the overall megapixel system. A second-generation ASIC, presently in production and scheduled for delivery in 2016, is expected to further improve the performance of the final camera.

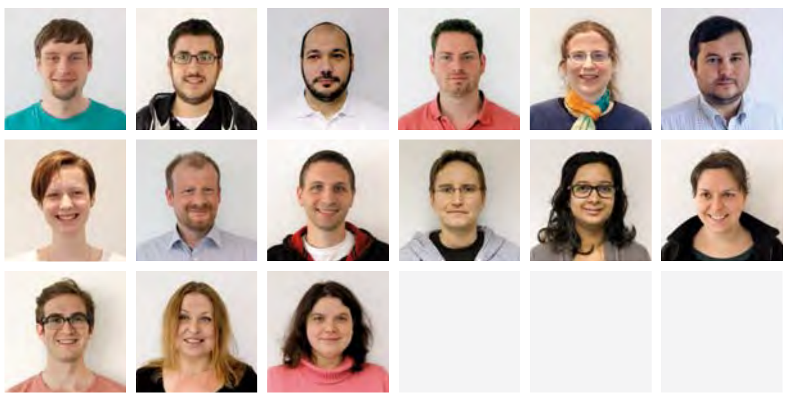
Throughout 2015, the group laid the foundations to test large-scale detector systems in its laboratory in the HERA South hall, putting additional detector calibration and test environments into operation. After the Hamburg authorities granted licences to operate these environments at the European XFEL premises, the group has been able to test and operate small and large detector systems up to a megapixel scale in their laboratory. Preparation of the required data acquisition and control system and calibration database was continuously expedited in close corporation with the IT and Data Management group and the Control and Analysis Software group.

Outlook for 2016

In 2016, the Detector Development group will face a number of important milestones in the final integration and operation of detectors at the scientific instruments. Following the delivery of the AGIPD, LPD, and FastCCD cameras, detailed end-to-end tests at the detector laboratory in HERA South will demonstrate the performance, functionality, and interplay of the imaging detectors with the complex European XFEL control, data acquisition, and data processing environment under real operating conditions. Preparing and conducting these complex tests will require a great deal of the group's time. Following the testing, the detectors will finally be installed and commissioned at the scientific instruments Femtosecond X-Ray Experiments (FXE) and Single Particles, Clusters, and Biomolecules and Serial Femtosecond Crystallography (SPB/SFX). Parallel to these activities, members of the group will promote detector calibration.

In mid-2016, the DSSC consortium will deliver the first DSSC detector prototype module, including a sensor, to European XFEL. Subsequent testing and calibration will enable the group to find the optimum operating parameters of the first low-energy 2D imaging camera system.

Furthermore, the group will ramp up activities on small-area detectors, such as avalanche photodiodes or similar devices. Because it takes several years to develop technologies for the next generation of detectors, the planning and preparation of such technologies will become increasingly important. ■



Group members
Thomas Dietze, Mattia Donato (student), Marko Ekmedžić, Steffen Hauf, Friederike Januschek, Alexander Kaukher, Ivana Klačková (student), Markus Kuster (group leader), Philipp-Michael Lang, Astrid Münnich, Sneha Nidhi (DSSC project), Matteo Porro (DSSC project, not shown), Natascha Raab, Tonn Rüter (student), Stephan Schlee (student, DSSC project, not shown), Rüdiger Schmitt (not shown), Jolanta Sztuk-Dambietz, Monica Turcato, and Georg Weidenspointner (DSSC project, not shown)

References

[1] Detectors and Calibration Concept for the European XFEL
M. Kuster, D. Boukhelef, M. Donato, J. Sztuk-Dambietz, S. Hauf, L. Maia, N. Raab, J. Szuba, M. Turcato, K. Wrona, C. Youngman
Synchrotron Radiation News **27** (4), 35–38 (2014)
doi:10.1080/08940886.2014.930809

[2] Integrated Detector Control and Calibration Processing at the European XFEL
A. Münnich, S. Hauf, B.C. Heisen, F. Januschek, M. Kuster, P.M. Lang, N. Raab, T. Rüter, J. Sztuk-Dambietz, M. Turcato
Proceedings of ICALEPCS, WEPGF050 (2015)
arXiv:1601.01794

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 the photon beamlines and instruments of the European XFEL. In 2015, the group focused on setting up and starting the production, testing, and commissioning of the required electronics.

From prototypes to production systems

An important part of the work done in 2015 was the transition from prototyping and testing electronics to preparing the final systems for production. This transition mainly related to the programmable logic controllers (PLCs), which form the core of the control and monitoring electronics. Significant progress was made in the final design and production processes for PLC electronics through a new IKC contract with NCBJ in Poland.

Towards production, installation, commissioning, and operation

To support tasks related to production, installation, and commissioning, which started in autumn 2015, the group structure was changed. Tobias Freyermuth joined the group, strengthening its PLC programming and in-field support capabilities. Jörn Reifschläger was transferred to the electrical computer-aided design (CAD) team within the Central Instruments Engineering (CIE) group, and Daniel Mau started as an electronics technician taking care of PLC electronic testing, installation, and maintenance. Juri Zach joined the group to support electronic and programming tasks as a student assistant. In 2015, the European Cluster of Advanced Laser Light Sources (EUCALL) project started. The AE group participates in EUCALL together with other European institutes on topics related to ultrafast data acquisition systems.

Compact and scalable PLC electronics

An important part of the beamline and instruments are the control electronics based on commercial PLC systems, which will control and monitor equipment such as pumps, motors, valves, and sensors. Specific PLC electronic components have to be selected, assembled, and wired within mechanical frames compatible with standard electronic racks. Jörn Reifschläger provided the key design concepts, which led to the final modular design depicted in Figure 1. The solution—which is based on industry-standard components and allows for easy modifications and repair that can be carried out even in-field—drove down production time, costs, and errors. Through an

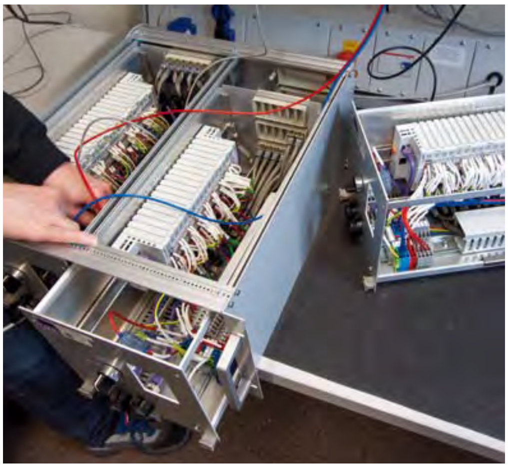


Figure 1 One assembled PLC electronics module, shown here not fully inserted into a 19-inch rack-mountable frame. The design concept was developed in collaboration with the CIE group based on industry-standard components.

IKC contract, established with NCBJ in 2015, the production of about 200 fully assembled and tested modules started.

Synchronization and real-time processing electronics demonstrated

The European XFEL will use various detector devices that must be able to capture properties of individual X-ray pulses at a repetition rate of 4.5 MHz. In many cases, the sampling rate of detected signals is even on the order of multiple GHz. Precise synchronization of the individual electronic components in relation to the X-ray pulses is therefore required. This is accomplished with the European XFEL timing system [1] and the clock and control system. While the timing system is provided by the DESY Accelerator Control System group, the AE group is closely collaborating with all European XFEL scientific and technical groups, participating in developments and providing additional support. Stable operation of the timing system was demonstrated in 2015. The clock and control system, which is required for the fast imaging detectors, was developed by UCL in London. After more than a year of successful system use, the project was finalized; the contract ended in September 2015. Since then, group member Bruno Fernandes has taken over support and maintenance.

Fernandes and Hamed Sotoudi Namin also made significant progress in developing firmware for the fast and high-speed digitizers. Key algorithms for online processing and data transfer were implemented and successfully demonstrated in a permanent installation for the Optical Lasers group and in experiments at PETRA III and ESRF.

Outlook for 2016

In 2016, the AE group will focus on the production, testing, installation, and commissioning of the control and data acquisition electronics for the photon beamlines in the tunnels and the first scientific instruments. In addition, the group will finalize firmware developments and demonstrate their stable operation. ■

References

[1] **Synchronization and Sequencing of Data Acquisition and Control Electronics at the European X-Ray Free Electron Laser**
Patrick Geßler
Ph.D. Dissertation, DESY-THESIS-2015-049 (2015)
doi:10.15480/882.1262

Group members
Frank Babies, Kai-Erik Ballak, Nicola Coppola, Bruno Fernandes, Tobias Freyermuth, Patrick Geßler (group leader), Daniel Mau (not shown), Jörn Reifschläger (until August 2015), Hamed Sotoudi Namin, Jan Tolkiehn, and Juri Zach (student, not shown)

CONTROL AND ANALYSIS SOFTWARE

The Control and Analysis Software (CAS) group provides software development, support, maintenance, and expertise in the areas of beamline control and data analysis using the custom-made Karabo framework.

Summary of 2015

By the end of 2015, the CAS group successfully demonstrated control of the first imager component installed at its final location in the XTD2 tunnel (see Chapter 3, "Civil Construction"). To reach this goal, the group combined the resources of several other groups and established interfaces to them. The CAS group began this major coordination effort by setting up a comprehensive inventory of components to be controlled and of their requirements in terms of control hardware, firmware, and software. During the year, the group finalized the list of almost 400 components and provided the documentation required for firmware and crate design, cable planning, and software preparation. In addition to these coordination activities, a central task of the CAS group is the development of the Karabo supervisory control and data acquisition system. Stability, scalability, and graphical visualization were further improved. For example, a data pipelining system now enables shipping and modular processing of large data sets collected at high repetition rate (such as detector images), which can be simultaneously monitored in the GUI.

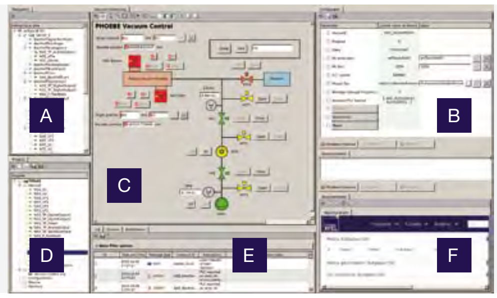


Figure 1 Screenshot of the Karabo GUI.
A Navigation, showing computers, servers, device classes, and devices.
B Configuration of one device, automatically generated from its self-description.
C Scene with several device properties shown.
D Project.
E Message logs.
F Documentation.
Most important is the "Scene" panel, which allows dragging and dropping of interactive control elements and graphical items (such as text boxes, lines, and so on). Once assembled, a single button click is sufficient to turn the scene into an online remote panel.

Two new versions of Karabo

Karabo is a software framework used to coordinate a broad spectrum of software technologies, such as multithreading, network connectivity, graphical visualization, plug-in loading, and multiple programming language interaction. Continuous testing, functionality checking, and performance tuning of such a complex system is of crucial importance.

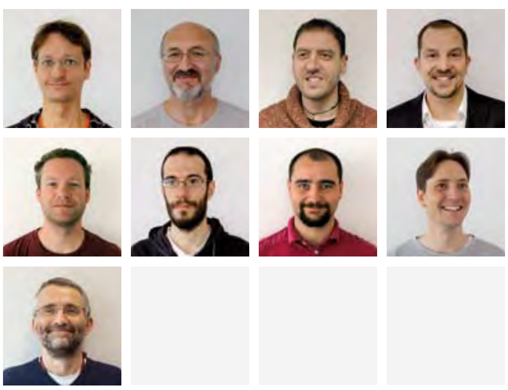
In 2015, the CAS group released two new versions of the Karabo framework (1.3 and 1.4). Each version included substantial new features and performance improvements most visibly in the GUI (Figure 1). Thanks to progress made on the point-to-point data exchange, a camera device in Karabo can now be connected to a general-purpose image processing module, which can then pass the data on to the central archive. Such data-streaming pipelines can be configured in the GUI, and images can be monitored online during processing.

The CAS group also released the first version of the new Karabo macro language. This language, which is written in Python, can be used to express complex sequenced or coordinated tasks between equipment.

References

[1] The Large Scale European XFEL Control System: Overview and Status of the Commissioning
R. Bacher, A. Aghababyan, P. Bartkiewicz, T. Boeckmann, T. Bruns, M. Clausen, T. Delfs, P. Duval, L. Froehlich, W. Gerhardt, C. Gindler, J. Hatje, O. Hensler, J. Jaeger, R. Kammering, S. Karstensen, H. Keller, V. Kocharyan, O. Korth, A. Labudda, T. Limberg, S. Meykopff, M. Moeller, J. Penning, A. Petrosyan, G. Petrosyan, L. Petrosyan, V. Petrosyan, P. Pototzki, K. Rehlich, S. Rettig-Labusga, H. Rickens, G. Schlesselmann, B. Schoeneburg, E. Sombrowski, M. Staack, C. Stechmann, J. Szczesny, M. Walla, J. Wilgen, T. Wilksen, H.G. Wu, S. Abeghyan, A. Beckmann, D. Boukhelef, N. Coppola, S. Esenov, R. Fernandes, P. Gessler, G. Giambartolomei, S. Hauf, B. Heisen, S. Karabekyan, M. Kumar, L. Maia, A. Parenti, A. Silenzi, H. Sotoudi Namin, J. Szuba, M. Teichmann, J. Tolkiehn, K. Weger, J. Wiggins, K. Wrona, M. Yakopov, C. Youngman
15th International Conference on Accelerator and Large Experimental Control Systems, Melbourne, Australia, 17–23 October 2015
Proceedings of ICALEPCS 2015 (pre-press release)
Project Status Reports, MOA3O02 (2015)
ISBN 978-3-95450-148-9

[2] Karabo-GUI: A Multi-Purpose Graphical Front-End for the Karabo Framework
M. Teichmann, B.C. Heisen, K. Weger, J. Wiggins
15th International Conference on Accelerator and Large Experimental Control Systems, Melbourne, Australia, 17–23 October 2015
Proceedings of ICALEPCS 2015 (pre-press release)
User Interfaces and Tools, WEPGF153 (2015)
ISBN 978-3-95450-148-9



Group members
Andreas Beckmann, Sergey Esenov, Gero Flucke (not shown), Gabriele Giambartolomei, Burkhard Heisen (group leader), Marc Messerschmidt (guest), Andrea Parenti, Alessandro Silenzi, Martin Teichmann (not shown), Kerstin Weger (not shown), John Wiggins, and Christopher Youngman

The Karabo macros can be coded directly in the GUI and, once running, can be added as graphical elements to other control panels. The macros proved useful to pump down or vent vacuum setups, perform motor scans, and implement software-based feedback loops.

New control system setups

Several new in-house control system setups were installed, comprising equipment such as turbomolecular pumps, scroll pumps, motors, valves, gauges, cameras, and so on. A key software interface bridging the industrial real-time programmable logic controller (PLC) system to Karabo was brought back into use after it was refactored to improve testability and performance. Another important achievement was the implementation and demonstration of the Large Pixel Detector (LPD) subsystem, featuring control, data-taking, calibration, and visualization tasks. The close collaboration with the Detector Development, IT and Data Management, and Advanced Electronics groups made this project a success.

Data acquisition and control project coordination

In 2015, the CAS group carried out an exhaustive survey that identified almost 400 components requiring control—such as attenuators, imagers, and detectors—to be installed in the photon tunnels or instruments. The group generated naming conventions and implemented workflows for collecting detailed requirements. Using template documents, almost all information needed to design control crates, plan cables, and implement firmware and software for the SASE1 tunnels and experiments was collected. Standardized tasks for installing and commissioning components from a control perspective were identified and fed into the central European XFEL project plan.

Outlook for 2016

In 2016, many tunnel components and the first instruments will be installed, and commissioning will start. The Karabo framework will then prove itself under real operating conditions. Graphic panels for the control of vacuum components, diagnostic devices, and instruments will be designed with the help of the corresponding experts. Interfaces will be developed to other systems, such as the accelerator control system and the experiment interlock system. In addition, the CAS group will support extensive end-to-end tests of the large 2D detectors, including control, calibration, data acquisition, and data catalogues. ■

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.

ITDM accomplishments

In 2015, first installations of IT infrastructure for the X-ray photon beam system and the core network components in Schenefeld were completed and put into operation. Data storage systems for the SASE1 data recording system and for offline data processing were selected, purchased, and delivered to European XFEL. Significant progress was achieved in the development and deployment of web applications.

IT support

In 2015, the ITDM group continued to provide IT support to European XFEL staff members and guest scientists. The support covered all aspects of IT for everyday work in offices and laboratories, as well as dedicated projects in various scientific and administrative groups.

Significant progress was made in the further design and installation of the network and computer room infrastructure required for control, data acquisition, and online data processing.

IT infrastructure

Significant progress was made in the further design and installation of the network and computer room infrastructure required for control, data acquisition (DAQ), and online data processing. At this point, all server racks for DAQ computer rooms have been delivered and installed. The core network components are in operation, and the backbone connection to the DESY data centre has been established. The DAQ and control network is available in the first photon beam tunnels. In the new headquarters building (XHQ) in Schenefeld, IT infrastructure has been planned and is being installed: office network, video conferencing and communication services, as well as a building access system.

Figure 1 Installations in the balcony rooms of the experiment hall

Data recording and management system

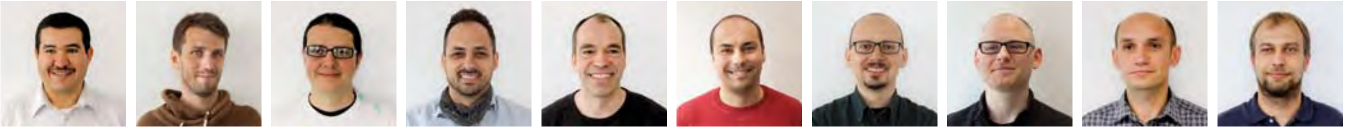
In 2015, the implementation of the data recording system was modified, taking into account feedback from tests based on the prototype solution. In particular, in cooperation with the DESY IT group, hardware was selected for the online data cache and offline data storage system. After subsequent optimization, the ITDM group achieved the required data recording throughput rate up to the disk storage layer for the equivalent of a 1 Mpx 2D detector.

Development projects

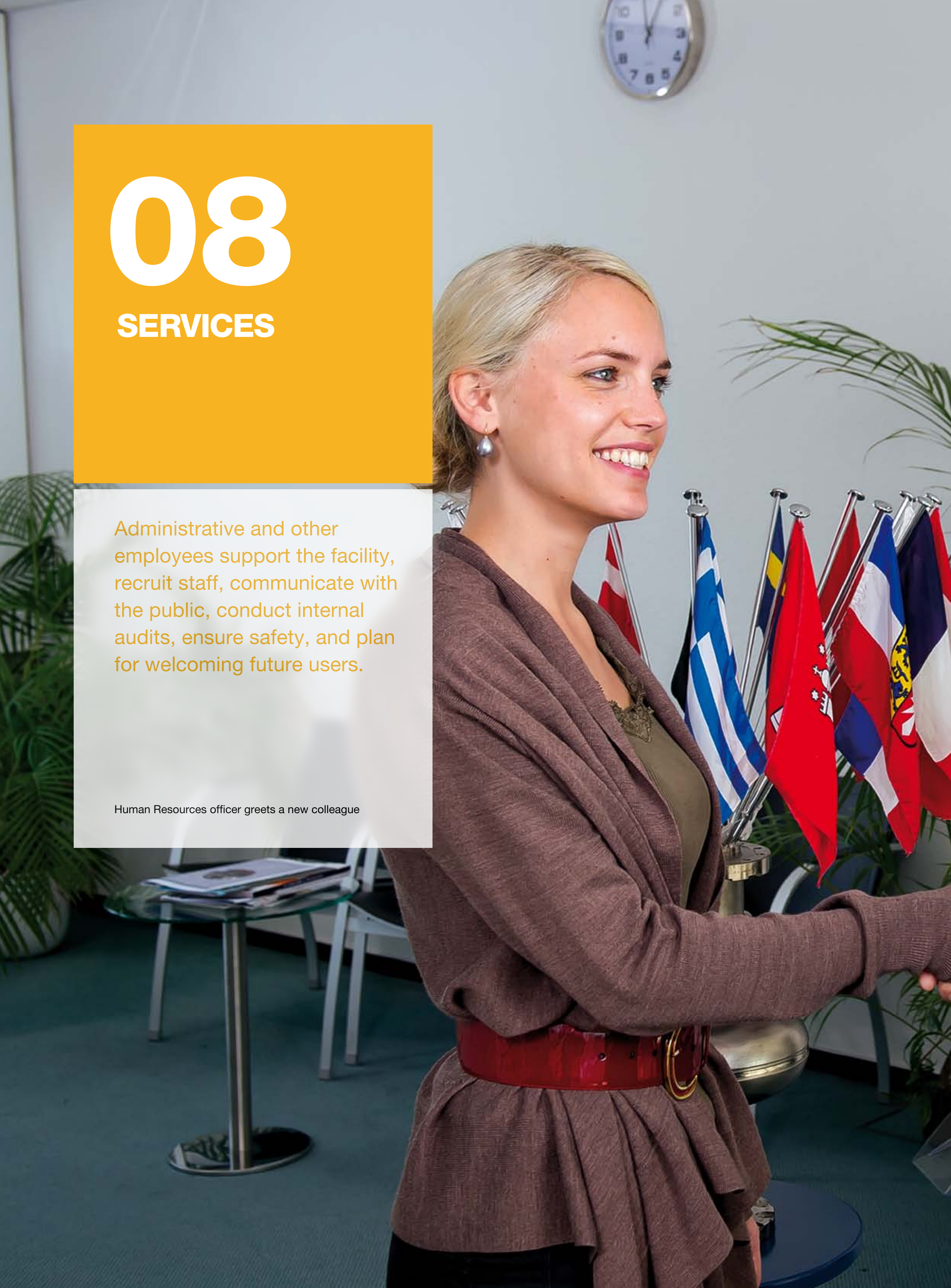
The updated software for handling detector calibration data was released in 2015. A repository of calibration data files and a catalogue were deployed and are now being used by the Detector Development group. Metadata catalogue implementation has progressed significantly and will be deployed and tested in the first half of 2016.

Outlook for 2016

In 2016, the ITDM group will continue to install the IT infrastructure required for operating scientific instruments and performing experiments. The full DAQ chain—including run management, interactions with the metadata catalogue, and the raw-data repository—will be deployed and commissioned. ■



Group members
Djelloul Boukhelef, Illia Derevianko, Jorge Elizondo, Kimon Filippakopoulos, Manfred Knaack, Luís Maia, Maurizio Manetti, Bartosz Poljancewicz, Janusz Szuba, and Krzysztof Wrona (group leader)



08
SERVICES

Administrative and other employees support the facility, recruit staff, communicate with the public, conduct internal audits, ensure safety, and plan for welcoming future users.

Human Resources officer greets a new colleague


PHYSIK
IN UNSERER ZEIT

ADMINISTRATIVE SERVICES

The European XFEL administration fulfils an enabling role. The members of the administration provide the necessary resources for the construction of the European XFEL facility and are preparing for the start of operation. They recruit highly qualified staff from all over the world and purchase needed 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.

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 slightly more than 20 staff members—less than 10% 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. Liquid funds not immediately needed to pay invoices are invested as time deposits. 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. As in previous years, external auditors issued an unconditional certification for the annual statement 2014.

Cost controlling of a complex project like the European XFEL with a budget of around 1.2 billion euro (in 2005 value) is a big challenge. It is a joint effort involving all groups within the company and coordinated by the Controlling group. Working at the frontier of technology means that a high level of uncertainty has to be met through 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.

Legal

The Legal group supports the other administrative groups and the scientific work packages, giving legal advice on a wide range of subjects. In addition to drafting contracts with external partners, the Legal group is involved in activities such as administrative preparations for the transition to the operation phase and agreements with the user consortia.

Members of the Legal group serve as secretary and vice-secretary of the European XFEL Council. Their task is to support the council chair in all council matters. They stay in close contact with the international shareholders of European XFEL.

Procurement

The Procurement group ensures a legally proper and sound procurement process in accordance with German law and aims to achieve cost reductions through intensive negotiations, well-executed public tenders, and comparison of prices on quotations handed in with purchase requests. It is the responsibility of the Procurement group to create as much competition as possible, ensuring the rules and regulations of existing public tender laws and bylaws are being followed.

For the Procurement group, 2015 was another challenging year. A total of 30 tender procedures covering big single purchases over 209 000 € and 45 tender procedures covering purchases below that value were processed in 2015, a significant 50% increase as compared to 2014. In total, the group processed 3012 purchase requests in 2015, an increase of 25% as compared to 2014. The value of the goods and services purchased amounted to 33.7 million euro (including civil construction).

A total of 30 tender procedures covering big single purchases over 209 000 € and 45 tender procedures covering purchases below that value were processed in 2015.

As part of procurement for civil construction, supported by seconded staff from DESY, 144 requests were processed, more than double the number in 2014. For above-ground construction on the Schenefeld campus, orders were placed for the roofing and the interior construction and technical equipment of the headquarters building (XHQ) as well as for the construction of the gate building (XHGATE). For below-ground construction, orders were placed for the construction of the experiment hutches and the corresponding technical equipment. Many other orders were placed to support the progress of the construction work while staying on schedule.

European XFEL very seldom buys off-the-shelf products, but rather very unique equipment or components. A good example of a very complex piece of equipment with a limited market is the interaction chamber at the HED instrument. It took a considerable effort by the scientists and the Procurement 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.

Customs and public transports were another challenging topic. A good example involves the mirrors for the X-Ray Optics group. The extremely high specifications of these mirrors require a worldwide-unique polishing method, and the only suitable supplier is located in Japan. Transport of the unpolished mirror substrates had to be organized from Germany to Japan, then back to Germany for the first metrology, and then back to Japan for further polishing. This process must be repeated until the specifications are fully met, and it involves much documentation and processing via customs offices in Germany and Japan.

In 2016, the Procurement group will define, create, and implement new processes in response to upcoming, anticipated changes to the rules and regulations regarding European and German public tender laws, as well as to the development of the company itself (including procedures for asset management, goods receiving, and warehousing).

Planning an ERP system

To facilitate a 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 process is steered by an internal working group that is composed of members of various groups, including the administrative groups, Technical Services (TS), IT and Data Management (ITDM), and further scientific and support groups. The timeframe for the implementation will likely extend to 2017, as careful preparation and optimization of business processes are crucial for the success of an ERP system.

Library

Library services for European XFEL staff and guests are performed in close collaboration with the DESY Library. A small Library group is being established to ensure the provision of library services also in the future on the Schenefeld campus.

European XFEL is an active member of the Librarian group of EIROforum, a collaboration between eight European intergovernmental research organizations of which European XFEL is also a member.

Preparing for user operation

With the start of user operation of the European XFEL facility approaching, the administrative preparations for the transition from construction to operation phase are in full swing. Given that European XFEL will become the responsible operator of the facility, administrative procedures have to be carried out that involve public authorities and considerable lead time. Internal preparations for the operation phase, such as developing staffing and budget plans, are in progress. Setting up the User Office and designing the related workflows and infrastructure are integral parts of this activity.

INTERNAL AUDIT

In 2015, 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

During 2015, staff buildup accelerated. Besides this scheduled ramp-up, an increasing number of third-party funded employees as well as students and interns were recruited. For the third time, leadership development training was conducted.

Continuing to grow

The year 2015 was characterized by a significant increase in the size of our workforce. This year, the number of employees, students, and guest scientists grew from 233 to 278 (+19%). Seventy-two signed contracts resulted in a net growth of 45 people compared to the previous year. During 2015, the HR group processed 1611 applications.

The recruitment activities once again proved to be efficient and all released job openings could be filled. The share of women among our scientists was increased by 3% to a total of 17%. Nevertheless, the gender split among the scientists and engineers could be further improved. The share of staff members from countries other than Germany remained at the same level as previous years. Five percent of the employees with German citizenship come from outside the country.

As the last open key position, the leading scientist and group leader of the High Energy Density Science (HED) group was finally filled in May. In August, the X-Ray Optics and Beam Transport group was divided into an X-Ray Optics group and a Vacuum group.

EURAXESS

EURAXESS – Researchers in Motion is a pan-European initiative of the European Commission. It provides access to a range of information and support services to researchers wishing to pursue their careers in Europe.

The EURAXESS Rights programme aims at high common standards for employment and working conditions as well as fair and transparent recruitment processes throughout Europe. Enhancing the attractiveness of European research careers is one of its main objectives. After the European XFEL endorsed the European Charter and Code for Researchers in December 2014, the HR group aimed for the “HR Excellence in Research” certificate and started the stipulated process to compile an internal analysis and action plan.

Leadership development training and language courses

During February and March 2015, the HR group coordinated mandatory leadership development training for all supervisors.

The following goals were set:

- Raise awareness for the importance of leadership
- Stimulate self-reflection of supervisors about their own leadership behaviour

- Improve the feedback culture at European XFEL (through feedback talks, conflict talks, and agreements on objectives)
- Develop interaction, trust, and exchange between the supervisors
- Provide training to improve stress management
- Provide individual feedback to each supervisor and develop individual development plans for them

Following the common training sessions, individual and team training is now offered to advance the internal communication and leadership culture of European XFEL.

The popular in-house German language classes for employees and their families continued in 2015. Since the German government no longer funds the initiative, the costs are now shared between the company and the employees.

Co-determination

Several works agreements are currently being negotiated between the management, represented by the HR Group, and the employees, represented by the Works Council. As with co-determination tasks, negotiations can be laborious.

Currently, the works agreement agenda contains the following topics:

- Hiring guidelines
- Social compensation plan (move to Schenefeld)
- Access regulation for the Schenefeld campus
- Contract management system
- Hardship allowances (currently discontinued)
- Shift work (to be started)

Equal opportunities policy

With the involvement of the HR group and the Legal group, the Equal Opportunities Spokespersons (EOS) completed a comprehensive revision of our equal opportunities policy, which was first compiled in 2010. The main goal of this revision was a more detailed description of measures and processes. By the end of 2015, the biennial mandate of the EOS ended. During this period, no complaints were reported.

In December, the election of the new EOS was conducted. Meike Flammer from the Legal group and Motoaki Nakatsutsumi from the HED group were elected. For the first time, an electronic voting system, which was provided by the IT and Data Management group, could be used for this purpose. The voter participation reached a remarkable 83.5%.

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 on the research opportunities at the new facility and ensure its long-term acceptance locally, nationally, and internationally. The PR group also gives advice to European XFEL staff on how to interact with the media and the public.

Objectives

The PR group works to promote the European XFEL among the public and in the scientific community as follows:

- Sustaining and improving regional, national, and international press and other media coverage of the European XFEL project
- 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 future users) through news articles, exhibitions, presentations, and special events
- Fostering neighbourhood relations
- Providing visitor services at the construction sites

Figure 1 The group manages media contacts with print, web, radio, television, and documentary journalists.

In addition, the PR group organizes events, represents European XFEL at selected external events, manages corporate identity, and develops communication concepts.

Accomplishments

In 2015, the PR group implemented the following communication measures, among others:

- Published news releases, press releases, and newsletters.
- Produced and published the *European XFEL Annual Report 2014*.
- Supplied editorial and layout support for the brochure T*he European X-Ray Free-Electron Laser Facility and the Challenges of our Time*. In 2015, print versions in English and Russian were distributed. The flyer "Enlightening Science" was updated, and English and German versions were printed.
- Produced a tunnel flight video exploring the underground structures of the European XFEL as well as updates to the the short European XFEL informational video, "Light of the Future", about the facility's construction progress, and time-lapse compositions of the activities at the construction sites and in the experiment hall. All films can be viewed on the European XFEL YouTube channel and are available for download on the European XFEL media database (www.xfel.eu/mediabank).
- Organized more than 90 guided tours for 1090 visitors of the European XFEL construction sites, including representatives from the diplomatic corps of different countries, scientists, journalists, politicians, PR specialists, students from universities and schools, and other stakeholders.
- Organized the topping-out ceremony for the new European XFEL headquarters building in Schenefeld as well as accompanying public relations work. PR also supported scientific events, such as the 2015 European XFEL Users' Meeting, with news and photo coverage, posters, and merchandising items.
- Organized the participation of European XFEL at the Hamburg Night of Science on the DESY campus in Bahrenfeld—an event attracting 18000 visitors to an exhibition with

Figure 2 The group organized European XFEL's exhibit during the Hamburg Night of Science on the DESY campus, which attracted thousands of visitors.

experiments, demonstrations, film programmes, and tunnel tours, presented by 96 employees from both organizations (Figure 2).

- Together with DESY, organized a weeklong event for students and scientists in Turkey to promote German–Turkish collaboration in photon science. A science day on the DESY campus in Hamburg later in 2015 attracted more than 300 guests of Turkish origin. Both events were a follow-up to the 2014 German–Turkish Year of Research, Education, and Innovation.
- Represented European XFEL with a booth and exhibits at the physics festival *Highlights of Physics* in Jena, Germany, and with a presentation at the Schenefeld Stadtzentrum shopping centre.
- Organized European XFEL's participation in the 2015 HSH Nordbank Run in Hamburg, which raised 155 000 euro for a children's fund.
- Participated in a working group—which included European XFEL Administrative Director Claudia Burger, representatives of the cities of Schenefeld and Hamburg and the district of Pinneberg, and the project company Projektgesellschaft Norderelbe—to support the construction and operation of a visitor centre at the European XFEL Schenefeld site. In 2015, the results of a feasibility study were presented to several stakeholders and the public.
- Developed a proposal for a visitor information point at the DESY-Bahrenfeld site.
- Started preparations for a website relaunch, defining requirements and a basic structure. A selection process was carried out to find an agency for graphic design, programming, and consulting.
- Offered media training for staff members.
- Helped establish a communication experts group in EIROforum, a collaboration of eight major international research organizations in Europe, and assumed the first chairmanship. Also contributed to the content, editing, and strategy of *Science in School*, the EIROforum journal for teachers.

Neighbourhood work

Throughout civil construction of the European XFEL (since 2009), the PR group is placing major emphasis on communication with local residents, as the facility is located in a predominantly residential area.

Local residents can contact the PR group's neighbourhood office at any time. Likewise, the office makes a concerted effort to reach out to all residents living near the three sites of the European XFEL and along the tunnel route. The PR group regularly takes part in the weekly DESY construction group meeting so that the office can inform these long-term neighbours and the public about the state of the construction project, current and upcoming work, and the extent and duration of any inconveniences.

The office participates regularly in a working group about the Osdorfer and Schenefelder Feldmark landscape conservation areas, presenting the compensation measures being implemented by European XFEL.

USER OFFICE

The User Office is in charge of coordinating user services and related administrative procedures for the operation phase of the facility. In 2015, the User Office helped plan the administrative infrastructure for the start of user operation and coordinated the selection of a software platform for the user portal.

Planning the administrative infrastructure

In 2015, the User Office continued to be involved in the planning of the administrative infrastructure for the start of user operation (such as access, accommodation, and travel support for user experiments). This effort included close communication with scientific and technical groups about their planned support in order to determine the requirements for interfaces between these groups and the User Office. The planning effort also involved an extensive search for best-practice models inside and outside the company.

Furthermore, in brainstorming sessions involving the leading scientists, the User Office provided support to the management board in further developing the beamtime allocation policy, with the aim of implementing an efficient and transparent peer-reviewed process.

Developing a user portal

The User Office is working with groups across the company to develop a user portal called UPEX (User Portal to the European XFEL) that will manage all calls for proposals. In early 2015, DUO (Digital User Office), which is in use at PSI, and DOOR (DESY Online Office for Research with Photons), which is from the DESY Photon Science department, were identified as suitable starting points. Both systems, which are quite familiar to many users of large-scale research facilities in Europe and have some functional similarities, were assessed by the ITDM group and the User Office. UPEX will be developed from this basis to the specific requirements of the European XFEL facility. In July 2015, an additional programmer joined the ITDM group and was assigned to the UPEX team. In the final months of the year, the focus shifted to detailed requirements for the implementation.

Early User Experiment program

In order to fully commission and develop the facility, it is planned to start operation with an Early User Experiment programme. This programme is planned to start in early summer 2017 and will last for approximately 20 months. The goals of the program are to provide users with access to the European XFEL, produce the first scientific output of the facility, and qualify the performance of the facility through real experiments. Details on the status of the facility will be included in the calls for proposals for this program.

Expanding the User Office

At the end of 2015, Gabriela Heeßel, an experienced administrative assistant, was recruited. She brings expertise essential to the group's core task of providing user services.

The User Office gratefully acknowledges the decisive support received throughout 2015 from colleagues at other facilities, in particular DESY (especially Daniela Unger, Ulrike Lindemann, and Jan-Peter Kurz) and PSI (Stefan Janssen, Markus Knecht, and colleagues).

Outlook for 2016

In 2016, the User Office will continue to develop administrative procedures, user services, and related tools in close cooperation with work packages and groups at European XFEL, with the aim of preparing for the Early User Experiment programme and beyond. The first call for proposals is expected towards the end of 2016. Recruitment of additional User Office staff is also planned.


Group members
Silvia Bertini (group leader) and Gabriela Heeßel

SAFETY AND RADIATION PROTECTION

The Safety and Radiation Protection (SRP) group coordinates a complex network of safety engineers and representatives—as well as specialists for laser protection, hazardous materials, radiation protection, and biological safety—from individual groups throughout the company. The group reports directly to the managing directors. In the management board, the administrative director, Claudia Burger, is responsible for occupational safety and radiation protection matters at the company.

SRP group

The task of the SRP group is to support and advise the management board and staff on how to provide a safe and healthy working environment. The group includes occupational safety specialists, among them a biological safety officer. All safety officers are also trained as radiation protection officers. Additionally, Medical Service is run by the DESY company doctor, Katharina Bünz.

Each research group has an assigned safety representative, who is in close contact with the SRP group. The safety representatives receive special training from the accident insurer. Besides their day-to-day work, they make sure that safety rules within their assigned work areas are followed and check that personal protective equipment is available where necessary. Together with members of the works council and the medical service, they take part in incident and accident investigations of their work areas as well as in a legally required work safety committee, which meets every three months. At these meetings, the SRP group informs the committee members about new legal changes and requirements. Ongoing work safety risk assessments, day-to-day tasks, safety programmes, and safety monitoring tours are discussed as well.

Occupational safety

The SRP group offers laser and radiation protection training, and organizes first aid, fire extinguishing, and crane operation training. General safety training for new staff and guests is conducted once a month. All training is conducted in English and German.

One major task of the group is the follow-up of work safety risk assessments of present and future work areas. The latter are being assessed in parallel with the planning and coordination of the construction and installation work for the facilities and photon beamlines on the future Schenefeld campus.

In cooperation with the User Office, a workflow on safety aspects is being developed. This also includes web-based training, which will be linked to the user portal and to the access control system.

The SRP group cooperates closely with the DESY safety group. In 2015, the two groups drew up a draft agreement for the safety organization during the operation phase. Internal roles and those of the group's partners were clarified, and responsibilities and services were further defined. The two safety groups will supervise all occupational safety aspects in their assigned areas of responsibility. For occupational safety matters, the SRP group will be responsible for all facilities from the Osdorfer Born site to the Schenefeld site, whereas the DESY safety group will be responsible for the DESY-Bahrenfeld site and the accelerator tunnel.

The emergency control centre located in the entrance building (XHGATE) on the Schenefeld campus will be staffed by DESY Technical Emergency Service, which will also guard the facility once the company offices move to Schenefeld in 2016. First recruitments took place in 2015 and will continue in 2016.

Radiation protection

The SRP group is also responsible for the handling of radioactive sources and the operation of X-ray equipment for detector development and calibration. Further in-house X-ray setups have been approved and will be used to test detector prototypes for the scientific instruments. The radiation protection officers were involved in the planning of the radiation protection hutches as well as the personnel safety system (PSS) for the instruments in the experiment hall (XHEXP1), which will be developed and implemented by DESY in the frame of an IKC. The conceptual planning was done in close collaboration with the DESY radiation protection officers, who are responsible for the European XFEL accelerator. The overall radiation protection organization for the commissioning and operation phase was prepared together with the DESY radiation protection group.

Outlook for 2016

In 2016, the SRP group will update the safety documents for the operation phase of the European XFEL facility. Together with the Technical Services (TS) group and the Central Instruments Engineering (CIE) team, the SRP group will closely monitor the implementation of machine and electrical safety measures. Electrical safety training will be organized for all staff working with electrical research equipment.

The group plans to enhance its expertise in areas that will become more critical closer to operation, including hazardous materials handling and laser safety. In 2016, the SRP group will recruit a laser safety expert and a safety technician. The group will also implement laser safety guidelines and a laser safety training programme upon the opening of the Schenefeld campus in June 2016.

Risk assessments of work areas and installation tasks in XHEXP1 and in the photon tunnels will continue, along with regular monitoring of those sites. In 2016, the SRP group will further intensify efforts to help group leaders assess and mitigate safety risks in their work areas.

In the framework of the radiation protection organization, all radiation protection officers at European XFEL will be additionally certified for accelerators in 2016 so they can assume responsibilities in the experiment hall and in the photon tunnels during the operation phase.

In collaboration with the TS group and the IT and Data Management group, the SRP group will continue to implement the access management system. Together with the User Office, the group will finalize the workflow on the safety aspects of the procedure that users will have to follow to submit their proposals for experiments at the European XFEL.

In collaboration with the DESY safety group, the SRP group will host the International Technical Safety Forum in May 2016. In October 2016, the 7th EIROforum Safety Group meeting will take place in Schenefeld, where safety engineers of all eight EIROforum member institutes will discuss ongoing safety issues and emergency management.

Occupational Safety Team

Safety specialists:

- Sigrid Kozielski (biological safety officer)
- Michael Prollius

Laser safety officers:

- Andreas Galler (Scientific Instrument FXE)
- Martin Kellert (Optical Lasers)
- Kai Kruse (Optical Lasers)

Radiation Protection Team

Responsible for radiation protection:

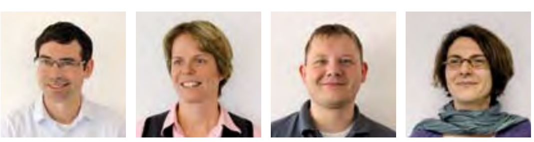
- Claudia Burger

Radiation protection commissioners:

- Sigrid Kozielski
- Thomas Tschentscher

Radiation protection officers:

- Eric Boyd
- Sigrid Kozielski
- Frédéric Le Pimpec
- Michael Prollius
- Joachim Schulz

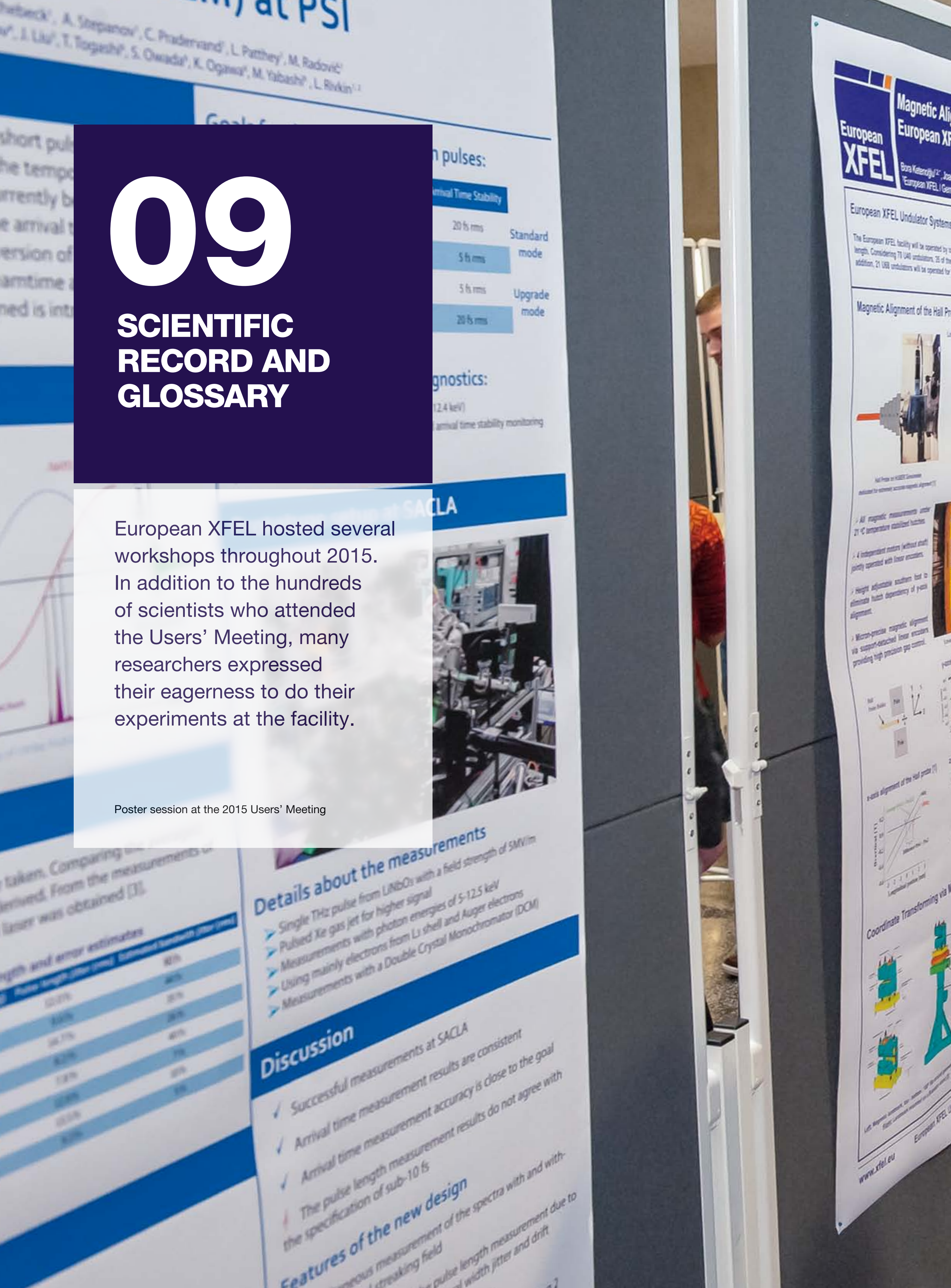


Group members
Eric Boyd, Sigrid Kozielski (group leader), Michael Prollius, and Sabrina Scherz

09

SCIENTIFIC RECORD AND GLOSSARY

European XFEL hosted several workshops throughout 2015. In addition to the hundreds of scientists who attended the Users' Meeting, many researchers expressed their eagerness to do their experiments at the facility.



Poster session at the 2015 Users' Meeting


European
XFEL

EUROPEAN XFEL USERS' MEETING

28–30 January 2015
DESY, Hamburg, 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 ninth meeting, the number of participants broke the record from the previous year yet again: over 800 people came to the full meeting, and more than 600 people attended the first days' sessions, which were specifically organized for European XFEL. The programme included talks, several workshops, a satellite meeting for early science at the Materials Imaging and Dynamics (MID) instrument, and a poster session with more than 340 posters. Participants discussed details of the European XFEL project, future experiments, user consortia, and recent updates within the field of photon science. More than 40 students from around the world attended on travel grants disbursed by European XFEL.

The Users' Meeting focused on the following topics:

- Progress and current status of the European XFEL
- Initial concepts for early user operation
- Instrument design developments and advances
- Selected science applications
- Current developments and recent results in the field of X-ray FEL facilities
- Job opportunities at European XFEL

Figure 1 Participants of the 2015 European XFEL Users' Meeting

THIRD RACIRI SUMMER SCHOOL ON TIME-RESOLVED AND IN-SITU STUDIES OF MATERIALS

22–29 August 2015
Rügen, Germany

Jointly organized by leading research organizations from Russia, Sweden, and Germany, the third RACIRI Summer School featured lectures representatives of operating and upcoming X-ray and neutron sources worldwide, as well as scientists from universities and laboratories around the world. The summer school originated from cooperation between the Röntgen-Ångstrom Cluster (RAC), a partnership between Germany and Sweden, and the Ioffe-Röntgen Institute (IRI), a partnership between Germany and Russia. The third iteration of the summer school focused on various aspects of the study of materials at facilities such as FELs, synchrotrons, and neutron sources. Lectures emphasized new methods in time-resolved and *in-situ* studies of various materials and were given by speakers from European XFEL and DESY in Germany, MAX-lab in Sweden, and NRC KI in Russia, among others. Nobel Laureate Ada Yonath (2009, Chemistry) gave the keynote address.

WORKSHOPS

23–24 April 2015
4th Collaboration Meeting of the European XFEL
Organized by European XFEL and Deutsches Elektronen-Synchrotron (DESY) on the DESY campus, Hamburg, Germany

This meeting gathered the international collaboration that is constructing the European XFEL. The meeting covered the accelerator construction and its related infrastructure, the photon beamlines, and the instruments.

28 June – 2 July 2015
17th International Workshop on Radiation Imaging Detectors (iWoRiD)
Organized by European XFEL, DESY, and the University of Hamburg on the DESY campus, Hamburg, Germany

This workshop provided an international forum for discussing current research and developments in the area of position sensitive detectors for radiation imaging, including semiconductor detectors, gas-based detectors, and scintillator-based detectors. Topics included processing and characterization of detector materials, hybridization and interconnect technologies, design of counting or integrating technologies, readout and data acquisition systems, and applications in various scientific and industrial fields.

Figure 1 Poster session at iWoRiD

18–20 July 2015
Intense field, Short Wavelength Atomic and Molecular Processes 3 (ISWAMP3)
Organized by European XFEL on the DESY campus, Hamburg, Germany

ISWAMP3 is an official satellite workshop of the International Conference on Photonic, Electronic and Atomic Collisions (ICPEAC). The workshop was designed to provide a focus for the growing community of atomic, molecular, and optical physicists who are working on the interaction of atomic systems with intense laser fields extending from the ultraviolet to the X-ray region of the electromagnetic spectrum. The workshop also focused on the complementary fields of high harmonic generation and attosecond science.

23–25 September 2015
Joint Workshop on High Pressure, Planetary, and Plasma Physics
Organized by DESY, European XFEL, DLR, the University of Rostock, and Bayerisches Geoinstitut at the University of Bayreuth, Germany

This workshop aimed to continue discussions on scientific questions on extreme planetary environments in terms of high pressure and high temperature. Several key scientific challenges in this field were discussed, including generation of such conditions at FLASH and the future European XFEL, generation of higher pressures in static experiments both in the laboratory and at synchrotron facilities, development of new diagnostic tools, prediction of high pressure and temperature properties of materials from *ab initio* methods, and application of such results to the study of the interiors of planetary and astrophysical bodies. ■

Figure 2 ISWAMP3 participants

SEMINARS

19 January 2015
Polarisation dependent X-ray spectroscopy: recent advances
Andrei Rogalev, ESRF, Grenoble, France

27 January 2015
***Bacillus subtilis* as a tool in basic science and applied research**
Imrich Barák, Institute of Molecular Biology, Slovak Academy of Sciences, Bratislava, Slovakia

26 February 2015
Developments for ultrafast time-resolved experiments at SACLA
Tetsuo Katayama, SACLA, JASRI, Sayo, Hyogo, Japan

6 March 2015
Towards the use of XFEL facilities for creation of warm dense matter and phase transition probing
Anna Lévy, UPMC, Paris, France

19 May 2015
Bound states in warm dense matter
Dirk O. Gericke, University of Warwick, UK

18 June 2015
Recent undulator work at SLAC
Zachary Wolf, LCLS, SLAC, Menlo Park, California, USA

23 June 2015
Looking into thin metal films: surface and interface effects on quantum confined electrons
Paolo Moras, Istituto di Struttura della Materia – CNR, Trieste, Italy

21 August 2015
A brave new world of ultrafast optics in the mid-infrared
Aleksei Zheltikov, Physics Department, International Laser Center, M.V. Lomonosov Moscow State University; NRC KI, Moscow, Russia; Department of Physics & Astronomy, Texas A&M University; Russian Quantum Center, Skolkovo, Russia

16 September 2015
Hard X-ray emission spectroscopy in transition metal complexes at the LCLS
Uwe Bergmann, SLAC, Menlo Park, California, USA

26 October 2015
Anomalous correlations of crystal lattice, magnetic and electronic properties in the rare-earth cobaltites $RCoO_3$ with strong fluctuations of multiplicity
Sergei Ovchinnikov, Kirensky Institute of Physics, Krasnoyarsk, Russia

11 December 2015

Progress in user-friendly X-ray sources based on plasma accelerators

Ralph W. Aßmann, DESY, Hamburg, Germany

16 December 2015

hRIXS: a flexible instrument for high resolution resonant inelastic soft X-ray scattering

Giacomo Ghiringhelli, Physics Department – Politecnico di Milano and CNR/SPIN, Milan, Italy ■

PUBLICATIONS

CONTRIBUTIONS TO BOOKS

Self-Seeded Free-Electron Lasers
G. Geloni
Synchrotron Light Sources and Free-Electron Lasers: Accelerator Physics, Instrumentation and Science Applications,
1–28, Springer International Publishing, Cham, Switzerland (2015)
ISBN 978-3-319-04507-8
doi:10.1007/978-3-319-04507-8_4-1

Structural Dynamics of Materials Probed by X-Ray Photon Correlation Spectroscopy
A. Madsen, A. Fluerasu, B. Ruta
Synchrotron Light Sources and Free-Electron Lasers: Accelerator Physics, Instrumentation and Science Applications, 1–21,
Springer International Publishing, Cham, Switzerland (2015)
ISBN 978-3-319-04507-8
doi:10.1007/978-3-319-04507-8_29-1

THESES

Design and Optimization of the Grating Monochromator for Soft X-Ray Self-Seeding FELs
S. Serkez
Ph.D. Thesis, University of Hamburg (2015)
DESY-THESIS-2015-043
urn:nbn:de:gbv:18-76132

Synchronization and Sequencing of Data Acquisition and Control Electronics at the European X-Ray Free Electron Laser
P. Gessler
Ph.D. Thesis, Technische Universität Hamburg–Harburg (2015)
DESY-THESIS-2015-049
doi:10.15480/882.1262

JOURNALS

A new Dynamic-XPS End-Station for Beamline P04 at PETRAIII/DESY
S. Babenkov, V. Aristov, O. Molodtsova, K. Winkler, L. Glaser, I. Shevchuk,
F. Scholz, J. Seltmann, J. Viefhaus
Nucl. Instrum. Methods Phys. Res., Sect. A **777** (2015), 189–193 (2015)
doi:10.1016/j.nima.2014.12.065

A split-beam probe-pump-probe scheme for femtosecond time resolved protein X-ray crystallography
J.J. van Thor, A. Madsen
Struct. Dyn. **2** (2015), 014102
doi:10.1063/1.4906354

Adaptive X-Ray Mirror tuning Simulation through influence Functions' Modeling and Error Function Minimization
M. Vannoni, F. Yang, H. Sinn
Opt. Eng. **54** (2015) 1, 015104
doi:10.1117/1.OE.54.1.015104

An Organized Co-assembly of Clathrin Adaptors Is Essential for Endocytosis
M. Skruzny, A. Desfosses, S. Prinz, S. Dodonova, A. Gieras, C. Uetrecht, A. Jakobi,
M. Abella, W.H. Hagen, J. Schulz, R. Meijers, V. Rybin, J.G. Briggs, C. Sachse,
M. Kaksonen
Dev. Cell **33** (2015) 2, 150–162
doi:10.1016/j.devcel.2015.02.023

Attachment of Norovirus to Histo Blood Group Antigens: A Cooperative Multistep Process
A. Mallagaray, J. Lockhauserbäumer, G. Hansman, C. Uetrecht, T. Peters
Angew. Chem. Int. Edit. **54** (2015) 41, 12014–12019
doi:10.1002/anie.201505672

Beamline P02.1 at PETRA III for High-Resolution and High-Energy Powder Diffraction
A.-C. Dippel, H.-P. Liermann, J.T. Delitz, P. Walter,
H. Schulte-Schrepping, O. Seeck, H. Franz
J. Synchrotron Radiat. **22** (2015) 3, 675–687
doi:10.1107/S1600577515002222

Brightness of synchrotron radiation from undulators and bending magnets
G. Geloni, V. Kocharyan, E. Saldin
J. Synchrotron Radiat. **22** (2015) 2, 1–29
doi:10.1107/S1600577514026071

Comparative study of the X-ray reflectivity and in-depth profile of a–C, B_4C and Ni Coatings at 0.1–2 keV
I.V. Kozhevnikov, E.O. Filatova, A.A. Sokolov, A.S. Konashuk, F. Siewert, M. Störmer, J. Gaudin, B. Keitel, L. Samoylova, H. Sinn
J. Synchrotron Radiat. **22** (2015) 2, 348–353
doi:10.1107/S1600577515000430

Correlated heterogeneous dynamics in glass-forming polymers
H. Conrad, F. Lehmkuehler, B. Fischer, F. Westermeier, M. Schroer, Y. Chushkin, C. Gutt, M. Sprung, G. Gruebel
Phys. Rev. E **91** (2015), 042309
doi:10.1103/PhysRevE.91.042309

Correlation-Driven Charge and Spin Fluctuations in $LaCoO_3$
M. Karolak, M. Izquierdo, S. Molodtsov, A. Lichtenstein
Phys. Rev. Lett. **115** (2015) 4, 046401
doi:10.1103/PhysRevLett.115.046401

Creation of X-Ray Transparency of Matter by Stimulated Elastic Forward Scattering
J. Stöhr, A. Scherz
Phys. Rev. Lett. **115** (2015) 10, 107402
doi:10.1103/PhysRevLett.115.107402

Detailed Characterization of a Nanosecond-Lived Excited State: X-ray and Theoretical Investigation of the Quintet State in Photoexcited $[Fe(terpy)_2]^{2+}$
G. Vankó, A. Bordage, M. Pápai, K. Haldrup, P. Glatzel, A.M. March, G. Doumy, A. Britz, A. Galler, T. Assefa, D. Cabaret, A. Juhin, T.B. van Driel, K.S. Kjær, A. Dohn, K.B. Møller, H.T. Lemke, E. Gallo, M. Rovezzi, Z. Németh, E. Rozsályi, T. Rozgonyi, J. Uhlig, V. Sundström, M.M. Nielsen, L. Young, S.H. Southworth, C. Bressler, W. Gawelda
J. Phys. Chem. C **119** (2015) 11, 5888–5902
doi:10.1021/acs.jpcc.5b00557

Disorder-Induced Localization in Crystalline Pseudo-Binary GeTe–Sb_2Te_3 Alloys between $Ge_3Sb_2Te_6$ and GeTe
P. Jost, H. Volker, A. Poitz, C. Poltorak, P. Zalden, T. Schäfer, F.R.L. Lange, R.M. Schmidt, B. Holländer, M.R. Wirtssohn, M. Wuttig
Adv. Funct. Mater. **25** (2015) 40, 6399–6406
doi:10.1002/adfm.201500848

Dynamic Structural Response and Deformations of Monolayer MoS_2 Visualized by Femtosecond Electron Diffraction
E.M. Mannebach, R. Li, K.-A. Duerloo, C. Nyby, P. Zalden, T. Vecchione, F. Ernst, A.H. Reid, T. Chase, X. Shen, S. Weathersby, C. Hast, R. Hettel, R. Coffee, N. Hartmann, A.R. Fry, Y. Yu, L. Cao, T.F. Heinz, E.J. Reed, H.A. Dürr, X. Wang, A.M. Lindenberg
Nano Lett. **15** (2015) 10, 6889–6895
doi:10.1021/acs.nanolett.5b02805

Extreme biomimetic approach for developing novel chitin-GeO_2 nanocomposites with photoluminescent properties
M. Wysokowski, M. Motylenko, J. Beyer, A. Makarova, H. Stöcker, J. Walter, R. Galli, S. Kaiser, D. Vyalikh, V.V. Bazhenov, I. Petrenko, A.L., S. Molodtsov, D. Stawski, K.J. Kurzydłowski, E. Langer, M.V. Tsurkan, T. Jesionowski, J. Heitmann, D.C. Meyer, H. Ehrlich
Nano Res. **8** (2015) 7, 2288–2301
doi:10.1007/s12274-015-0739-5

Feasibility of a ring FEL at low emittance storage rings
I. Agapov
Nucl. Instrum. Methods Phys. Res., Sect. A **793** (2015), 35–40
doi:10.1016/j.nima.2015.04.069

Feasibility of Valence-to-Core X-ray Emission Spectroscopy for Tracking Transient Species
A.M. March, T.A. Assefa, C. Bressler, G. Doumy, A. Galler, W. Gawelda, E.P. Kanter, Z. Németh, M. Pápai, S.H. Southworth, L. Young, G. Vankó
J. Phys. Chem. C **119** (2015) 26, 14571–14578
doi:10.1021/jp511838q

Fluence thresholds for grazing incidence hard x-ray mirrors
A. Aquila, R. Sobierajski, C. Özkan, V. Hajkova, T. Burian, J. Chalupsky, L. Juha, M. Störmer, S. Bajt, M.T. Klepka, P. Dłużewski, K. Morawiec, H. Ohashi, T. Koyama, K. Tono, Y. Inubushi, M. Yabashi, H. Sinn, T. Tschentscher, A.P. Mancuso, J. Gaudin
Appl. Phys. Lett. **106** (2015) 24, 241905
doi:10.1063/1.4922380

Girder deformation related phase errors on the undulators for the European X-Ray Free Electron Laser
Y. Li, B. Ketenoglu, J. Pflueger
Phys. Rev. ST Accel. Beams **18** (2015) 6, 060704
doi:10.1103/PhysRevSTAB.18.060704

How Supercooled Liquid Phase-Change Materials Crystallize: Snapshots after Femtosecond Optical Excitation
P. Zalden, A. von Hoegen, P. Landreman, M. Wuttig, A.M. Lindenberg
Chem. Mater. **27** (2015) 16, 5641–5646
doi:10.1021/acs.chemmater.5b02011

Imaging single cells in a beam of live cyanobacteria with an X-ray laser
G. van der Schot, M. Svenda, F.R.N.C. Maia, M. Hantke, D.P. DePonte, M.M. Seibert, A. Aquila, J. Schulz, R. Kirian, M. Liang, F. Stellato, B. Iwan, J. Andreasson, N. Timneanu, D. Westphal, F.N. Almeida, D. Odic, D. Hasse, G.H. Carlsson, D.S.D Larsson, A. Barty, A.V. Martin, S. Schorb, C. Bostedt, J.D. Bozek, D. Rolles, A. Rudenko, S. Epp, L. Foucar, B. Rudek, R. Hartmann, N Kimmel, P. Holl, L. Englert, N.-T. Duane Loh, H.N. Chapman, I. Andersson, J. Hajdu, T. Ekeberg
Nat. Comm. **6** (2015) 5704
doi:10.1038/ncomms6704

Indications of Radiation Damage in Ferredoxin Microcrystals using High-Intensity X-FEL Beams
K. Nass, L. Foucar, T.R.M. Barends, E. Hartmann, S. Botha, R.L. Shoeman, R.B. Doak, R. Alonso-Mori, A. Aquila, S. Bajt, A. Barty, R. Bean, K. Beyerlein, M. Bublitz, N. Drachmann, J. Gregersen, H.O. Jönsson, W. Kabsch, S. Kassemeyer, J.E. Koglin, M. Krumrey, D. Mattle, M. Messerschmidt, P. Nissen, L. Reinhard, O. Sitsel, D. Sokaras, G.J. Williams, S. Hau-Riege, N. Timneanu, C. Caleman, H.N. Chapman, S. Boutet, I. Schlichting
J. Synchrotron Rad. **22** (2015) 2, 225–238
doi:10.1107/S1600577515002349

Insight into Bio-metal Interface Formation in vacuo: Interplay of S-layer Protein with Copper and Iron
A.A. Makarova, E.V. Grachova, V.S. Neudachina, L.V. Yashina, A. Blüher, S. Molodtsov, M. Mertig, H. Ehrlich, V.K. Adamchuk, C. Laubschat, D.V. Vyalikh
Sci. Rep. **5** (2015), 8710
doi:10.1038/srep08710

Isotope effects in resonant two-color photoionization of Xe in the region of the $5p^5(^2P_{1/2})4f[5/2]_2$ autoionizing state
E. Gryzlova, P. O'Keeffe, D. Cubaynes, G.A. Garcia, L. Nahon, A.N. Grum-Grzhimailo, M. Meyer
New J. Phys. **17** (2015), 043054
doi:10.1088/1367-2630/17/4/043054

Joint European XFEL and DESY Photon Science Users' Meeting 2015
W. Laasch, A. Schwarz
Synchrotron Radiat. News **28** (2015), 50–53
doi:10.1080/08940886.2015.1037684

Local structure of semicrystalline P3HT films probed by nanofocused coherent X-rays
R. Kurta, L. Grodd, E. Mikayelyan, O. Gorobtsov, I. Zaluzhnyy, I. Fratoddi, I. Venditti, M.V. Russo, M. Sprung, I. Vartaniants, S. Grigorian
Phys. Chem. Chem. Phys. **17** (2015), 7404–7410
doi:10.1039/C5CP00426H

Magnetic Measurement Techniques for the Large-Scale Production of Undulator Segments for the European XFEL
Y. Li, S. Abeghyan, K.-H. Berndgen, M. Bagha-Shanjani, G. Deron, U. Englisch, S. Karabekyan, B. Ketenoglu, M. Knoll, F. Wolff-Fabris, M. Viehweger, M. Yakopov, J. Pflueger
Synchrotron Radiat. News **28** (2015), 23–28
doi:10.1080/08940886.2015.1037679

Mechanical properties of niobium radio-frequency cavities
G. Ciovati, P. Dhakal, J. Matalevich, G. Myneni, J. Iversen, A. Matheisen, W. Singer, A. Schmidt
Mater. Sci. Eng., A **642** (2015), 117–127
doi:10.1016/j.msea.2015.06.095

NEXAFS Study of the Composite Materials MWCNTs—Pyrolytic Metals by Synchrotron Radiation
V.N. Sivkov, O.V. Petrova, S.V. Nekipelov, A.M. Obiedkov, B.S. Kaverin, A.I. Kirillov, N.M. Semenov, G.A. Domrachev, V.A. Egorov, S.A. Gusev, D.V. Vyalikh, S. Molodtsov
Fuller. Nanotub. Car. N. **23** (2015), 17–19
doi:10.1080/1536383X.2012.758113

Novel nanostructured hematite–spongin composite developed using an extreme biomimetic approach
T. Szatkowski, M. Wysokowski, G. Lota, D. Pęziak, V.V. Bazhenov, G. Nowaczyk, J. Walter, S. Molodtsov, H. Stöcker, C. Himcinschi, I. Petrenko, A.L. Stelling, S. Jurga, T. Jesionowski, H. Ehrlich
RSC Adv. **5** (2015), 79031–79040
doi:10.1039/C5RA09379A

Optimized Finite Difference Method for the Full-Potential XANES Simulations: Application to Molecular Adsorption Geometries in MOFs and Metal–Ligand Intersystem Crossing Transients
S.A. Guda, A.A. Guda, M.A. Soldatov, K.A. Lomachenko, A.L. Bugaev, C. Lamberti, W. Gawelda, C. Bressler, G. Smolentsev, A.V. Soldatov, Y. Joly
J. Chem. Theory Comput. **11** (2015), 4512–4521
doi:10.1021/acs.jctc.5b00327

Powder diffraction and synchrotron radiation, a powerful tool in the investigation of new compounds: $CdBr_2$(3-fluoroaniline)$_2$ and $CdBr_2$ (4-fluoroaniline)$_2$
M. Grzesiak-Nowak, G. Appleby, W. Łasocha
X-Ray Spectrom. **44** (2015), 398–403
doi:10.1002/xrs.2647

Probing photoelectron angular distributions in molecules with polarization-controlled two-color above-threshold ionization
T. Leitner, R. Taïeb, M. Meyer, P. Wernet
Phys. Rev. A **91** (2015), 06341
doi:10.1103/PhysRevA.91.063411

Sensitivity of Nonlinear Photoionization to Resonance Substructure in Collective Excitation
T. Mazza, A. Karamatskou, M. Ilchen, S. Bakhtiarzadeh, A.J. Rafipoor, P. O'Keeffe, T.J. Kelly, N. Walsh, T.J. Costello, M. Meyer, R. Santra
Nat. Commun. **6** (2015), 6799
doi:10.1038/ncomms7799

Single Shot Polarization Characterization of XUV FEL Pulses from Crossed Polarized Undulators
E. Ferrari, E. Allaria, J. Buck, G. De Ninno, B. Diviacco, D. Gauthier, L. Giannessi, L. Glaser, Z. Huang, M. Ilchen, G. Lambert, A.A. Lutman, B. Mahieu, G. Penco, C. Spezzani, J. Viefhaus
Sci. Rep. **5** (2015), 13531
doi:10.1038/srep13531

Soft X-ray Free-Electron Laser Induced Damage to Inorganic Scintillators
T. Burian, V. Hájková, J. Chalupský, L. Vyšín, P. Boháček, M. Přeček, J. Wild, C. Özkan, N. Coppola, S.D. Farahani, J. Schulz, H. Sinn, T. Tschentscher, J. Gaudin, S. Bajt, K. Tiedtke, S. Toleikis, H.N. Chapman, R.A. Loch, M. Jurek, R. Sobierajski, J. Krzywinski, S. Moeller, M. Harmand, G. Galasso, M. Nagasono, K. Saskl, P. Sovák, L. Juha
Opt. Mater. Express **5** (2015), 254–264
doi:10.1364/OME.5.000254

Solvothermal synthesis of hydrophobic chitin–polyhedral oligomeric silsesquioxane (POSS) nanocomposites
M. Wysokowski, K. Materna, J. Walter, I. Petrenko, A.L. Stelling, V.V. Bazhenov, Ł. Klapiszewski, T. Szatkowski, O. Lewandowska, D. Stawski, S. Molodtsov, H. Maciejewski, H. Ehrlich, T. Jesionowski
Int. J. Biol. Macromol. **78** (2015), 224–229
doi:10.1016/j.ijbiomac.2015.04.014

Spatially resolved x-ray studies of liquid crystals with strongly developed bond-orientational order
I.A. Zaluzhnyy, R. Kurta, E.A. Sulyanova, O. Gorobtsov, A. Shabalin, A. Zozulya, A.P. Menushenkov, M. Sprung, B.I. Ostrovskii, I.A. Vartanyants
Phys. Rev. E **91** (2015), 042506
doi:10.1103/PhysRevE.91.042506

Specification of X-ray Mirrors in Terms of System Performance: new Twist to an old Plot
V.V. Yashchuk, L. Samoylova, I.V. Kozhevnikov
Opt. Eng. **54** (2015), 025108
doi:10.1117/1.OE.54.2.025108

Studying planetary matter using intense x-ray pulses
K. Appel, M. Nakatsutsumi, A. Pelka, G. Priebe, I. Thorpe, T. Tschentscher
Plasma Phys. Contr. F. **57** (2015), 014003
doi:10.1088/0741-3335/57/1/014003

Synthesis, crystal structure, and magnetism of $A_2Co_{12}As_7$ (A=Ca, Y, Ce–Yb)
X. Tan, V. Ovidiu Garlea, P. Chai, A. Geondzhian, A. Yaroslavtsev, Y. Xin, A. Menushenkov, R. Chernikov, M. Shatruk
J. Solid State Chem. **233** (2015), S0022459615301407
doi:10.1016/j.jssc.2015.08.038

The European X-ray Free-Electron Laser: toward an ultra-bright, high repetition-rate x-ray source
M. Altarelli
High Power Laser Sci. Eng. **3** (2015), e18
doi:10.1017/hpl.2015.17

The Extreme Conditions Beamline P02.2 and the Extreme Conditions Science Infrastructure at PETRA III
H.-P. Liermann, Z. Konôpková, W. Morgenroth, K. Glazyrin, J. Bednarčik, E.E. McBride, S. Petitgirard, J.T. Delitz, M. Wendt, Y. Bican, A. Ehnes, I. Schwark, A. Rothkirch, M. Tischer, J. Heuer, H. Schulte-Schrepping, T. Kracht, H. Franz
J. Synchrotron Radiat. **22** (2015), 908–924
doi:10.1107/S1600577515005937

Theoretical computation of the polarization characteristics of an X-ray Free-Electron Laser with planar undulator
G. Geloni, V. Kocharyan, E. Saldin
Opt. Commun. **356** (2015), 435–444
doi:10.1016/j.optcom.2015.07.048

Three-dimensional coherent X-ray diffractive imaging of whole frozen-hydrated cells
J.A. Rodriguez, R. Xu, C.-C. Chen, Z. Huang, H. Jiang, A.L. Chen, K.S. Raines, A. Pryor Jr, D. Nam, L. Wiegart, C. Song, A. Madsen, Y. Chushkin, F. Zontone, P.J. Bradley, J. Miao
IUCrJ **2** (2015), 575–583
doi:10.1107/S205225251501235X

Three-Dimensional Reconstruction of the Giant Mimivirus Particle with an X-Ray Free-Electron Laser
T. Ekeberg, M. Svenda, C. Abergel, F.R.N.C. Maia, V. Seltzer, J.-M. Claverie, M. Hantke, O. Jönsson, C. Nettelblad, G. van der Schot, M. Liang, D.P. DePonte, A. Barty, M.M. Seibert, B. Iwan, I. Andersson, N.D. Loh, A.V. Martin, H. Chapman, C. Bostedt, J.D. Bozek, K.R. Ferguson, J. Krzywinski, S.W. Epp, D. Rolles, A. Rudenko, R. Hartmann, N. Kimmel, J. Hajdu
Phys. Rev. Lett. **114** (2015) 9, 098102
doi:10.1103/PhysRevLett.114.098102

Tomography of a Cryo-immobilized Yeast Cell Using Ptychographic Coherent X-Ray Diffractive Imaging
K. Giewekemeyer, C. Hackenberg, A. Aquila, R. Wilke, M. Groves, R. Jordanova, V. Lamzin, G. Borchers, K. Saksl, A. Zozulya, M. Sprung, A.P. Mancuso
Biophys. J. **109** (2015), 1986–1995
doi:10.1016/j.bpj.2015.08.047

Tuning method for phase shifters with very low first field integral errors for the European X-ray Free Electron Laser
Y. Li, J. Pflueger
Phys. Rev. ST Accel. Beams **18** (2015), 030703
doi:10.1103/PhysRevSTAB.18.030703

Ultra-high-resolution inelastic X-ray scattering at high-repetition-rate self-seeded X-ray free-electron lasers
O. Chubar, G. Geloni, V. Kocharyan, A. Madsen, E. Saldin, S. Serkez, Y. Shvyd'ko, J. Sutter
J. Synchrotron Rad. 23 (2016), 410-424
doi:10.1107/S1600577515024844

Ultrafast electron kinetics in short pulse laser-driven dense hydrogen
U. Zastrau, P. Sperling, C. Fortmann-Grote, A. Becker, T. Bornath, R. Bredow, T. Döppner, T. Fennel, L.B. Fletcher, E. Förster, S. Göde, G. Gregori, M. Harmand, V. Hilbert, T. Laarmann, H.J. Lee, T. Ma, K.H. Meiwes-Broer, J.P. Mithen, C.D. Murphy, M. Nakatsutsumi, P. Neumayer, A. Przystawik, S. Skruszewicz, J. Tiggesbäumker, S. Toleikis, T. White, S. Glenzer, R. Redmer, T. Tschentscher
J. Phys. B: At. Mol. Opt. Phys. **48** (2015), 224004
doi:10.1088/0953-4075/48/22/224004

Ultrafast Terahertz Gating of the Polarization and Giant Nonlinear Optical Response in $BiFeO_3$ Thin Films
F. Chen, J. Goodfellow, S. Liu, I. Grinberg, M.C. Hoffmann, A.R. Damodaran, Y. Zhu, P. Zalden, X. Zhang, I. Takeuchi, A.M. Rappe, W.L. Martin, H. Wen, A.M. Lindenberg
Adv. Mat. **27** (2015), 6371–6375
doi10.1002/adma.201502975

Visualizing the non-equilibrium dynamics of photoinduced intramolecular electron transfer with femtosecond X-ray pulses
S.E. Canton, K.S. Kjær, G. Vankó, T.B. van Driel, S.-I. Adachi, A. Bordage, C. Bressler, P. Chabera, M. Christensen, A.O. Dohn, A. Galler, W. Gawelda, D. Gosztola, K. Haldrup, T. Harlang, Y. Liu, K. B. Møller, Z. Németh, S. Nozawa, M. Pápai, T. Sato, T. Sato, K. Suarez-Alcantara, T. Togashi, K. Tono, J. Uhlig, D.A. Vithanage, K. Wärnmark, M. Yabashi, J. Zhang, V. Sundström, M.M. Nielsen
Nat. Commun. **6** (2015), 6359
doi:10.1038/ncomms7359

XPS study of the effects of long-term Ar^+ ion and Ar cluster sputtering on the chemical degradation of hydrozincite and iron oxide
R. Steinberger, J. Walter, T. Greunz, J. Duchoslav, M. Arndt, S. Molodtsov, D.C. Meyer, D. Stifter
Corros. Sci. **99** (2015), 66–75
doi:10.1016/j.corsci.2015.06.019

REPORTS

Detector Alignment at European XFEL: Concepts and Responsibilities
S. Hauf
Technical Note (2015)
XFEL.EU TN-2015-001

Effect of Aberration of Light in X-ray Free Electron Lasers
G. Geloni, V. Kocharyan, E. Saldin
Red Report (2015)
DESY 15-208
arXiv:1511.01375v1

HV Guidelines for Scientific Instruments
A. Schmidt, M. Dommach
Technical Note (2015)
XFEL.EU TN-2015-003

Modulated Electron Bunch with Amplitude Front Tilt in an Undulator
G. Geloni, V. Kocharyan, E. Saldin
DESY Red Report (2015)
DESY 15-236
arXiv:1512.01056

CONTRIBUTIONS TO CONFERENCE PROCEEDINGS

340W Femtosecond Burst-mode Non-collinear Optical Parametric Amplifier for the European XFEL Pump-probe-laser
M. Pergament, M. Kellert, K. Kruse, J. Wang, G. Palmer, L. Wissmann, U. Wegner, M. Emons, M. Lederer
Advanced Solid State Lasers 2015, Berlin, Germany, 4–9 October 2015
Proceedings of Advanced Solid State Lasers, ATu4A.4 (2015)
ISBN 978-1-943580-02-6
doi:10.1364/ASSL.2015.ATu4A.4

5kW burst-mode femtosecond amplifier system for the European XFEL pump-probe laser development
M. Kellert, M. Pergament, K. Kruse, J. Wang, G. Palmer, G. Priebe, L. Wissmann, U. Wegner, M. Emons, J. Morgenweg, T. Mans, M. Lederer
2015 European Conference on Lasers and Electro-Optics – European Quantum Electronics Conference (CLEO Europe – EQEC 2015), Munich, Germany, 21–25 June 2015
Proceedings of CLEO Europe, CA_3_5 (2015)
ISBN 978-1-4673-7475-0

Control of gap dependent phase errors on the undulator segments for the European XFEL
Y. Li, J. Pflueger
International Free Electron Laser Conference (FEL 2015), Daejeon, South Korea, 23–28 August 2015
Proceedings of FEL2015, FEL Technology and HW: Undulator, Magnets, Photon Diagnostics, and Beamlines, WEP054 (2015)
ISBN 978-3-95450-134-2

Design and Initial Characterisation of X-ray Beam Diagnostic Imagers for the European XFEL
A. Koch, W. Freund, J. Grünert, M. Planas, T. Roth, L. Samoylova, V. Lyamayev, S.G. Biedron
SPIE Optics + Optoelectronics: Advances in X-ray Free-Electron Laser Instrumentation, Prague, Czech Republic, 12 May 2015
Proc. SPIE 9512, Advances in X-ray Free-Electron Lasers Instrumentation III, 95121R (2015)
doi:10.1117/12.2182463

FEL Simulations with OCELOT
I. Agapov, G. Geloni, S. Tomin, M. Dohlus, I. Zagorodnov
6th International Particle Accelerator Conference (IPAC 2015), Richmond, VA, USA, 3–8 May 2015
Proceedings of IPAC 2015, 210–212 (2015)
ISBN 978-3-95450-168-7

Integrated Detector Control and Calibration Processing at the European XFEL
A. Münnich, S. Hauf, M. Kuster, P.-M. Lang, B. Heisen, F. Januschek, N. Raab, T. Rüter, M. Turcato, J. Sztuk-Dambiet
15th International Conference on Accelerator and Large Experimental Control Systems (ICALEPS 2015), Melbourne, Australia, 18–23 October 2015
Proceedings of ICALEPS 2015, WEPGF050 (2015)
arXiv:1601.01794

Karabo-GUI: The Multi-Purpose Graphical Front-End for the Karabo Framework
B. Heisen, M. Teichmann, K. Weger, J. Wiggins
15th International Conference on Accelerator and Large Experimental Physics Control Systems (ICALEPCS 2015), Melbourne, Australia, 17–23 October 2015
Proceedings of ICALEPCS 2015, User Interfaces and Tools, WEPGF153 (2015)
ISBN 978-3-95450-148-9

Long Range Order and Spin-Fluctuations in Strongly Correlated Electron System with Valence Instability
P.A. Alekseev, A. Menushenkov, J.-M. Mignot, K.S. Nemkovski, A.A.Yaroslavtsev, D. Kozlenko
18th Conference on Plasma-Surface Interactions (PSI 2015), Moscow, Russia, Physics Procedia **71** (2015), 303–307
doi:10.1016/j.phpro.2015.08.331

Metrological characterization of a large aperture Fizeau for x-ray mirrors measurement
M. Vannoni, I. Freijo-Martin, B. Bodermann, K. Frenner, R.M. Silver
SPIE Optical Metrology, Munich, Germany, 21 June 2015
Proc. SPIE 9526, Modeling Aspects in Optical Metrology V, 95260A (2015)
doi:10.1117/12.2184748

Photon Diagnostics and Photon Beamlines Installations at the European XFEL
J. Gruenert, A. Koch, N. Kujala, W. Freund, M. Planas, F. Dietrich, J. Buck, J. Liu, H. Sinn, M. Dommach, S. Molodtsov
37th International Free Electron Laser Conference (FEL 2015), Daejeon, South Korea, 23–28 Aug 2015
Proceedings of FEL 2015, FEL Technology and HW: Undulator, Magnets, Photon Diagnostics, and Beamlines, WED03 (2015)
ISBN 978-3-95450-134-2

Possibility of Longitudinal Bunch Compression in Petra III
I. Agapov, S. Tomin, R. Wanzenberg
2015 International Personnel Assessment Council Conference (IPAC 2015), Atlanta, Georgia, USA, 19–22 July 2015
Proceedings of IPAC 2015, Photon Sources and Electron Accelerators: Synchrotron Radiation Facilities, TUPWA036 (2015)
ISBN 978-3-95450-168-7

Scheme to increase the output average spectral flux of the European XFEL at 14.4 keV
G. Geloni, V. Kocharyan, E. Saldin
37th International Free Electron Laser Conference (FEL 2015), Daejeon, South Korea, 23–28 Aug 2015
Proceedings of FEL 2015, Seeded FELs, MOP085 (2015)
ISBN 978-3-95450-134-2

Statistical Optimization of FEL Performance
I. Agapov, G. Geloni, I. Zagorodnov
6th International Particle Accelerator Conference (IPAC 2015), Richmond, Virginia, USA, 3–8 May 2015
Proceedings of IPAC 2015, Photon Sources and Electron Accelerators: Free Electron Lasers, 1496–1498 (2015)
ISBN 978-3-95450-168-7

The Large Scale European XFEL Control System: Overview and Status of the Commissioning
R. Bacher, A. Aghababyan, P. Bartkiewicz, T. Boeckmann, T. Bruns, M. Clausen, T. Delfs, P. Duval, L. Froehlich, W. Gerhardt, C. Gindler, J. Hatje, O. Hensler, J. Jaeger, R. Kammering, S. Karstensen, H. Keller, V. Kocharyan, O. Korth, A. Labudda, T. Limberg, S. Meykopff, M. Moeller, J. Penning, A. Petrosyan, G. Petrosyan, L. Petrosyan, V. Petrosyan, P. Pototzki, K. Rehlich, S. Rettig-Labusga, H. Rickens, G. Schlesselmann, B. Schoeneburg, E. Sombrowski, M. Staack, C. Stechmann, J. Szczesny, M. Walla, J. Wilgen, T. Wilksen, H.G. Wu, S. Abeghyan, A. Beckmann, D. Boukhelef, N. Coppola, S. Esenov, R. Fernandes, P. Gessler, G. Giambartolomei, S. Hauf, B. Heisen, S. Karabekyan, M. Kumar, L. Maia, A. Parenti, A. Silenzi, H. Sotoudi Namin, J. Szuba, M. Teichmann, J. Tolkiehn, K. Weger, J. Wiggins, K. Wrona, M. Yakopov, C. Youngman
15th International Conference on Accelerator and Large Experimental Physics Control Systems (ICALEPCS 2015), Melbourne, Australia, 17–23 October 2015
Proceedings of ICALEPCS 2015, Project Status Reports, MOA3O02 (2015)
ISBN 978-3-95450-148-9

Ultrafast Dynamics Related to Spin Crossover Processes in Single Crystal $[Fe^{II}(bpy)_3](PF_6)_2$
K. Yamanouchi, S. Cundiff, R. de Vivie-Riedle, M. Kuwata-Gonokami, L. DiMauro, R. Field, L. Liu, C. Lu, Y. Jiang, W. Gawelda, R.J.D. Miller
19th International Conference, Okinawa Convention Center, Okinawa, Japan, 7–11 July 2014
Ultrafast Phenomena XIX **162** (2015) 279–282
ISBN 978-3-319-13241-9 (print)
ISBN 978-3-319-13242-6 (electronic)
doi:10.1007/978-3-319-13242-6_68

Use of Automation in Commissioning Process of the Undulators of the European X-Ray Free Electron Laser
S. Karabekyan, J. Pflueger, H. Lin, Y. Liu, X. Wang
15th International Conference on Accelerator and Large Experimental Physics Control Systems (ICALEPCS 2015), Melbourne, Australia, 17–23 Oct 2015
Proceedings of ICALEPCS 2015, Systems Engineering, Project Management, MOD3O05 (2015)
ISBN: 978-3-95450-148-9 ■

AMO
Atomic, Molecular and Optical Science [LCLS instrument]

ANL
Argonne National Laboratory in Argonne, Illinois, USA

APS
Advanced Photon Source in Argonne, Illinois, USA

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

BMBF
German Federal Ministry of Education and Research

BNL
Brookhaven National Laboratory in Upton, New York, USA

CAD
computer-aided design

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

CLF
Central Laser Facility at Rutherford Appleton Laboratory in Didcot, UK

CNR
National Research Council in Italy

CNRS
Centre National de la Recherche Scientifique in Orsay, France

CUI
Centre for Ultrafast Imaging in Hamburg, Germany

DFG
Deutsche Forschungsgemeinschaft in Germany

DESY
Deutsches Elektronen-Synchrotron in Hamburg and Zeuthen, Germany

DLR
Deutsches Zentrum für Luft- und Raumfahrt in Germany

DTU
Technical University of Denmark

Elettra
Elettra Sincrotrone Trieste in Italy

ESRF
European Synchrotron Radiation Facility in Grenoble, France

FEL
free-electron laser

FERMI
Free Electron Laser for Multidisciplinary Investigations at Elettra Sincrotrone Trieste in Italy

FLASH
Free-Electron Laser in Hamburg at Deutsches Elektronen-Synchrotron (DESY), Germany

GU
Gothenburg University

GUI
graphical user interface

HZB
Helmholtz-Zentrum Berlin (HZB) in Germany

HZDR
Helmholtz-Zentrum Dresden-Rossendorf in Germany

IFJ-PAN
Henryk Niewodniczański Institute of Nuclear Physics of the Polish Academy of Sciences in Kraków, Poland

IHEP
Institute of High Energy Physics at the Chinese Academy of Sciences in Beijing, China

INFN
Istituto Nazionale di Fisica Nucleare in Italy

INR
Institute for Nuclear Research of the Russian Academy of Sciences (RAS) in Troitsk, Russia

IPJ
Andrzej Soltan Institute for Nuclear Studies in Swierk, Poland

IRFU
Institut de Recherche sur les lois Fondamentales de l'Univers in Saclay, France

JASRI
Japanese Synchrotron Radiation Research Institute

JINR
Joint Institute for Nuclear Research in Dubna, Russia

KIT
Karlsruhe Institute of Technology in Germany

KTH
Royal Institute of Technology in Stockholm, Sweden

LAL in Orsay
Laboratoire de l'Accélérateur Linéaire in Orsay, France

LCLS
Linac Coherent Light Source at SLAC National Accelerator Laboratory in Menlo Park, California, USA

MBI
Max Born Institute for Nonlinear Optics and Short Pulse Spectroscopy in Berlin, Germany

MEC
Matter in Extreme Conditions [LCLS 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

PETRA III
PETRA III at DESY in Hamburg, Germany

PSI
Paul Scherrer Institut in Villigen, Switzerland

PTB
Physikalisch-Technische Bundesanstalt in Berlin, Germany

RAL
Rutherford Appleton Laboratory in the UK

SACLA
SPring-8 Angstrom Compact Free Electron Laser in Hyogo, Japan

SASE
self-amplified spontaneous emission

SLAC
SLAC National Accelerator Laboratory in Menlo Park, California, USA

SU
Stockholm University in Sweden

TU Dortmund
Technische Universität Dortmund in Germany

TUHH
Technische Universität Hamburg-Harburg in Germany

UCL
University College London in the UK

UPM
Universidad Politécnica de Madrid, Spain

UPMC
University Pierre and Marie Curie in Paris, France

UU
Uppsala University in Sweden

WUT
Wrocław University of Technology in Poland

XUV
extreme ultraviolet radiation

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 2016

European XFEL Annual Report 2015

Published by
European XFEL GmbH

Editor in chief
Massimo Altarelli

Managing editor
Bernd Ebeling

Copy editors
Kurt Ament
Ilka Flegel, Textlabor, Jena
Joseph W. Piergrossi

Image editor
Frank Poppe

Coordination
Joseph W. Piergrossi
Frank Poppe

Layout and graphics
blum design und kommunikation GmbH, Hamburg

Photos and graphs
Blunck+Morgen Architekten, © European XFEL (pp. 15, 69);
Brookhaven National Laboratory (p. 93); DESY (pp. 17, 50–52, 59–61, 70–77, 78, 79–84, 90, 117);
FHH, Landesbetrieb Geoinf. und Vermessung (aerial views pp. 20–21); Giewekemeyer et al. (p. 134);
Nature Publishing Group (p. 138); RAL, Harwell Oxford (p. 153); Rey.Hori, © European XFEL (pp. 116, 133);
Uppsala University (p. 14); WTM Engineers, © European XFEL (p. 68)
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:10.3204/XFEL.EU/AR-2015
http://www.xfel.eu/documents

Copy deadline
31 December 2015

www.xfel.eu