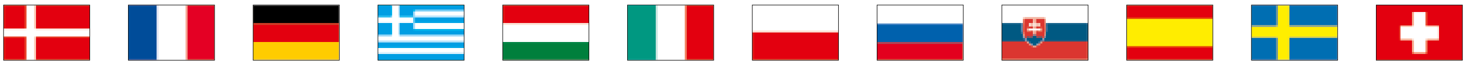
European
XFEL

ANNUAL REPORT

European X-Ray Free-Electron Laser Facility GmbH

2013

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



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XFEL

2013

ANNUAL REPORT

European X-Ray
Free-Electron Laser
Facility GmbH

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

Dear Readers,

This annual report is intended to bring you up to date on the progress, activities, and challenges 2013 brought to the European XFEL facility.

In this complex and technically demanding project, which is being implemented at many laboratories and companies throughout Europe and beyond, there are many areas in which we can report very good progress, and a few critical issues that are generating delays and that require a high level of attention.

In 2013, we were very glad to announce the completion of underground construction, with no substantial trespassing of the planned time and budget boundaries and without any serious accidents. This important milestone was celebrated in June with a small ceremony attended by our staff, employees of Deutsches Elektronen-Synchrotron (DESY), and representatives of local authorities and European XFEL shareholders. The 4500 m^2 experiment hall and the tunnels produced a lasting impression on our guests. With the completion of underground construction, the tunnels became available for infrastructure installation work, which has been making vigourous progress. Also during the year, the first above-ground buildings at the DESY-Bahrenfeld and Osdorfer Born sites have been moving towards completion.

The series production of components for the nearly 2 km long linear accelerator and for a total of 0.5 km of undulators went into full swing. Of the first produced batches of the required 800 superconducting accelerating cavities, nearly all show a performance exceeding the specification for the accelerating gradient. This is a very good sign of future reliable performance of the accelerator.

As the infrastructure installation for the electron beam injection systems progressed, the first accelerator component, the electron source, was installed. Commissioning with radio frequency was started before the end of the year—another important milestone.

By the end of 2013, more than 60 of the 91 required 5 m long undulator segments had been delivered and tested on the measuring benches of the European XFEL Undulator Systems group. First prototypes of the very demanding, 80 cm long high-quality mirrors for the photon transport systems gave solid indication that the specifications, which are pushing the state of the art, can be met. Two small-area tiles of the future Large Pixel Detector (LPD) and Adaptive Gain Integrating Pixel Detector (AGIPD) imaging detectors demonstrated the acquisition speed required to keep up with the high number of pulses that the facility will generate. The LPD system also underwent the first tests using the free-electron laser (FEL) pulses of the Linac Coherent Light Source (LCLS) at SLAC National Accelerator Laboratory in Menlo Park, California. Progress on the electron and photon beam diagnostic systems was good; in particular, photon beam diagnostics intensity and polarization monitors were successfully tested at FEL sources. The development of experiment laser systems and data acquisition hardware and software also gives good reason for optimism that the respective work packages will achieve their ambitious goals.

There are, however, critical items in the production of components for the accelerator complex that led to an adjustment of the schedule. In close cooperation with our shareholders, the European XFEL Management Board and DESY, as the coordinator of the Accelerator Consortium, are developing countermeasures to mitigate further schedule problems. The expected disappointment of our future user communities is providing strong motivation for our efforts to contain delays. These efforts are continuing with increased energy in 2014.

User interest in the facility continues to be very strong. The number of participants in our user meetings is steadily increasing, and the seven approved user consortia, which intend to contribute to the European XFEL by constructing scientific instruments, ancillary instrumentation, and technical infrastructure beyond the original scope of the facility, have made good progress towards acquiring the necessary funds. In particular, two user consortia in the area of the life sciences, the Serial Femtosecond Crystallography (SFX) and the XFEL-based Integrated Biology Infrastructure (XBI) projects, obtained sufficient funding to start construction of their infrastructure in the experiment hall and of the laboratory facilities at the same time as the baseline equipment. And in some countries that did not yet sign the European XFEL Convention, we see indications of a strong and growing scientific interest, which might lead to those respective countries later joining European XFEL as shareholders.

All achievements of 2013 were made possible by the hard work and the dedication of our staff—which now comprises more than 200 people—and of the many colleagues at DESY, in the laboratories participating through in-kind contributions, in user consortia, and in the European XFEL Council as well as in the various committees. To all of them, and to the science community at large for their trust and interest in the European XFEL, we want to express our sincere thanks.

Massimo Altarelli

Claudia Burger

Managing Directors

Serguei Molodtsov

Andreas S. Schwarz

Thomas Tschentscher

Scientific Directors

Robert K. Feidenhans'l

Dear Readers,

Almost four years have passed since European XFEL was founded and I was appointed chairman of the European XFEL Council. In this short time, significant accomplishments have been achieved. X-ray science at free-electron laser facilities has made such tremendous progress in these years that it is difficult to make predictions that will not be superseded by experimental and technological advances themselves.

In 2009, civil construction of the European XFEL facility had just started. Today, the tunnels, injector hall, and experiment hall are finished and ready to be filled with world-leading accelerator and X-ray science technology. In the past four years, I have had the pleasure of attending numerous celebrations of building and tunnel completion. The staff has increased from fewer than 50 employees in December 2009 to more than 200 in December 2013. Staff spirit and motivation is high.

User expectations for the facility are also very high. Last year, the DESY auditorium was packed for the 2013 Users' Meeting, and the same is expected for the coming years. The user community sees the huge potential that will be exploited as soon as the European XFEL facility starts operation, and they want to be at the forefront.

It has also been a pleasure to see that the European aspect of the facility is evolving. France will become a full member in 2014, and serious discussions are under way with new countries, such as Finland and Turkey, which will bring new know-how and skills to the facility.

In 2013, the European XFEL Council met three times, taking note of the reports of the European XFEL Council Chairman, Management Board, Administrative Finance Committee (AFC), Machine Advisory Committee (MAC), and Scientific Advisory Committee (SAC). Furthermore, the council discussed and decided a number of legal, financial, and organizational matters, as well as those related to user consortia and in-kind contributions.

At the end of my term, I am particularly pleased to have the opportunity to propose the extension of the contracts of the managing director and chairman of the management board, Massimo Altarelli, and the three scientific directors, Thomas Tschentscher, Andreas S. Schwarz, and Serguei Molodtsov, so they can complete their work with the managing and administrative director, Claudia Burger, to guide the European XFEL into the operation phase. We still face a few more years of hard work, but I am confident that the new facility has the staff, management, and council to overcome these final challenges.

I would like to thank the council delegates, observers and advisors, the management board, and the staff for all their efforts to make the European XFEL a world-leading facility. I look forward to seeing the facility go into operation in just a few years and to witnessing the opening of scientific fields that are yet to be discovered.

Robert K. Feidenhans’l

Chairman of the European XFEL Council

01

NEWS AND EVENTS

European XFEL made big strides in 2013, as underground construction finished and installation of the injector began. Scientists and other European XFEL employees met politicians, academics, and the public at a variety of events.

Accelerator tunnel during the Night of Science

January 2013

25 January

Record attendance at DESY and European XFEL Users' Meeting

The 2013 European XFEL and DESY Photon Science Users' Meeting sets a new participant record. From 23 to 25 January, about 800 scientists participate in the conference to hear the latest news about the advances in construction and research at the European XFEL and the newest developments at the Deutsches Elektronen-Synchrotron (DESY) light sources FLASH and PETRA III.

More than 500 participants, many of them young scientists, register for the first day, which is dedicated to European XFEL. In 2013, European XFEL is able to support more than 45 of them with travel grants—almost twice as many as in 2012. European XFEL wants to make the upcoming generation of scientists aware of the huge potential and research opportunities offered by X-ray free-electron lasers (FELs), says European XFEL Scientific Director Thomas Tschentscher.

February 2013

11 February

First technical design reports for scientific instruments and beamlines published

Work is in full swing at European XFEL to elaborate the technical details of the beamlines and the scientific instruments. A major milestone is achieved with the publication of the first three technical design reports (TDRs).

TDR: Scientific Instrument FXE describes the technical design of the Femtosecond X-Ray Experiments (FXE) instrument, which will be used for time-resolved X-ray absorption, emission, and diffuse-scattering studies.

TDR: Scientific Instrument SQS describes the technical design of the Small Quantum Systems (SQS) instrument, which will enable scientists to investigate processes in atoms, ions, molecules, and clusters occurring under highly intense beams using a variety of spectroscopy and imaging techniques.

TDR: X-Ray Optics and Beam Transport describes the technical realization of the X-ray beam transport systems that will be used to guide the X-ray radiation to the scientific instruments. The report includes a discussion of radiation safety and equipment protection.

14 February

Poland's Science Minister visits European XFEL and DESY

Poland's Minister of Science and Higher Education, Barbara Kudrycka, visits DESY and the European XFEL construction site. Poland is one of the eight shareholders of the European XFEL and is contributing, among other things, a test facility for more than 800 superconducting cavities to the construction of the X-ray laser. Together with European XFEL Managing Director Massimo Altarelli and DESY Board of Directors Chairman Helmut Dosch, Minister Kudrycka officially inaugurates the Accelerator Module Test Facility (AMTF) on the DESY campus.

The minister underlines that the construction of the European XFEL is—apart from research projects carried out at CERN near Geneva—the most important project to which Polish scientists contribute.

April 2013

19 April

European XFEL and LBNL start cooperation

European XFEL and Lawrence Berkeley National Laboratory (LBNL) in Berkeley, California, plan to cooperate in the areas of development and use of FELs. A memorandum of understanding outlining the framework of the cooperation is signed on 16 April at the European XFEL headquarters in Hamburg.

LBNL Director Paul Alivisatos says that the collaboration offers exciting opportunities. He adds that LBNL and European XFEL share common scientific goals and both sides can benefit from a close cooperation, especially when it comes to equipment that takes years to develop.

LBNL is a US Department of Energy (DOE) National Laboratory conducting a wide variety of scientific research. Among others, it operates the Advanced Light Source (ALS), a third-generation synchrotron, and is pursuing studies for a soft X-ray FEL based on a superconducting accelerator.

June 2013

6 June

European XFEL underground construction completed

An important milestone is reached: the underground civil engineering work for the European XFEL has been completed. About 300 guests from politics, academia, administration, and business gather to celebrate in Schenefeld. European XFEL Director Massimo Altarelli and DESY Director Helmut Dosch thank the construction companies and their personnel as well as the DESY construction department and other involved staff at European XFEL and DESY for their achievements.

The tunnels, which were completed in 2012, were excavated with two tunnel boring machines. Five photon tunnels end in the underground experiment hall in Schenefeld, where the X-ray flashes will be guided to up to 15 scientific instruments.

28 June

Russian Minister Livanov visits European XFEL

Russian Minister of Education and Science Dmitry Livanov visits European XFEL research facilities on the DESY campus in Hamburg, and the construction site in Schenefeld. The European XFEL Management Board and the DESY Board of Directors inform the minister about the progress and the scientific research opportunities at the X-ray FEL.

Like other shareholders, Russia contributes to the construction of the European XFEL not only in cash but in kind. Russian research institutes produce a number of different components, among them high-tech cryogenic components, thousands of parts for vacuum systems, 840 electromagnets weighing between 25 kg and 6 tonnes each, and three test stands for accelerator modules.

On his tour of European XFEL sites, Minister Livanov inaugurates the first test stand for the accelerator modules at the newly established European XFEL Accelerator Module Test Facility (AMTF).

August/September 2013

5 August

CORPES meeting puts spotlight on photoemission spectroscopy

From 29 July to 2 August 2013, European XFEL hosts the CORPES13 workshop, where 170 physicists from around the world present results from research in photoemissions of electron-correlated materials.

The CORPES13 workshop allows experimentalists and theoreticians to plan their next projects and build collaborations, many of which will utilize the European XFEL.

26 September

European XFEL participates in science festival

European XFEL participates in the 2013 Highlights der Physik science festival in Wuppertal, Germany. The event is hosted by the German Federal Ministry of Education and Research (BMBF), the German Physical Society (DPG), and Bergische Universität Wuppertal. It has the theme “From the Big Bang to the Universe”.

September 2013

30 September

Installation of European XFEL injector begins

The devices that create the electron beam necessary for producing the world’s brightest X-ray flashes start to find their place in Bahrenfeld. The electron injector will fire the electron bunches into the accelerating section of the European XFEL. Scientists and engineers at the European XFEL injector hall begin to install the different systems of the injector, many of which are uniquely tailored to produce a high number of intense X-ray flashes. DESY is building the injector as part of the German contribution to the European XFEL.

The special technology used includes a high-precision water-cooled electron gun, the first part of the injector. The electrons come from a negatively charged electrode, a piece of caesium telluride located inside the electron gun at the tunnel entrance seven storeys underground in the injector hall. When exposed to a UV laser pulse, the electrons are ejected from the electrode surface and form a cloud, called a “bunch”.

October 2013

16 October

Schleswig-Holstein’s Minister for Economic Affairs visits European XFEL

Reinhard Meyer, Minister of Economic Affairs, Employment, Transport, and Technology of the German federal state of Schleswig-Holstein, visits the European XFEL construction site in Schenefeld. The minister acquaints himself with the current status and next steps in the construction of the X-ray laser. Minister Meyer also discusses the current feasibility study for a European XFEL visitor centre as well as the consequences of the project for the local economy and infrastructure.

After the talks, European XFEL Managing and Administrative Director Claudia Burger and European XFEL Scientific Director Thomas Tschentscher lead Minister Meyer on a tour of the future experiment hall and part of the underground tunnel system. The minister states that the new X-ray laser will allow scientists to do cutting-edge research in Europe and will ensure that Germany retains a leading role in research and industry.

November 2013

6 November

European XFEL Night of Science exhibition attracts thousands

The European XFEL exhibition at the Hamburg Night of Science on the DESY campus attracts more visitors than ever before. DESY sees a record number of 18 000 visitors. Many of them come to the European XFEL exhibition at the injector complex entrance hall. Hundreds also go on a tour of the accelerator tunnel seven storeys below the entrance hall.

Visitors are able to build motors from batteries, experiment with vacuum pumping, use a zoetrope to mimic femtosecond serial imaging of molecules, view holographic images, and manipulate a simple optical laser array. DESY scientists help guide visitors through the tunnel exhibit. A light show in the tunnel demonstrates how electrons will be accelerated, and a composition made from sounds from the tunnel accompanies the exhibit.

European XFEL Managing Director Massimo Altarelli gives a lecture, and visitors also view a series of films showing the construction sites, along with a 3D film fly-through of the European XFEL tunnel.

December 2013

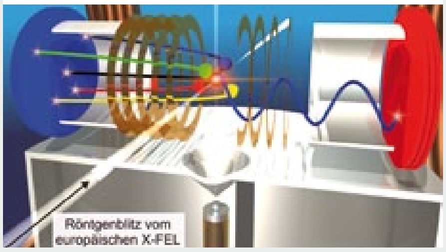
6 December

Ministry funds university research at the European XFEL

From 2013 to 2016, the German Federal Ministry of Education and Research (BMBF) will provide 7.5 million euro to fund 14 projects at 11 universities and one Max Planck Institute. The projects focus on the development of instruments, devices, and technologies for unique experiments at the European XFEL. The funds are available as part of a larger investment in collaborative research projects studying condensed matter at large research facilities.

European XFEL Scientific Director Thomas Tschentscher says he is pleased by the broad interest at the universities, which will allow European XFEL to benefit from their excellent research and ideas. He points out that the cooperation will help to prepare the next generation of scientists for the research opportunities at free-electron lasers (FELs).

The BMBF has made FEL research a funding priority, with the intent of further strengthening exceptional university research along with expertise in FEL development and use.

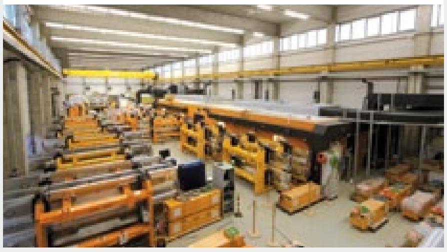


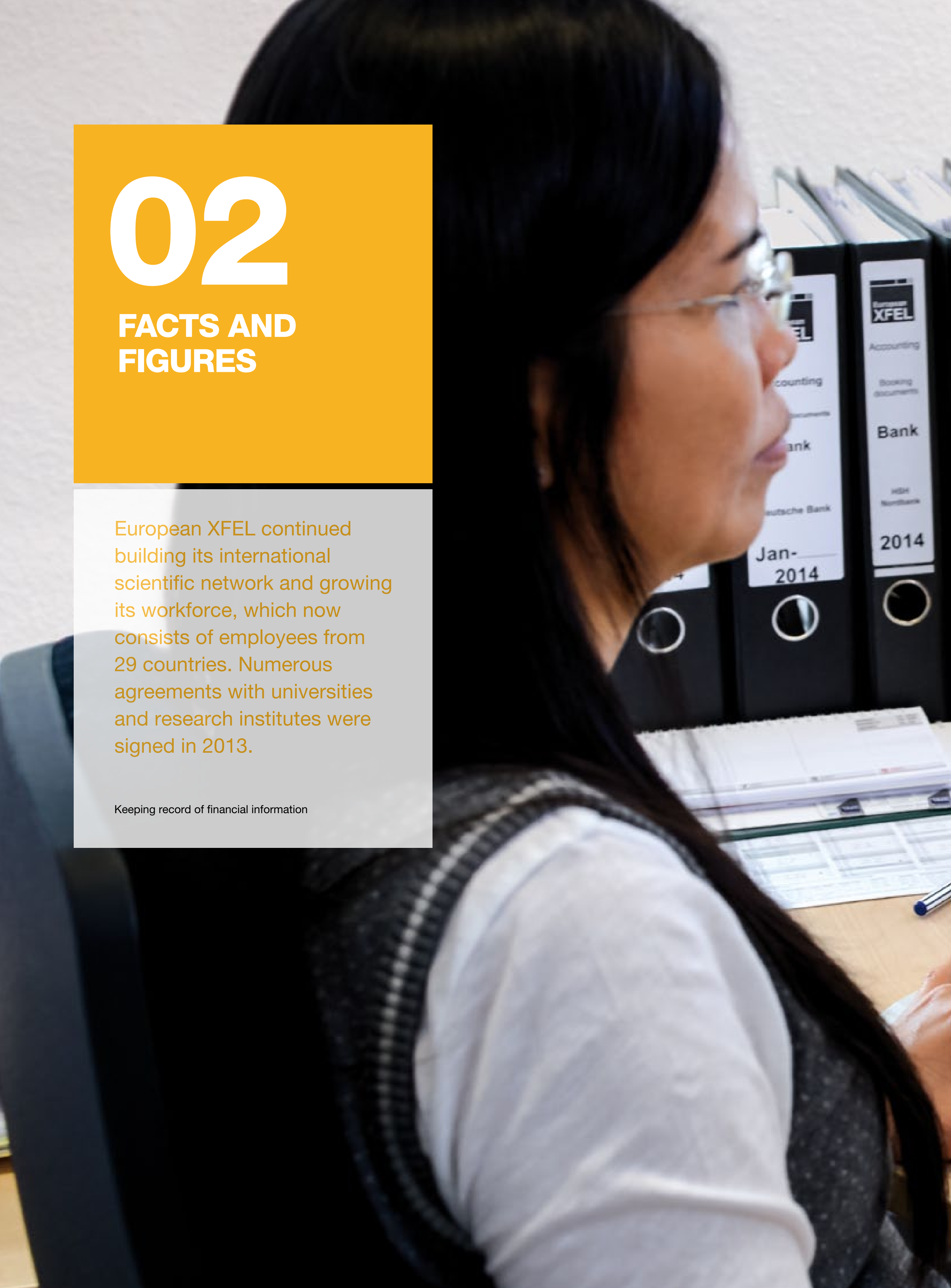
12 December

More than half of the undulator segments ready for installation

The undulator group has fully tuned 52 of the altogether 92 undulator segments. Tuned segments have been placed into storage, awaiting installation in the facility tunnels, which will begin in late 2014.

The undulators have to be finely tuned in order for the X-ray flashes to be generated reliably. After delivery of the assembled segments from external manufacturers to European XFEL, the most critical steps are done in house at the undulator hall on the DESY campus. The undulator group makes precise magnetic measurements that inform the tuning of the undulator segments. Following strict specifications, the poles are adjusted to micrometre precision. Tuning of the segments began in October 2012 and over time, the pace of production ramped up to one undulator segment per week.



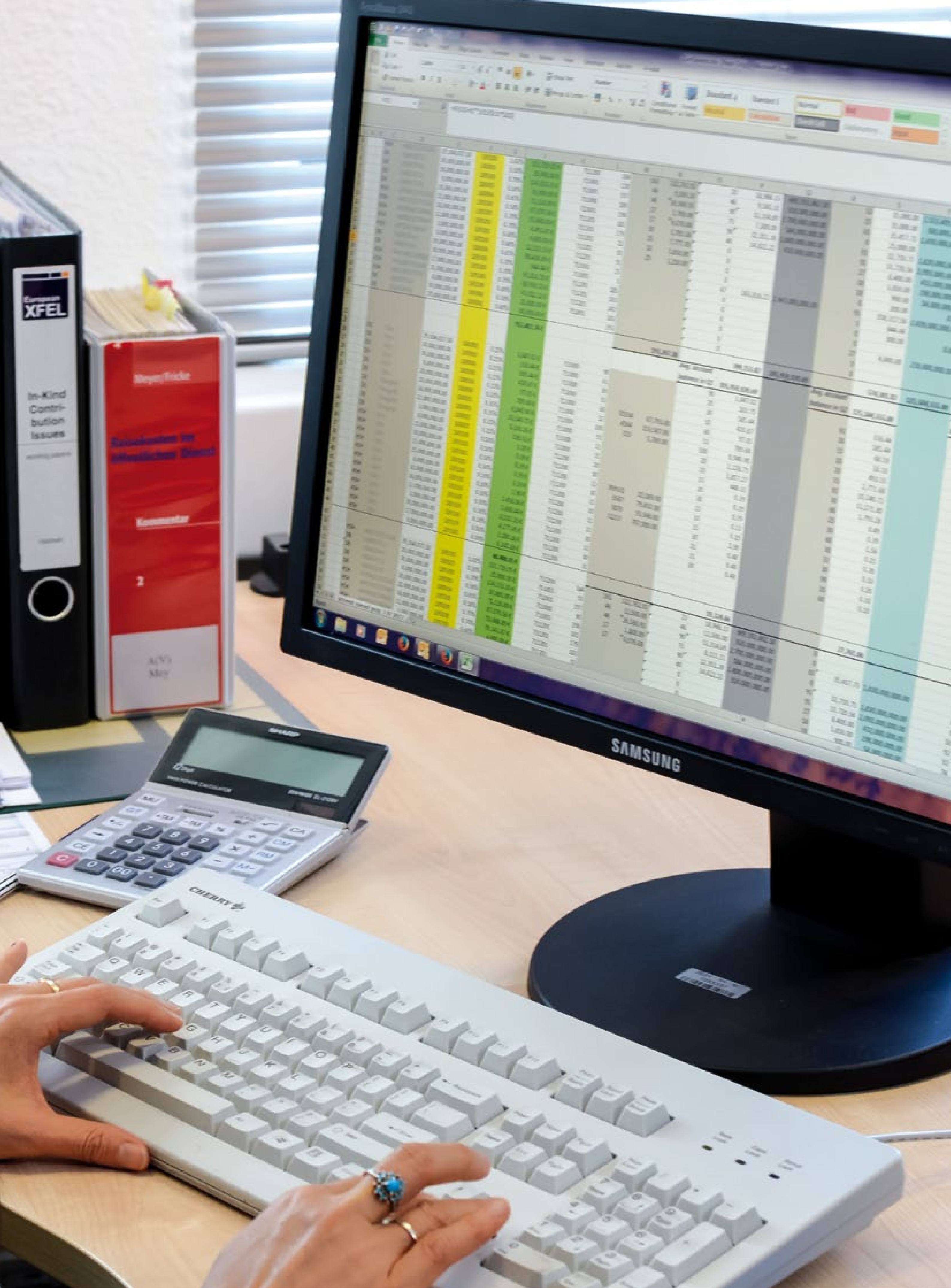


02

FACTS AND FIGURES

European XFEL continued building its international scientific network and growing its workforce, which now consists of employees from 29 countries. Numerous agreements with universities and research institutes were signed in 2013.

Keeping record of financial information


European XFEL
In-Kind Contribution Issues
Meyer/Fricke
Reisekosten im öffentlichen Dienst
Kommentar
2
SAMSUNG
SHARP
CHERRY

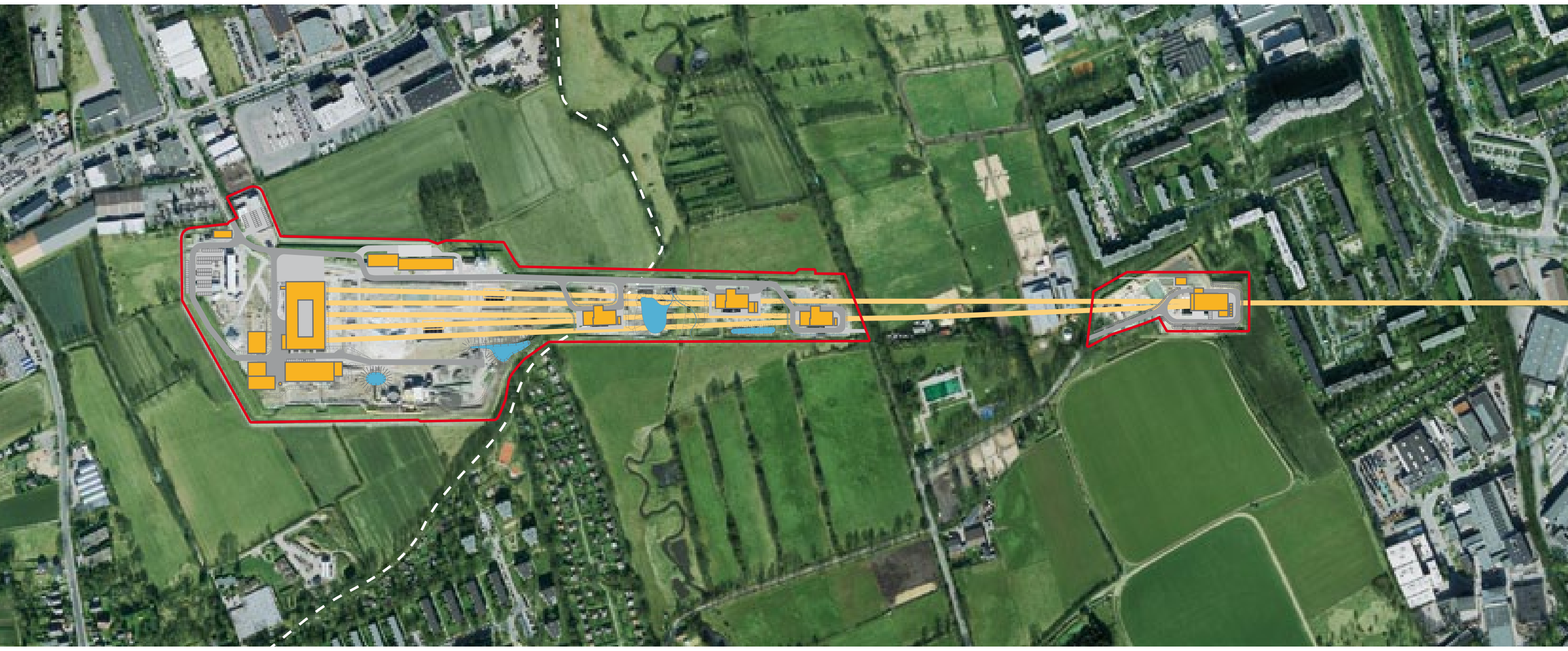


Figure 1 Aerial view of the European XFEL facility. **Right to left** DESY-Bahrenfeld, Osdorfer Born, and Schenefeld sites.

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 free-electron laser (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 synchrotron X-ray radiation sources.

Brilliant light 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 Deutsches Elektronen-Synchrotron (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 2013, 12 countries are participating in the European XFEL project: Denmark, France, Germany, Greece, Hungary, Italy, Poland, Russia, Slovakia, Spain, Sweden, and Switzerland. The international partners have entrusted the construction and operation of the European XFEL 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 European XFEL 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 250 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 1.15 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 2013, the European XFEL workforce of employees, students, and guests grew from 163 to 202 (+24%), including seven employees who signed contracts in 2013 but started at the beginning of 2014.

The number of employees increased as follows:

- Scientists: 89 (+ 15)
- Engineers: 56 (+ 16)
- Technicians: 18 (+ 6)
- Administrative staff: 39 (+ 2)

The national composition of the total European XFEL staff remained nearly unaltered in the past year, while the share of the scientific staff from Germany increased slightly:

- Total staff: 55% (+ 1% from 2012) from Germany, 45% from other countries
- Scientific staff: 45% (+ 7% from 2012) from Germany, 55% from other countries

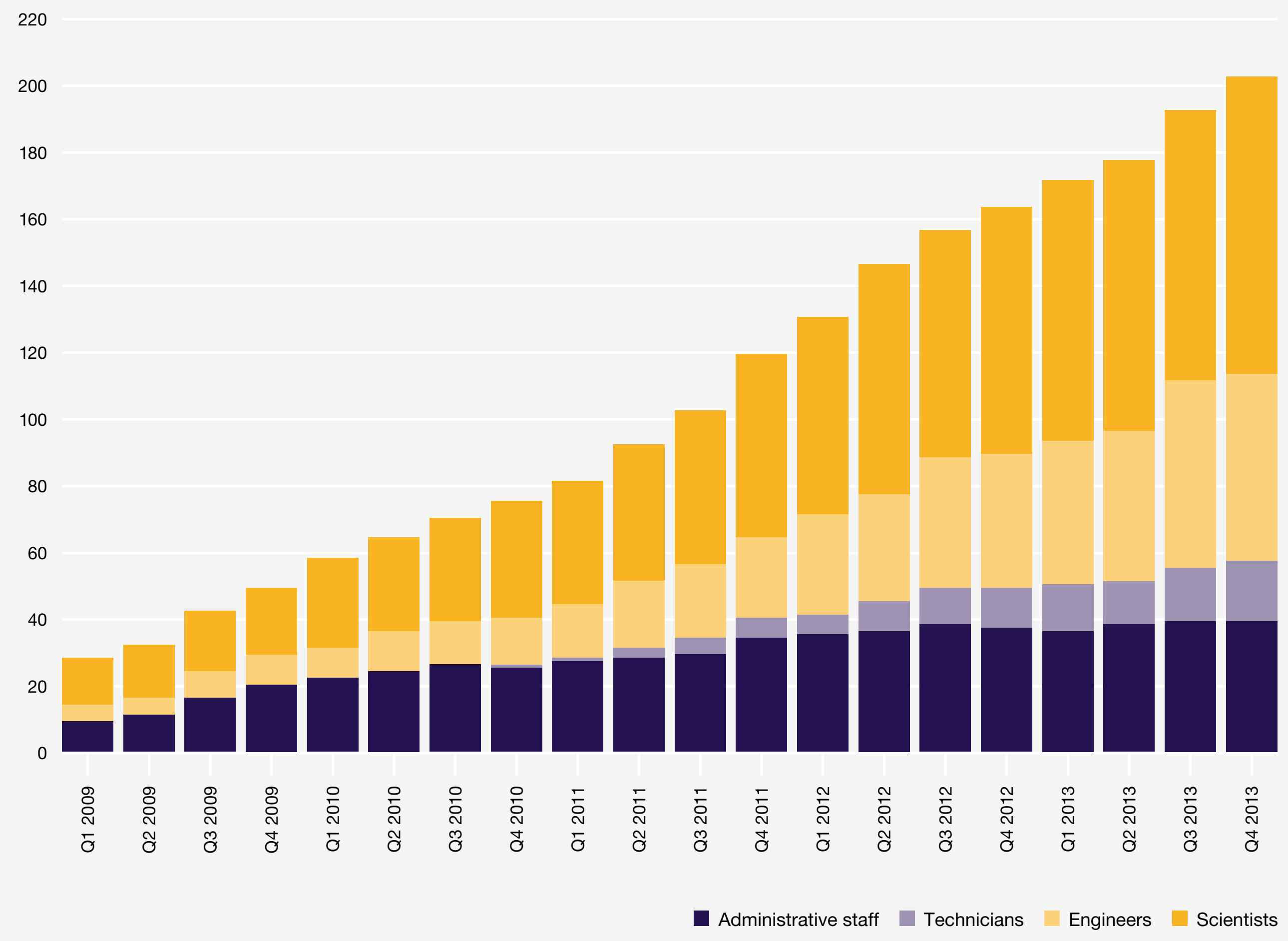
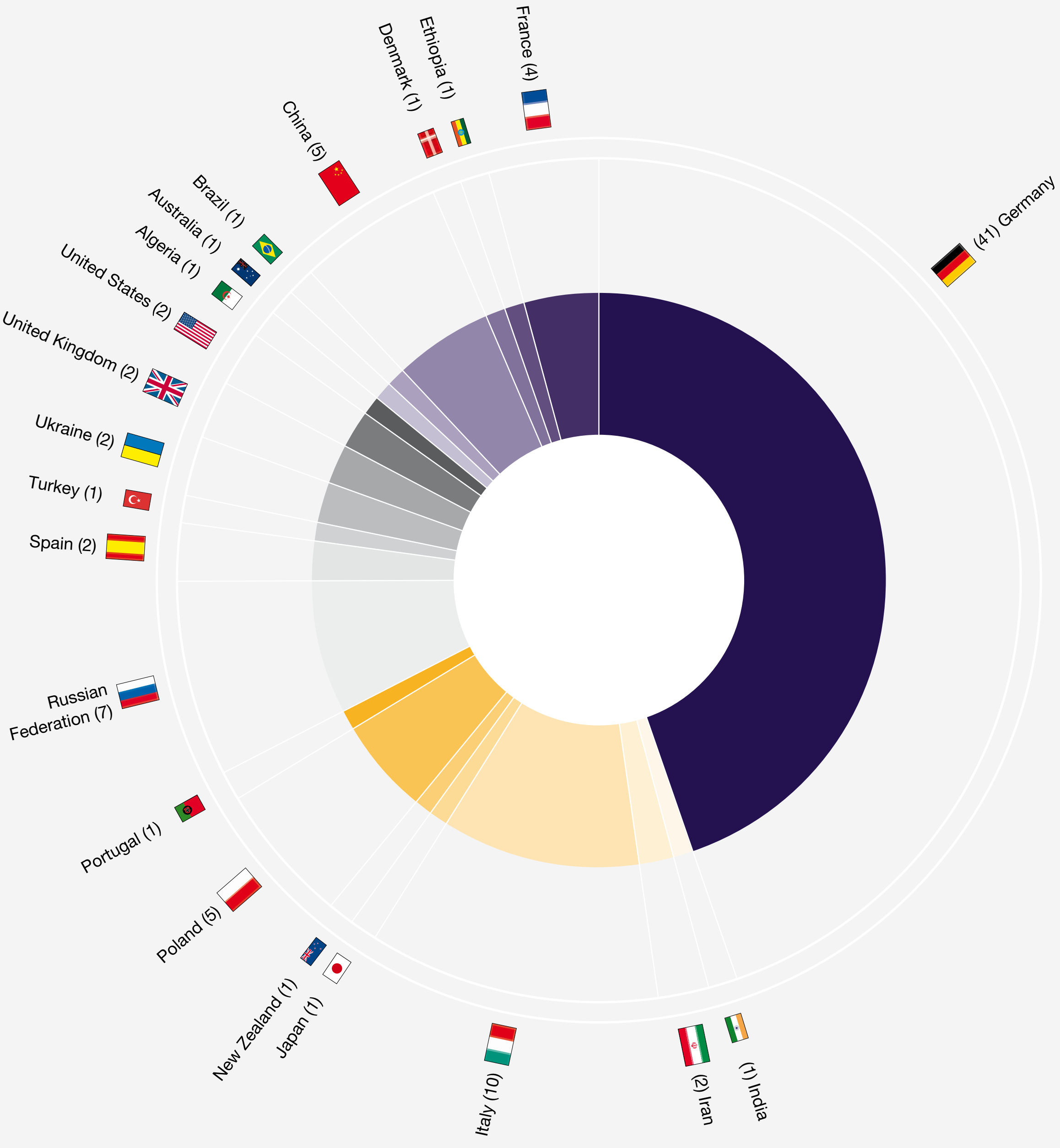
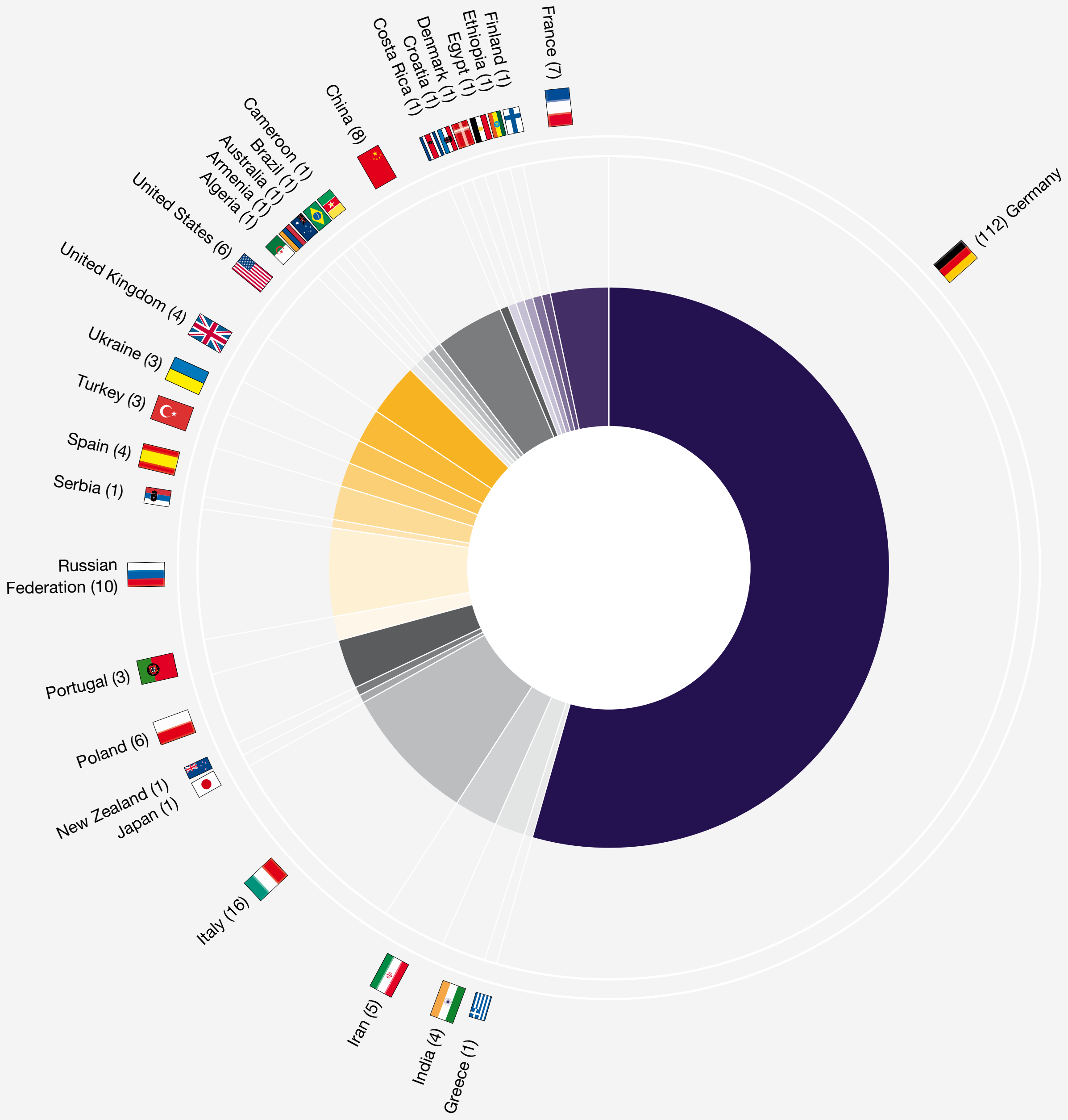


Figure 1 Overall growth by end of quarter (Q1–Q4) in the number of employees, students, and guests (2009–2013)



Germany: 45%
Other countries: 55%
21 nationalities

Figure 2 Nationalities of scientific staff



Germany: 55%
Other countries: 45%
29 nationalities

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

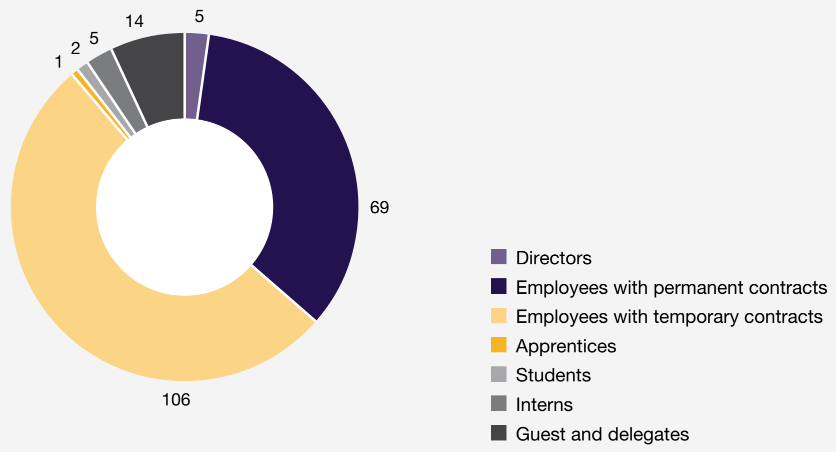


Figure 4 Contractual status of staff

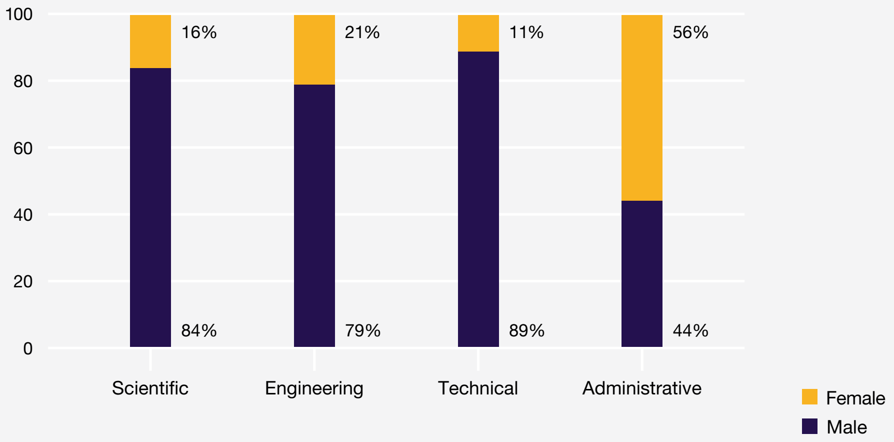


Figure 5 Gender of staff by work area

A total of 29 (+1 from 2012) nationalities are now represented within the company. In 2013, 25% of all employees and 16% of scientists employed at European XFEL were female.

The average employee age was 39 years.

Staff of European XFEL as of 31 December 2013

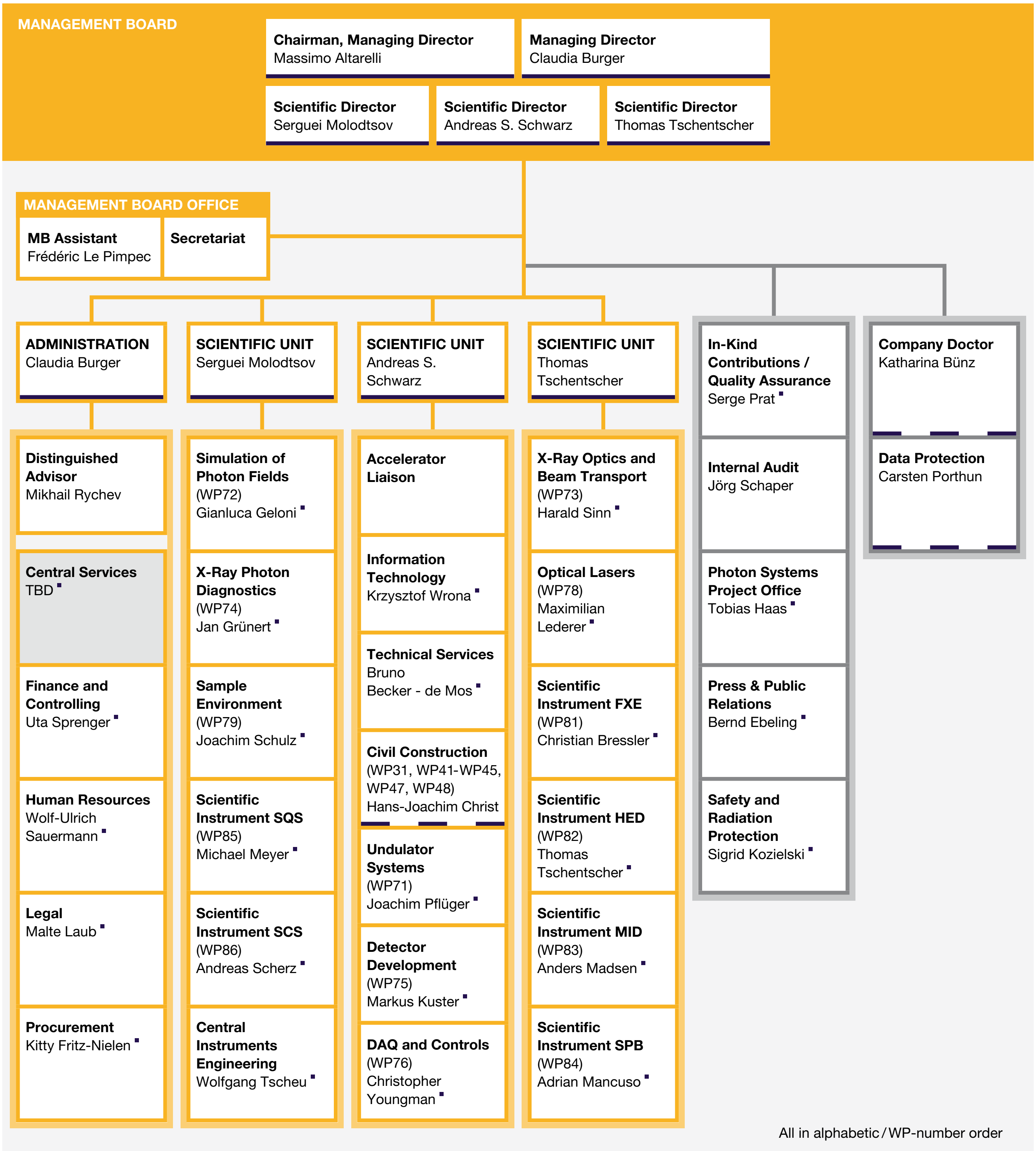
Agapov, Ilya
Altarelli, Massimo
Ament, Kurt
Ansaldi, Gabriele
Appel, Karen
Aquila, Andrew Lee
Arnold, Mathias
Arslan, Süleyman
Babies, Frank
Bagha-Shanjani, Majid
Ballak, Kai-Erik
Bari, Sadia
Bartmann, Alexander
Baskaran, Balakumaar
Batchelor, Lewis
Becker-de Mos, Bruno
Beckmann, Andreas
Berndgen, Karl-Heinz
Bertini, Silvia
Bohlen, Markus
Borchers, Gannon
Boukhelef, Djelloul
Boyd, Eric
Bressler, Christian
Britz, Alexander
Buck, Jens
Burger, Claudia
Cankaya, Zeynep
Carley, Robert
Coppola, Nicola
Cunis, Sabine
Da Costa Pereira, Maria Helena
De Fanis, Alberto
Deiter, Carsten
Delitz, Jan Torben
Delmas, Elisa
Deron, Georg Christian
Di Felice, Massimiliano
Dickert, Bianca
Dietrich, Florian
Dommach, Martin
Donato, Mattia
Dong, Xiaohao
Ebeling, Bernd
Eder, Catherine Ann Wamuyu
Eich, Melanie
Eidam, Janni
Ekmedzic, Marko
Elizondo, Jorge
Englisch, Uwe
Esenov, Sergey
Ferreira Maia, Luís Goncalo
Flammer, Meike
Frankenberger, Paul
Freijo Martín, Idoia
Freund, Wolfgang
Fritz, Mareike
Fritz-Nielen, Kitty
Galler, Andreas
Gawelda, Wojciech
Geloni, Gianluca
Gembalies, Imke
Gerasimova, Natalia
Geßler, Patrick
Giambartolomei, Gabriele
Giewekemeyer, Klaus
Grünert, Jan
Guhlmann, Florian
Haas, Tobias
Hagitte, Magdalena
Hagitte, Martin C.
Hallmann, Jörg
Harms, Gesa
Hauf, Steffen
Heeßel, Gabriela
Heisen, Burkhard
Hosseini Tarhani, Seied Amin
Ilchen, Markus
Izquierdo, Manuel
Karabekyan, Suren
Kellert, Martin
Kirsch, Jan
Knaack, Manfred
Knoll, Martin
Koch, Andreas
Kohlstrunk, Nicole
Korsch, Timo
Kozielski, Sigrid Susanne
Kozlova, Iryna
Kraft, Timm Florian
Kristic, Hrvoje
Kruse, Kai
Kumar, Mayank
Kunz, Marc
Kuster, Markus
La Civita, Daniele
Lalechos, Antonios-Vassilios
Lange, Torsten
Laub, Malte
Le Pimpec, Frédéric
Lederer, Maximilian Josef
Li, Yuhui
Liu, Jia
Lyamayev, Viktor
Madsen, Anders
Mancuso, Adrian
Mazza, Tommaso
Meger-Farshad, Danuta
Meier, Bernd
Mergen, Julia
Meyer, Michael
Molodtsov, Serguei
Mulá Mathews, Gabriella
Nakatsutsumi, Motoaki
Neumann, Maik
Nidhi, Sneha
Nillon, Julien
Osterland, Christiane
Palmer, Guido
Parenti, Andrea
Pereira Bahia, Liliane
Pergament, Mikhail
Pflüger, Joachim
Piergrossi, Joseph
Piórecki, Konrad
Planas Carbonell, Marc
Poljancewicz, Bartosz
Poppe, Frank
Prat, Serge
Priebe, Gerd
Raab, Natascha
Reifschläger, Jörn
Reimers, Nadja
Rodrigues Fernandes, Bruno Jesus
Roth, Thomas
Rüscher, Jan Christoph
Rychev, Mikhail
Saaristo, Niko
Salem, Osama Ahmed
Samoylova, Liubov
Sauermann, Wolf-Ulrich
Schaper, Jörg
Scherz, Andreas
Scherz, Sabrina
Schrage, Marco
Schulz, Carola
Schulz, Joachim
Schwarz, Andreas S.
Shie, Halimah
Sinn, Harald
Sotoudi Namin, Hamed
Sprenger, Uta
Sztuk-Dambietz, Jolanta
Szuba, Janusz
Teichmann, Martin
Thorpe, Ian
Tolkiehn, Jan
Trapp, Antje
Tschentscher, Thomas
Tscheu, Wolfgang
Turcato, Monica
Uetrecht, Charlotte
van Hees, Brunhilde
Vannoni, Maurizio
Viehweger, Marc Simon
Villanueva Guerrero, José
Wang, Jinxiong
Weger, Kerstin

Wegner, Ulrike
Wellenreuther, Gerd
Winterhoff, Gundel
Wißmann, Laurens
Wolff Fabris, Frederik
Wrona, Krzysztof
Yakopov, Mikhail
Yang, Fan
Yoon, Chunhong
Youdjeu Tangwe,
  Melchiade Auguste
Youngman, Christopher
Zhang, Haiou

Guests of European XFEL on 31 December 2013

Ananthaneni, Sunil
Assefa, Tadesse Abebaw
Bakhtiarzadeh, Sadegh
Chavas, Leonard
Galstyan, Alexander
Kabachnik, Nikolay
Ketenoglu, Bora
Liang, Menging
Liu, Yongtao
Muller, Bruno
Nawrath, Günther
Pelka, Alexander
Raabe, Steffen
Rafipoor, Amir Jones

Figure 6 European XFEL staff members during the company outing at the International Garden Show in Hamburg (September 2013)



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
- **Central Services** TBD ▪
- **Finance and Controlling** Uta Sprenger ▪
- **Human Resources** Wolf-Ulrich Sauermann ▪
- **Legal** Malte Laub ▪
- **Procurement** Kitty Fritz-Nielen ▪

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 ▪
- **Central Instruments Engineering** Wolfgang Tscheu ▪

SCIENTIFIC UNIT
Andreas S. Schwarz

- **Accelerator Liaison**
- **Information Technology** Krzysztof Wrona ▪
- **Technical Services** Bruno Becker - de Mos ▪
- **Civil Construction** (WP31, WP41-WP45, WP47, WP48) Hans-Joachim Christ
- **Undulator Systems** (WP71) Joachim Pflüger ▪
- **Detector Development** (WP75) Markus Kuster ▪
- **DAQ and Controls** (WP76) Christopher Youngman ▪

SCIENTIFIC UNIT
Thomas Tschentscher

- **X-Ray Optics and Beam Transport** (WP73) Harald Sinn ▪
- **Optical Lasers** (WP78) Maximilian Lederer ▪
- **Scientific Instrument FXE** (WP81) Christian Bressler ▪
- **Scientific Instrument HED** (WP82) Thomas Tschentscher ▪
- **Scientific Instrument MID** (WP83) Anders Madsen ▪
- **Scientific Instrument SPB** (WP84) Adrian Mancuso ▪

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

- **Company Doctor** Katharina Bünz
- **Data Protection** Carsten Porthun

All in alphabetic / WP-number order

Director

External staff

▪ Work package / group leader

Vacant position

European X-Ray Free-Electron Laser Facility GmbH (December 2013)

BUDGET

The overall budget for the construction phase of the European XFEL project amounts to around 1.15 billion euro (2005 value). Almost half of the project volume is contributed in kind by the various partners. The remaining fraction, amounting to more than 0.7 billion euro (current value), is contributed in cash to the company by its shareholders and associated partners. At the end of 2013, as the construction of the European XFEL progresses, more than 50% of the total cash budget has been spent.

The company's shareholder assembly, called the European XFEL Council, decides on the annual budget available to cover all project expenses during the corresponding year. The total European XFEL payment budget for 2013 amounted to 103.5 million euro (M€).

Major activities

In 2013, the most important major activity was machine and technical infrastructure, with a budget of 54.8 M€ (53%). More than half of the budget for this activity, 30.7 M€, was allocated to civil construction, of which 16.0 M€ was related to the final work for underground buildings. For the major activity beamlines and experiments, the payment budget was 43.0 M€ (42%). Of this, the largest fraction, 33.5 M€, was spent on capital investment.

In 2013, the most important major activity was machine and technical infrastructure, representing 53% of the year's budget.

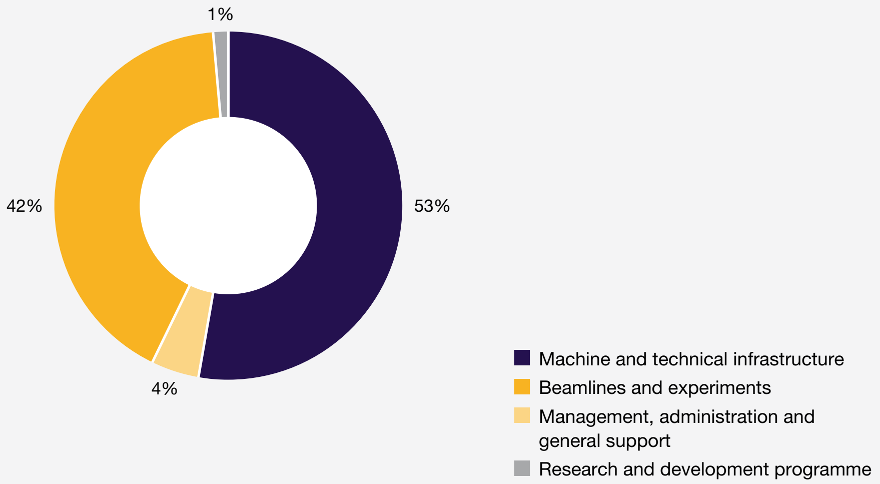


Figure 1 Payments by major activity in 2013

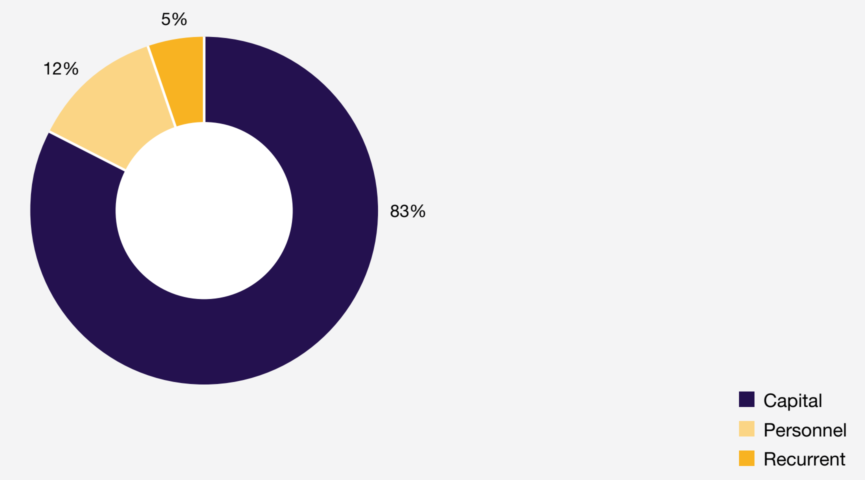


Figure 2 Payments by budget items in 2013

Budget items

In the 2013 payment budget, the overwhelming fraction (83%) was related to capital investment (Figure 2). This trend is going to 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 costs being only of subordinate importance.

Outlook for 2014

For the budget year 2014, an annual payment budget of 120 M€ was approved. The increase over the 2013 budget was mainly caused by the expected costs for the construction of the headquarters offices in Schenefeld, which will start in 2014. 🟧

SHAREHOLDERS

The European X-Ray Free-Electron Laser Facility GmbH, 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 2013)

Denmark	DASTI (Danish Agency for Science, Technology and Innovation)
Germany	DESY (Deutsches Elektronen-Synchrotron)
Hungary	NIH (National Innovation Office)
Poland	NCBJ (National Centre for Nuclear Research)
Russia	OJSC RUSNANO (Russian Corporation of Nanotechnologies)
Slovakia	Slovak Republic
Sweden	VR (Swedish Research Council)
Switzerland	Swiss Confederation

New shareholders of the European XFEL GmbH in 2014

France	CEA (Alternative Energies and Atomic Energy Commission), CNRS (National Center for Scientific Research)

Likely future shareholders of the European XFEL GmbH

Italy	Republic of Italy
Spain	Kingdom of Spain

ORGANS AND COMMITTEES

The Council of the European XFEL GmbH 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	Robert K. Feidenhans'l (University of Copenhagen, Denmark)
Vice Chairman	Pavol Sovák (P.J. Šafárik University, Košice, Slovakia)
Delegates	
Denmark	Anders Kjær (DASTI, Copenhagen) and Martin Meedom Nielsen (Technical University of Denmark, Kongens Lyngby)
Germany	Helmut Dosch (DESY, Hamburg) and Beatrix Vierkorn-Rudolph (BMBF, Bonn)
Hungary	Dénes Lajos Nagy (Wigner Research Centre for Physics, Budapest)
Poland	Grzegorz Wrochna (NCBJ, Otwock-Świerk)
Russia	Mikhail Kovalchuk (NRC Kurchatov Institute, Moscow) and Andrey Svinarenko (OJSC RUSNANO, Moscow)
Slovakia	Karel Saksl (Institute of Materials Research, Košice)
Sweden	Lars Börjesson (Chalmers University of Technology, Gothenburg) and Johan Holmberg (Swedish Research Council, Stockholm)
Switzerland	Bruno Moor (State Secretariat for Education, Research, and Innovation, Bern)
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 GmbH 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 the European XFEL GmbH in various matters: Administrative and Finance Committee, Machine Advisory Committee, Scientific Advisory Committee, In-Kind Review Committee, Detector Advisory Committee, Laser Advisory Committee, and Advisory Review Teams for scientific instruments as well as for X-ray optics and beam transport systems.

Administrative and Finance Committee (AFC)	
Chairman	Leif Eriksson (Swedish Research Council, Stockholm)
Vice Chairman	Xavier Reymond (State Secretariat for Education and Research, Bern, Switzerland)
Delegates	
Denmark	Anders Kjær (DASTI, Copenhagen) and Troels Rasmussen (DASTI, Copenhagen)
Germany	Rafael Paplocki (BMBF, Bonn) and Christian Scherf (DESY, Hamburg)
Hungary	Barbara Tóth-Vizkelety (NIH, Budapest)
Poland	Zbigniew Golebiewski (NCBJ, Otwock-Świerk)
Russia	Alexey Raykevich (OJSC RUSNANO, Moscow) and Valeriy Nosik (NRC Kurchatov Institute, Moscow)
Slovakia	Pavol Sovák (P.J. Šafárik University, Košice)
Sweden	Inger Andersson (Swedish University of Agricultural Sciences, Uppsala) and Elin Swedenborg (Swedish Research Council, Stockholm)
Switzerland	Peter Allenspach (PSI, Villigen)
Secretary	
	Uta Sprenger (European XFEL, Hamburg)
Vice Secretary	
	Liliane Pereira Bahia (European XFEL, Hamburg)

In-Kind Review Committee (IKRC)

Chairman & Russian Delegate	Leonid V. Kravchuk (INR, Moscow, Russia)
Vice Chairman & Swiss Delegate	Volker Schlott (PSI, Villigen, Switzerland)
Members	
Denmark	Søren Schmidt (Technical University of Denmark, Kongens Lyngby)
France	Alex Mueller (CNRS, Paris)
Germany	Reinhard Brinkmann (DESY, Hamburg)
Hungary	Gyula Faigel (Wigner Research Centre for Physics, Budapest)
Italy	Carlo Pagani (INFN Sezione di Milano, Laboratorio LASA, Milano)
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 accelerators) and Thomas Tschentscher (for the beamlines)
Secretary	
	Serge Prat (European XFEL, Hamburg, Germany)
Lawyer	
	Malte Laub (European XFEL, Hamburg, Germany)

Machine Advisory Committee (MAC)

Chairman	Richard Walker (DIAMOND, Oxfordshire, United Kingdom)
Members	
	Hans-Heinrich Braun (PSI, Villigen, Switzerland)
	Massimo Ferrario (INFN, Frascati, Italy)
	Zhirong Huang (SLAC, Menlo Park, California)
	Andreas Jankowiak (HZB, Berlin, Germany)
	Leonid V. Kravchuk (INR, Moscow, Russia) since October 2013
	Jacek Krzywinski (SLAC, Menlo Park, California)
	Gennady Kulipanov (BINP, Novosibirsk, Russia) until October 2013
	John Mammosser (Jefferson Lab, Newport News, Virginia)
	Pantaleo Raimondi (ESRF, Grenoble, France)
	Felix Rodriguez Mateos (CERN, Geneva, Switzerland; ITER, Saint-Paul-lès-Durance, France)

Scientific Advisory Committee (SAC)

Chairman	Rafael Abela (PSI, Villigen, Switzerland)
Members	
	Patrick Audebert (LULI, École Polytechnique, Palaiseau, France)
	Dimitrios Charalambidis (Foundation for Research and Technology-Hellas, Institute of Electronic Structure and Laser, Greece)
	Stefan Eisebitt (HZB, Berlin, Germany)
	Gyula Faigel (Wigner Research Centre for Physics, Budapest, Hungary)
	Salvador Ferrer (CELLS–ALBA, Cerdanyola de Vallès, Spain)
	Jerome Hastings (SLAC, Menlo Park, California)
	Sine Larsen (University of Copenhagen, Denmark)
	Joseph Nordgren (University of Uppsala, Sweden)
	Natalia Novikova (NRC Kurchatov Institute, Moscow, Russia) since June 2013
	Vladislav Panchenko (Russian Foundation for Basic Research, Moscow, Russia) until May 2013
	Aymeric Robert (LCLS SLAC, Menlo Park, California)
	Karel Saksl (Institute of Materials Research, Košice, Slovakia)
	Francesco Sette (ESRF, Grenoble, France)
	David Stuart (University of Oxford and DIAMOND, Oxfordshire, United Kingdom)
	Edgar Weckert (DESY, Hamburg, Germany)
Secretary	
	Gianluca Geloni (European XFEL, Hamburg)

Detector Advisory Committee (DAC)	
Chairman	Karl Tasso Knöpfle (MPI for Nuclear Physics, Heidelberg, Germany)
Members	
	Michael Campbell (CERN, Geneva, Switzerland)
	Pablo Fajardo (ESRF, Grenoble, France) until June 2013
	Sol M. Gruner (Cornell University, Ithaca, New York)
	Roland Horisberger (PSI, Villigen, Switzerland) since June 2013
	Christopher J. Kenney (SLAC, Menlo Park, California)
	Jörg Klora (ITER, Saint-Paul-lès-Durance, France)
	Tim Nicholls (STFC, Oxfordshire, United Kingdom) until June 2013
	Paul O’Connor (NSLS BNL, Upton, New York) until June 2013
	Amadeo Perazzo (SLAC, Menlo Park, California)
	David Quarrie (LBNL, Berkeley, California) since June 2013
	Peter Siddons (NSLS BNL, Upton, New York) until June 2013
	Jörn Wilms (University of Erlangen, Germany) since June 2013
Guest	Takaki Hatsui (RIKEN Spring-8, Hyogo, Japan)

Laser Advisory Committee (LAC)

Chairman	Uwe Morgner (Laser Zentrum Hannover, Germany)
Members	
	Giulio Cerullo (Politecnico di Milano, Italy)
	Mike Dunne (LLNL, Livermore, California) since October 2013
	Patrick Georges (Institut d'Optique, Paris, France)
	Alfred Leitensdorfer (University Konstanz, Germany)
	Robert Schoenlein (LBNL, Berkeley, California)
	William E. White (SLAC, Menlo Park, California)
Secretaries	
	Lucia Incoccia-Hermes (DESY, Hamburg, Germany) and Andreas Galler (European XFEL, Hamburg, Germany)

Advisory Review Team (ART)—Scientific Instrument FXE

Chairman	Martin Meedom Nielsen (Technical University of Denmark, Kongens Lyngby, Denmark)
Members	
Reporter to SAC	Rafael Abela (PSI, Villigen, Switzerland)
	David Fritz (SLAC, Menlo Park, California)
	Pieter Glatzel (ESRF, Grenoble, France)
	Steven L. Johnson (ETH Zürich, Switzerland)
	Alke Meents (DESY, Hamburg, Germany)
	Simone Techert (MPI for Biophysical Chemistry, Göttingen, and DESY, Hamburg, Germany)
	Aymeric Robert (LCLS SLAC, Menlo Park, California)

Advisory Review Team (ART) — Scientific Instrument HED	
Chairman	Richard W. Lee (SLAC, Menlo Park, California)
Members	
Reporter to SAC	Patrick Audebert (LULI, École Polytechnique, Palaiseau, France)
	Andrew Higginbotham (University of Oxford, United Kingdom)
	Hae Ja Lee (SLAC, Menlo Park, California)
	Hanns-Peter Liermann (DESY, Hamburg, Germany)
	David Neely (STFC, Oxfordshire, United Kingdom)
	Paul Neumayer (GSI, Darmstadt, Germany)
	Klaus Sokolowski-Tinten (University of Duisburg, Germany)
	Sven Toleikis (DESY, Hamburg, Germany)

Advisory Review Team (ART) — Scientific Instrument MID	
Chairman	Jerome Hastings (SLAC, Menlo Park, California)
Members	
	Gerhard Grübel (DESY, Hamburg, Germany)
	Henning Friis Poulsen (Risø DTU, Roskilde, Denmark)
	Ian K. Robinson (UCL, London, United Kingdom)
	Giancarlo Ruocco (Sapienza – Università di Roma, Italy)
	Tim Salditt (Georg-August-Universität Göttingen, Germany)

Advisory Review Team (ART)—Scientific Instrument SCS

Chairman	Jan Lüning (Université Pierre et Marie Curie, Paris, France; Synchrotron SOLEIL, Saint Aubin, France)
Members	
Reporter to SAC	Stefan Eisebitt (HZB, Berlin, Germany)
	Giacomo Ghiringhelli (Politecnico di Milano, Italy)
	Gerhard Grübel (DESY, Hamburg, Germany)
	Nina Rohringer (CFEL and DESY, Hamburg, Germany)
	William F. Schlotter (LCLS SLAC, Menlo Park, California)
	Wilfried Wurth (DESY, Hamburg, Germany)

Advisory Review Team (ART)—Scientific Instrument SPB

Chairman	David Stuart (University of Oxford and DIAMOND, Oxfordshire, United Kingdom)
Members	
	Anton Barty (CFEL and DESY, Hamburg, Germany)
	Sebastien Boutet (LCLS SLAC, Menlo Park, California)
	Daniel DePonte (LCLS SLAC, Menlo Park, California)
	Victor Lamzin (EMBL, Hamburg, Germany)
	Ilme Schlichting (MPI for Medical Research, Heidelberg, Germany)
	Garth Williams (LCLS SLAC, Menlo Park, California)

Advisory Review Team (ART)—Scientific Instrument SQS

Chairman	Thomas Möller (TU Berlin, Germany)
Members	
	John Bozek (SLAC, Menlo Park, California)
Reporter to SAC	Joseph Nordgren (University of Uppsala, Sweden)
	Henrik Pedersen (Aarhus University, Denmark)
	Artem Rudenko (CFEL ASG MPG, Hamburg, Germany)
	Joachim Ullrich (MPI for Nuclear Physics, Heidelberg, Germany)
	Jens Viefhaus (DESY, Hamburg, Germany)
	Marc Vrakking (MBI, Berlin, Germany)

Advisory Review Team (ART)—X-Ray Optics and Beam Transport

Chairman	Christian Schroer (TU Dresden, Germany)
Members	
	John Arthur (SLAC, Menlo Park, California)
	Ray Barrett (ESRF, Grenoble, France)
	Rolf Follath (HZB, Berlin, Germany)
	Aymeric Robert (LCLS SLAC, Menlo Park, California)
	Horst Schulte-Schrepping (DESY, Hamburg, Germany)
Reporter to SAC	Edgar Weckert (DESY, Hamburg, Germany)
	Timm Weitkamp (Synchrotron SOLEIL, Saint Aubin, France)

COOPERATION

European XFEL has established an extensive international research network with partners around the world. In 2013, European XFEL signed a Memorandum of Understanding (MoU) with Lawrence Berkeley National Laboratory (LBNL) and cooperation agreements with France's National Centre for Scientific Research (CNRS), Hamburg University of Applied Sciences (HAW Hamburg), as well as agreements with Helmholtz-Zentrum Berlin (HZB) and Science and Technology Facilities Council (STFC). Additionally, European XFEL and several other institutions joined CALIPSO, a European Union consortium for light sources.

Cooperations with research institutions

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, National Centre for Scientific Research (CNRS), one France's largest research organizations, signed a collaboration agreement with European XFEL regarding design, development, construction, and delivery of a MHz prototype noncollinear optical parametric amplifier (NOPA) through the Cluster of Research Infrastructures for Synergies in Physics (CRISP) framework.

Collaboration of European FEL and SPS Facilities

European research facilities that operate or develop X-ray free-electron lasers (FELs) and advanced short-pulse and coherent light sources (SPS) 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 Deutsches Elektronen-Synchrotron (DESY) in Germany, Sincrotrone Trieste (Elettra) in Italy, Helmholtz-Zentrum Berlin (HZB) in Germany, Istituto Nazionale di Fisica Nucleare (INFN) in Italy, MAX IV Laboratory in Sweden, Paul Scherrer Institut (PSI) in Switzerland, SOLEIL in France, Science and Technology Facilities Council (STFC) in the UK, and National Centre for Nuclear Research (NCBJ) in Poland.

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.

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.

In 2013, European XFEL signed an additional cooperation agreement in the framework of the Helmholtz Virtual Institute "Dynamic Pathways in Multidimensional Landscapes" initiative.

Kurchatov Institute

European XFEL cooperates with National Research Centre "Kurchatov Institute" (NRC KI) in Moscow in calculating radiation parameters and organizing European XFEL schools for young scientists.

Lawrence Berkeley National Laboratory

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.

Figure 1 Signing of the MoU between LBNL and European XFEL on 16 April 2013
Left to right Claudia Burger, Administrative Director, European XFEL; Paul Alivisatos, Director, LBNL; Massimo Altarelli, Managing Director, European XFEL

LNLS

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

SLAC

Regular contacts with SLAC National Accelerator Laboratory in California provide an important opportunity to gain hands-on experience at an X-ray FEL in operation, the Linac Coherent Light Source (LCLS). An MoU was signed on 27 July 2009.

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, 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.

Turkish Accelerator Center
European XFEL collaborates with the 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 the TAC.

University College London
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.

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

CALIPSO
CALIPSO is a European Union (EU) consortium that coordinates the European synchrotrons and free-electron lasers (FELs), including the three European Strategy Forum on Research Infrastructures (ESFRI) roadmap projects—European XFEL, EuroFEL, and the ESRF Upgrade Programme—towards a fully integrated network. CALIPSO receives funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 312284. The project began in June 2012 and will continue through December 2015. Within CALIPSO, 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.

BioStruct-X

BioStruct-X is a consortium of 19 institutions from 11 European Union (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.

CRISP

The Cluster of Research Infrastructures for Synergies in Physics (CRISP) is an EU research network of 11 European research infrastructures currently being planned or under construction. CRISP receives funding from the EU Seventh Framework Programme (FP7/2007–2013) and was launched on October 2011. A consortium agreement between the partners was signed in 2012. The network focuses on four key areas of physics: accelerator technology, physics instrumentation and experiments, detectors and data acquisition technologies, and IT and data management systems.

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 Fusion Development Agreement—Joint European Torus (EFDA-JET), 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 (formerly “FEL three-site meeting”)

The LCLS, the Japanese SPring-8 Compact SASE Source (SCSS), 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

User consortia contribute to the facility outside the baseline scope of the project, in particular to the construction of scientific instruments, to the ancillary instrumentation, and to the technical infrastructure. Currently seven proposals have been approved by the European XFEL Council.

Integrated Biology Infrastructure Life-Science Facility at the European XFEL (XBI)

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 headquarter building (XHQ). This proposal is led by EMBL and includes DESY, a research centre of the Helmholtz Association.

Serial Femtosecond Crystallography (SFX)

The Serial Femtosecond Crystallography (SFX) user consortium proposes to build a second instrument for nanocrystallography and sample screening in the Single Particles, Clusters, and Biomolecules (SPB) instrument hutch downstream of the SPB instrument and reusing the transmitted X-ray FEL beam. This proposal is led by DESY.

DataXpress

DataXpress is a user consortium providing a data analysis toolkit and hardware aiming 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.

CircPol

The CircPol user consortium seeks to build afterburner undulators to create X-ray pulses with controllable polarization states by exploiting the electron beam microbunching generated in the baseline XFEL undulators. This proposal is led by Budker Institute of Nuclear Physics (BINP).

Helmholtz International Beamline for Extreme Fields at the European XFEL (HIBEF)

The Helmholtz International Beamline for Extreme Fields at the European XFEL (HIBEF) user consortium proposes to contribute two high energy optical lasers, a high field pulsed magnet instrument, and a number of scattering diagnostics to be integrated into the High Energy Density Physics (HED) instrument. A laser building could house future upgrades of these optical lasers and would provide offices for the staff to build up and operate these systems. This proposal is led by Helmholtz-Zentrum Dresden-Rossendorf (HZDR) and includes DESY, both research centres of the Helmholtz Association.

COMO

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. This proposal is led by DESY.

Heisenberg Resonant Inelastic X-ray Scattering (h-RIXS)

The Heisenberg Resonant Inelastic X-ray Scattering (h-RIXS) user consortium proposes to build high resolution spectrometers complementing the capabilities of the Spectroscopy and Coherent Scattering (SCS) instrument and facilitate RIXS-type experiments. This proposal is led by HZB, a research centre of the Helmholtz Association. ■

SHORT HISTORY OF EUROPEAN XFEL

In the 1990s, Deutsches Elektronen-Synchrotron (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 free-electron laser (FEL) for photon science. The X-ray FEL part of the project, as a European facility to be implemented in collaboration with other countries, 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 free-electron laser at the TESLA test facility produces a laser beam for the first time—with the shortest wavelengths ever generated by a free-electron laser.

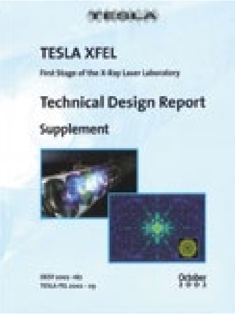
2001

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.



TESLA XFEL

Technical Design Report

Supplement

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 facility, 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 new records for the shortest wavelength ever produced with an FEL, is renamed the “Free-Electron Laser in Hamburg”, or “FLASH”.

Figure 6 On 27 April 2005, DESY directors Jochen Schneider (centre) and Albrecht Wagner (right) hand over the planning documents for the European XFEL project and the application letter initiating the public planning approval procedure to Friedhelm Wiegel, the representative of the State Authority for Mining, Energy and Geology of Lower Saxony.

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 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.

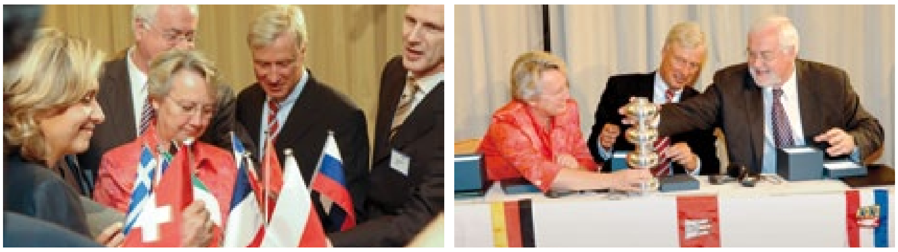


Figure 8 The European XFEL is officially launched on 5 June 2007.
Left Valérie Pécresse, French Minister of Higher Education and Research; Peter Harry Carstensen, Minister President of Schleswig-Holstein; Annette Schavan, German Federal Minister of Education and Research; Ole von Beust, Mayor of the 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" later 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 National Accelerator Laboratory in Menlo Park, California, 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 whole network of tunnels is completed according to plan. 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 free-electron lasers. 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 (Lawrence Berkeley National Laboratory) 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 free-electron lasers.

Figure 14 Arrival of the tunnel boring machine AMELI 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 tonnes 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. Special technology used includes a high-precision, water-cooled electron gun, the first part of the injector.

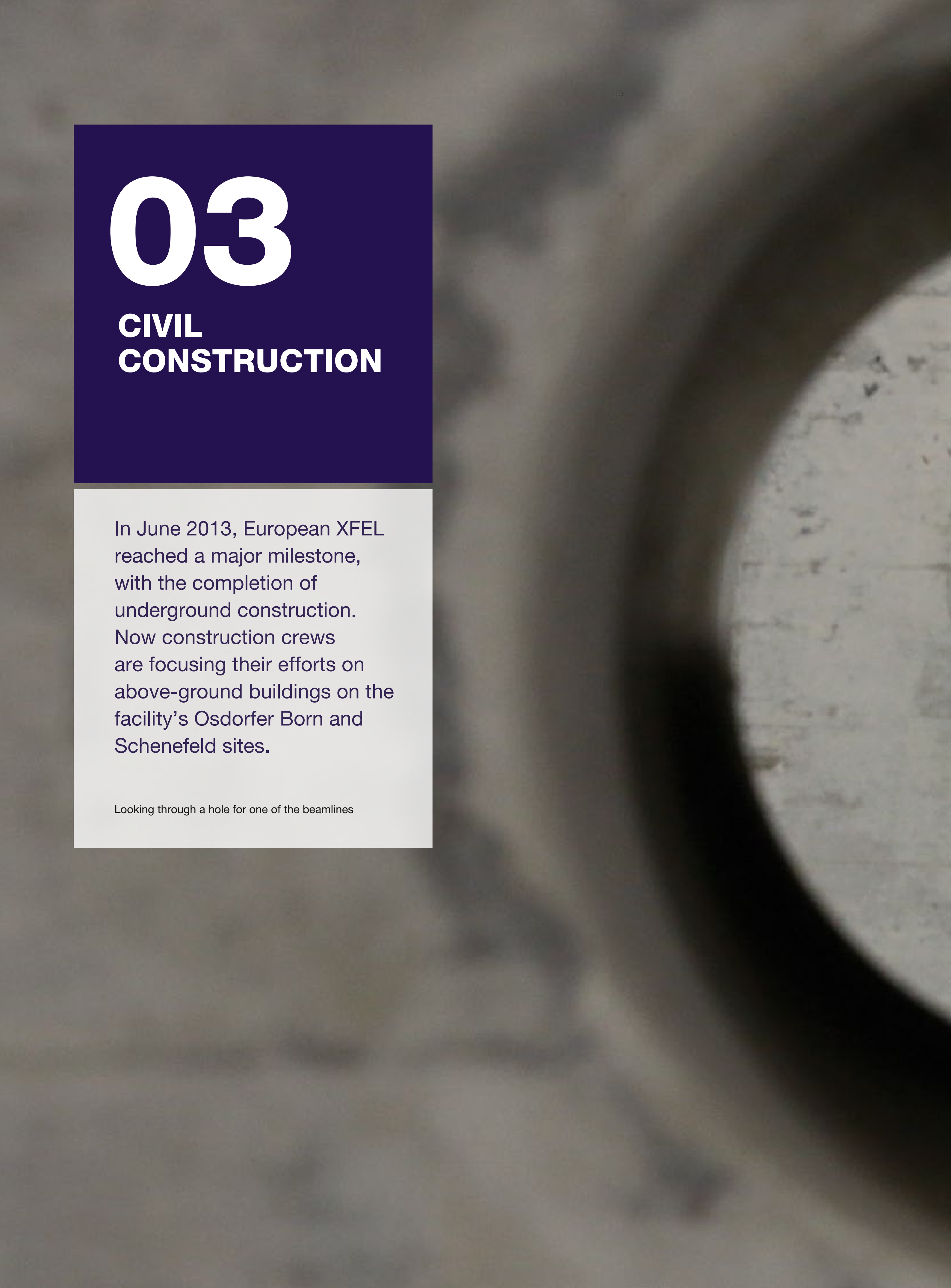
In December, more than half of the European XFEL's 92 undulator segments are fully tuned. Tuned segments are placed into storage, awaiting installation in the tunnels.

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

03

CIVIL CONSTRUCTION

In June 2013, European XFEL reached a major milestone, with the completion of underground construction. Now construction crews are focusing their efforts on above-ground buildings on the facility’s Osdorfer Born and Schenefeld sites.



Looking through a hole for one of the beamlines

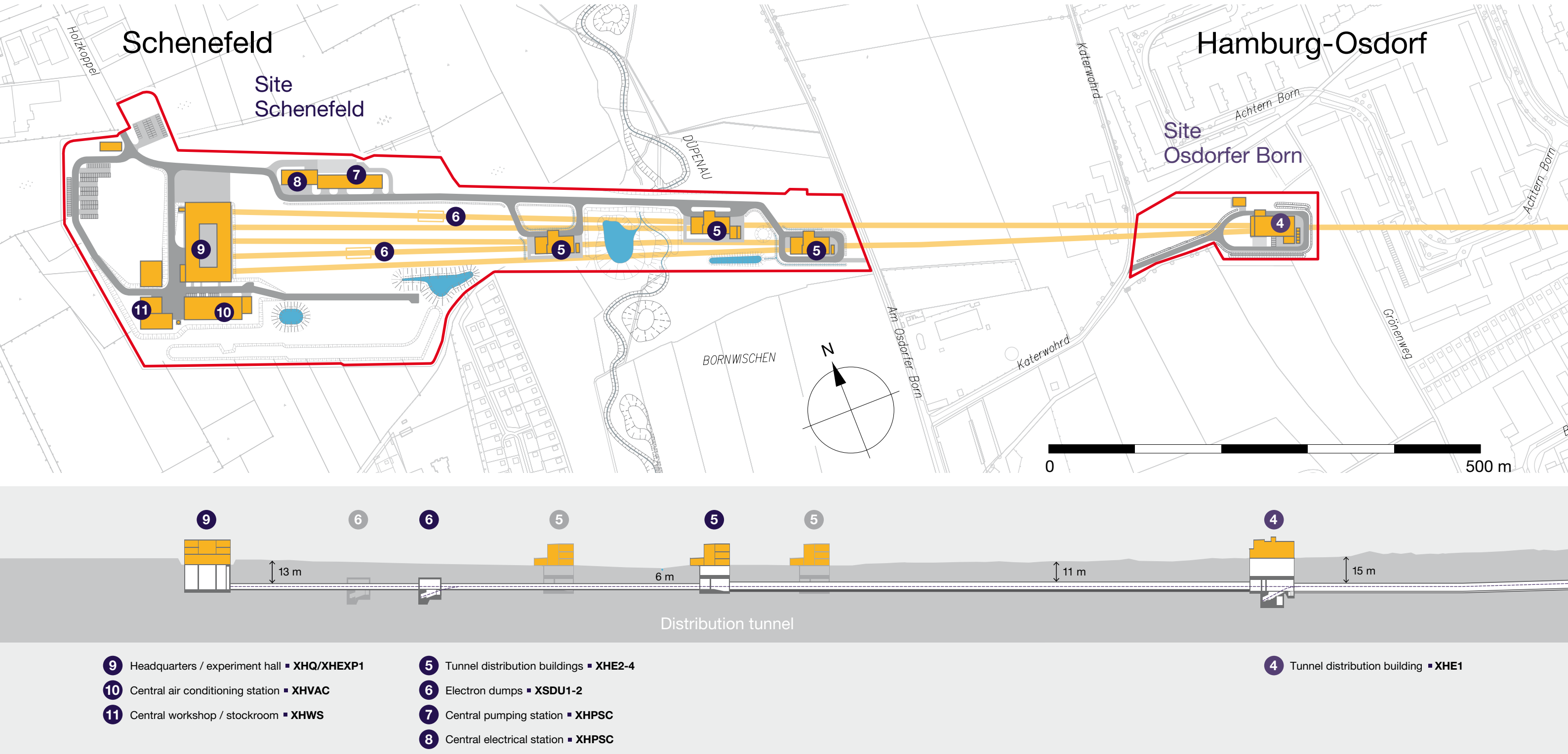


Figure 1 Layout of the European XFEL facility

CIVIL CONSTRUCTION

In 2013, the civil construction project proceeded according to plan and all major milestones were met. With tunnel construction complete, work in the first half of 2013 concentrated on finishing the shaft buildings, including the large underground experiment hall. In June, underground construction at all three building sites was concluded, and the main focus shifted to the above-ground buildings. While the halls on the DESY-Bahrenfeld and Osdorfer Born sites are essentially finished, work has started on the supply buildings on the Schenefeld campus. The planning of the facility headquarters building was finalized, and the call for tender was published in December.

Overview

The overall layout of the European XFEL facility is shown in Figure 1. The top view indicates the dimensions and the placement in the surrounding area. The side cross-sectional view shows the ground profile and the various shaft buildings.

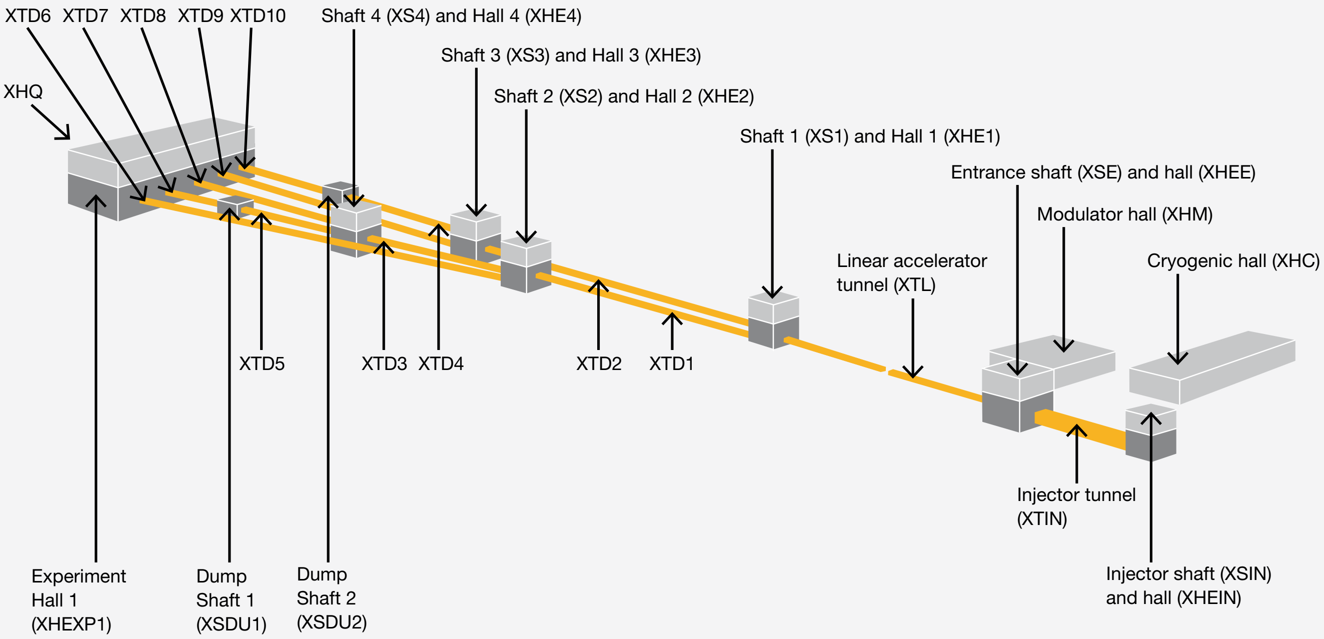
The facility is approximately 3.4 km long and stretches from Deutsches Elektronen-Synchrotron (DESY) in Hamburg-Bahrenfeld

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 lies underground. The network of tunnels has a total length of about 5.77 km.

The heart of the facility will be the underground experiment hall in Schenefeld, with a large laboratory and office building on top. The latter will serve as the European XFEL headquarters. Figure 2 shows a schematic view of all the underground and surface buildings of the European XFEL facility.

Status of tunnel construction—December 2013

With tunnel construction complete and the two tunnel boring machines (for the accelerator and photon tunnels) removed from the target shafts, work in 2013 concentrated on finishing the shafts themselves. Until then, they had been needed as start or end points for the tunnel boring process.



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

> In June 2013, all underground construction at all three sites was finished. About 300 guests from politics, academia, administration, and business, as well as many employees of DESY and European XFEL, celebrated the occasion and visited the underground facilities in Schenefeld.

Work on the shafts progressed on schedule, including work on the largest, the 4500 m^2 underground experiment hall (XHEXP1) on the Schenefeld site. In June 2013, all underground construction at all three sites was finished, and they were officially transferred from the construction companies to the owner. As this transfer marked a major milestone in the civil construction work package, about 300 guests from politics, academia, administration, and business, as well as many employees of DESY and European XFEL, were invited to celebrate the occasion and visit the underground facilities in Schenefeld.

Figure 3 Completed underground experiment hall (XHEXP1)

Figure 4 Hamburg science senator and second mayor, Dorothee Stapelfeldt, addressing the guests at the ceremony celebrating the completion of underground construction (June 2013)

Figure 3 shows the completed underground experiment hall, ready for visitors. Figure 4 shows the Hamburg science senator and second mayor, Dorothee Stapelfeldt, addressing the guests in the welcome ceremony on 6 June 2013.

Figure 5 Aerial view of the Bahrenfeld building site (August 2013)

Figure 6 Completed road between the modulator hall (XHM, left) and the injector entrance hall (XHEIN, right)

DESY-Bahrenfeld site

The modulator hall (XHM) and the entrance halls to the injector complex (XHEIN and XHEE) were the first above-ground buildings to be finished. Figure 5 shows an aerial view of the Bahrenfeld building site in August 2013. Work there focused on installing the technical infrastructure needed for the operation of the accelerator. The few remaining tasks for civil construction included landscaping and preparing the access roads. Figure 6 shows the completed road between XHM (left) and XHEIN (right).

Figure 7 Aerial view of the Osdorfer Born construction site (August 2013)

Figure 8 Almost completed Hall 1 (XHE1) with its anthracite façade (February 2014)

Osdorfer Born site

At the Osdorfer Born site, the linear accelerator tunnel (XTL) ends in Shaft 1 (XS1), the large shaft where one of the electron dumps is situated and where the first two undulator tunnels start (XTD1 and XTD2, for the undulator lines SASE2 and SASE1). The construction of the tunnel distribution building, Hall 1 (XHE1), which covers XS1 and houses the crane for transport of technical infrastructure, was started in March 2013 and has proceeded rapidly.

Figure 7 shows an aerial view of the Osdorfer Born construction site in August 2013. Figure 8 shows the almost completed XHE1 in February 2014 with its anthracite façade.

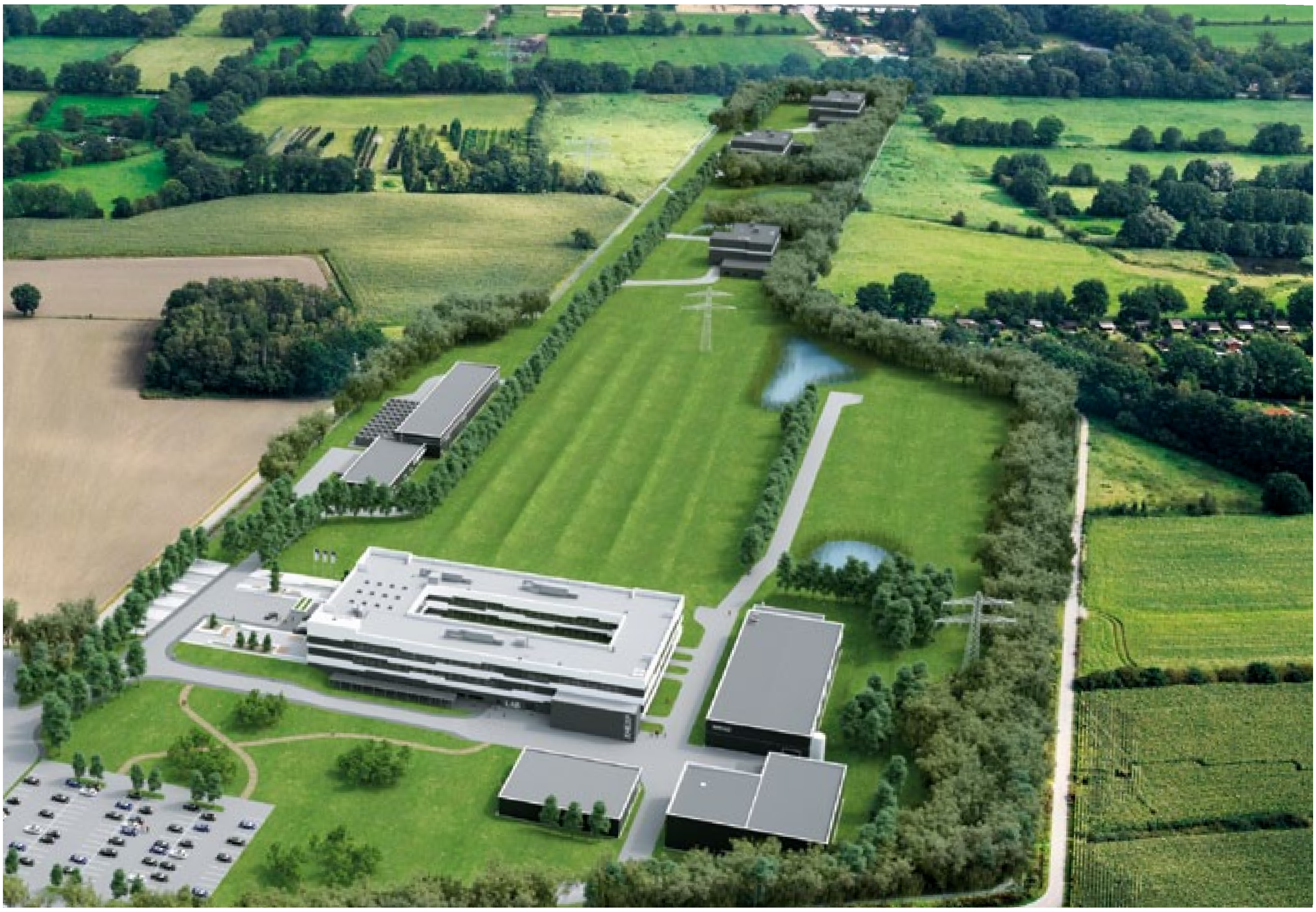


Figure 9 Artistic rendering of an aerial view of the completed Schenefeld campus with the three halls XHE2–4 in the back towards the Osdorfer Born site

The connection building for the district heating and the supply tunnel for electricity and heat from the Osdorfer Born site to the Schenefeld site are still in the planning stage.

Schenefeld campus

Figure 9 shows an artistic rendering of an aerial view of the completed Schenefeld campus with the three tunnel distribution buildings (XHE2–4) in the back towards the Osdorfer Born site and Figure 10 shows the status of the construction site in August 2013. The heart of the campus is the large headquarters building (XHQ), which comprises a laboratory complex on the ground floor and offices on the first and second floors. To the left of XHQ is the central electrical station (XHPSC), which provides electrical power to the facility. The large building to the right of XHQ is the air conditioning building (XHVAC), which provides air ventilation and conditioning to the experiment hall and the entire tunnel system.

Figure 10 Aerial view of the Schenefeld construction site in August 2013

XHPSC and XHVAC are connected to the XHQ building complex through large underground media channels. The building directly in front of XHVAC is for the mechanical workshop and storage space (XHWS). The small building in front and to the right of XHQ is a placeholder for a building possibly accommodating a large petawatt-class optical laser for use in connection with the High Energy Density Physics (HED) scientific instrument, which is housed in the adjacent underground experiment hall beneath XHQ. To facilitate the transfer of the laser beam from this building to the experiment hall with minimum disturbance to facility operation, a large “petawatt tunnel” has already been built and connected to the experiment hall.

Figure 11 shows the preparation of the petawatt tunnel. The wall at the end of the construction pit is the top part of the experiment hall (XHEXP1) in the area of the HED instrument.

Figure 11 Preparation of the petawatt tunnel

Work started as well on the underground media channels, the ground preparation for XHPSC and XHVAC, and the petawatt tunnel. In these cases, the call for tender had only a very limited market response with rather high prices, indicating the current rather heated state of the economy in the civil construction market segment.

The contracts for the three halls XHE2–4 (seen at the top of Figure 9) were awarded in February 2013, and construction started in the summer. The halls are now 70% complete. Figure 12 shows the status of Hall 4 (XHE4) at the end of November 2013.

Figure 12 Hall 4 (XHE4) in November 2013

During the year, a lot of work was devoted to finalizing the plans and preparing the call for tender documents for the facility headquarters (XHQ). By incorporating a number of changes resulting from refined scientific requirements, the load distribution of the building on the grid of concrete beams forming the roof of the experiment hall changed significantly, requiring a new calculation of the statics of the entire building complex. This recalculation was successful, but it delayed the publication of the call for tender for XHQ to December 2013. As a further consequence, reinforcement measures must now be performed for a few concrete girders before construction of the building shell can start. The start of construction of XHQ (Figure 13) is currently scheduled for May 2014.

Summary and forecast

In 2013, all major milestones in civil construction were met. Costs for civil construction remained within the budget foreseen for the year. For 2014, a major milestone is the successful completion of the call for tender for XHQ, the largest remaining civil construction task for the project. It will be a challenge to recover some of the time needed for the reinforcement of the concrete girder grid so the building can be occupied in late 2015 or early 2016.

The remaining calls for tender include the building for XHWS and the entrance building (XHGATE). Finally, planning and implementation of the environmental compensation measures (for example, planting trees) and the groundwork associated with the finalization of roads and other infrastructure will commence. ■

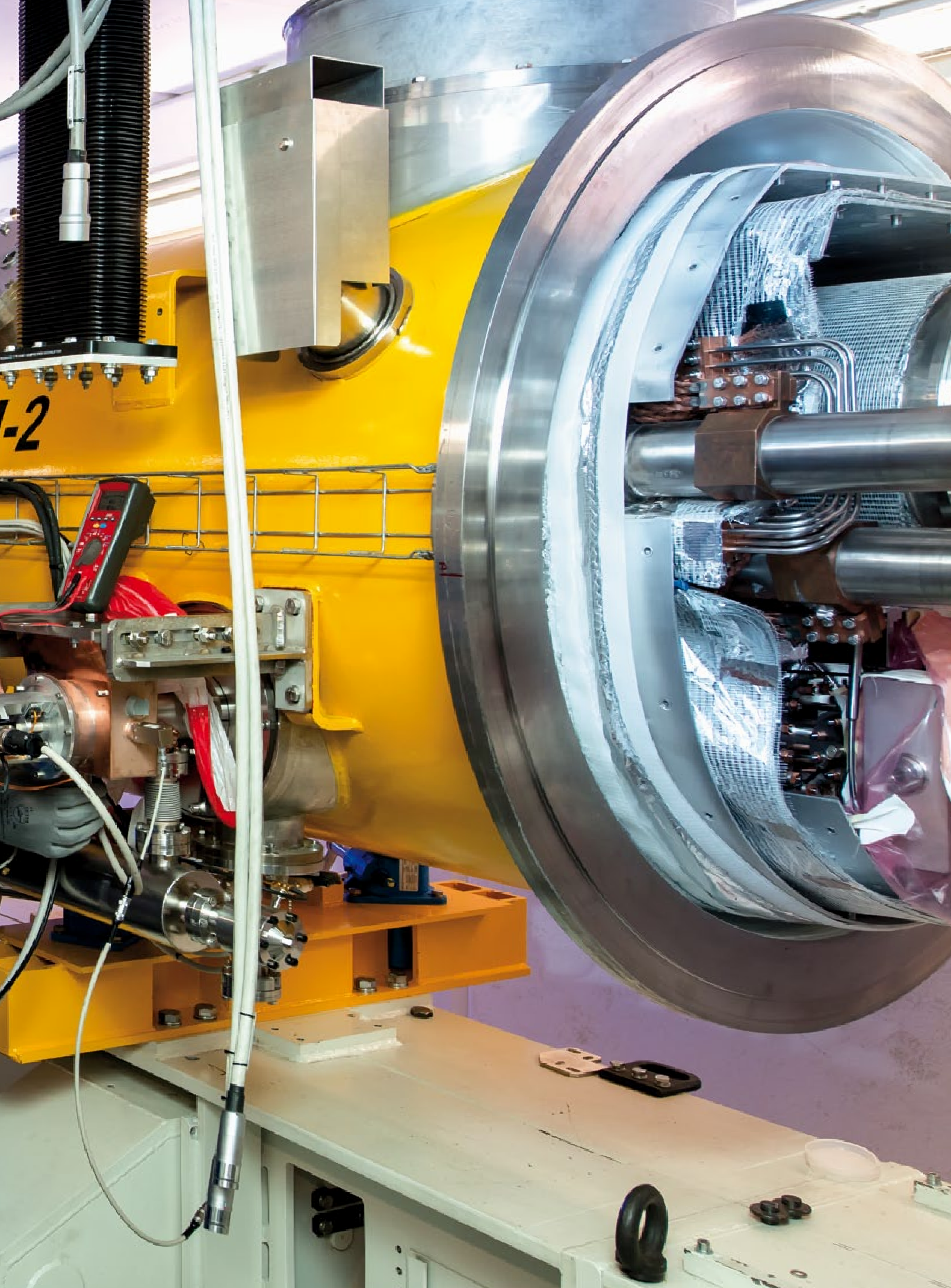
Figure 13 Artistic rendering of the completed laboratory and office building XHQ

04

IN-KIND CONTRIBUTIONS

Our worldwide partners continued advancing with their contributions to the facility in the form of components or human resources. In 2013, the 17-institute Accelerator Consortium initiated series production of 100 accelerator modules.

Quality check on an accelerator module power coupler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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, 75 IKCs by 21 institutes from 9 different countries are under way for a total of 560 million euro (M€), while a few other proposals are in preparation. Eighty-six milestones were reached in 2013. Of particular importance were the start of series production of components for the nearly 2 km long linear accelerator, the completion of the infrastructure at the Accelerator Module Test Facility (AMTF), and the start of testing activities.

Overall contributions

In 2013, adjustments were made in the relative amounts of some IKCs. However, the total value of IKCs under way remains approximately 560 M€, including contracts to Russian institutes (Table 1).

Countries contributing in kind

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

Abbreviation	Country	Number of IKCs	IKC value (k€)
DK	Denmark	1	2 860
FR	France	4	36 000
DE	Germany	34	407 587
GR	Greece	0	0
HU	Hungary	0	0
IT	Italy	3	33 000
PL	Poland	4	15 895
RU	Russia	13	43 007
SK	Slovakia	0	0
ES	Spain	4	7 608
SE	Sweden	10	4 948
CH	Switzerland	2	8 835
Total		**75**	**559 740**

Table 1 Projected IKC amounts by country (in 2005 prices) in thousands of euro (k€) as of December 2013

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.

Contributing institutes

As of December 2013, a total of 21 institutes are contributing in kind to the European XFEL facility (Table 2). Photos of activities going on in 2013 in the collaborating institutes are shown in Figures 1–7.

Country	Abbreviation	Institute	Location	Work packages
DK	DTU	Technical University of Denmark – Physics Department	Risø	81
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	1–21, 28, 32–36, 38–40, 45, 46
IT	INFN	Istituto Nazionale di Fisica Nucleare	Milano	3, 4, 46
PL	NCBJ	National Centre for Nuclear Research	Świerk	6
	IFJ-PAN	Henryk Niewodniczański Institute of 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 Institute of Electrophysical Apparatus	St. Petersburg	12
ES	CELLS	Consortium for the Exploitation of the Synchrotron Light Laboratory	Barcelona	71
	CIEMAT	Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas	Madrid	11, 71
	UPM	Universidad Politécnica de Madrid	Madrid	34
SE	KTH	Royal Institute of Technology	Stockholm	73
	MSL	Manne Siegbahn Laboratory	Stockholm	12, 71
	SU	Stockholm University	Stockholm	28, 71
	UU	Uppsala University	Uppsala	14, 79, 84, 85
CH	PSI	Paul Scherrer Institut	Villigen	16, 17

Table 2 Institutes contributing in kind to the European XFEL facility

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). Meetings of the IKRC are scheduled one to three times per year, depending on the number of proposals to discuss.

In 2013, the IKRC recommended a supplement to an ongoing IKC, “Four quadrupole movers and intersection control racks”, to augment the contribution ES04 by CIEMAT to Work Package 71, at the 2005 value of 102 k€. In total, 74 proposals have received favourable recommendations from the IKRC since the start of the project.

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Allocations of IKCs

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

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

In 2013, three contributions were allocated by the management board (Table 3), and 19 contributions were allocated by the council (Table 4).

In 2013, 22 contributions with a total value of 145.8 M€ were allocated to the respective institutes. Since the start of the project, a total of 67 IKCs have been allocated.

Abbreviation	Institute	IKC No.	Work package	Title	Value € 2005 (2013)
DESY	Deutsches Elektronen-Synchrotron, Germany	DE09	09	Supervision of cavity string assembly	931 600
		DE39	39	Electromagnetic compatibility (EMC)	823 350
SU	Stockholm University, Sweden	SE09	71	Radiation dose measurement system	421 190

Table 3 IKCs allocated in 2013 by the European XFEL Management Board (in 2005 prices)

Abbreviation	Institute	IKC No.	Work package	Title	Value € 2005 (2013)
CEA	Commissariat à l'Énergie Atomique et aux Énergies Alternatives, France	FR02	09	Assembly of 103 cavity strings	7 861 460
		FR03	03	Assembly of 103 cryomodules	9 673 540
DESY	Deutsches Elektronen-Synchrotron, Germany	DE02	02	Low-level RF system	17 200 840
		DE03	03	Procurement, installation, and commissioning of accelerator modules	9 585 610
		DE08	08	Cold vacuum system	7 017 680
		DE11	11	Current leads and tests of the superconducting magnets	2 347 000
		DE14	14	Photocathode laser, solenoid magnets, and cathode system for the injector	2 582 600
		DE15	15	Bunch compression and start-to-end simulation	1 447 200
		DE18	18	Synchronization and special diagnostics	10 234 000
		DE21	21	FEL concepts	2 355 000
		DE28	28	Accelerator control system	22 031 300
		DE32	32	Survey and alignment	4 830 300
		DE35	35	Radiation protection	3 266 100
		DE38	38	Personnel interlock system	4 399 000
		DE40	40	Information and process support	2 645 000
		DE46	46	High-power RF system, magnet, diagnostics, and vacuum accessories for the third-harmonic system	3 164 640
INFN	Istituto Nazionale di Fisica Nucleare – Sezione di Milano, LASA laboratory, Italy	IT01	04	Manufacturing of 320 niobium cavities, including helium tank	22 069 991
		IT02	03	Production of 25 cryostats (pressure vessels and cold masses) and payment of costs for 17 additional cryostats	7 879 409
		IT03	46	Cavities and cryomodule for the third-harmonic system	3 050 600

Table 4 IKCs allocated in 2013 by the European XFEL Council (in 2005 prices)

In 2013, 22 contributions with a total value of 145.8 M€ were allocated to the respective institutes. Since the start of the project, a total of 67 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.

Figure 1 Mover for beam size measurement system (IKC DE17b by DESY)

Figure 2 Producing 715 warm magnets (Contract RU11 to NIIEFA).
Left Preparing a coil for a dipole magnet.
Right Connecting cooling pipes to a quadrupole magnet.

Progress of IKC contracts

In 2013, the series production of IKC components for the accelerator complex progressed at full speed.

In particular, the following items were delivered:
- Superconducting cavities: 213 of 800 delivered
- Cryostats: 47 of 100 delivered
- Warm magnets: 383 of 715 delivered
- Cold magnets: 65 of 100 delivered

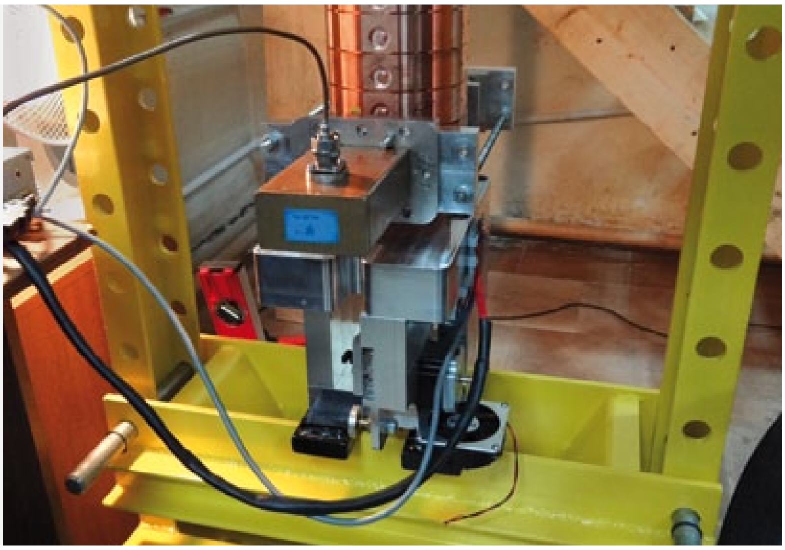

Figure 3 Tuning the transverse deflecting structure for Bunch Compressor 1 (Contract RU22 to INR)

In 2013, the series production of IKC components for the accelerator complex progressed at full speed. The start of testing in the AMTF was a major event. The testing of cavities in cold condition by the Polish team of IFJ-PAN reached its nominal rate.

Eighty-six milestones were completed and validated in 2013. 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, 188 milestones have been completed since the start of the project. All related documentation is stored in a specific IKC database for future traceability.

The start of testing in the AMTF was a major event in 2013. The testing of cavities in cold condition by the Polish team of IFJ-PAN reached its nominal rate (IKC PL05).

However, some critical difficulties arose in the manufacturing processes of two IKCs for the accelerator complex: the production of power couplers and the assembly of accelerating modules. Initial countermeasures to mitigate schedule problems are implemented.

Figure 4 Designing and producing power supplies for the superconducting magnets in Madrid, Spain (IKC ES03 by UPM).
Left Test parameter monitoring screen.
Right UPM team and power supply prototype.

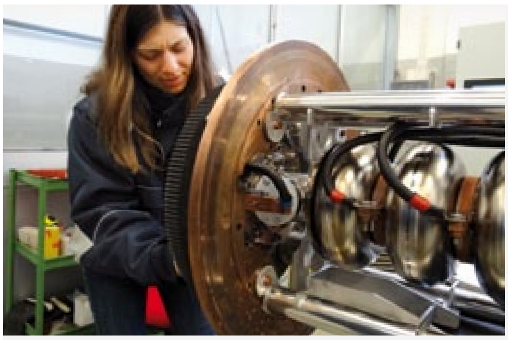

Figure 5 Manufacturing superconducting niobium cavities (IKC IT01 by INFN)

In 2013, three IKCs were successfully completed:

- **PL04, “Transfer line XATL1 and two vertical cryostats for AMTF”, by Wrocław University of Technology (WUT), Poland, for WP10**
  All components were delivered and installed by WUT personnel, were tested and commissioned successfully by DESY, and received third-party certification from TÜV Nord. The vertical cryostats are in full operation and are currently used for the cold testing of the superconducting cavities.

- **RU20, “Three cryomodule test benches for AMTF”, by Budker Institute of Nuclear Physics, Russia, for WP10**
  The three test benches in the AMTF hall were commissioned successfully and received third-party certification from TÜV Nord.

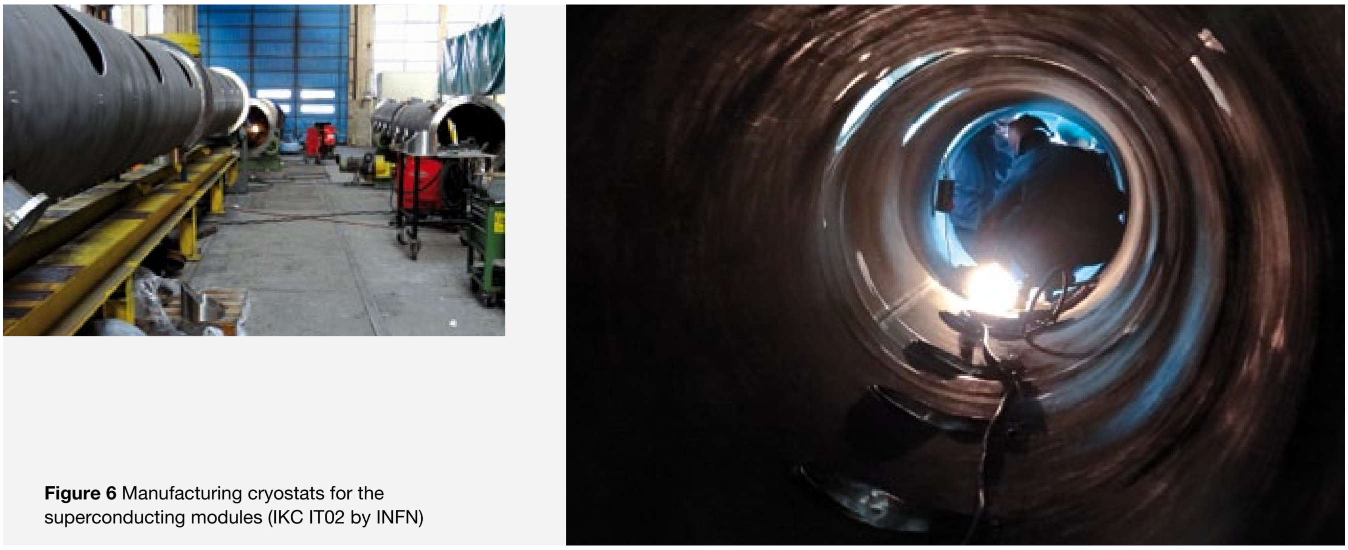

Figure 6 Manufacturing cryostats for the superconducting modules (IKC IT02 by INFN)

The benches are now ready for the tests of the first series cryomodules, planned for the beginning of 2014.

- **SE02, “Heat load investigations on diffractive optics”, by Royal Institute of Technology, Sweden, for WP73**
  Heat load simulations and damage studies of tungsten and diamond zone plates were performed, and valuable results were obtained. Damage experiments were conducted at the Linac Coherent Light Source (LCLS) at SLAC National Accelerator Laboratory in Menlo Park, California, indicating better resistance by diamond structures to higher energy levels. In addition, two methods of measuring the wavefront quality after focusing optics were tested.

To follow up on IKC activities and strengthen relationships with contributors, the IKC coordinator visited the facilities of several contributors (Table 5). Significant progress was made in 2013: several components were manufactured and passed acceptance tests, while most of the other contributions successfully passed production readiness reviews.

Significant progress was made in 2013: several components were manufactured and passed acceptance tests, while most of the other contributions successfully passed production readiness reviews. In 2014, allocation of the eight remaining IKCs is expected to be completed and a large number of milestones should be achieved in the ongoing IKCs.

Institute	Name of visited location	Contribution
PSI	Paul Scherrer Institut in Villigen, Switzerland	**CH03 for WP17** Development of a modular system for the beam position monitor (BPM) electronics, consisting of a custom crate, radio frequency (RF) front ends for the button and cavity BPMs, analogue-to-digital converters (ADCs), and a digital back end. **CH04 for WP16** Development of specific hardware, software, and firmware allowing operation of a transverse intra-bunch train feedback (IBFB). The IBFB system will enable feedback-based and feed-forward–based corrections of individual transverse bunch positions within the European XFEL macropulses, thus enabling the suppression of transverse perturbations of the electron and X-ray beam.
NIIEFA	D.V. Efremov Institute of Electrophysical Apparatus in St. Petersburg, Russia	**RU11 for WP12** Production, testing, and delivery of 715 warm magnets of 23 different types. A total of 411 magnets were produced, and 383 delivered.
INR	Institute for Nuclear Research RAS in Troitsk, Russia	**RU22 for WP18** Design, production, delivery, and installation of the transverse deflecting structures (TDSs) and high-power RF systems for the TDS systems in the injector and in the bunch compressor sections BC1 and BC2. The TDS for the injector was produced and is awaiting final brazing. The prototype RF system is under final evaluation.
UPM	Universidad Politécnica de Madrid, Spain	**ES03 for WP34** Design, production, test, delivery, and commissioning of 240 power supplies for the superconducting magnets. The final crated prototype successfully passed performance tests and EMC qualification.
INFN	Istituto Nazionale di Fisica Nucleare – Sezione di Milano, LASA laboratory, Italy	**IT01 for WP04** Supervision of the manufacturing of 320 niobium cavities, including helium tanks. Infrastructure at Ettore Zanon S.p.A. is fully operational and staffed with 46 trained personnel. A total of 119 cavities were delivered. **IT02 for WP03** Supervision of the production of 42 cryostats (pressure vessels and cold masses). A total of 25 cryostats were delivered. **IT03 for WP46** Production of cavities and cryomodule for the third-harmonic system. The first cavities were produced at Ettore Zanon S.p.A. and are under evaluation.

Table 5 IKC contributors visited by the IKC coordinator in 2013

Participation in other European projects

On 12–14 November 2013, the IKC coordinator took part in the European Spallation Source (ESS) annual review in Lund, Sweden, as a review committee member.

Figure 7 Producing cavities for the third-harmonic system (IKC IT03 by INFN).
Left Naked cavity.
Right Cavity assembled for the vertical cryogenic test.

Outlook

In 2014, allocation of the eight remaining IKCs is expected to be completed. In addition, a large number of milestones should be achieved in the ongoing IKCs. Delivery of the first cryomodules of the series production is expected at the beginning of 2014, marking the start of cryomodule testing activities in the AMTF. In parallel, other serial components of the accelerator complex should be delivered, and installation of the injector system should be completed. ■

Group members
Silvia Bertini and Serge Prat (group leader)

ACCELERATOR CONSORTIUM

The accelerator complex of the European XFEL is being constructed by an international Accelerator Consortium under the leadership of Deutsches Elektronen-Synchrotron (DESY). Seventeen European research institutes are contributing to the accelerator complex and its comprehensive infrastructure. Beamline magnets and major vacuum components are being delivered from Russia. Beam diagnostics elements are being produced at different institutes. The accelerator modules are being constructed in a shared effort by partners from several countries. DESY contributes many accelerator components as well as technical building equipment and general infrastructure. With the completion of the accelerator tunnel infrastructure, the installation phase has begun.

Quality control for accelerator components

The production of accelerator components for the European XFEL is in full swing. In all accelerator and facility infrastructure work packages, delivery of small- or large-series orders started. While the main emphasis in 2012 was on long-lead items, in 2013, first components were made available for tunnel installation. The electron source—the radio frequency (RF) gun—was installed in the injector building, and commissioning began. The required RF power was generated by the first installed multibeam klystron, with energy supplied from the first commissioned modulator, located in the above-ground modulator hall (XHM) on the DESY-Bahrenfeld site.

Almost all technical solutions have been finalized, and many coordination meetings now address logistical issues. Constant component delivery rates have to be guaranteed, and slight variations of the rates have to be compensated. Deviations from specifications have to be either corrected or, in some cases, accepted within the bounds of possibility. Quick but reliable quality control is of the highest importance. Such quality control requires sufficiently high test rates in a variety of test stands, including the Accelerator Module Test Facility (AMTF) at DESY (Figure 1), but also using many other inspection tools. Procedures were established in all work packages.

In 2013, first components were made available for tunnel installation. The electron source was installed in the injector building, and commissioning began.

Component integration now plays a major role. At Institut de Recherche sur les Lois Fondamentales de l’Univers (IRFU) of Commissariat à l’Énergie Atomique et aux Énergies Alternatives (CEA) in Saclay, France,

Figure 1 Accelerator module XM-2 during installation on the AMTF module test stand

accelerator module assembly has started. The Technical Coordination team at DESY is taking care of the integration of the warm (that is, not cryogenically cooled) beamline sections. Several stakeholders are defining the final configuration of electronics racks along the linear accelerator.

Production ramp-up

The industrial production of superconducting cavities for the accelerator started at the end of 2012. Two vendors ensure the mechanical fabrication, surface treatment, and assembly of the cavities, which are then ready for "vertical testing", the qualification check at DESY. Both vendors ramped up their production in 2013 and together reached the required rate of eight cavities per week. The overall industrial production within the European XFEL is remarkable, as an average rate of only one cavity per month was reached during the R&D phase. DESY and Istituto Nazionale di Fisica Nucleare (INFN) in Milano, Italy, are supervising the industrial cavity production. National Centre for Nuclear Research (NCBJ) in Świerk, Poland, is contributing essential parts, such as higher-order mode (HOM) antennas and special RF feed-throughs. Henryk Niewodniczański Institute of Nuclear Physics (IFJ-PAN) in Kraków, Poland, is testing the finished cavities at DESY. At the end of 2013, more than 200 cavities had been delivered and almost all of them tested. In general, their performance exceeds European XFEL specifications. Many cavities can be used at an accelerating field of about 30 MV/m, which is more than 20% above the design value. About one third of the cavities still require additional high-pressure water rinsing at DESY to overcome field emission, which would otherwise limit the cavity accelerating gradient to well below the possible maximum.

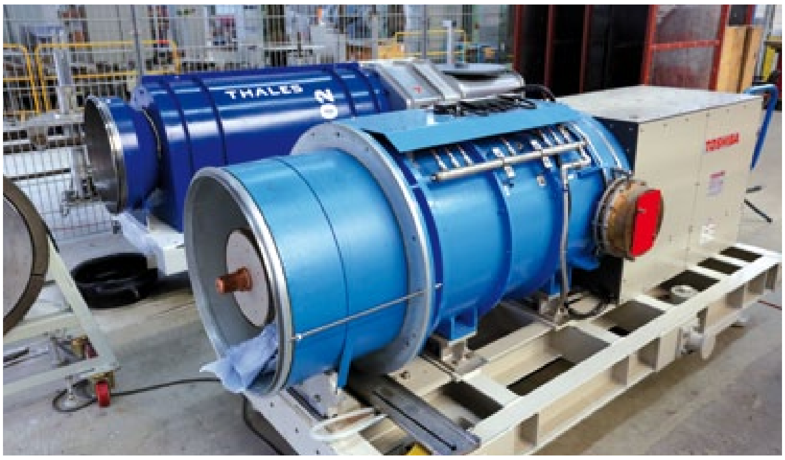

Figure 2 Klystrons ready for tunnel installation. These special RF sources, which are produced by two different vendors, supply a pulse power of up to 10 MW.

High-power RF couplers have turned out to be the most challenging components needed for the accelerator modules. Brazing and copper plating during production has to be done with care. By the end of 2013, Laboratoire de l'Accélérateur Linéaire (LAL) in Orsay, France, produced and conditioned almost 50 of 800 European XFEL couplers and made couplers for the first accelerator modules available to IRFU. The delivery rate reached four per week. The necessary ramp-up to eight per week will require excellent quality control during all individual production steps. To establish a buffer of available couplers and thereby avoid shortages, a search for a second vendor for part of the remaining couplers was started.

The superconducting quadrupole packages required for the accelerator modules are built in a collaboration between Centro de Investigaciones Energéticas, Medioambientales y Technológicas (CIEMAT) in Madrid, Spain, IRFU, and DESY, with magnet tests performed by IFJ-PAN. The cryostats have been contracted, and production is supervised by DESY together with INFN Milano. Cold (that is, cryogenically cooled) vacuum components are provided by Budker Institute of Nuclear Physics (BINP) in Novosibirsk, Russia.

IRFU has subcontracted a company to assemble all the accelerator modules in its new European XFEL infrastructure in Saclay. Pre-series modules were used to train personnel and to start the ramp-up of module production. In 2013, almost all personnel were trained, and standard procedures were established. The first module completely assembled by the industrial partner was shipped to DESY and tested. Its performance fulfilled all expectations (that is, the cavity accelerating gradient matched the results of preceding vertical tests).

Figure 3 View into one of the first power modulators supplying the klystrons in the accelerator tunnel of the European XFEL

In the last quarter of 2013, an unexpected problem occurred during the assembly of the last pre-series module (XM-1). After cavity string assembly in the cleanroom and roll-out, the helium service pipe sections of the individual cavities need to be connected, a task that includes orbital welding of titanium tubes. X-ray pictures of the welds revealed pores, which were unacceptably large according to the requirements of pressure equipment directives. An action plan was developed, and many sample welds were done at DESY and IRFU. During welding, exacting standards of cleanliness (for the surface, welding gas, gloves, and so on) must be observed. Initial mistakes made during orbital welding could be corrected, but investigations also revealed some non-acceptable pores in the longitudinal welds. As a consequence, replacement of all service pipes is now required, and some remaining short sections have to be X-rayed.

The welding problem halted the assembly of further modules, which had a direct impact on the project schedule. A repair procedure was defined, allowing the overall assembly schedule to be adjusted. Based on the currently assumed resources, the last module (XM-100) will be assembled in spring 2016. An accelerated module assembly that takes profit of additional resources could reduce the delay by a few months.

Many accelerator components are now available for installation. More than half of the RF power system's klystrons (Figure 2), modulators (Figure 3), pulse transformers, and waveguides have been delivered. Many modulators are in place, while other components are ready for tunnel installation. More than half of the warm beamline magnets have been delivered, mostly by D.V. Efremov Institute of Electrophysical Apparatus (NIIEFA) in St. Petersburg, Russia. Quality control, including magnetic measurement, started at DESY and, so far, could confirm the requisite magnetic-field quality. All magnets required for the injector

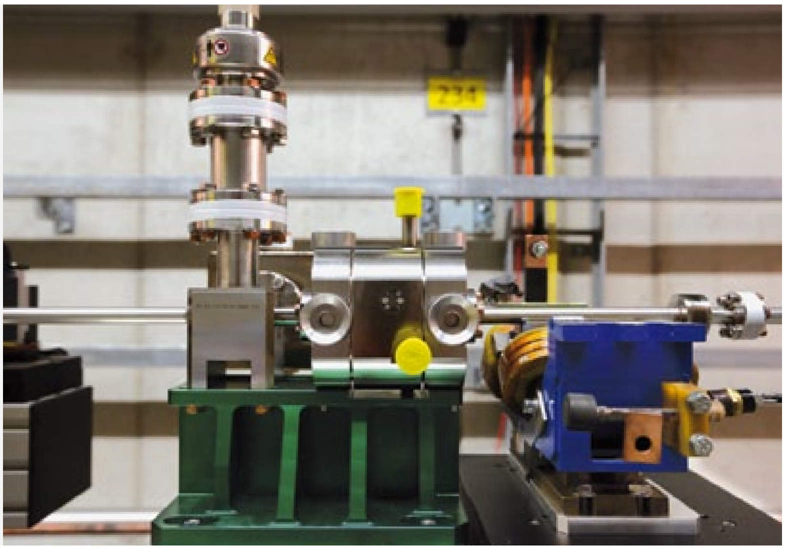

Figure 4 Components installed in the new, second beamline at FLASH.
Left Undulator beam pipe and adjustable beam pipe supports.
Right Combination of cavity beam position monitor and spontaneous-radiation absorber as it will be used in the European XFEL undulator intersections.

installation are available. Vacuum components are being designed and produced by DESY and BINP. Stringent requirements for the inner surface, the material permeability, and even the vacuum chamber alignment (Figure 4) have to be met, leading to elaborate multistep production processes. The production of the about 500 m of undulator vacuum chamber with a wall thickness less than 0.5 mm is in full swing, and the installation and alignment procedures have already been tested at the new, second beamline that is currently under construction at DESY's Free-Electron Laser in Hamburg (FLASH). The integration of pre-series and prototype components into the new FLASH beamline has been a valuable experience for other work packages as well, proving, for instance, alignment and interface concepts for diagnostic devices. In addition, almost the entire FLASH low-level RF (LLRF) system is now operated with micro-telecommunications computing architecture (μTCA) components, providing valuable input and experience for the European XFEL startup as well as enhanced stability and performance for FLASH.

Infrastructure and installation planning

In 2013, the infrastructure and installation planning advanced rapidly.

Installation in the modulator hall (XHM), the injector area, and the main linear accelerator tunnel (XTL) is finished. The XHM hall already houses many of the delivered modulators, and a first modulator connected to the electron gun's klystron (Figure 5) was successfully commissioned. In the injector tunnel, the electron gun was installed. A first commissioning was completed at the end of 2013, such that further installation of beamline sections can follow in early 2014.

Figure 5 First multibeam klystron installed in the XTIN underground building. The klystron supplies RF power to the RF gun installed in the injector tunnel. The connection is done using rectangular waveguides.

Gun operation should resume in early summer 2014. At the end of 2014, installation of the main cryogenic transfer line for the linear accelerator will require another installation phase, which will be followed by the integration of the injector's accelerator module, including the special 3.9 GHz module.

The technical equipment for XTL was successfully installed in 2013. Accelerator installation started with a DN200 helium gas line right under the ceiling and with the steel frames required to suspend the accelerator modules from the ceiling. First modules are scheduled for tunnel installation in the second quarter of 2014.

The tunnel shaft (XS1) that connects the end of XTL with surface buildings is being fitted with all necessary technical equipment. For the first undulator tunnel (XTD2 for SASE1), tunnel infrastructure is almost finished, and first undulator installation will occur in the fourth quarter of 2014.

Regular reviews of all underground tunnels and beamline sections support the detailed planning and eventual installation of equipment in the sections.

Installation in the modulator hall, the injector area, and the main linear accelerator tunnel is finished. The modulator hall already houses many of the delivered modulators, and a first modulator connected to the electron gun's klystron was successfully commissioned. In the injector tunnel, the electron gun was installed.

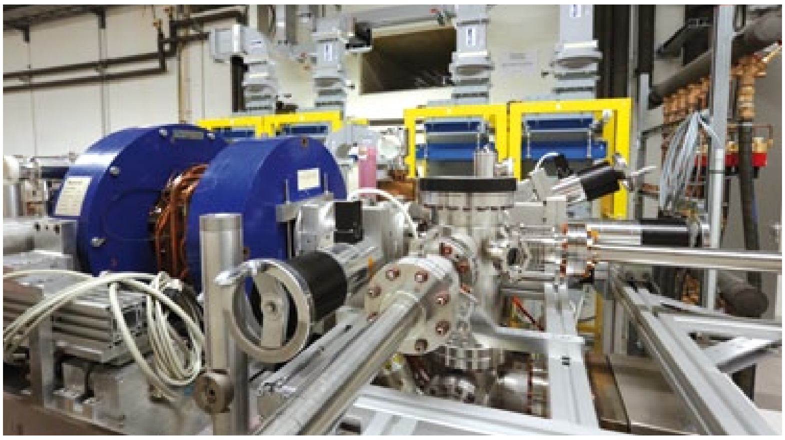

Figure 6 RF gun installed on the seventh floor of XTIN, with the four waveguides in the background, and the blue solenoid coils surrounding the gun body and the cathode exchange system in the foreground

Figure 7 Hot-water reservoirs for gun temperature control installed on the seventh floor of XTIN

Figure 8 Interlock door from XSIN to XTIN with a temporary-access key system and radiation-monitoring device

First commissioning of electron source

One of the most crucial accelerator subsystems needed for successful operation of the European XFEL is the photocathode electron gun system (Figure 6), essential parts of which were installed and tested in 2013. The RF gun cavity and the cathode exchange system were manufactured by DESY's vacuum group. In February 2013, the complete setup, including auxiliaries such as solenoid magnets, was transferred to the photoinjector test facility (PITZ) at DESY in Zeuthen, where the RF gun was conditioned to reach the peak and average RF power levels required for operation at the European XFEL. The stringent requirement on beam emittance of 0.9 mm mrad at 1 nC bunch charge in the injector had already been demonstrated at PITZ during the R&D phase.

Prior to the gun's installation and operation in the European XFEL injector building, numerous components had to be ready, such as a cooling-water circuit (Figure 7) that stabilizes the gun water temperature to within 0.1°C while the average RF power in the gun varies between 0 and 50 kW; the radiation protection and personnel interlock system (Figure 8) with shielding walls, radiation monitoring, temporary-access doors, and so on, which had to be approved by the authorities prior to gun operation; and the high-power RF system, which ranges from the modulator in XHM, to the klystron on the fourth floor of the injector tunnel (XTIN), to the RF waveguide distribution system. A crucial point of the RF distribution system is the final vacuum window, which separates the waveguides from the gun vacuum. This window has to transport up to 7 MW RF power, which is more than used at FLASH. The performance evaluation of this distribution option was a major objective of the gun test that was carried out in the European XFEL injector building in December 2013.

All of the systems had to be integrated into the control system and were operated from DESY's accelerator control room. One benefit of the test was to show, for the first time, how the different systems and their interfaces work together after installation in the European XFEL tunnel. The lessons learned will be valuable for future commissioning steps.

The gun was operated continuously for more than two weeks before operation had to be stopped for further installation work in the injector tunnel and building. These two weeks were not sufficient to fully qualify the RF distribution technology choices, although the performance development was very encouraging. Further tests will be performed in the summer of 2014. ■

05

PHOTON BEAM SYSTEMS

In 2013, photon beam systems groups at European XFEL continued preparation of undulators, devised ways to improve the X-rays, developed X-ray optical and beam transport components, and started production of diagnostics devices.

Working at the test beamline in HERA South


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UNDULATOR SYSTEMS

Undulator systems are of central importance for the European XFEL. In the undulators, the bunched electron beam triggers a process called self-amplified spontaneous emission (SASE), which results in the generation of ultrabrilliant pulses of X-ray radiation. In its baseline configuration, the European XFEL will include two hard X-ray undulators (SASE1 and SASE2), each 215 m long, and one soft X-ray undulator (SASE3), 129 m long. The construction of these systems is being organized by the Undulator Systems group.

Production of undulator segments

After a comprehensive R&D phase that included the construction of six pre-series prototypes, the serial production of 85 undulator segments was launched at the end of 2012. It is scheduled to end in December 2014, which means a challenging average production rate of almost one undulator segment per week. In 2013, the Undulator Systems group focused on organizing the industrial serial production and related in-house activities.

After providing innovative solutions to numerous technical challenges, the group set up an internal organization for production management and supervision to perform the following tasks:

- Prepare a quality management plan for all undulator systems.
- Define quality assurance and quality control (QA/QC) procedures for the industrial production and for commissioning, magnetic measurements, and tuning.
- Supervise industrial production. Develop suitable in-house control structures and logistics for all undulator-related tasks.
- Develop fast commissioning and validation tools for the motion control system of the undulator segments.
- Develop extensive documentation of the production process using the Engineering Data Management System (EDMS) of Deutsches Elektronen-Synchrotron (DESY).

The ultimate challenge was to ramp up production while ensuring homogeneous quality from all vendors. The Undulator Systems group got its three magnetic labs running in line with the intended production rate. Since summer 2013, about one segment per week is granted the status “ready for installation” (RFI) and stored in a hall of about 700 m^2.

By the end of 2013, 79 support systems, including controls, were produced and delivered; 70 magnetic structures were delivered; 64 were prepared for magnetic measurements; 54 were commissioned, underwent magnetic measurement and tuning, and were RFI.

Magnetic performance of undulator segments

The performance of the undulator segments depends on the following main parameters:

- ***K* parameter**
  Determines the radiation wavelength and tuneability.
- **Root mean square second field integral error (RMS $I2_{y,z}$)**
  Determines the degradation of the overlap between the laser field and the electron beam in the vertical (*y*) and horizontal (*z*) direction.
- **RMS phase jitter**
  Measures the longitudinal phasing between the free-electron laser (FEL) radiation field and the microbunched electron beam. For FEL operation on the first harmonic, a phase jitter of 8° is sufficient.
- **Validity range**
  Specifies the full operational gap range over which the RMS second field integral and phase jitter criteria must be fulfilled.

Table 1 lists magnetic measurement results of about 20 SASE1–SASE2 undulator segments (U40) and 6 SASE3 segments (U68). Only the maximum *K* parameter at 10 mm gap deviates from the specified values. For the U40 segments, the deviation is small; for the U68 segments, it is about 15%. However, because of the large *K* parameter, the FEL properties and tuning range are not affected. To reach the water window at 52 Å, the electron energy needs to be tuned to 8.5 GeV for $K = 9.0$ instead of 9.8 GeV for $K = 10.5$. No undulator segment is granted RFI status unless it achieves $K = 3.9$ and 9.0 for U40 and U68, respectively. This holds true especially for the *K* parameter at 10 mm gap, as shown in Table 1.

	SASE1–SASE2 (U40)		SASE3 (U68)	
	Specifications	**Results**	**Specifications**	**Results**
Period length [mm]	40	40	68	68
Operational gap range [mm]	10–20	10–20	10–25	10–25
B_0 at 10 mm gap [T]	1.14	1.13	1.69	1.66
K at 10 mm gap	4	≥ 3.9	10.5	≥ 9.0
RMS $I2_y$ [Tmm^2]	< 100	< 50	< 210	< 130
RMS $I2_z$ [Tmm^2]	< 100	< 40	< 100	< 80
Phase jitter [°]	< 8	< 7	< 8	< 8

Table 1 Specified and achieved properties for SASE1–SASE2 and SASE3 undulator segments

Table 1 lists only integral results to be fulfilled for the operational gap range. In contrast, Figure 1 shows the gap dependencies for *K* parameter, phase jitter, and overlap properties for two representative SASE3 U68 undulator segments. (The SASE1–SASE2 U40 results are quite similar.)

The top of Figure 1 shows the *K* parameter and phase jitter as a function of gap. The *K* parameters coincide within some tenths of a percent. The phase jitters of both segments display an almost identical behaviour, which is dominated by mechanical deformation of the 5 m long girders under changing magnetic forces of up to 17 t at 10 mm. The deformation causes a gap variation of up to ± 50 µm and a corresponding variation of the *K* parameter along the undulator, which leads to the observed additional phase jitter. The minimum at about 14 mm with a phase jitter below 2°

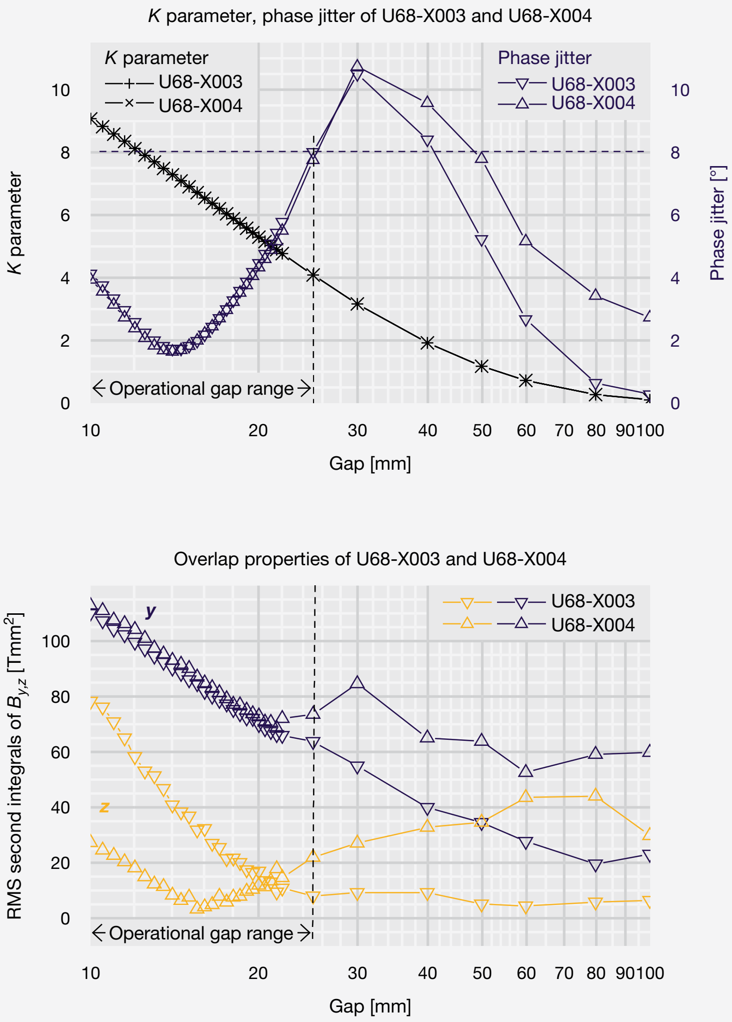


Figure 1 Magnetic measurement results as a function of gap for two SASE3 U68 undulator segments.
Top *K* parameter and phase jitter
Bottom RMS second field integrals for the vertical (*y*) and horizontal (*z*) direction

corresponds to the tuning gap where the pole tuning was done and all errors were minimized. The girders thus bend from convex (at small gaps) to flat (at 14 mm) to concave (at gaps greater than 14 mm), where forces get weaker.

The bottom of Figure 1 shows the overlap properties. In the horizontal direction (*z*), fields are small, and the RMS second integrals are well within specifications but dominated by random errors. In contrast, in the vertical direction (*y*), the RMS second integrals are dominated by a periodic wiggling motion. At 10 mm, these integrals amount to 117 Tmm^2. The effect dominates most of the operational gap range, but there are small error contributions in addition.

All commissioned undulator segments could be tuned to the specifications listed in Table 1.

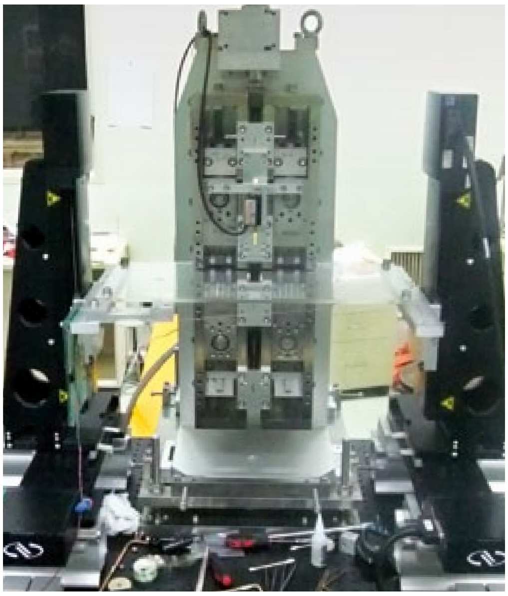


Figure 2 One of the first phase shifters aligned on a moving wire bench for magnetic tuning

Phase shifters

Phase shifters are needed to control the ponderomotive phase between the microbunched electron beam and the laser field at different undulator gaps. They must be completely transparent to the electron beam, meaning that they do not induce any steering errors when the gap is changed. The resulting tough specifications for the first field integrals in the horizontal and vertical plane are ± 4 μTm or less for gaps above 16 mm. For smaller gaps, requirements can be gradually relaxed to ± 18 μTm at the minimum gap of 10.5 mm. Permanent-magnet technology and a special magnetic design with a high degree of magnetic symmetry are used to keep gap-dependent steering errors as small as possible. In addition, a shimming technique to reduce residual gap dependencies was developed.

Most of the 91 required phase shifters were produced in 2013 by three suppliers in Germany, Italy and Slovenia, and China. Magnetic measurements and tuning started in the last quarter. A big effort was made to comply with the small tolerance limits. Figure 2 shows a typical measurement setup.

Figure 3 shows the measured gap dependence of the horizontal and vertical first field integral errors for PS#31, one of the first phase shifters of the serial production. A suitable set of shims was applied. The specification of ± 4 μTm in both directions can be fulfilled even at gaps below 16 mm. The other suppliers obtained similar results.

Most of the 91 required phase shifters were produced in 2013. Magnetic measurements and tuning started in the last quarter.

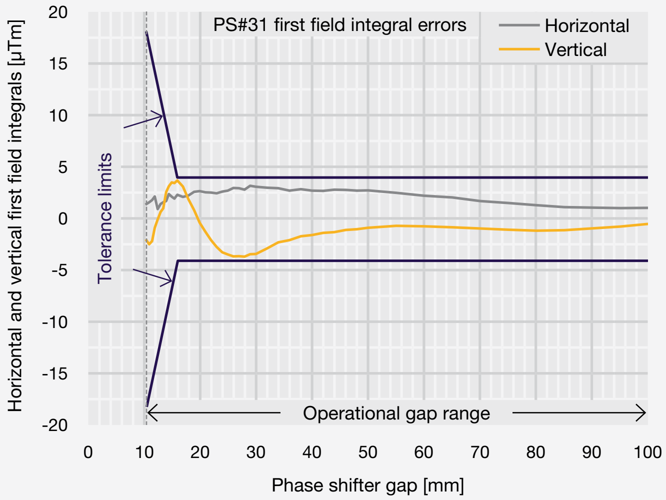


Figure 3 First horizontal and vertical field integral errors of phase shifter PS #31 as a function of its gap. The blue lines show tolerance limits.

Further plans

There will be three main areas of activity in 2014:

- Serial production of the undulator segments will be continued and finished as planned by the end of the year.
- All phase shifters will be produced and delivered, as well as the other components needed for the undulator intersections, such as quadrupole movers, beam position and loss monitors, vacuum systems, absorbers, support stands, and so on. Some of these components are in-kind contributions from participating countries.
- In spring, installation of the SASE1 undulator system will start. In autumn, SASE1 will be ready for the installation of the first undulator segments. ■

Group members
(left to right) Andreas Beckmann, Frederik Wolff-Fabris, Martin Knoll, Uwe Englisch, Joachim Pflüger (group leader), Karl-Heinz Berndgen, Georg Deron, Yuhui Li, Marc Viehweger, Majid Bagha-Shanjani, Suren Karabekyan, Bora Ketenoglu (guest), Mikhail Yakopov, Pitt Biermordt (not shown), and Yongtao Liu (not shown)

SIMULATION OF PHOTON FIELDS

The Simulation of Photon Fields (SPF) group devises schemes that go beyond the baseline concept of the European XFEL to improve the characteristics of the photon beams that the facility will produce. The group is also developing a software platform that enables simulations of spontaneous radiation (SR) and X-ray free-electron laser (FEL) radiation. Overall, the SPF group is engaged to ensure that the European XFEL will be the best facility of its kind in a quickly developing global scientific environment.

Collaboration with DESY and CFEL

In 2013, SPF group leader Gianluca Geloni collaborated with Vitali Kocharyan, Evgeni Saldin, Svitozar Serkez, Martin Tolkiehn, and Igor Zagorodnov at Deutsches Elektronen-Synchrotron (DESY) as well as with Oleksandr Yefanov at the Center for Free-Electron Laser Science (CFEL) in Hamburg, Germany. The collaboration's studies are largely based on the success of self-seeding, an approach to deliver nearly Fourier transform–limited X-ray pulses based on active amplification of a frequency-filtered FEL seed. Practical realizations of the filter vary from the hard X-ray self-seeding (HXRSS) case, where a thin single crystal can be used, to the soft X-ray (SXRSS) range, where gratings are needed. Combining self-seeding with tapering by appropriately varying the undulator field strength promises extreme peak powers in the TW range.

> The collaboration's studies are largely based on the success of self-seeding, an approach to deliver nearly Fourier transform–limited X-ray pulses based on active amplification of a frequency-filtered FEL seed. Practical realizations of the filter vary depending on the photon energy.

HXRSS and SXRSS

The collaboration members considered the possibility of using different reflections in a diamond single crystal for the HXRSS setup at the European XFEL. A diamond single crystal with one rotational degree of freedom allows the photon range of 3–13 keV to be covered using four different reflections.

The collaboration also studied [1] a very compact SXRSS setup by adapting a grating-based scheme that was experimentally proven at the Linac Coherent Light Source (LCLS) at SLAC National Accelerator Laboratory in Menlo Park, California. This setup could be installed in the SASE3 beamline at the European XFEL. The design (Figure 1) covers the spectral range of 300–1000 eV. Simulations show that the FEL power would reach 1 TW and that the spectral density would be about two orders of magnitude higher than pulses produced by self-amplified spontaneous emission (SASE) at saturation.

Purified SASE and non-linear post-saturation tapering

The purified SASE (pSASE) undulator configuration proposed at SLAC promises an increase in the spectral density of X-ray FELs for soft X-ray applications. The collaboration members studied how such a configuration could be implemented at the European XFEL. The scheme could increase the spectral density between 1.3 and 3 keV by an order of magnitude. This option, which could be implemented in the SASE3 baseline design without additional hardware, would be complementary to the SXRSS setup proposed for the same beamline.

Even when not combined with self-seeding, tapering the undulator field strength promises an increase in the quality of the output radiation characteristics of the European XFEL. The collaboration members analysed the case of an electron bunch with nominal parameters. Simulations of non-linear post-saturation tapering show up to a tenfold increase in peak power and photon spectral density with respect to the untapered case, without modification to the baseline design.

Large SASE bandwidth and high-intensity photon pulses

For some X-ray FEL applications, such as femtosecond X-ray nanocrystallography, a very large SASE bandwidth on the order of

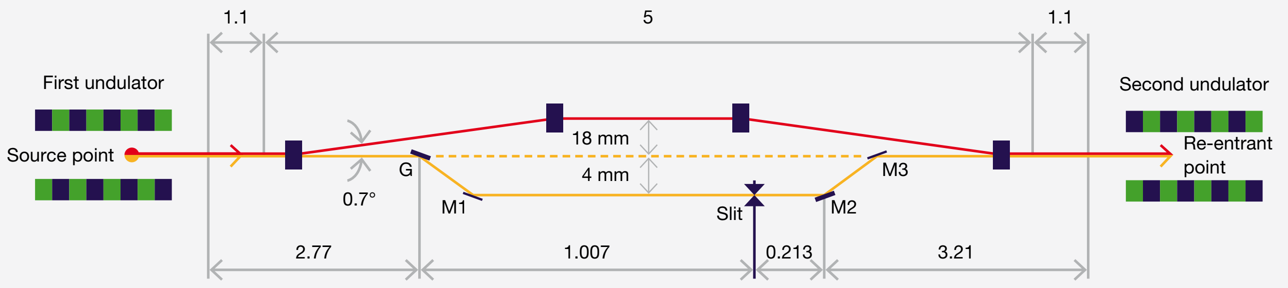


Figure 1 Schematic layout of the SXRSS setup for the European XFEL, adapted from a working LCLS scheme (G: grating; M: mirror; horizontal distances in metres)

a few percent is preferable. The collaboration studied the possibility of achieving up to a tenfold increase in SASE bandwidth, assuming that a high-current mode of operation for the European XFEL will be feasible. This possibility could increase the efficiency of protein structure determination at the European XFEL.

For other X-ray FEL applications, like single-biomolecule imaging, the collaboration proposed a configuration that combines HXRSS, undulator tapering, and an emittance spoiler method to increase the X-ray FEL output peak power and shorten the pulse duration up to a level sufficient for performing bio-imaging of single protein molecules in the optimal photon energy range. Further studies will be made to gauge the potential of this technique.

xframework software for radiation calculations

Group member Ilya Agapov made significant progress in developing software for radiation calculations. Better understanding of X-ray FEL radiation requires studies of the interaction between undulators, beam dynamics, and photon beam transport. To enable such studies, Agapov created a transparent software framework, called “xframework”, based on open source software applications, such as the Genesis and Synchrotron Radiation Workshop (SRW) code [2]. Using expanding computing power, SPF group members can now run extensive simulations that enable them to predict performance, improve their understanding of expected accelerator parameters, and incorporate these parameters into the figures of merit requested by users (for example, duration, peak power, maximum spectral density, spectral width, brightness, pulse energy, and variance of energy fluctuations).

xframework has a generic hardware interface that makes it possible to use the same tools in simulation and operation. Together with the software distribution, this interface has already been successfully employed by guest scientist Sergey Tomin for orbit correction at the National Research Centre Kurchatov Institute (NRC KI) synchrotron in Moscow, Russia. The interface is an important asset that will allow for high-level ad hoc tuning and diagnostics during commissioning and operation of the European XFEL.

xframework is being developed as a multiphysics package, which could be used during commissioning as well as for planning and interpreting experiments to help users with their tasks. Moreover, xframework can be used to perform systematic studies of proposed methods for improving the output characteristics of the European XFEL, such as non-linear tapering.

Additionally, xframework allows for accurate estimation of SR backgrounds, accounting for effects like energy spread, emittance, and quantum diffusion. SR is an important tool for SASE FEL tuning and diagnostics. Software for machine tuning based on SR properties is being developed in collaboration with Sergey Tomin (NRC KI) and Oleg Chubar of Brookhaven National Laboratory in Upton, New York. Guest scientists Tomin and Nikolay Smolyakov (NRC KI) continued to develop alternative routines for SR calculations, to be included in xframework.

Outlook for 2014

In 2014, the SPF group plans to carry on with research activities in the areas outlined above. The group will continue to host guest scientists Smolyakov and Tomin, who will proceed with their studies of SR and beam dynamics. In parallel to the development of xframework, Geloni and Agapov will continue collaborative work to study novel upgrade possibilities for the European XFEL. ■

References

[1] Grating monochromator for soft x-ray self-seeding the European XFEL
S. Serkez, G. Geloni, V. Kocharyan, E. Saldin
Red Report (2013)
DESY 13-040
arXiv:1303.1392

[2] Towards more accurate modelling of the FEL radiation for the European XFEL
I. Agapov and G. Geloni
Synchrotron Light Sources and FELs: Free Electron Lasers
Shanghai, China, 12–17 May 2013
Proc. IPAC 2013, TUPEA006 (2013)

Group members
Ilya Agapov and Gianluca Geloni (group leader)

X-RAY OPTICS AND BEAM TRANSPORT

The task of the X-Ray Optics and Beam Transport group is to develop and install the X-ray optical and beam transport components between the undulators and the experiment hall. These devices will be located in the tunnels and shaft buildings of the facility and include offset and distribution mirrors, monochromators for hard and soft X-rays, shutters, slits, attenuators, collimators, and the vacuum system. To minimize contamination of and damage to the sensitive X-ray optical surfaces, high standards for vacuum cleanliness and residual dust particle concentration are required.

Progress made in 2013

In 2013, five staff members joined the group: Janni Eidam (mechanical engineer), Paul Frankenberger (technician), Natalia Gerasimova (physicist), Timm Florian Kraft (bachelor student), and Maik Neumann (mechanic).

Prototypes for adaptive mirrors (Figure 1), mirror chambers, and differential-pumping stages were received and tested, and the assembly of the SASE3 gas attenuator system was started. The detailed design for the installation in the XTD2 tunnel was finished, and a first test installation of beam pipe holders was performed.

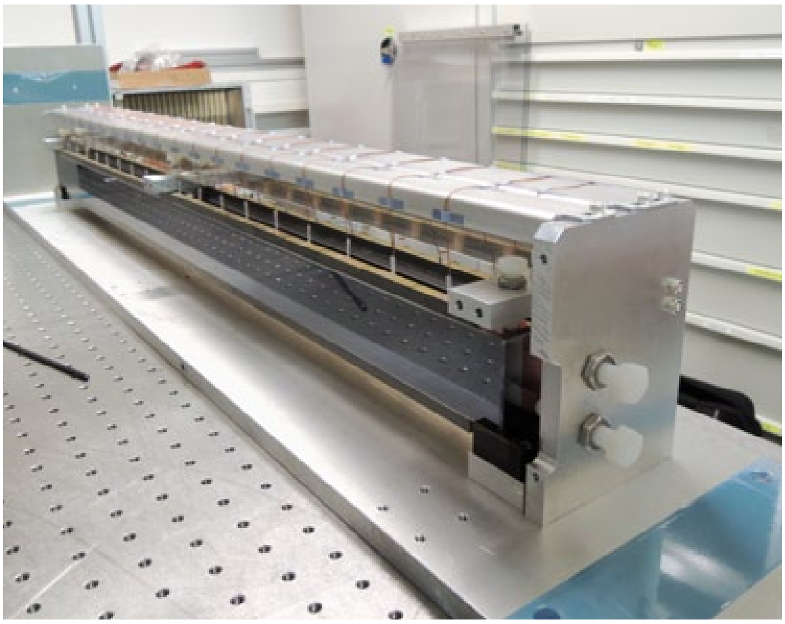


Figure 1 Prototype of an adaptive mirror. The mirror deflects in horizontal geometry with the deflecting surface facing the camera. Bending can be controlled using piezo elements located at the four edges on the top and bottom of the mirror.

Prototype adaptive mirror

The beam transport system of the European XFEL will use nine horizontally deflecting mirrors to guide the beams to the six scientific instruments. The specifications of these mirrors are extremely tight: 2 nm peak-to-valley profile error and a flatness corresponding to a radius of curvature of more than 6000 km are required to keep distortions of the beam at an acceptable level. In some cases, the mirror curvature has to be adjusted to radii of typically 50 km to generate an intermediate focus. To test the concept of bending control, a 950 mm long prototype adaptive mirror was developed, with 18 groups of piezo elements that generate local bending moments to the mirror when voltage is applied. The prototype mirror was built in collaboration with the companies Bruker ASC (Köln, Germany), Thales SESO (Aix-en-Provence, France), and Cinel Strumenti Scientifici s.r.l. (Vigonza, Padua, Italy) and tested at the metrology laboratory of Helmholtz-Zentrum Berlin (HZB) in Germany.

Test results show a bending behaviour very close to the previously simulated values. Overall bending radii between 12 km and 6000 km can be achieved by applying a corresponding homogeneous voltage to all piezo elements. Applying different voltages to the piezo elements can correct long-range profile distortions arising from the mounting.

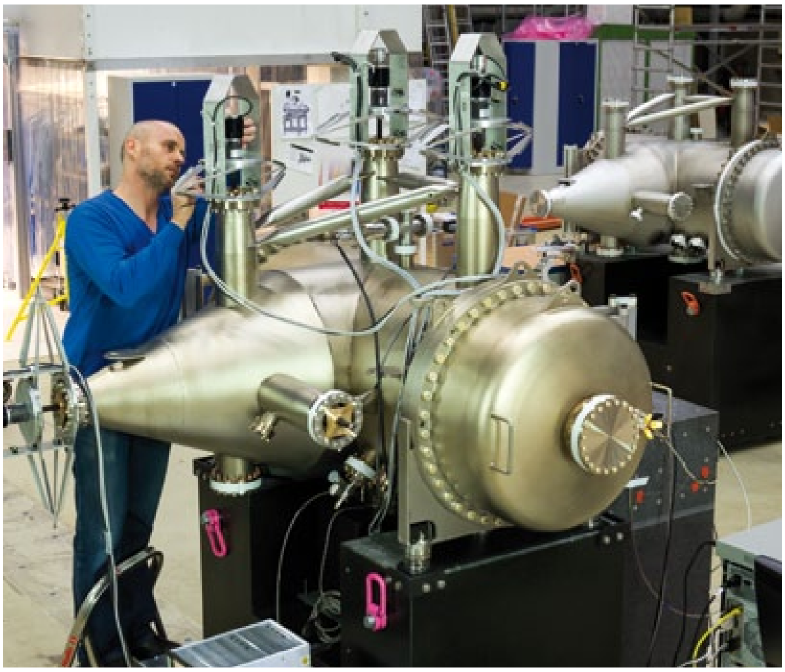


Figure 2 Mirror chamber for offset and distribution mirrors

Mirror chambers

The mirrors of the beam distribution system described above will be placed in ultrahigh-vacuum (UHV) chambers. The high requirements for the optical quality of the mirrors have to be matched by mirror chambers providing a high degree of vibrational and long-term stability. A mirror chamber was developed together with HZB and tested at the vacuum laboratory in the HERA South building (Figure 2). The tests revealed a vibration level of less than 20 nm root mean square (RMS), which fulfils the requirements. The long-term stability of about 1 µrad per week has to be improved by thermal stabilization and is the subject of ongoing studies.

First tunnel installations

The first elements of the beam transport system to be installed will be located in the tunnel XTD2. The detailed design of the beam transport system in XTD2 was completed in 2013 and checked for conflicts with other planned components using the CAD model of the tunnel. At the end of the tunnel, the photon beam is located very close to the tunnel wall at a height of about 2.6 m above the floor, which poses special challenges for the installation of the UHV components under clean conditions. To test installation procedures, a sequence of beam pipe supports has been installed in XTD2 (Figure 3) even before the scheduled start of beam transport installation in 2014.

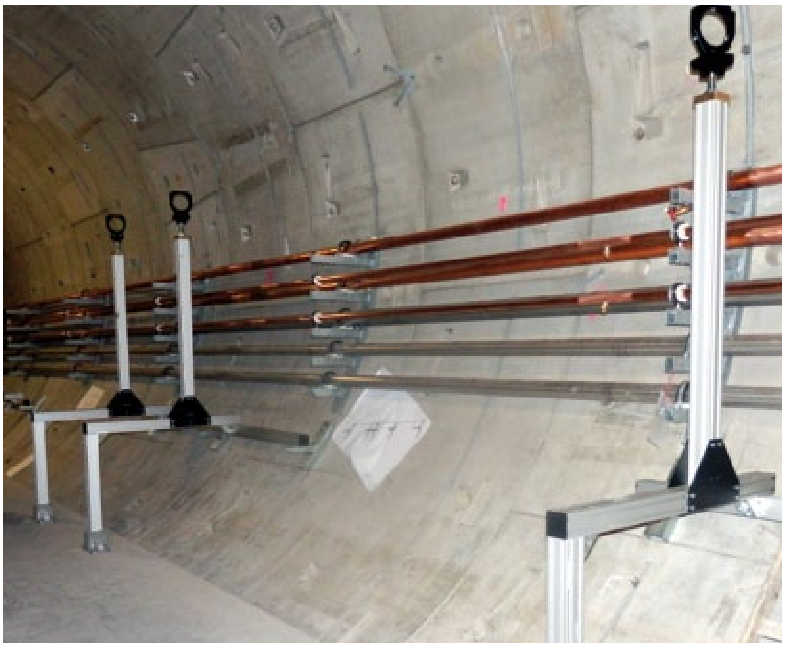


Figure 3 First installation of beam pipe supports in XTD2. The X-ray beam will be located on top of the aluminium structure, where UHV beam pipes will be installed.

Perspectives for 2014

In spring 2014, installation of the beam transport components will start in XTD2. At the same time, installation in the subsequent tunnels XTD9 and XTD10, which is due to begin in late 2014, will be prepared. The serial production of several components has already started. However, substantial effort will be required to design the remaining components and perform quality control and acceptance tests. The ongoing R&D efforts will concentrate on mirror systems, monochromators, and beam loss monitors. ■

Group members
(left to right) Martin Dommach, Harald Sinn (group leader), Daniele La Civita, Idoia Freijo Martín, Paul Frankenberger, Antje Trapp, Liubov Samoylova, Fan Yang, Maurizio Vannoni, Massimiliano Di Felice, Maik Neumann, Natalia Gerasimova, Xiaohao Dong, Nicole Kohlstrunk, Bianca Dickert, Alexander Bartmann (not shown), Janni Eidam (not shown), Timo Korsch (not shown), Timm Florian Kraft (not shown), and Raúl Villanueva Guerrero (not shown)

X-RAY PHOTON DIAGNOSTICS

The X-Ray Photon Diagnostics group is responsible for designing, constructing, and operating the diagnostics devices that will measure and monitor the properties of the X-ray photon pulses generated by the European XFEL. In 2013, the group started production of the devices, including X-ray gas monitors and imaging stations, and carried out important tests.

Purpose of diagnostics devices

At the European XFEL, diagnostics devices are necessary to monitor each photon beam pulse in order to provide reference data essential for calibration, normalization, and interpretation of the data, especially during commissioning. The diagnostics information will encompass beam properties such as pulse intensity, position, and spectral and temporal information. The shot-to-shot capability is challenging because of the 4.5 MHz repetition rate, but is particularly important when radiation is created through self-amplified spontaneous emission (SASE), where each pulse is unique because it originates from shot noise.

Overall progress

While 2012 was mainly dedicated to prototype tests and conceptual studies [1], 2013 saw the start of production of the finalized devices. The main parts of the X-ray gas monitors were manufactured, and their functions checked with synchrotron radiation. The imaging stations for beam alignment were tendered, and their commercial production was started. Decisive progress was made in the engineering implementation of the diagnostics devices in the photon tunnels, such as detailed designs of device girders, support pillars, and frames for motion.

The X-Ray Photon Diagnostics group was also involved in the first demonstration of online, non-destructive, shot-resolved free-electron laser (FEL) polarization monitoring; in a test of non-destructive, high-resolution hard X-ray spectral monitoring; in relative arrival time measurements; and in a test of the group’s own diamond detector prototypes.

Gas-based intensity and position monitors

The X-ray gas monitors (XGM) are gas-based intensity and position monitors, contributed by Deutsches Elektronen-Synchrotron (DESY), Germany. The design (Figure 1) features two main chambers and two huge-aperture open multiplier (HAMP) chambers per XGM unit, assembled on a common girder. The HAMP chambers are essential

Figure 1 CAD drawing of the complete X-ray gas monitor, including girder and support pillars

to resolve individual pulses at MHz rates, and a prototype was successfully tested with beam at Physikalisch-Technische Bundesanstalt (PTB) in Berlin, Germany. Each of the four chambers can now deliver intensity measurements and one transverse position measurement, a functionality that was also verified experimentally.

Online photoemission spectrometer

The X-Ray Photon Diagnostics group participated in the commissioning of a novel variable-polarization option at the Free Electron Laser for Multidisciplinary Investigations (FERMI) at the Elettra Sincrotrone Trieste laboratory in Italy, which served as proof of principle of the setup provided by the PETRA III (P04) group at DESY. For the first time, novel digitizer hardware and its Karabo front end (developed by the European XFEL DAQ and Control Systems group) were used at an FEL, enabling single-shot polarimetry at an extreme-ultraviolet (XUV) FEL. The acquired data allowed the validation of strategies for real-time computing of diagnostic data, although initially only on conventional computing hardware. The feedback provided to the FERMI machine group serves as a benchmark for machine performance in variable-polarization mode. The observed online photoemission spectrometer (PES) performance can be extrapolated to X-ray FELs, which makes the X-Ray Photon Diagnostics group confident that it will provide a powerful photon diagnostics spectrometer and polarimeter for the European XFEL.

Figure 2 Final design of the undulator commissioning spectrometer

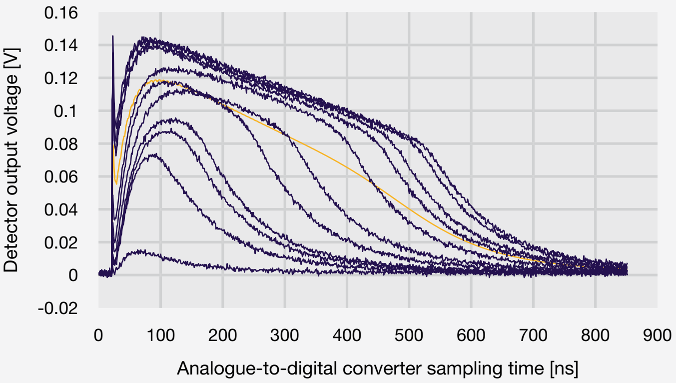
Undulator commissioning spectrometer

The prototype of the undulator commissioning spectrometer (*K* monochromator), which was built and tested with synchrotron radiation at DESY in 2012, is being expanded into the full SASE1 version (Figure 2). A cooling system and a new absolute in-vacuum encoder were implemented, and assembly has started, so that the device will be ready for installation in the tunnel in the second quarter of 2014.

For energy calibration and diagnostics purposes, it will be necessary to insert filters or attenuators into the beam. A newly designed filter chamber will be used with spontaneous radiation (SR) together with the *K* monochromator and SR imager.

Diamond detectors

Single-crystal electronic-grade chemical vapour deposition (CVD) diamond is a promising material for shot-to-shot beam position and intensity monitors for hard X-ray beamlines. Since the high pulse intensity would cause single-shot damage to metal contacts, a special electrode geometry is used. The group carried out the first tests at an X-ray FEL using two diamond detectors at the X-ray Pump–Probe (XPP) instrument of the Linac Coherent Light Source (LCLS) at SLAC National Accelerator Laboratory in Menlo Park, California, at a maximum pulse energy of 20 µJ behind a monochromator. Results of the pulse-resolved measurements are shown in Figure 3.



Diamond: 50 µm
Photon energy: 8.8 keV
Transmission: 0.5
Bias: 200 V (front)
Channel 1
Single pulses (blue)
Average (orange)

Figure 3 Diamond detector intensity measurement of single X-ray FEL pulses, showing saturation at higher intensities. Good linearity was observed up to a pulse energy of 1 µJ.

Temporal diagnostics

The X-Ray Photon Diagnostics group participated in experiments at the Atomic, Molecular and Optical Science (AMO) instrument at LCLS, where spatial and spectral encoding were combined to allow sub-femtosecond–precision measurements of the relative arrival time between the X-ray FEL beam and an optical pump laser beam [2]. Jia Liu, a scientist specializing in temporal diagnostics who joined the group in 2013, focused on optical laser–based THz generation for streaking as a promising pulse duration measurement method. For arrival time monitoring, the group prioritized work on spectral encoding.

In 2014, the group will continue to participate in experiments with the aim of exploring and implementing novel diagnostics methods for European XFEL users.

More diagnostics

In close collaboration with the X-Ray Photon Diagnostics group, the company JJ X-Ray in Kongens Lyngby, Denmark, concluded the final design for the pop-in monitors that will be used for beam alignment. Production has started, and delivery will be completed by May 2014. The same schedule applies for the microchannel plate (MCP)–based detectors provided by Joint Institute for Nuclear Research (JINR) in Dubna, Russia. At FERMI, the group tested scintillators for the imagers and studied FEL-related damage processes.

Together with colleagues from Paul Scherrer Institut (PSI) in Villigen, Switzerland, and SLAC, the group applied thin transmissive diamond gratings in combination with bent silicon crystals for minimally invasive monitoring of each single-shot spectrum with high resolution and high transmission while avoiding damage to the monitor itself. The horizontally diffracted beam from the grating was spectrally dispersed in the vertical direction by a bent crystal either onto a traditional slow imager or onto a fast line detector that matches the European XFEL MHz repetition rates.

The group’s collaborators at Helmholtz-Zentrum Berlin (HZB) in Germany continued to provide simulations of the ray tracing of such bent-crystal monitors. The technical specification for tendering will be developed in 2014.

Summary and outlook

In 2014, the X-Ray Photon Diagnostics group will continue the production of devices and begin their installation in the photon tunnels, starting with the SASE1 tunnel XTD2. Further work will be dedicated to developing smart analysis algorithms. In addition to construction-related work, the group will continue to participate in experiments at existing X-ray FEL facilities, with the aim of exploring and implementing novel diagnostics methods for European XFEL users. ■

References

[1] **Development status of the X-ray beam diagnostics devices for the commissioning and user operation of the European XFEL**
J. Grünert, J. Buck, W. Freund, C. Ozkan, S. Molodtsov
J. Phys.: Conf. Ser. 425, 072004 (2013)
doi:10.1088/1742-6596/425/7/072004

[2] **Towards diagnostics of spectral and temporal pulse properties for the European XFEL**
J. Grünert, J. Buck, C. Ozkan, W. Freund, M. Planas, S. Molodtsov: SPIE Optics + Optoelectronics 2013, Conference 8778: Advances in X-ray Free-Electron Lasers II: Instrumentation, SPIE 2013, Prague, Czech Republic, 17–18 April 2013

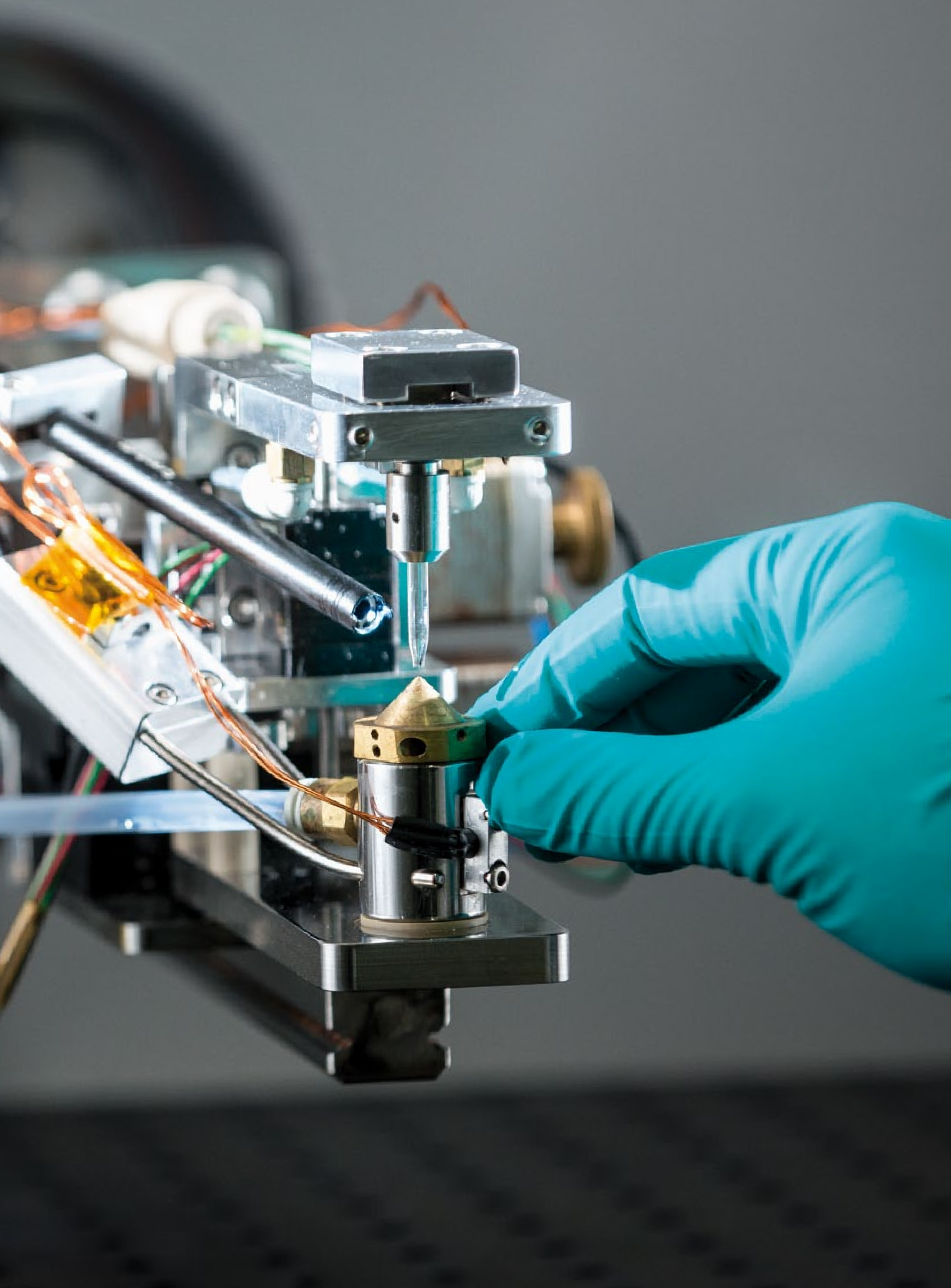
Group members
(left to right) Jia Liu, Florian Dietrich, Andreas Koch, Marc Planas, Jan Grünert (group leader), Wolfgang Freund, Jens Buck, and Cigdem Ozkan (until October 2013, not shown)

06

SCIENTIFIC INSTRUMENTS AND EQUIPMENT

Six scientific instruments are currently being prepared. The instrument groups—partnered with optical laser experts, sample preparation specialists, and a central engineering team—are preparing for the start of assembly of their devices.

Testing the liquid-jet system



SCIENTIFIC INSTRUMENT FXE

The Femtosecond X-Ray Experiments (FXE) instrument will be used to perform time-resolved pump–probe experiments on ultrafast time scales. In 2013, the FXE group furthered the design and started the construction of the scientific instrument. In addition, the group is using laboratory laser sources, synchrotron sources combined with the FXE MHz laser system, and free-electron lasers (FELs) to advance new strategies foreseen for the FXE instrument and to acquire hands-on experience with X-ray FEL pump–probe measurements.

Design status of the FXE instrument

Following the publication of the technical design report (TDR) in 2012, the FXE group continued to work on the final instrument design (Figure 1) together with its in-kind contributing partners, Technical University of Denmark (DTU) in Lyngby and subcontractor JJ X-Ray. This included finalizing the design and starting the production of the first components for the FXE instrument, the high-power X-ray slits. Many more beamline components, including the solid attenuator and the compound refractive lens assemblies, are also nearing the fabrication stage. Rollout of these key components will start in 2014, so the FXE project is well within schedule.

Figure 1 FXE instrument in its current design stage

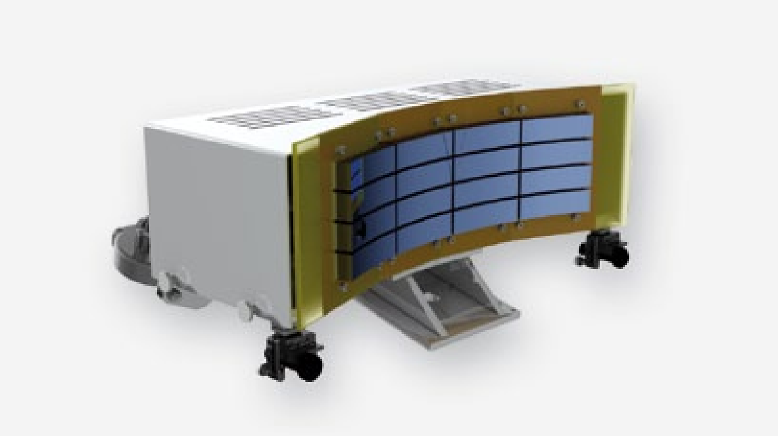


Figure 2 Secondary 16-element dispersive von Hamos X-ray spectrometer. The device, which is part of the Danish in-kind contribution to the FXE instrument, will be tested and used within the BMBF project FSP302 launched in 2013 for X-ray Raman studies of charge transfer reactions in light-triggered transition metal compounds.

New BMBF project supports instrument development

The FXE group is one of the partners in a collaborative research project that is funded by the German Federal Ministry of Education and Research (BMBF) within the framework of FSP 302, a research programme focusing on the development of instruments, devices, and technologies for unique experiments at the European XFEL. The project, which is led by TU Dortmund University and includes Deutsches Elektronen-Synchrotron (DESY), seeks to implement time-resolved X-ray Raman scattering on solvated transition metal compounds. The goal is to observe not only the changes in the central metal atom itself but also in the ligand structure, which is responsible for the overall functionality of such molecules, for example, for solar energy conversion. The project will exploit a secondary spectrometer provided by the Danish partners for the FXE instrument. This device comprises a dispersive von Hamos–type arrangement with 16 cylindrically shaped crystals (Figure 2). Delivery is foreseen in 2014. The collaborative project also includes a special flat-sheet liquid jet with variable thicknesses in the 3–100 µm range for time-resolved experiments.

MHz DAQ system test at PETRA III

The MHz burst mode of the European XFEL poses challenges for data acquisition in terms of data transfer speed and overall data rate. The FXE group, together with Patrick Geßler from the DAQ and Control Systems group, tested European XFEL–ready MHz data acquisition systems and Karabo controls at Beamline P01 at the PETRA III synchrotron at DESY in August 2013 (Figure 3). The device can handle the burst mode operation and is also very useful for point detectors.

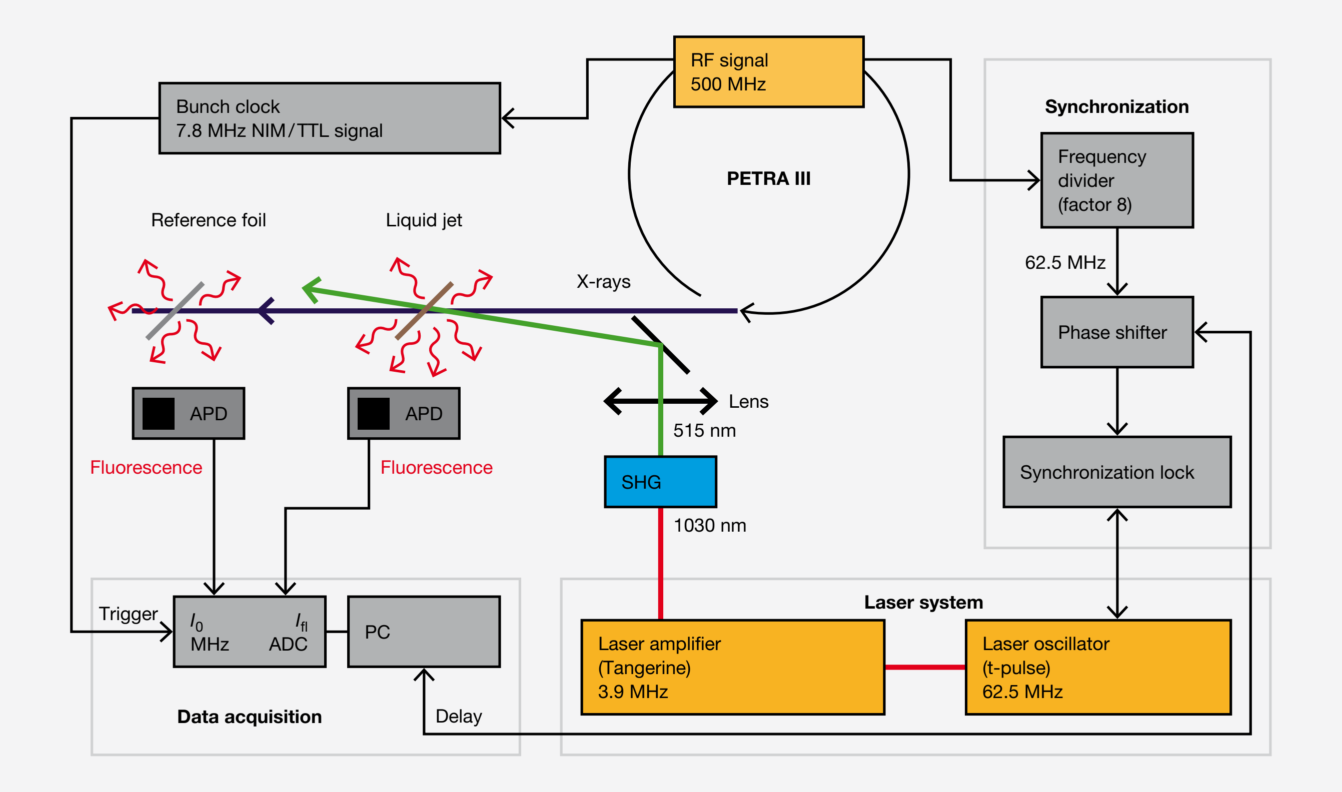


Figure 3 Schematic layout of the high repetition rate pump–probe experiment using a MHz femtosecond fibre amplifier and a MHz pulse train of hard X-ray pulses from PETRA III.
ADC = analogue-to-digital converter
APD = avalanche photodiode
SHG = second-harmonic generation

The NOPA system will greatly enhance the optical capabilities of the FXE instrument, such as generating optical veto probe signals at a multitude of wavelengths tailored to the requirements of individual experiments.

Figure 4 Prototype high repetition rate NOPA now installed inside the FXE–SQS laser lab

Benefits from the CRISP project

The EU-funded Cluster of Research Infrastructures for Synergies in Physics (CRISP) project was well under way in 2013, with group member Julien Nillon working on the realization of a non-collinear optical parametric amplifier (NOPA) capable of MHz repetition rates to be used with the FXE MHz laser. A prototype NOPA system (Figure 4) was delivered and tested in the joint laser lab for the FXE and Small Quantum Systems (SQS) instruments in the PETRA III hall. The NOPA system will greatly enhance the optical capabilities of the FXE instrument, such as generating optical veto probe signals at a multitude of wavelengths tailored to the requirements of individual experiments.

Scientific experiments

The FXE group led a beamtime at the Linac Coherent Light Source (LCLS) at SLAC National Accelerator Laboratory in Menlo Park, California, in February 2013 to investigate nascent iodine atoms following 400 nm excitation of aqueous iodide. This project was performed in collaboration with groups from DTU Lyngby, Lund University, Sweden, Wigner Research Centre for Physics in Budapest, Hungary, and SLAC. The initial data analysis demonstrates the functionality of the time-sorting tool at LCLS to visualize dynamic processes with a resolution of better than 100 fs, currently only limited by the cross-correlation time of this special experiment (also 100 fs). As part of the R&D work on a suitable time arrival detector for the European XFEL, the FXE group joined the group led by Ryan Coffee at LCLS, whose efforts originally led to the LCLS time-sorting tool. In this context, FXE group member Andreas Galler took part in an experimental campaign at LCLS in February 2013. The data analysis of this experiment shows that sub-femtosecond precision in measuring the time delay between X-ray and laser pulses can be achieved on a shot-by-shot basis.

The group's teaching activities will provide students with detailed information about European XFEL and related science opportunities.

In November 2013, group member Wojciech Gawelda led a beamtime at the Advanced Photon Source (APS) of Argonne National Laboratory (ANL) in Argonne, Illinois, investigating a series of iron-based solvated complexes of different complexity on 266 nm and 355 nm excitation. The FXE group also participated in a time-resolved experiment on photoinduced carrier dynamics in zinc oxide nanoparticles, led by Christopher Milne and Jakub Szlachetko of SwissFEL at Paul Scherrer Institut in Villigen, Switzerland. Such scientific campaigns [1, 2] are very useful in order to fine-tune the capabilities of the FXE instrument.

Teaching and educational activities

A new PhD student, Alexander Britz, joined the group in 2013 to work on optical and X-ray transient absorption spectroscopy as part of his thesis within the International Max Planck Research School for Ultrafast Imaging and Structural Dynamics (IMPRS-UFAST). In 2013, the close ties between DTU Lyngby and the FXE group were underlined by the appointment of group leader Christian Bressler as adjunct professor of physics at DTU. The group also taught two courses in physics at the University of Hamburg, Germany. This activity will provide students with detailed information about European XFEL and related science opportunities.

Outlook for 2014

In 2014, the FXE group will continue to work on the FXE instrument design, and components will enter fabrication stage. In addition, the group will explore further strategies in an experimental campaign at SPring-8 Angstrom Compact Free Electron Laser (SACLA) in Hyogo, Japan, in June 2014. ■

References

[1] Femtosecond x-ray absorption spectroscopy at a hard x-ray free electron laser: Application to spin crossover dynamics
H. T. Lemke, Ch. Bressler, L.X. Chen, D. M. Fritz, K. J. Gaffney, A. Galler, W. Gawelda, K. Haldrup, R. W. Hartsock, H. Ihee, J. Kim, K. H. Kim, J. H. Lee, M. M. Nielsen, A. B. Stickrath, W. Zhang, D. Zhu, M. Cammarata
J. Phys. Chem. A **117**, 735–740 (2013)
doi:10.1021/jp312559h

[2] Spin-state studies with XES and RIXS: From static to ultrafast
G. Vankó, A. Bordage, P. Glatzel, E. Gallo, M. Rovezzi, W. Gawelda, A. Galler, Ch. Bressler, G. Duomy, A.-M. March, E. P. Kanter, L. Young, S. H. Southworth, S. E. Canton, J. Uhlig, V. Sundström, K. Haldrup, T. B. van Driehl, M. M. Nielsen, K. S. Kjaer, H. T. Lemke
J. El. Spec. Rel. Phenom. **188**, 166–171 (2013)
doi:10.1016/j.elspec.2012.09.012

Group members
(left to right) Wojciech Gawelda, Tadesse Assefa, Christian Bressler (group leader), Alexander Britz (PhD student), Andreas Galler, and Julien Nillon (Strasbourg, not shown)

SCIENTIFIC INSTRUMENT HED

The High Energy Density Physics (HED) instrument will be a unique platform for experiments combining hard X-ray free-electron laser (FEL) radiation and the capability to place matter under extreme conditions of pressure, temperature, or electric field using high-energy optical lasers or pulsed magnets. Scientific applications will include studies of the properties of matter within exoplanets, new extreme-pressure phases and solid-density plasmas, and structural phase transitions of complex solids in high magnetic fields. In 2013, the conceptual design report (CDR) for the HED instrument was published and, as a first step toward building the instrument, the enclosure to house the experiment setup was tendered.

Progress and achievements in 2013

Two early achievements in 2013 were the successful review of the HED conceptual design by the HED advisory review team (HED-ART) as well as the European XFEL Scientific Advisory Committee (SAC) and the subsequent publication of the CDR [1]. The CDR has been used to further define the instrument and inform the user community at workshops and conferences about the scope and capabilities of the HED instrument.

In 2013, the HED group contributed to two events in particular. In June, during the kick-off meeting for the Helmholtz International Beamline for Extreme Fields at the European XFEL (HIBEF) user consortium (UC) at Deutsches Elektronen-Synchrotron (DESY) in Hamburg, Germany, an extended discussion with different user groups helped to clarify the needs of the user community and to identify groups interested in contributing to the instrument. In October, the HED group co-organized a workshop for high-pressure and plasma physics applications in planetary science at Deutsches Zentrum für Luft- und Raumfahrt (DLR) in Berlin, Germany. During the year, the group presented the HED instrument at about 10 international conferences and workshops.

As recommended by the HED-ART and in preparation of the technical design report (TDR), the group started to gather information about experiment requirements for the most prominent scientific applications. A questionnaire was issued to selected future users, and their feedback was analysed in terms of requisite X-ray and optical laser beam properties, experiment setup, and infrastructure. This exercise helped to clarify major requirements for the development of an X-ray beam delivery system and experiment setup that will provide excellent conditions for the proposed science. The results will form the basis of the TDR and the future construction of the HED instrument.

Figure 1 Sketch of the optics hutch of the HED instrument.
Left to right Beam-defining slits, a screen, a section for optical laser–X-ray time correlation measurement, attenuators for intensity adjustment, final focusing optics, and a beam shutter to separate the optics hutch from the experiment hutch. The second beam tube transports the pump–probe laser from the instrument laser hutch to the experiment hutch.

As a first major infrastructure component, the HED experiment room (Figure 1) was tendered at the end of 2013. This enclosure for the HED instrument has an inner area of 11.4 m × 9 m. It has to be constructed using iron-enriched concrete, with wall thicknesses ranging between 0.5 and 1.0 m, because of potentially high radiation background generated when focused, high-energy, and ultrashort optical laser pulses hit a solid. Such laser pulses are required to study relativistic laser–matter interaction at the atomic level. Following technical specifications and an internal review, the tender procedure for the HED experiment room was launched in November.

Building up the HED group

In 2013, the HED group grew significantly, with the addition of mineralogist Karen Appel and engineer Ian Thorpe. Appel gathered considerable experience with high-pressure phases, X-ray fluorescence and absorption measurements, and X-ray instrumentation in her former position at DESY, where she was also responsible for one of the instruments at the PETRA III facility extension. Thorpe's broad background in mechanical engineering, scientific equipment, and system integration will allow him to make important contributions to the technical design of the HED instrument.

Alexander Pelka, a scientist with extensive experience in high-power laser and relativistic laser–matter interaction experiments from Helmholz-Zentrum Dresden-Rossendorf (HZDR) in Germany, joined the group as a long-term guest. Pelka acts as liaison to the HIBEF UC, which relocated him to Hamburg.

The HED group also hosted engineering student Bruno Muller as a guest from Laboratoire pour l'Utilisation des Lasers Intenses (LULI) in Palaiseau, France, who is helping to define the mechanical mounts and layout of the optical laser transport system. In addition, Gerd Priebe, a specialist for high-energy ultrashort-pulse optical lasers hired in 2013 by the European XFEL Optical Lasers group, works very closely with the HED group and is responsible for the high-energy laser systems to be installed at the HED instrument.

HIBEF user consortium

Following the approval of the HIBEF UC in 2012, activities in 2013 centred on defining the contributions of the UC and on preparing their integration into the HED baseline instrumentation. A major event in 2013 was the HIBEF kick-off meeting with more than 120 attendees. Another important activity of the UC coordinators was to secure funding for the UC from various contributing countries, a process still in progress at the end of 2013. European XFEL also prepared to integrate the future HIBEF contributions. One measure was to build a tunnel, funded by the HIBEF UC, which will allow the high-power optical laser beams to be transferred from an adjacent laser building to the HED instrument in the experiment hall. The laser building, which would be part of the HIBEF contribution, will house large optical lasers and infrastructure proposed by the UC. The collaboration contract between European XFEL and the UC, as well as the internal organization of the UC itself, are still under development.

Towards the TDR

Significant progress has been made in many areas. Details of the HED X-ray delivery system inside the tunnel and the HED instrument areas were examined. The beam delivery devices, such as slits, attenuators, and lens systems, were specified in cooperation with the other scientific instruments. At the end of 2013, an in-kind contribution for these devices was in preparation. A preliminary layout of the HED vacuum system was produced. The interface to the optical laser radiation, as provided by the Optical Lasers group, was specified. The instrument layout and room definitions were reviewed, and the requirements for infrastructure equipment (power, media, and air conditioning) were gathered as part of the preparation of the overall implementation of the SASE2 instruments. Towards the end of 2013, the HED group began to document all of these technical details in the TDR.

Research activities

In preparation of the science programme at the HED instrument, the group participated in experiments at the Matter in Extreme Conditions (MEC) instrument at the Linac Coherent Light Source

(LCLS) at SLAC National Accelerator Laboratory in Menlo Park, California, and at DESY's Free-Electron Laser in Hamburg (FLASH). The LCLS experiments were particularly instructive, as the design and instrumentation of the MEC instrument are closely related to the HED instrument. In addition, the group carried out studies of high-pressure states of systems relevant for geosciences at PETRA III at DESY.

Outlook for 2014

In 2014, the HED group plans to take the next steps toward building the instrument, including the necessary infrastructure. In January, the group plans to award the contract for the HED experiment room, which will house the experiment setup. The concrete enclosure needs to be completed in the first half of the year, before the final floor cover of the experiment hall is made. Also in January, at a workshop at the 2014 European XFEL Users' Meeting, the HED group will discuss the instrument layout with the user community. In March, the HED group plans to publish its TDR. ■

References

[1] Conceptual Design Report: Scientific Instrument HED
M. Nakatsutsumi, Th. Tschentscher (2013)
XFEL.EU TR-2013-003
doi:10.3204/XFEL.EU/TR-2013-003

Group members
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SCIENTIFIC INSTRUMENT MID

The aim of the Materials Imaging and Dynamics (MID) instrument is to 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 2013, the MID group published the technical design report (TDR) for the instrument and conducted related R&D with experiments at other light sources.

Progress in 2013

The TDR of the MID instrument was presented to the European XFEL Scientific Advisory Committee (SAC) in March 2013 and published in October 2013. The TDR restates the scientific goals and describes in detail how the MID instrument must be configured with experiment chambers, X-ray optics, detectors, and optical lasers to achieve these goals. The engineering design and technical drawings of the various instrument components are well under way, and the first calls for tender will be sent out in 2014.

The MID group continued its R&D activities in 2013 with experimental work at the Linac Coherent Light Source (LCLS) at SLAC National Accelerator Laboratory in Menlo Park, California, the European Synchrotron Radiation Facility (ESRF) in Grenoble, France, and at PETRA III at Deutsches Elektronen-Synchrotron (DESY) in Hamburg, Germany. Of particular importance, the first hard X-ray coherent-scattering experiments with a seeded beam were performed recently at LCLS.

The MID group was involved in several successful R&D grant applications that received funding in 2013. For instance, a crystal-based X-ray split and delay line for the MID instrument will be built over the next three years in collaboration with Stefan Eisebitt’s group at Technische Universität Berlin (TU Berlin), which received a German Federal Ministry of Education and Research (BMBF) grant for this project.

The core staff of the MID group remained constant in 2013 with four full-time equivalents (one group leader, two scientists, and one engineer).

MID technical design report

The requirements for the detectors, X-ray optics, and instrumentation were first described in the MID conceptual design report (CDR) in 2012 and then further elaborated in the TDR in 2013. The TDR provides the fundament for the technical realization of the MID instrument, with detailed descriptions and studies of every component. The core instrumentation of the MID instrument will reside in two safety hutches (one optics hutch and one experiment hutch) in the SASE2 area of the European XFEL underground experiment hall. In addition, optical-laser hutches and a control cabin are foreseen. Some of the devices detailed in the TDR (for example, a beryllium lens–based focusing unit that is essential for the beam transport to the MID instrument) will be located in the tunnel more than 700 m upstream of the hall.

In developing the TDR, the MID group benefitted from the collaboration and support of the Instrument Engineering group at ESRF. In particular, the input from ESRF was essential to specifying and defining the differential-pumping section. This section will enable windowless operation of the MID instrument by connecting the high-vacuum beam pipes upstream of the experiment hutch with the less-good vacuum around the interaction region within the instrument. Windowless operation is important to prevent damaging any windows with the intense X-ray free-electron laser (FEL) beam as well as to eliminate unwanted stray scattering from the window material, which can be stronger than the signal from the sample.

The “detector challenge” will gain even more importance at the European XFEL. Cutting-edge technology is mandatory to realize the next generation detectors.

The detector motion concept is also being developed in close collaboration with the ESRF engineers. Proper detector integration is of outmost importance for the performance of the MID instrument. In many experiments at FELs or third-generation synchrotron sources, the detector is already the bottleneck that limits the quality and quantity of data output. This “detector challenge” will gain even more importance at the European XFEL. Cutting-edge technology is mandatory to realize the next generation of FEL detectors. Users at MID are expected to use the Adaptive Gain Integrating Pixel Detector (AGIPD) for most experiments. The mechanical design and integration of the AGIPD is being worked out in close collaboration with the Detector Development group at European XFEL and the Photon Science Detector group at DESY.

Materials science covers a wide variety of scientific topics. For this reason, the MID instrument will feature a versatile platform for sample conditioning and manipulation. Samples may require cooling or heating or high magnetic (pulsed) fields, or may need to be continuously injected (for example, in an aerosol spray). The boundary condition for the MID sample environment is that X-rays as well as optical laser light can interact with the sample. Nanofocusing optics and detectors might need to be positioned only a few centimetres from the interaction region. All in all, these requirements call for a complex sample chamber with many degrees of freedom and yet very stable operating conditions.

Research activities

In 2013, the MID group pursued its R&D activities with experiments at LCLS, PETRA III, and ESRF in order to explore the capabilities and potential of techniques that will be used at the MID instrument as well as to improve and test the instrumentation. At LCLS, the possibility of performing X-ray photon correlation spectroscopy (XPCS) with a self-seeded beam to access the atomic dynamics of disordered glassy materials was investigated for the first time. The experiment, which was performed at the X-ray Correlation Spectroscopy (XCS) instrument, underlined the importance of a well-calibrated 2D detector in such studies, with very few photon events per frame. The self-seeding provided a much better control of the longitudinal beam coherence than experienced in previous experiments at LCLS. For the first time, dynamics could be measured in the liquid state of a supercooled network glass at the structure factor maximum.

At PETRA III, the MID group was involved in different materials science experiments aimed at elucidating structure and dynamics. For example, through nanobeam scattering at Beamline P06, hidden local symmetries in atomic and molecular glasses were investigated using spatial correlation techniques. In another experiment at Beamline P10, the group investigated critical scattering and dynamics in a phase-ordering binary alloy. Both of these data sets are currently being analysed.

The MID group was involved in a first attempt to perform X-ray speckle visibility spectroscopy (XSVS) and to measure liquid dynamics with this new technique. By making use of a split and delay line, the XSVS technique has the potential to provide access to femtosecond and picosecond dynamics on atomic length scales.

At ESRF, the MID group characterized the structure of beryllium metal sheets used for the production of X-ray lenses. Different beryllium grades were compared as well as non-processed and processed sheets. The experiments were performed using the digital computed laminography setup at Beamline ID19 in collaboration with Lukas Helfen (ESRF) and Bruno Lengeler (RXOPTICS, Jülich, Germany). The images obtained can be directly used in wave field simulations of the optics for the future MID instrument (Figure 1). At Beamline ID10, the MID group was involved in a first attempt to perform X-ray speckle visibility spectroscopy (XSVS) and to measure liquid dynamics with this new coherent-scattering technique. XSVS is expected to be used at the MID instrument as it takes advantage of the short, coherent pulses of the European XFEL. By making use of a split and delay line, the XSVS technique has the potential to provide access to femtosecond and picosecond dynamics on atomic length scales.

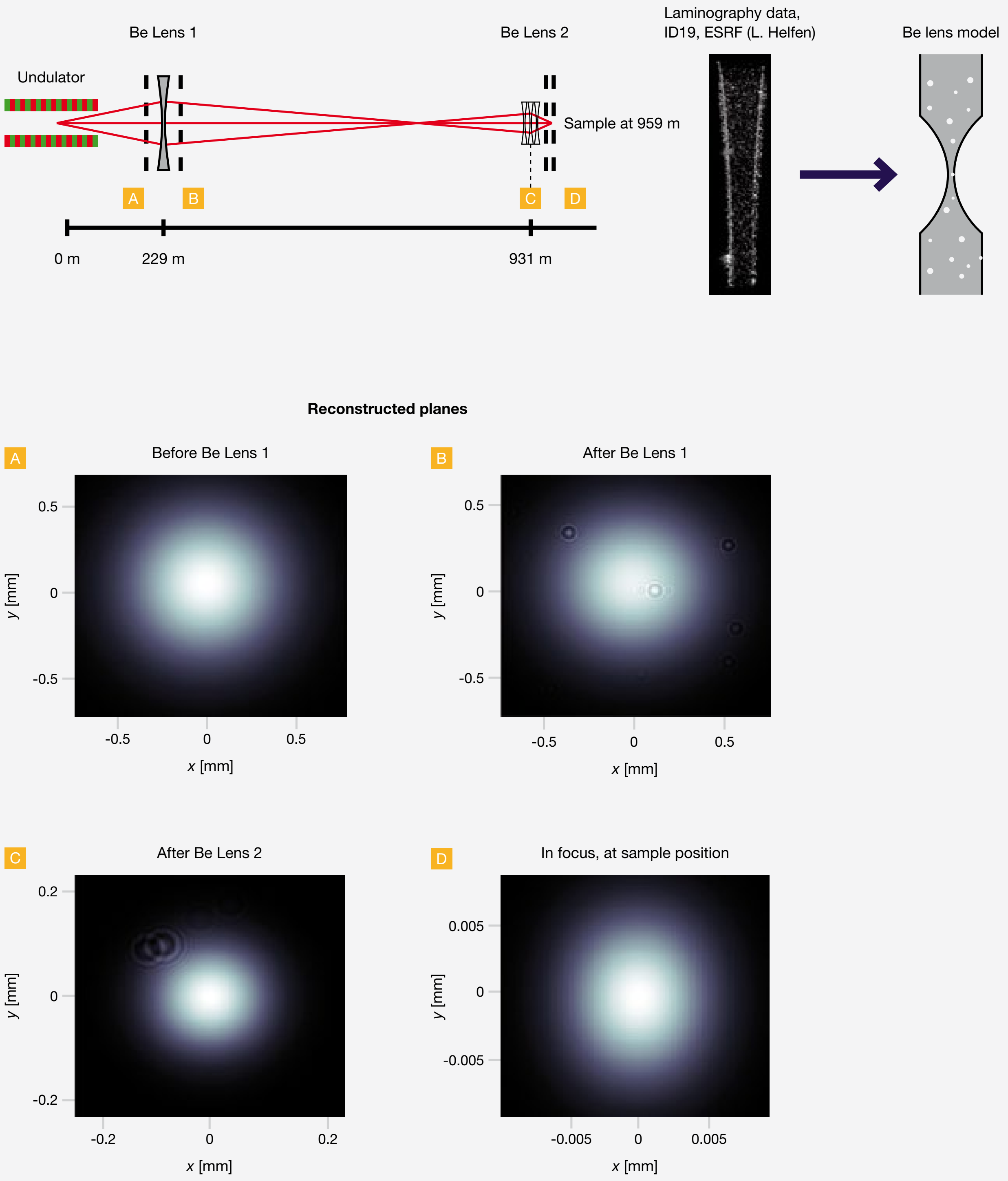


Figure 1 Schematics of wave field simulations performed in collaboration with Liubov Samoylova from the European XFEL X-Ray Optics and Beam Transport group. The results of computed laminography on beryllium sheets and lenses were important to assess the material quality and build a realistic model for the simulations.

Outlook for 2014

The MID group will pursue its R&D activities and experimental work in 2014. A postdoc is expected to start in early 2014 to work jointly with TU Berlin on the design and calculations of the split and delay line. For the coming year, the main focus of the MID group will be on advancing several instrumentation parts towards blueprints and tendering. The group will also continue to build up an MID laboratory in the HERA South underground hall. In addition to providing support for the group's research activities, the HERA laboratory will serve as a test bench for instrumentation and equipment of the future MID instrument in Schenefeld. ■

Group members
(left to right) Anders Madsen (group leader), Wei Lu (guest, since January 2014), Jörg Hallmann, Thomas Roth, and Gabriele Ansaldi

SCIENTIFIC INSTRUMENT SCS

The Spectroscopy and Coherent Scattering (SCS) instrument will be dedicated to the study of electronic, spin, and atomic structures on the nanoscale using soft X-rays. Its purpose is to enable users to explore excited-state dynamics on ultrafast time scales and to unravel the function of complex materials [1, 2]. Areas of application are materials science, nanoscience, and condensed-matter dynamics as well as bioscience.

Buildup of the group

In 2013, the SCS group added three group members, thereby quadrupling in size. In October, Jan Torben Delitz, an experienced instrument engineer from PETRA III at Deutsches Elektronen-Synchrotron (DESY), joined the SCS team. Shortly after that, the group welcomed Robert Carley, a scientist experienced in femtosecond laser systems and time- and angle-resolved photoelectron spectroscopy. In November 2013, Manuel Izquierdo, a former SCS visiting scientist from Synchrotron SOLEIL in Saint Aubin, France, complemented the SCS group as a full member.

Conceptual and technical design

In March 2013, the conceptual design report (CDR) for the SCS instrument was completed and presented to the European XFEL Scientific Advisory Committee (SAC). One of the major goals of the conceptual design was to allow for a diverse scientific scope by providing a wide platform for spectroscopy and coherent-scattering techniques. As part of the work on the eventual SCS technical design, this concept is now being quantified in the form of modular instrumentation of experiment stations and detectors.

The tunable monochromator grating illumination will enable high energy-resolution spectroscopy experiments and ultrafast dynamic studies.

In further preparation for the technical design, first integration meetings were held with a user consortium that intends to complement the capabilities of the SCS instrument and facilitate time-resolved resonant inelastic scattering (RIXS). Another international group of users has expressed its interest in providing instrumentation for photoelectron spectroscopy (PES) experiments, a suggestion that was positively evaluated by the European XFEL Management Board and SAC in 2013. This group has been invited to write a full proposal to form yet another SCS user consortium in 2014.

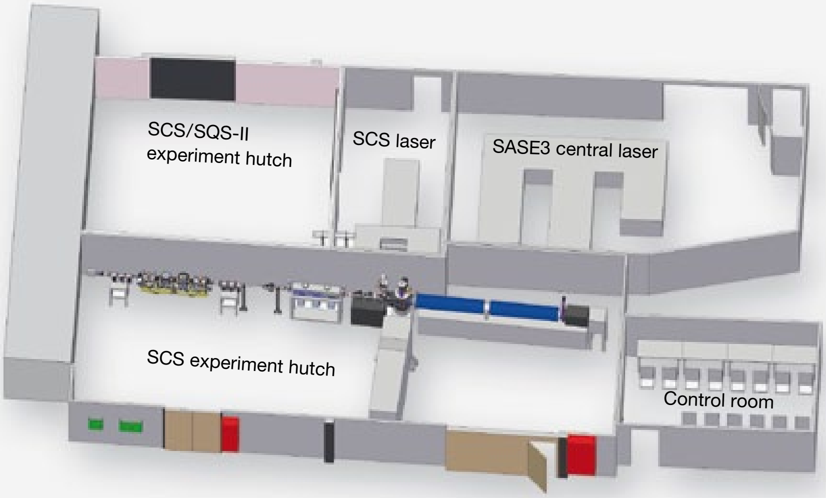
The SCS conceptual design includes monochromatic-beam operation at high and medium resolving powers as well as pink (non-monochromatized) beam operation. The soft X-ray SASE3 upgrades—such as self-seeding and circular and linear afterburner schemes—have been implemented in the SCS technical design, including considerations of potential thermal load and radiation damage of the beamline optics.

The tunable monochromator grating illumination concept is intended to provide a minimum spectral bandwidth–time duration product for a broad range of user experiments, which will enable, at the same instrument, high energy-resolution spectroscopy experiments with lower time resolution and ultrafast dynamic studies at reduced energy resolutions.

A bending mechanism of the SCS Kirkpatrick-Baez (KB) refocusing optics will provide an adjustable X-ray spot of up to 1 mm in size on the sample position. In this way, experimenters could make the best use of the high average X-ray flux for time-resolved spectroscopy studies without beam attenuation. High peak intensities for coherent diffraction imaging experiments can be achieved in the 1.5 µm nominal focus.

An overview of the technical layout of the SCS experiment area with further description is given in Figure 1.

Figure 1 3D rendering of the SCS experiment floor area at the end of the XTD10 tunnel. The last 10 m of X-ray beam transport system from the XTD10 tunnel to the sample comprise a monitor of the intensity and beam position, KB bent refocusing optics, and an optical laser in-coupling. The SCS experiment stations can be exchanged and controlled via a patch panel. Depending on the experiment, the stations can be interfaced to the SCS detectors.



The SCS instrument allows for X-ray resonant diffraction (XRD) studies in Bragg scattering and forward small-angle scattering geometries as well as absorption spectroscopy. The second half of the experiment hutch provides space for a 6 m long Depleted P-Channel Field Effect Transistor (DEPFET) Sensor with Signal Compression (DSSC) detector girder and RIXS spectrometer. The SCS laser hutch will house the frequency conversion system and time delay controls of the central laser system. From there, the laser beam will be delivered to the experiment hutch.

One of the challenges in the technical design is the changeover of the large-scale instrumentations between XRD, RIXS, and PES user runs. In the long term, the setup time will be under less constraint when part of the user instrumentation can be rolled up and experiments can be run at the third soft X-ray SASE3 branch, SCS/SQS-II.

Results of one of the first experimental campaigns for understanding non-equilibrium spin dynamics on the nanoscale emphasize the potential for new materials science that could be done at the SCS instrument.

Research activities

Investigating electron and spin dynamics on the smallest space–time dimensions to explore the function of complex materials will be a key scientific programme at the SCS instrument. In pursuing this direction, the SCS group in 2013 ran experiments at the BESSY synchrotron at Helmholtz-Zentrum Berlin (HZB) in Germany and the Free Electron Laser for Multidisciplinary Investigations (FERMI) at Elettra Sincrotrone Trieste in Italy. The group also led preparations for an upcoming 2014 beamtime at the Linac Coherent Light Source (LCLS) at SLAC National Accelerator Laboratory in Menlo Park, California. This beamtime is part of a multinational scientific campaign on controlling magnetism on femtosecond time scales.

Results of one of the first experimental campaigns for understanding non-equilibrium spin dynamics on the nanoscale, which were published in 2013, emphasize the potential for new materials science that could be done at the SCS instrument [1]. The study investigated the nanoscale spin dynamics in a ferrimagnetic gadolinium–iron–cobalt (GdFeCo) compound, a material that reveals macroscopic all-optical magnetization reversal. The presence of nanoscale chemical and magnetic inhomogeneities reveals a spin reversal mechanism that is very different from the macroscopic switching (Figure 2). It was found that Gd spin reversal occurs in Gd-rich nanoregions within the first picosecond, driven by non-local transfer of angular momentum from adjacent Fe-rich regions.

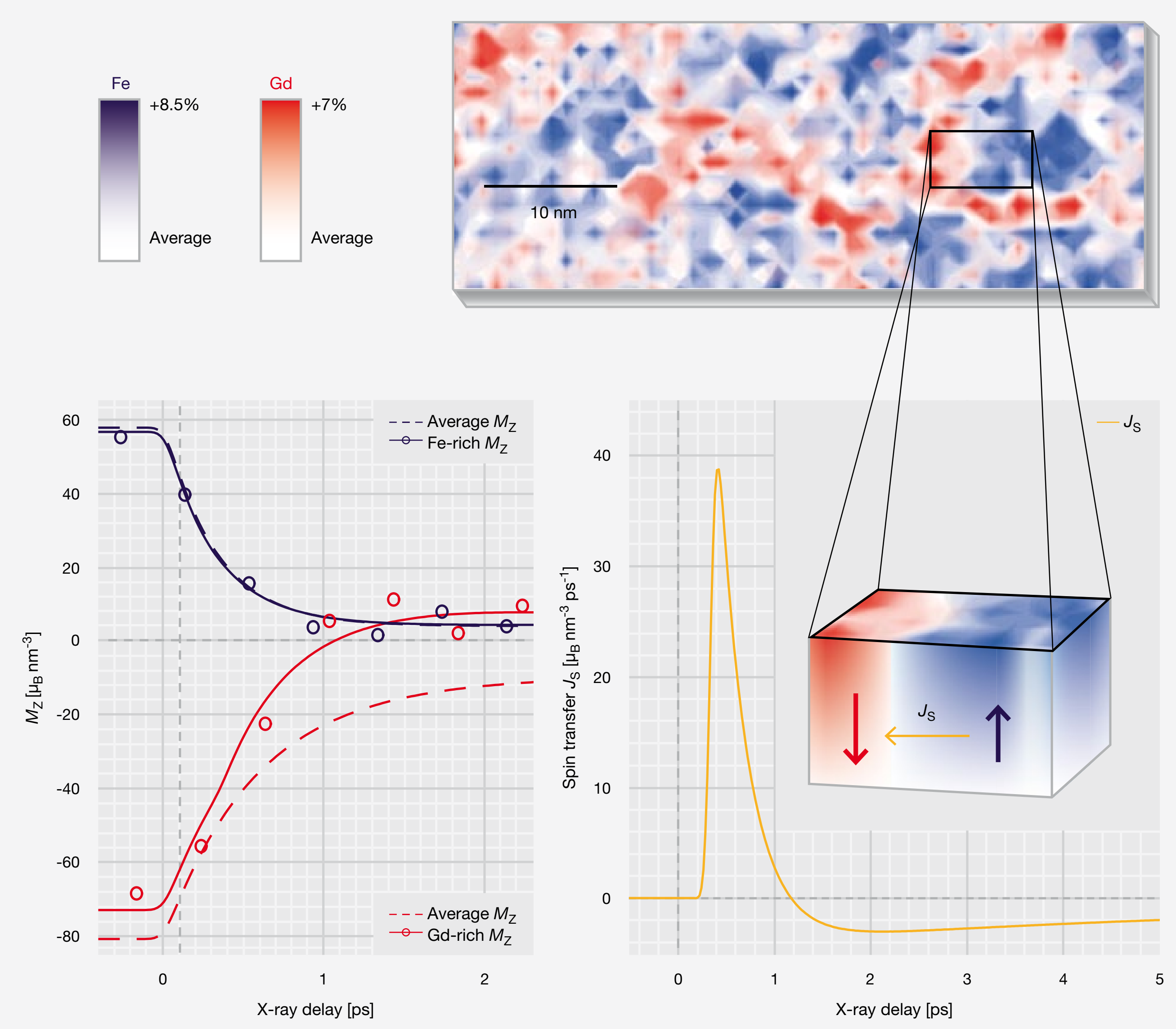


Figure 2
Top Local variations of Fe and Gd content in a ferrimagnetic GdFeCo compound form Fe- and Gd-rich nanoregions of about 10 nm in size.
Bottom Ultrafast spin reversal in Gd-rich nanoregions (left) by non-local angular-momentum flow from adjacent Fe-rich regions (right).
The results are summarized in [1].

Outlook for 2014

At the beginning of 2014, the SCS and Small Quantum Systems (SQS) instrument groups will organize a satellite meeting on a potential scientific programme at SASE3, based on X-ray pump–probe experiments. The aim of this workshop is to collect the requirements for a soft X-ray split and delay line that would produce two-colour X-ray pulses at variable time delay.

The main objective is the completion of the SCS technical design report (TDR) in March 2014 and the approval of the report by the SCS advisory review team (ART) and the SAC. After that, the KB refocusing optics will be ordered as one of the long–lead time beamline components. In March and April, the team looks forward to experiments at LCLS. In the second half of the year, the SCS assembly lab will be furnished to start with first installations and test stands for the SCS instrument. ■

References

[1] Nanoscale spin reversal by non-local angular momentum transfer following ultrafast laser excitation in ferrimagnetic GdFeCo
C.E. Graves, A.H. Reid, T.Wang, B.Wu, S. de Jong, K. Vahaplar, I. Radu, D.P. Bernstein, M. Messerschmidt, L. Müller, R. Coffee, M. Bionta, S.W. Epp, R. Hartmann, N. Kimmel, G. Hauser, A. Hartmann, P. Holl, H. Gorke, J.H. Mentink, A. Tsukamoto, A. Fognini, J.J. Turner, W.F. Schlotter, D. Rolles, H. Soltau, L. Strüder, Y. Acremann, A.V. Kimel, A. Kirilyuk, Th. Rasing, J. Stöhr, A.O. Scherz, H.A. Dürr
Nature Materials **12**, 293–298 (2013)
doi:10.1038/nmat3597

[2] Speed limit of the insulator–metal transition in magnetite
S. de Jong, R. Kukreja, C. Trabant, N. Pontius, C. F. Chang, T. Kachel, M. Beye, F. Sorgenfrei, C.H. Back, B. Bräuer, W.F. Schlotter, J.J. Turner, O. Krupin, M. Doehler, D. Zhu, M.A. Hossain, A.O. Scherz, D. Fausti, F. Novelli, M. Esposito, W.S. Lee, Y. D. Chuang, D.H. Lu, R.G. Moore, M. Yi, M. Trigo, P. Kirchmann, L. Pathey, M.S. Golden, M. Buchholz, P. Metcalf, F. Parmigiani, W. Wurth, A. Föhlisch, C. Schüßler-Langeheine, H. A. Dürr
Nature Materials **12**, 882–886 (2013)
doi:10.1038/nmat3718

Group members
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SCIENTIFIC INSTRUMENT SPB

The Single Particles, Clusters, and Biomolecules (SPB) group aims to deliver a state-of-the-art single-particle imaging instrument for the European XFEL. Imaging capabilities will cover the whole range of single particles—from larger biological particles, such as cells and organelles, to certain material particles and nanocrystalline biomolecules, with aspirations to also image individual, biologically relevant molecules. In 2013, the SPB group published the technical design report (TDR) for the instrument, carried out experiments and simulations exploring the limitations of X-ray imaging at the European XFEL, and welcomed the first visiting scientists from a user consortium project.

Technical design of the SPB instrument

The SPB group began the year by successfully presenting the technical design of the instrument for external review by the SPB advisory review team (ART), composed of international experts in X-ray instrumentation and structural biology. The TDR, which describes the planned instrumentation in some detail, was then published in August [1]. Of particular importance to the entire instrument design are the optics required to produce the two focal spots of different size—about 100 nm and 1 μm—that will be used to illuminate the samples. The TDR includes a penultimate design of the mirror optic system, which was subsequently refined (Figure 1). It was also critical to verify experimentally that the proposed mirror coatings—which make the mirror more reflective across the instrument's entire energy range—will not be damaged or ablated in the bright European XFEL beam. The practical details of the design, alignment, and installation procedures for these optics were also addressed in 2013.

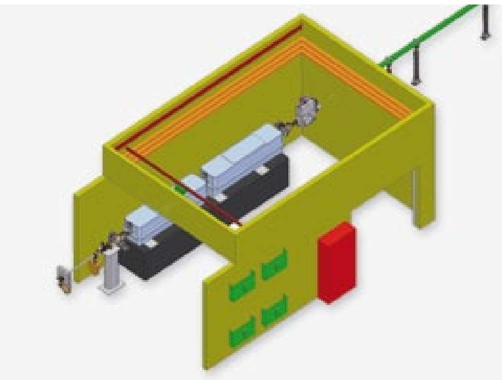

Figure 1 View of the design of the SPB optics hutch, including two vacuum chambers, each hosting two long X-ray mirrors. These mirrors will be used to produce the 1 μm-scale focus of the SPB instrument.

No less important than delivering the X-ray beam is measuring how it is scattered from a sample under study. The SPB group has explicitly addressed the issue of what detector geometry best suits the imaging needs at the SPB instrument. The findings of a detailed study—including descriptions of the best locations for 2D imaging detectors to image different-scale samples at SPB—were documented by Klaus Giewekemeyer and Adrian Mancuso of the SPB group and Monica Turcato of the European XFEL Detector Development group [2]. These findings have since informed the ongoing work on the mechanical integration of the 2D detectors into the SPB instrument.

On the instrument engineering front, the first components for the differential pumping [1] of the SPB vacuum system have arrived to be tested. The differential-pumping section will be assembled and optimized prior to its use in the instrument, to ensure the best and safest possible performance when deployed.

Research activities

In 2013, the SPB group undertook a number of research projects, including experiments at the SPring-8 Angstrom Compact Free Electron Laser (SACLA) in Hyogo, Japan, and the PETRA III storage ring at Deutsches Elektronen-Synchrotron (DESY) in Hamburg (Figure 2). In an attempt to understand the feasibility of imaging experiments at the European XFEL, these experiments explicitly addressed the limitations of X-ray imaging of biological samples and objects of biological density. Additional work to even better quantify the limits of imaging—whether in terms of resolution, signal, contrast, or all three properties—is planned at a number of large-scale X-ray facilities for 2014.

Modelling and simulations

Although experimental investigations may yield the most reliable estimates of the limits of X-ray free-electron laser (FEL) imaging, the novel and challenging nature of these experiments, and the limited number of opportunities to perform them, mean that modelling and simulations have an important role to play too. In 2013, the SPB group and collaborators from European XFEL, the Center for Free-Electron Laser Science (CFEL) Theory Division, National University of Singapore, and the DESY Machine Physics group produced possibly the most sophisticated simulation of a 3D imaging experiment at an FEL by modelling such an experiment from start to end—from the generation of the X-ray pulses, through a suitable focusing system, through modelling the physics of the X-ray–matter interaction, to inverting the modelled measurements at a detector to a 3D reconstructed “image” of a sample. Such simulations enable the collaboration to systematically explore the significance of individual effects in the imaging problem and to identify the most important parameters to control in an experiment.

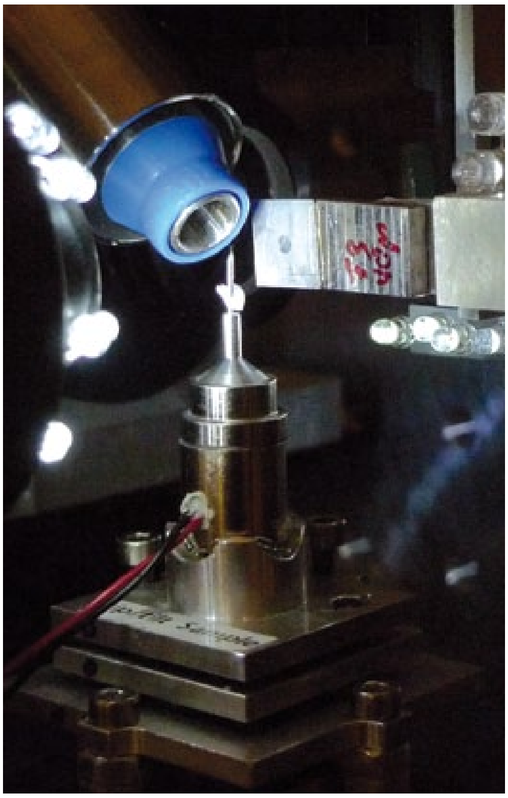

Figure 2 Sample area setup of a single-particle imaging experiment at Beamline P10 of PETRA III. A single biological cell that has been prepared by rapid freezing in its aqueous environment is kept frozen by a cryostreamer while being imaged using coherent X-rays. The imaging method used here is closely related to those to be used at the SPB instrument.

Serial Femtosecond Crystallography project

In late 2013, the first visiting scientists arrived at European XFEL to work on the Serial Femtosecond Crystallography (SFX) user consortium (UC) project. This project, led by Henry Chapman of CFEL and including a number of other international partners, proposes to reuse the European XFEL beam in the SPB instrument downstream of its first interaction with a sample in the SPB hutch. The integration challenges to successfully incorporate this additional instrumentation are significant, and the assignment of SFX personnel to the SPB group is a welcome and essential first step towards realizing the SFX project. The hiring of SFX personnel is expected to continue into 2014.

Outlook for 2014

Along with the imminent differential-pumping tests, the process of procuring the large grazing-incidence X-ray mirror systems will continue into 2014, as these items have a significant lead time. The design of the sample chamber that will accommodate a liquid-jet injection system, a gas-jet injection system, and fixed stages for sample mounting—all required to deliver the different samples—will be developed during 2014 and face a mid-year review. Ongoing research work on the limits of X-ray FEL imaging will be continued at synchrotron and X-ray FEL sources. ■

References

[1] Technical Design Report: Scientific Instrument SPB
A.P. Mancuso, A. Aquila, G. Borchers, K. Giewekemeyer, N. Reimers
XFEL.EU TR-2013-004 (2013)
doi:10.3204/XFEL.EU/TR-2013-004

[2] Detector Geometries for Coherent X-Ray Diffractive Imaging at the SPB Instrument
K. Giewekemeyer, M. Turcato, A.P. Mancuso
XFEL.EU TR-2013-007 (2013)
doi:10.3204/XFEL.EU/TR-2013-007

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(left to right) Klaus Giewekemeyer, Chun Hong Yoon (jointly with CFEL), Adrian Mancuso (group leader), Andrew Aquila, and Gannon Borchers
SFX project (not on picture) Sunil Ananthaneni (guest student), Leonard Chavas (guest scientist), Mengning Liang (guest scientist), Steffen Raabe (guest scientist), and Stephan Stern (guest scientist)

SCIENTIFIC INSTRUMENT SQS

In accordance with the construction plan for the Small Quantum Systems (SQS) scientific instrument, the SQS group in 2013 focused on defining the experiment area layout, including the final design of the focusing optics, the hutch infrastructure, and the integration of specific user instrumentation. The group also continued its science programme—dedicated to the application of two-colour experiments for studying atomic and molecular photoionization dynamics and to investigations of non-linear processes in prototype atomic samples—with experiments at other free-electron laser (FEL) sources.

Construction of the SQS instrument

After publication of the SQS technical design report (TDR) in 2012, further steps were taken towards the final realization of the SQS instrument. In particular, the floor plan and the detailed layout of the experiment area behind the SASE3 soft X-ray undulator were completed to a large extent (Figure 1).

Work on the experiment area included the following:

- **KB focusing optics**
  The group defined the layout of the Kirkpatrick–Baez (KB) focusing optics, consisting of a pair of extremely long (about 80 cm), bendable high-quality mirrors. These mirrors will enable the size of the extreme ultraviolet (XUV) FEL beam in the interaction regions to be adjusted and the radiation to be focused into one of two interaction areas located about 2 m apart. In the first focal point, a beam diameter of about 1 µm and intensities of up to 10^{18} W/cm^2 will be achieved,

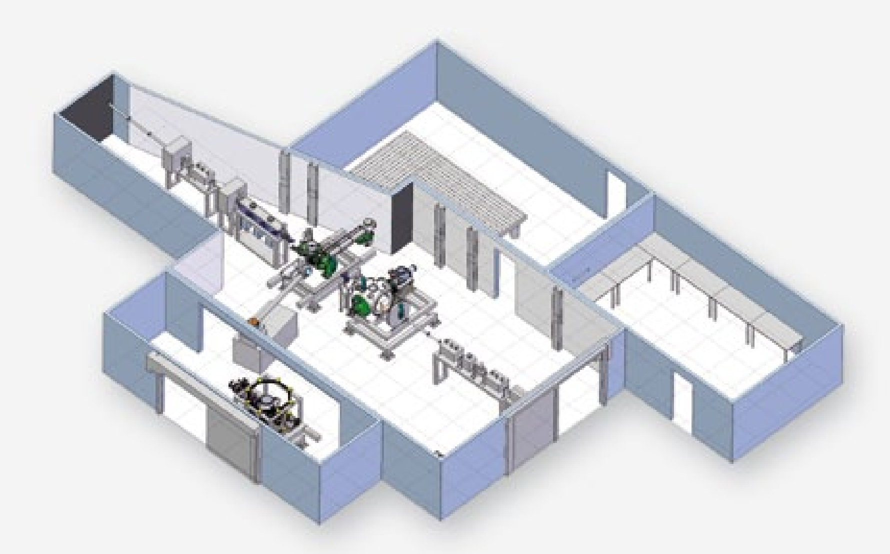

Figure 1 Global view of the SQS experiment area behind the SASE3 undulator

providing ideal conditions for studying non-linear phenomena. The second focal point is characterized by slightly relaxed focus parameters (diameter of several micrometres), which is essential for imaging experiments on larger samples and for time-resolved studies, that is, under conditions where non-linear phenomena have to be avoided.

- **Optical laser hutch**
  Instrumentation and layout of the hutch accommodating the optical laser delivery system for the SQS instrument were further developed by the group. The adjustment and control of intensity, pulse duration, wavelength, and polarization for the synchronized optical laser are realized close to the experiments and require a specific beam transport system and various options for monitoring the individual beam parameters.
- **SQS preparation hutch**
  The group worked on the layout of the “SQS preparation” hutch, in which the third experiment chamber will be prepared while the other two chambers are installed in the beamline. With the provision of the SQS reaction microscope (SQS-REMI) chamber by a user group led by Goethe University Frankfurt in Germany, the routine and uncomplicated exchange of the atomic-like quantum systems (AQS), nano-size quantum systems (NQS), and SQS-REMI chambers in the experiment hutch will become necessary. While the AQS and NQS chambers are dedicated to investigations of small “atomic-like” and larger “nano-size” quantum systems, respectively, the SQS-REMI is optimized for detailed analysis of fragmentation dynamics in molecules using energy- and angle-resolved measurements of electrons and ions in coincidence. This type of coincidence spectroscopy, in particular, takes advantage of the high repetition rate available at the European XFEL.

Experiments at FLASH and FERMI

In parallel to working on the design of the SQS instrument, the group continued its science programme dedicated to the application of two-colour experiments for studying atomic and molecular photoionization dynamics and to investigations of non-linear processes in prototype atomic samples [1, 2]. The experiments were performed at the Free-Electron Laser in Hamburg (FLASH) at Deutsches Elektronen-Synchrotron (DESY) in Germany and the seeded XUV Free Electron Laser for Multidisciplinary Investigations (FERMI) at Elettra Sincrotrone Trieste in Italy.

In addition to the theoretical preparation for possible future research projects related to non-linear processes in atoms [1], a new experimental campaign at FLASH was devoted to the quantitative analysis of sequential and direct multiphoton ionization processes. Energy-resolved electron spectra allow ionization channels to be distinguished and their relative importance to be determined. The experimental results (Figure 2) provide an important basis for and crucial proof of the validity of theoretical approaches describing the photoionization dynamics of a multielectron system in the high-intensity regime. Up to now, experiment and theory are in good agreement for the investigated prototype systems.

The very first investigation of dichroic phenomena using circularly polarized vacuum ultraviolet (VUV) and XUV FEL radiation was realized at FERMI, which is presently the only facility providing this type of radiation. In the experiments, the FEL pulses were made to spatially and temporally overlap with those from an optical laser, and the photoionization of helium was recorded using an angle-resolved electron spectrometer. The simultaneous action of the XUV and

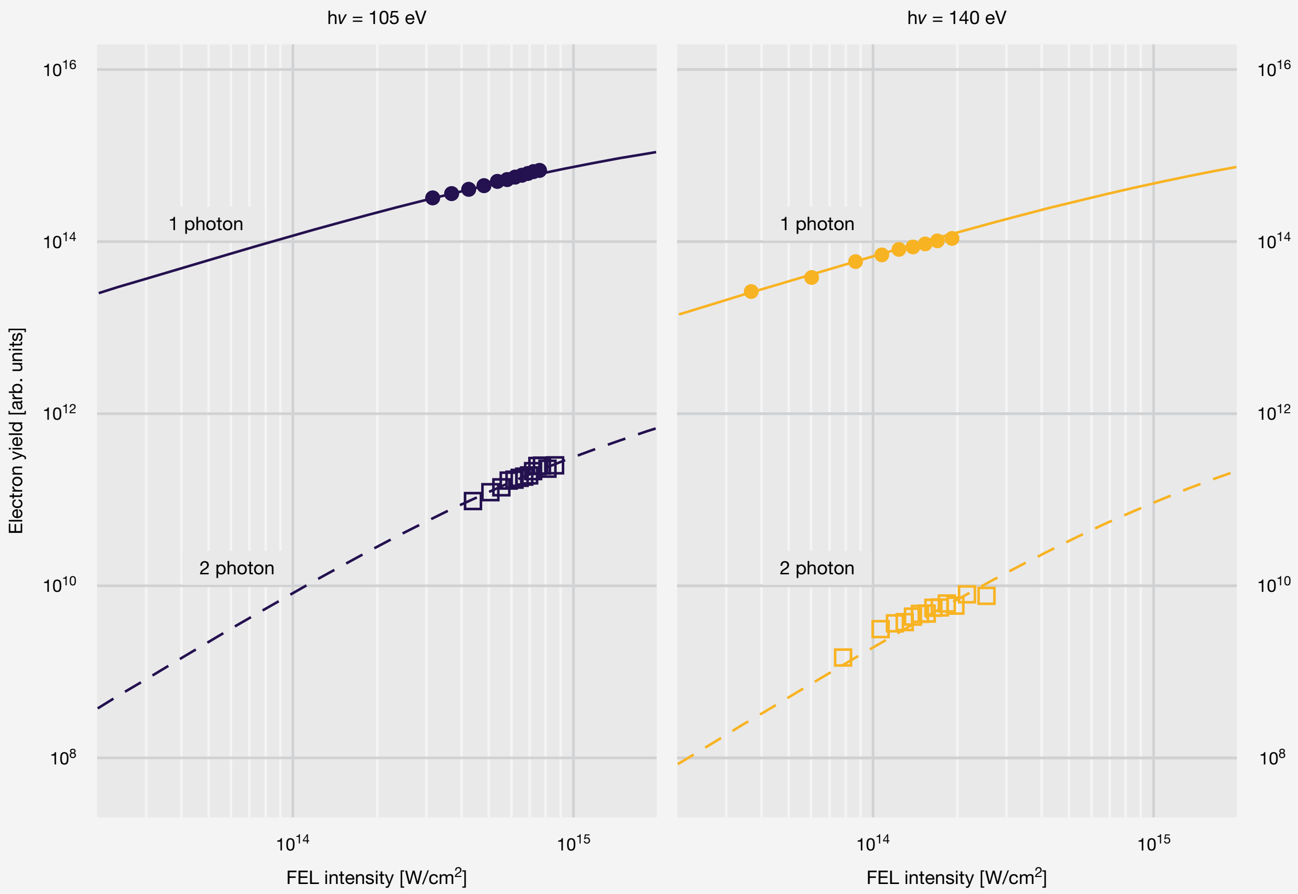

Figure 2 Intensity dependence of one-photon ionization (“1 photon”, full circles) and two-photon above-threshold ionization (“2 photon”, open squares) processes from the 3*p* shell of atomic argon at 105 eV (left) and 140 eV (right) photon energies. Full and dashed lines show the results of theoretical simulations.

optical radiation leads to the formation of so-called sidebands, whose intensities critically depend on the characteristics of both photon beams, in particular on the polarization of the ionizing FEL radiation and the optical dressing field. The circular dichroism is defined as the difference between two measurements recorded before and after changing the circular polarization of one of the two beams from right- to left-handed helicity (or vice versa). Typical angle-resolved spectra of kinetic-energy distribution and dichroism are shown in Figure 3, where they are also compared to theoretical simulations.

The group's measurements represent a powerful and unique tool to quantitatively characterize the circular polarization of the FEL beam. In addition, the experiments are the first to demonstrate circular dichroism in the regime of multiphoton ionization. Using a one-colour

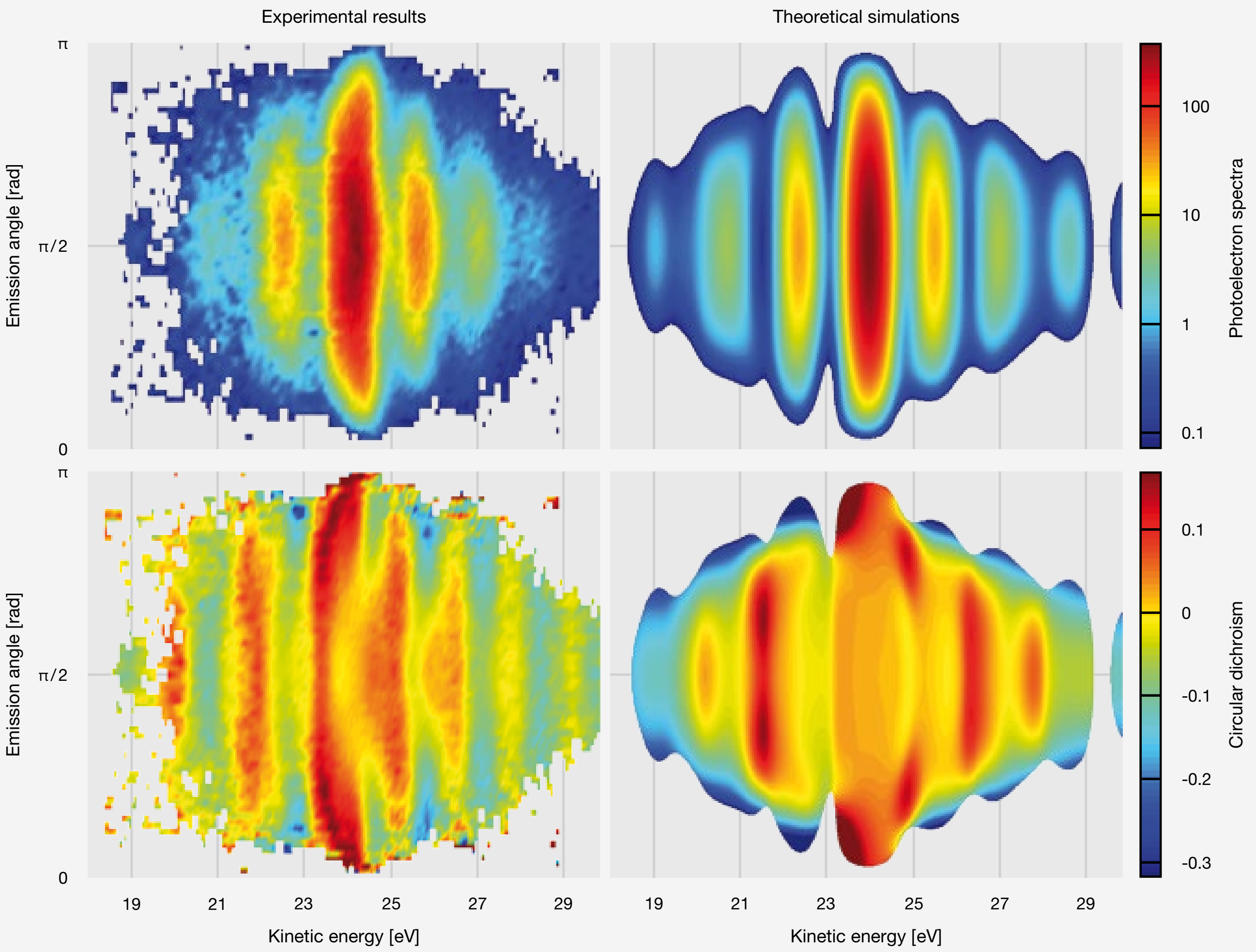

Figure 3 Angle-resolved photoelectron spectra of helium in the presence of an intense optical laser (top) and corresponding circular dichroism (bottom). The experimental results are shown on the left, results of theoretical simulations on the right.

ionization scheme, the effect is absent. Only the use of two combined and synchronized pulses enables the observation of the asymmetry that the circularly polarized radiation introduces into the photoionization process. The results are in excellent agreement with theoretical predictions (Kazansky, Grigorieva, Kabachnik, Phys. Rev. Lett. 107, 253002, 2011), which in fact initiated the present work.

Perspectives for 2014

In 2014, the SQS group plans to carry out first tests of some components related to the vacuum system, electronics, and mechanics of the SQS experiment chambers. The main challenges are the high precision required for some of the devices and the remote controls needed for almost all actions in the final operation of the SQS instrument. Furthermore, additional experimental campaigns at FLASH, FERMI, and the Linac Coherent Light Source (LCLS) at SLAC National Accelerator Laboratory in Menlo Park, California, are planned. These campaigns will focus on two-colour experiments, in particular on dichroic phenomena in atomic photoionization. ■

References

[1] **Non-dipole effects in the angular distribution of photoelectrons in sequential two-photon double ionization: argon and neon**
E.V. Gryzlova, A.N. Grum-Grzhimailo, S.I. Strakhova, M. Meyer
J. Phys. B **46**, 164014 (2013)
doi:10.1088/0953-4075/46/16/164014

[2] **AMO science at the FLASH and European XFEL free-electron laser facilities**
J. Feldhaus, M. Krukinova, M. Meyer, Th. Möller, A. Rudenko, Th. Tschentscher, J. Ullrich
J. Phys. B : At. Mol. Opt. Phys. **46**, 164002 (2013)
doi:10.1088/0953-4075/46/16/164002

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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 2013, the group successfully demonstrated all the features required of the European XFEL pump–probe laser for user operation at low to moderate pulse energy.

Optical lasers at European XFEL

The Optical Lasers group currently consists of nine laser scientists and engineers. In 2013, four new members joined the group.

In addition to continuing experimental R&D work on the pump–probe laser, the group initiated close cooperation with all the scientific instrument groups and developed schemes for laser beam delivery to the experiments. Together with the High Energy Density Physics (HED) instrument group, the Optical Lasers group started to plan the integration of a 100 TW laser and a 100 J laser.

The joint European XFEL and Deutsches Elektronen-Synchrotron (DESY) Laser Advisory Committee (LAC) convened twice in 2013, both times endorsing the efforts of the Optical Lasers group. The LAC agreed to add an expert in high-energy nanosecond lasers as its seventh member.

In addition to continuing experimental R&D work on the pump–probe laser, the group initiated close cooperation with all the scientific instrument groups and developed schemes for laser beam delivery to the experiments.

Pump–probe laser development

At the heart of the European XFEL pump–probe laser is a non-collinear optical parametric amplifier (NOPA) that enables the generation of the very short pulses required for many experiments. To match the emission pattern of the X-ray source, the laser needs to be capable of burst operation with an intra-burst pulse rate of up to 4.5 MHz. The pulse patterns are generated in an all-in-fibre amplifier seeded at 1030 nm and providing two outputs [1]. One output is used to generate a synchronized and fully compressible super-continuum to seed the first stage of the NOPA. The other output seeds the burst mode power amplifiers, which finally pump the NOPA, ensuring efficient and high-gain amplification [2].

In 2013, although still not yet equipped with the planned full pump power, the group focused on the experimental verification of the development goals for the pump–probe laser.

With the exception of the final pulse energy, all the goals were achieved to the full extent, resulting in the following parameters:

- 15 fs pulses with an intra-burst repetition rate of up to 4.5 MHz (from a single-stage NOPA) and a central wavelength of 800 nm.
- Single-pulse energy of up to 180 µJ from a dual-stage NOPA with an intra-burst repetition rate of 188 kHz. The generated pulses were essentially free of pedestals.
- Possibility of generating longer pulses with up to 75 fs, enabling efficient non-linear conversion and wavelength tuning over a range of more than 100 nm.
- Diffraction-limited beam quality in all cases.
- Burst shaping and arbitrary pulse selection from single pulses to 4.5 MHz.
- Second-harmonic generation of 15 fs, 800 nm pulses with an efficiency of up to 25%.

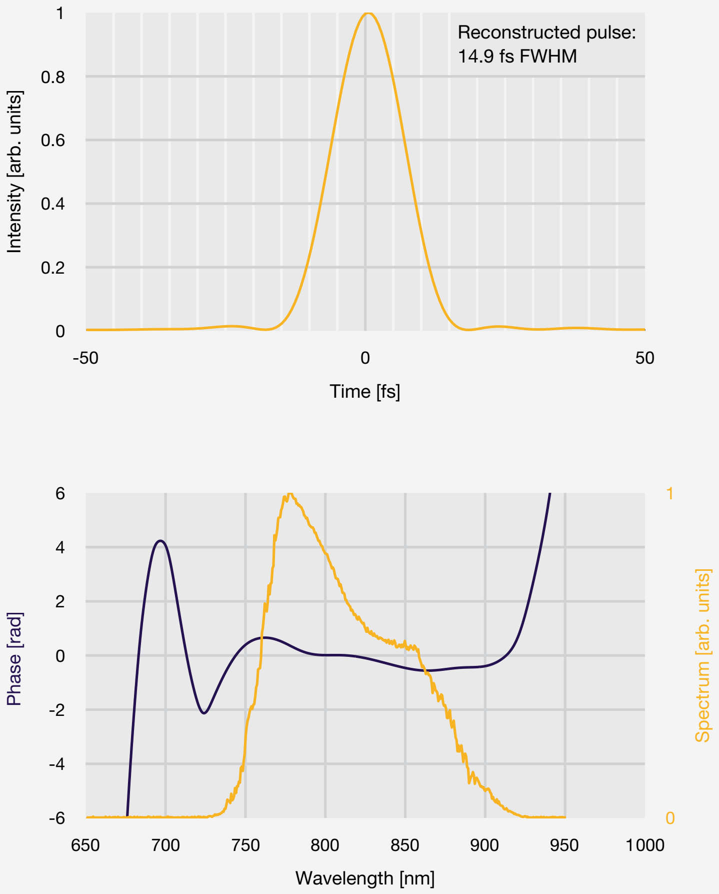

Figure 1 Complete characterization of 15 fs NOPA output pulse using spectral phase interferometry for direct electric field reconstruction (SPIDER).
Top Intensity.
Bottom Spectrum and spectral phase.
The pulses are essentially free of pedestals.

Figure 1 shows the intensity, spectrum, and spectral phase of the compressed 15 fs NOPA pulses. Spectral phase interferometry for direct electric field reconstruction (SPIDER) was used for this measurement. The single-pulse energy was 180 µJ at an intra-burst repetition rate of 188 kHz. The measurement demonstrates the high fidelity of the pulses, which will increase the quality of the planned pump–probe experiments. The pulses are close to Fourier-limited, which can be deduced from the fact that the measured spectrum supports only a marginally shorter pulse of 13.8 fs (assuming a flat phase).

Figure 2 shows the shape of the burst and an example of an arbitrarily selected sequence of pulses. The amplification of the NOPA pump

In 2013 the group focused on the experimental verification of the development goals for the pump–probe laser. With the exception of the final pulse energy, all the goals were achieved to the full extent.

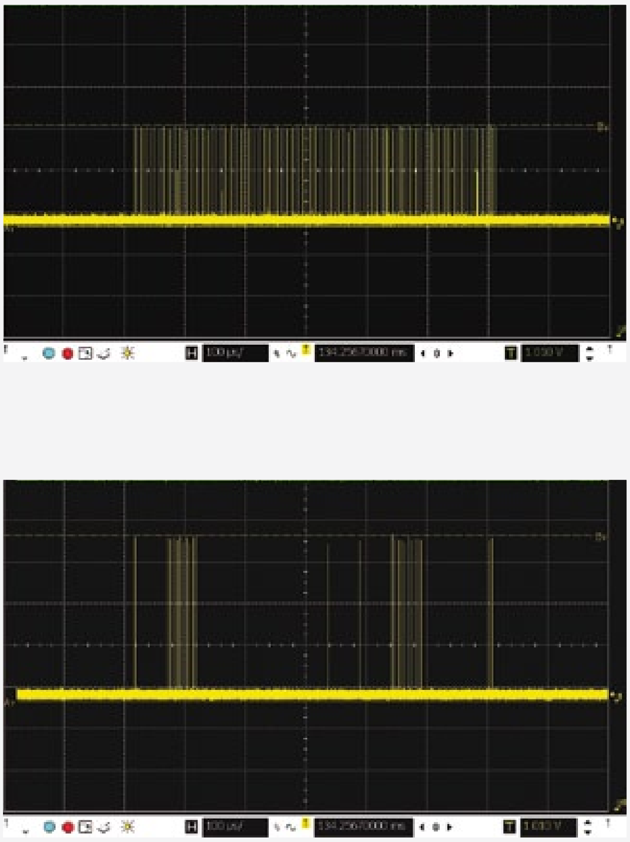

Figure 2 Oscilloscope traces for examples of NOPA output burst at 188 kHz. The central wavelength of the pulses is 800 nm. Each pulse has a compressed pulse width of 15 fs and an energy of 180 µJ. The burst length is 600 µs, which is the maximum required by the European XFEL.
Top Complete burst.
Bottom Arbitrary sequence of pulses, picked from 600 µs long burst (different vertical scale).

and seed pulses relies on classical laser amplification, utilizing inversion storage. However, this scheme does not allow the generation of burst shapes such as those shown in Figure 2. For that purpose, the Optical Lasers group has developed means for fast pulse switching and selection, which are applied after all classical laser amplifiers. Both the NOPA output pulses and the NOPA pump pulses will be available for direct use by experimenters or to drive a variety of possible non-linear conversion schemes, such as parametric amplification and wavelength tuning or THz generation.

In November 2013, after a two-year development time, the 20 kW burst mode power amplifier was finally installed. It will be characterized in due course, before being used to pump the final high-power NOPA scheme.

Close cooperation was established with the instrument groups regarding the planning of laser rooms for the processing and delivery of optical laser beams to the experiments. With the DAQ and Control Systems group, the Optical Lasers group began to address the topic of controlling and monitoring the laser systems.

Further activities

In parallel to working on pump–probe laser development, the Optical Lasers group started to plan the laser integration at the HED instrument at SASE2. In close collaboration with the HED group, provisions were made for a 100 TW laser and a 100 J–class nanosecond laser, both of which are contributions proposed by the Helmholtz International Beamline for Extreme Fields at the European XFEL (HIBEF) user consortium.

The Optical Lasers group was also involved in the planning of all laser facilities and R&D labs, including laser safety, at the new Schenefeld campus. Furthermore, close cooperation was established with all the scientific instrument groups regarding the planning of instrument laser rooms for the processing and delivery of optical laser beams to the experiments. Driven by the Optical Lasers group, possible conceptual designs for the layouts of the instrument laser rooms were proposed. Finally, together with the DAQ and Control Systems group, the Optical Lasers group began to address the topic of controlling and monitoring the various laser systems at the European XFEL, which is an ongoing process requiring continued attention.

Outlook for 2014

Major milestones and tasks for the Optical Lasers group in 2014 include:

- Characterizing the 20 kW burst mode booster
- Building and characterizing the high-power and high-energy multistage NOPA
- Finalizing the layout of the pump–probe lasers with a focus on stability for user operation
- Ongoing planning of the 100 TW and 100 J laser integration in cooperation with the HED instrument group and the HIBEF user consortium
- Increasing the group size to 10 full-time employees for the construction phase 🟨

References

[1] **All-fiber 1030nm burst-mode front-end amplifier for the European XFEL pump-probe laser development**
K. Kruse, M. Pergament, M. Kellert, C. Mendez, G. Kulcsar, M.J. Lederer
Paper Mo4.5, Ultrafast Optics Conference IX, 4–8 March 2013, Davos

[2] **High power femtosecond 1030nm burst-mode front-end and pre-amplifier for the European XFEL pump-probe laser development**
M. Kellert, K. Kruse, M. Pergament, G. Kulcsar, T. Mans, M.J. Lederer
European Conference on Lasers and Electro-Optics (CLEO Europe) 2013, International Quantum Electronics Conference, 12–16 May 2013, Munich, Germany
Optical Society of America, CA_P_23 (2013)
ISBN: 978-1-4799-0594-2

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SAMPLE ENVIRONMENT

The Sample Environment group develops state-of-the-art sample environment systems for the six baseline scientific instruments of the European XFEL. In four key areas—gas and liquid targets, preparation of biological samples, fast exchange of solid samples, and compact pulsed magnets—the group will tailor solutions to the special strengths of the European XFEL facility. Its high repetition rate and high peak power demand efficient, fast, and precise exchange of liquid and solid samples. Its unique pulse structure opens up the possibility of probing the temporal development of samples on the sub-microsecond time scale.

Liquid jets

A prototype of a liquid-jet setup was delivered in May 2013. Sadia Bari, specialist for liquids and gases in the Sample Environment group, set up a test environment to develop the liquid-sample delivery concept for the scientific instruments. The liquid-jet setup consists of a compact and versatile manipulator for independent movement of the liquid-jet nozzle and the liquid recovery catcher (Figure 1).

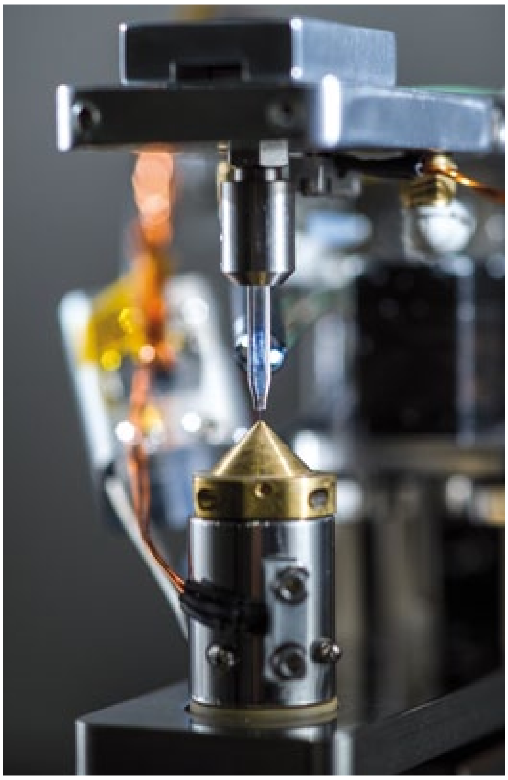


Figure 1 Liquid-jet system with a 25 µm glass nozzle and the recycling catcher. Both systems are independently exchangeable.

Both jet and catcher can be adjusted with sub-micrometre precision relative to the beam position. They are moved using in-vacuum stepper motors that will be controlled by an in-house control system compatible with the instruments' control systems. In collaboration with the DAQ and Control Systems group, the Sample Environment group started to develop a prototype for a generic sample environment control system.

The open design of the liquid-jet system provides a maximum amount of free space around the interaction point. This free space enables the recording of scattered photons in a large solid angle for maximum imaging resolution. It also allows for the placement around the sample of secondary detectors and additional light sources for optical pumping. The modular setup makes it possible to change the nozzle or catcher independently. In the design phase, the group is using the setup to test new technologies as they become available. In the operation phase, the system can easily be adapted to user needs in different experiments.

In 2013, Bari tested the liquid-jet and catcher system in air and vacuum with glass nozzles that had inner diameters on the order of 30 µm. In cooperation with the group of Lars Redecke from the Universities of Hamburg and Lübeck in Germany, Bari investigated the capability of the catcher to recover protein nanocrystals under realistic vacuum conditions. The potential to reuse biological samples that have not been hit by a European XFEL pulse can considerably raise the sample efficiency of the facility. Especially for samples that are expensive and difficult to produce, efficiency is of great importance.

In cooperation with Henry Chapman's group at Center for Free-Electron Laser Science (CFEL) in Hamburg, Germany, Bari also started to integrate gas dynamic virtual nozzles into the setup. In these nozzles, a stream of high-pressure helium gas around the liquid jet compresses the jet to diameters well below 1 μm. The size of these microjets best matches typical focus sizes at the European XFEL and thereby provides higher hit rates and sample efficiencies. In 2014, the Sample Environment group will test gas dynamic virtual nozzles in combination with sample recovery.

Preparation of biological samples

In March 2013, Charlotte Uetrecht, formerly a guest scientist with the Sample Environment group, became a full-time employee. She initiated a project to develop an ion sample delivery method based on native mass spectrometry. This method could potentially be used to prepare size- and conformation-selected proteins and protein complexes for coherent diffractive imaging. In the summer, Uetrecht, together with Hartmut Schlüter of University Medical Centre Hamburg-Eppendorf (UKE) in Germany, received a grant from the PIER Ideenfonds to get the project started. An electrospray ionization source—the first step in producing particles for this technique—has been ordered and is being installed in the preliminary laboratories of the Sample Environment group. Together with the X-Ray Photon Diagnostics group, the group simulated sample trapping and showed that sufficient ion densities for bio-imaging can be achieved [1]. In collaboration with Lars Redecke and Rob Meijers of European Molecular Biology Laboratory (EMBL) in Hamburg, Germany, Uetrecht tested native mass spectrometers from different vendors with relevant protein samples. These tests will lead to a basic design for the equipment. In addition, Uetrecht studied the applicability of mass spectrometry to the delivery of nanocrystals.

In 2013, the Sample Environment group also contributed to the final layout planning of the biology laboratories at the Schenefeld headquarters. This involved collaboration with the XFEL-based Integrated Biology Infrastructure (XBI) user consortium (UC), which will fund and operate the laboratories to a great extent. The UC will contribute expertise and equipment for sample preparation, quality control, and data analysis.

Fast sample changer

For solid-state samples and targets that are fixed on the surface of a carrier, it is challenging to change the target quickly and precisely between two consecutive bunch trains. In June 2013, solid-sample specialist Carsten Deiter joined the Sample Environment group. After defining the specifications and demands of the various experiments

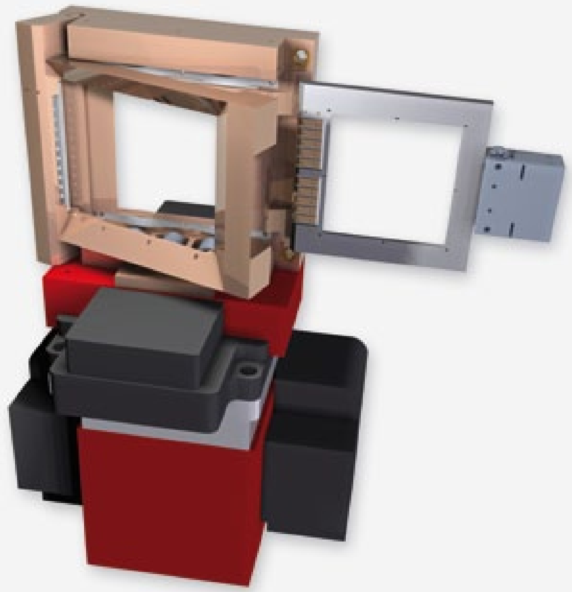


Figure 2 CAD model of the prototype for a fast sample changer for the SCS instrument. Samples on wavers can be inserted in a 50 mm x 50 mm open frame. The frames can be exchanged using a load-lock system without breaking the vacuum.

to be conducted at the scientific instruments, he began to develop a common concept for fast sample positioning and a load-lock sample exchange system to be installed at the instruments. The first parts of the prototype sample changer were delivered in December 2013 (Figure 2).

Compact pulsed magnets

Sample environments in strong magnetic fields are relevant for the hard X-ray instruments Materials Imaging and Dynamics (MID) and High Energy Density Physics (HED) as well as the soft X-ray instrument Spectroscopy and Coherent Scattering (SCS). In the first half of 2013, Nigel Poolton, a member of the Sample Environment group, developed a first concept for compact pulsed magnets for the MID and SCS instruments. This concept foresees either one split-coil magnet for each instrument, with opening angles matched to the acceptance angles of the detectors, or one magnet for all instruments. For the HED instrument, a concept will be developed in cooperation with the Helmholtz International Beamline for Extreme Fields (HIBEF) UC. All magnets will be designed to produce field pulses matching the 600µs length of a bunch train of the European XFEL, so that the dynamics of sample characteristics in a changing magnetic field can be measured. The magnets will be constructed in cooperation with the instrument groups and the HIBEF UC. The magnet development project will resume in January 2014, when a new magnetism expert will join the Sample Environment group.

User support and group development

In the operation phase, the Sample Environment group will support users in bringing their samples into the European XFEL beam. In 2013, the group planned the user laboratories and developed first concepts for user support. For sample preparation, users will have access to chemical and dry preparation laboratories as well as to facilities for sample preparation and quality control in vacuum or under inert gas.

Outlook for 2014

In 2014, the group, in cooperation with the XBI UC and in-house groups, will work out a common user support concept for the biology laboratories at the Schenefeld headquarters. In January, a mechatronics technician will join the Sample Environment group to assist the scientists in prototype development and to set up the electronic control systems. ■

References

[1] Sample refreshment schemes for high repetition rate FEL experiments
J. Schulz, S. Bari, J. Buck, Ch. Uetrecht
SPIE Optics + Optoelectronics 2013, Conference 8778: Advances in X-ray Free-Electron Lasers II: Instrumentation, Prague, Czech Republic, 18 April 2013
Proc. SPIE **8778** 87780T (2013)
doi:10.1117/12.2019754

Group members
(left to right) Sadia Bari, Matthäus Kitel (since January 2014), Joachim Schulz (group leader), Carsten Deiter, Charlotte Uetrecht, Elisa Delmas (not shown), and Nigel Poolton (not shown)

CENTRAL INSTRUMENTS ENGINEERING

European XFEL established the Central Instruments Engineering (CIE) team in autumn 2012 as part of the Technical Coordination (TC) group. Today, CIE supports the six instruments and helps standardize their common engineering processes.

Team structure

In autumn 2012, the CIE team was established as a subgroup of the TC group, and its first four members were recruited. At the end of 2012, CIE became an independent team reporting to European XFEL Scientific Director Serguei Molodtsov.

In 2013, two further engineers were recruited, expanding the team to a total of six members. Today, with the design concepts of all instruments at an advanced stage, the team's main task is to coordinate and facilitate engineering projects common to two or more of the six scientific instruments as well as to perform specific tasks, adding to the expertise of the instrument groups.

The team's main task is to coordinate and facilitate engineering projects common to two or more of the scientific instruments as well as to perform specific tasks.

Main activities

In 2013, the CIE team:

- Collected and documented detailed requirements for each instrument
- Coordinated device procurement and manufacture from various channels, such as in-kind contributions (IKCs), workshops, and external companies
- Developed several design concepts for standard beamline devices
- Engineered and standardized the design of the ultrahigh-vacuum systems for all instruments
- Assessed the cabling requirements of each instrument
- Selected the appropriate tools and processes for designing and documenting the cable layouts in the hutches
- Modelled the SASE1 beamline and hutches in support of calls for tender

Outlook for 2014

In 2014, the CIE team will continue to lay the foundation for standard instrument device designs and help to standardize the procurement and manufacturing of standard devices common to the scientific instruments. In addition, the team will organize the cable planning for all hutches and instruments in the new facility and provide special engineering expertise to specific instrument tasks for individual instruments. ■

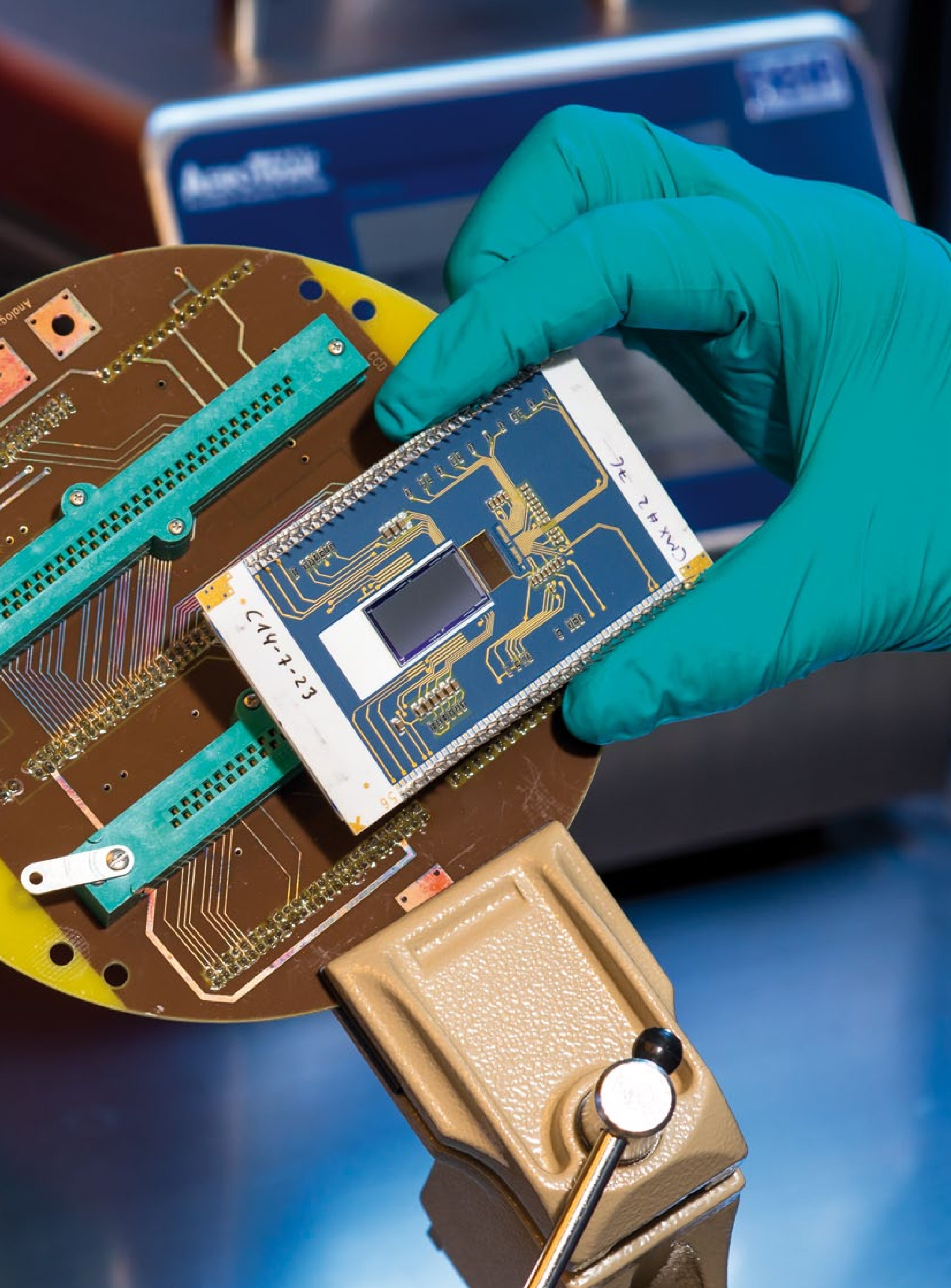
Team members
(left to right) Wolfgang Tscheu (team leader), Antonios Lalechos, Osama Salem, Christian Dauer (since January 2014), Lewis Batchelor, Viktor Lyamayev, and Nadja Reimers (not shown)

07

DETECTORS AND DATA ACQUISITION

High-speed imaging X-ray detectors are under development to exploit the European XFEL's unique characteristics. And the facility's integrated control, data acquisition, and computing system designed to handle large volumes of data has made its debut.

The prototype CCD sensor with its integrated circuit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DETECTOR DEVELOPMENT

High-speed imaging X-ray detectors are essential for users to exploit the full potential of the ultrafast burst mode of the European XFEL and record valuable data. In collaboration with national and international partners, the Detector Development group develops ultrafast large- and small-area X-ray detectors required by the photon experiments for imaging, monitoring, veto, and spectroscopic applications.

New group members and collaborations

In 2013, the Detector Development group was expanded to include four new staff members and three students. Natascha Raab joined the group as a calibration scientist, and software technician Frank Babies took over firmware and embedded system software responsibilities. Georg Weidenspointner and PhD student Stephan Schlee support the Depleted P-Channel Field Effect Transistor (DEPFET) Sensor with Signal Compression (DSSC) project at the Max Planck Institute for extraterrestrial Physics (MPE) in Garching, Germany, as does Sneha Nidhi as an electronics engineer in the Electronics Development Group C (FEC) at Deutsches Elektronen-Synchrotron (DESY), Germany. PhD student Mattia Donato is building a small DSSC prototype camera, and student Filip Kasnár is working to improve the understanding of radiation damage effects in charge-coupled device (CCD) detectors.

In 2013, the focus of activities on large 2D imaging detectors shifted from R&D to preparing the integration of the detectors into the instruments of the European XFEL.

Small-area detectors for spectroscopic and imaging applications

The detectors to be used at the European XFEL have to deal with the unique time structure of the facility, which will deliver up to 2700 pulses at a repetition rate of 4.5 MHz 10 times per second, as well as with a very high photon flux and the need to combine single-photon sensitivity and a large dynamic range. This represents a challenge for the large-area 2D imaging detectors and the smaller-area detectors, making the use of standard commercial devices impossible. Dedicated solutions are therefore envisaged for small imaging and strip detectors. In cooperation with Paul Scherrer Institut in Villigen, Switzerland, European XFEL will develop a new version of the Gotthard detector best suited to European XFEL needs. In another application, intended mainly for the spectrometer of the Small Quantum Systems (SQS) instrument, a microchannel plate detector will be used. In this case, European XFEL is aiming for a highly customized solution provided by Surface Concept GmbH in Mainz, Germany.

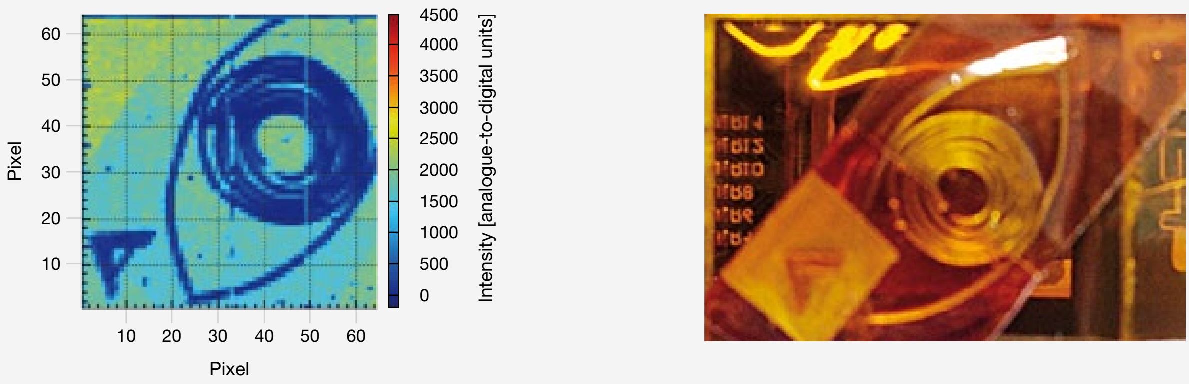


Figure 1
Left First X-ray image taken with an AGIPD Version 1.0 ASIC single chip with a silicon sensor.
Right Image of the mask used for creating the X-ray image shown on the left.

Progress of the DSSC and AGIPD 2D imaging detector projects

In 2013, the focus of activities on large 2D imaging detectors shifted from R&D to preparing the integration of the detectors into the instruments of the European XFEL [1]. Definition and realization of mechanics, cooling, and electronic interfaces became important aspects.

The year also marked the DSSC collaboration's transition from the development to the implementation phase. The project has been severely affected by the restructuring of MPI Halbleiterlabor (MPI HLL) in Munich, Germany, and the withdrawal of MPE as the leading institute of the DSSC project. Consequently, the DSSC collaboration had to be restructured to compensate for the loss of expertise and human resources in several project-critical areas. As one measure, European XFEL and its Detector Development group will become more strongly involved in the project and take over a substantial part of the detector integration tasks for the 1 Mpx DSSC camera. In addition, it has been decided to change the baseline sensor technology for this camera to more conventional silicon drift diode (SDD) technology. This step reduces the overall project risks and sensor production time and is strongly supported by the European XFEL Detector Advisory Committee (DAC). The extension of the contracts between the DSSC collaboration and European XFEL will be finalized in early 2014.

The Adaptive Gain Integrating Pixel Detector (AGIPD) collaboration received the final sensor and the application-specific integrated circuit (ASIC) for the 1 Mpx detector. First results from preliminary functional tests with a complete ASIC pixel matrix that includes a single silicon chip sensor are very encouraging. They demonstrate full functionality and good noise performance of the ASIC. The X-ray image of metal items shown in Figure 1 demonstrates the

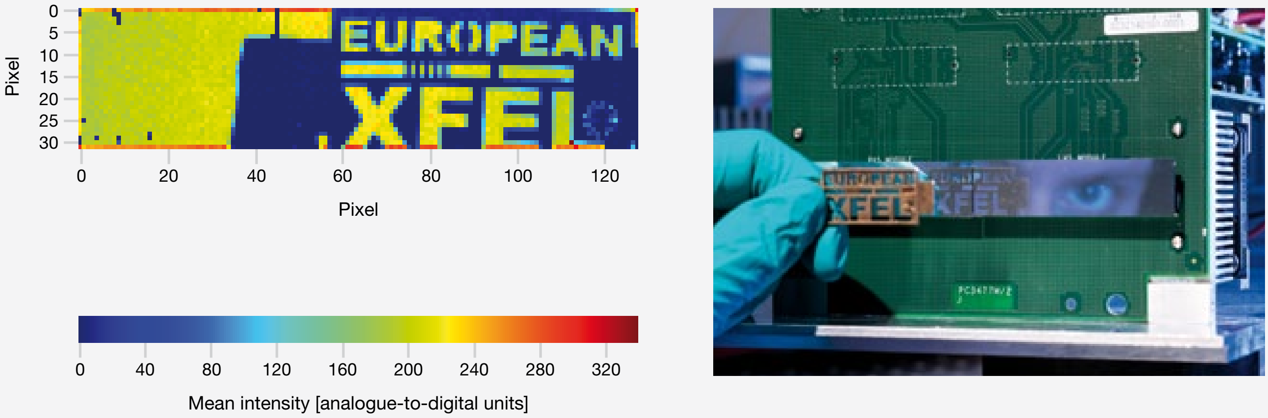


Figure 2
Left X-ray image taken with the LPD two-tile prototype detector system operated at a sampling rate of 4.5 MHz.
Right Image of the mask and the silicon sensor used for creating the X-ray image shown on the left.

functionality of the readout scheme, sensor, and ASIC chips. Further in-depth performance tests and device characterization will follow in 2014.

Tests at LCLS and PETRA III successfully demonstrated that the LPD detector can record images at a sampling rate of 4.5 MHz. Other measurements provided valuable input for further optimization of the detector's readout electronics and data processing software.

Testing the prototype LPD under real conditions

In mid-2013, a small prototype Large Pixel Detector (LPD) system was subjected to in-depth performance tests at the Linac Coherent Light Source (LCLS) at SLAC National Accelerator Laboratory in Menlo Park, California, and at DESY's PETRA III facility. This was the first time such a system was tested under real operating conditions at a high-intensity free-electron laser (FEL) source and at full operating speed at a synchrotron radiation source. The tests successfully demonstrated that the detector can record images at a sampling rate of 4.5 MHz [2]. Detector noise and radiation hardness of the silicon sensor and ASIC have been investigated in detail, as these two performance parameters are very important for the scientific applications at the European XFEL. The measurements taken at LCLS and PETRA III provided valuable input for further optimization of the detector's readout electronics and data processing software. Figure 2 shows an example demonstrating the imaging capability of the LPD system.

Outlook for 2014

In 2014, European XFEL will receive several low- and high-speed imaging cameras. A ¼ Mpx LPD module will be commissioned, calibrated, and integrated into Karabo, the European XFEL's data handling and analysis framework, during the first half of 2014. The first low-speed CCD imaging detector, operating at 10 Hz, will be delivered by Lawrence Berkeley National Laboratory (LBNL), California, in spring 2014. A small DSSC ladder system will be integrated in the second half of 2014.

Several X-ray test environments will be commissioned in the interim detector laboratory at one of the former experiment halls of the HERA accelerator at DESY. A full Karabo control system integration will allow the group to establish automatized calibration and test measurements of different types of detectors (imaging, spectroscopic, veto detectors, and so on) under different operating conditions. The group will also start to optimize detectors and detector control software for user operation. ■

References

[1] **Status of detector development for the European XFEL**
J. Sztuk-Dambietz, S. Hauf, A. Koch, M. Kuster, M. Turcato
Proc. SPIE **8778** (2013)
doi:10.1117/12.2020773

[2] **Performance of an LPD prototype detector at MHz frame rates under Synchrotron and FEL radiation**
A. Koch, M. Hart, T. Nicholls, C. Angelsen, J. Coughlan, M. French, S. Hauf, M. Kuster, J. Sztuk-Dambietz, M. Turcato, G. A. Carini, M. Chollet, S. C. Herrmann, H. T. Lemke, S. Nelson, S. Song, M. Weaver, D. Zhu, A. Meents, P. Fischer
Journal of Instrumentation **8**, 1, C11001 (2013)
doi:10.1088/1748-0221/8/11/C11001

Group members
(in alphabetical order) Frank Babies, Kai-Erik Ballak, Balakumaar Baskaran, Markus Bohlen (student assistant, University of Hamburg, not shown), Mattia Donato (PhD student, University of Hamburg / European XFEL), Melanie Eich (student assistant, University of Hamburg, not shown), Marko Ekmedzic, Patrick Geßler (head of joint electronics group WP75 and WP76), Steffen Hauf, Filip Kasnár (MSc student, The Slovak University of Technology Bratislava / European XFEL), Andreas Koch (until December 2013, not shown), Markus Kuster (group leader), Sneha Nidhi (DSSC project, DESY FEC / European XFEL), Natascha Raab, Stephan Schlee (PhD student, DSSC project at MPE, not shown), Jolanta Sztuk-Dambietz, Monica Turcato, Georg Weidenspointner (DSSC project at MPE, not shown)

DAQ AND CONTROL SYSTEMS

The DAQ and Control Systems group develops electronics and software systems to enable control and readout of instruments at the European XFEL. The software framework will make use of third-party packages when handling and processing the large data volumes generated at the facility.

Broad mandate

Data acquisition (DAQ) and control systems activities at European XFEL are broad, and the following development areas have been defined:

- Software and firmware development for control systems required to configure and control instruments, software analysis pipelines, and so on
- Electronics and related firmware developments for DAQ readout systems
- Development of data management concepts and related software services to allow easy access and use of data by facility users
- Development of scientific computing services and tools that allow users to analyse their data with algorithms of their choice within a supported analysis framework

In 2013, four full-time positions were filled, as were three intern positions of varying duration.

Karabo software framework

The first release of the Karabo software framework in August 2013 was a major step forward, enabling developments in all areas addressed by the group. A key feature of the design is the principle of equality of devices, whereby hardware (valves, pumps, motors, power supplies, commercial cameras, custom front-end electronics, and so on) and software (analysis algorithms, monitoring processes, and so on) are represented within the framework as devices with identical command and property handling functions. The equality principle allows the Karabo software to be used wherever control is required—starting with beamline and experiment configuration and control, through the DAQ systems, and on to user scientific data analysis. Three ingredients—communication, flow control, and configuration—have been added to the device view to enable the additional functionality needed to provide a user-friendly control system.

Figure 1 Group members, in-house collaborators, and external collaborators participating in the Karabo 1.0 software release workshop, which aimed at introducing concepts and providing hands-on coding experience

The release correlated well with the readiness of detectors—for example, portable Large Pixel Detector (LPD) camera, photoelectron spectrometer (PES), and photodiodes—and electronics developed for use at the facility. Tests performed at test beams at other light sources under realistic data-taking conditions have proved that the chosen conceptual design solutions satisfy the functionality requirements.

A successful three-day workshop in September 2013 was attended by over 50 in house and external participants, who received an introduction to Karabo's design concepts, followed by hands-on coding of device and analysis workflow pipelines (Figure 1).

> The release of Karabo correlated well with the readiness of detectors and electronics developed for the facility. Tests performed at other light sources have proved that the chosen conceptual design solutions satisfy the functionality requirements.

Electronics developments

The joint electronics subgroup created in 2011 with the Detector Development group has continued the development and integration of in house, e-machine, and commercial digital and analogue electronics required to synchronize, read out, and process detector data. Of particular importance has been the development of a field programmable gate array (FPGA) programming framework based on Simulink, which allows user analysis code to be inserted into front-end electronics. Successful tests of systems being developed for use at the facility have been made at the PETRA III facility and

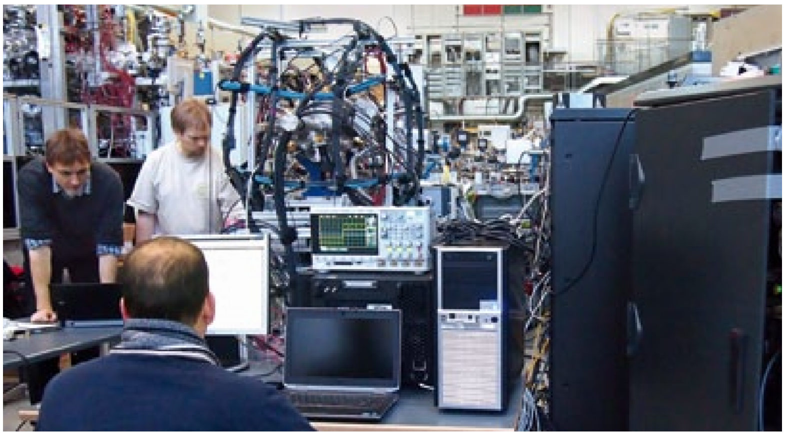


Figure 2 Operation of the photoelectron spectrometer at DESY's FLASH, synchronized to beam delivery using the European XFEL e-machine timing board and driving a multiboard digitizer readout system

the Free-Electron Laser in Hamburg (FLASH, Figure 2) at Deutsches Elektronen-Synchrotron (DESY) as well as at the Free Electron Laser for Multidisciplinary Investigations (FERMI) at Elettra Sincrotrone Trieste in Italy.

Outsourced development of electronics to synchronize (University College London, UK) and read out (Rutherford Appleton Laboratory, Didcot, UK) large-area cameras (AGIPD, DSSC, and LPD; see "Detector Development") specifically designed for the 4.5 MHz pulse frequency at the European XFEL reached the FPGA firmware and software integration phase.

Control systems

Low-level control of positioning equipment and vacuum systems is performed using industrial automotive control equipment from Beckhoff GmbH in Verl, Germany. The Ethernet for control automation technology (EtherCAT) fieldbus allows large numbers of widely distributed motors, pumps, gauges, valves, actuators, and sensors to be coupled and controlled by programmable logic controllers (PLCs). Pressure to implement and integrate over 20 test stands has been addressed by increasing our workforce, streamlining management actions, and improving the firmware framework and software integration.

Data management

Tests of a complete slice of the DAQ and data management architecture from front-end electronics to archive storage and analysis have continued. The slice test is an important testing environment that allows development of data-processing algorithms used to reject and reduce data during data taking and tests of data-handling solutions used during offline data analysis.

Significant progress has again been made in identifying and integrating web services and tools into the data and code management suite. Those in daily use include SVN (software and framework code management), Redmine (bug tracking), Jenkins (nightly builds), web and FTP repositories (code deployment), NetBeans (IDE), and Kerberos (authentication). In the testing phase are Puppet (host configuration) and in-house QR-driven (matrix barcode) inventory and object identification. Those requiring finalization are user portals and data catalogues.

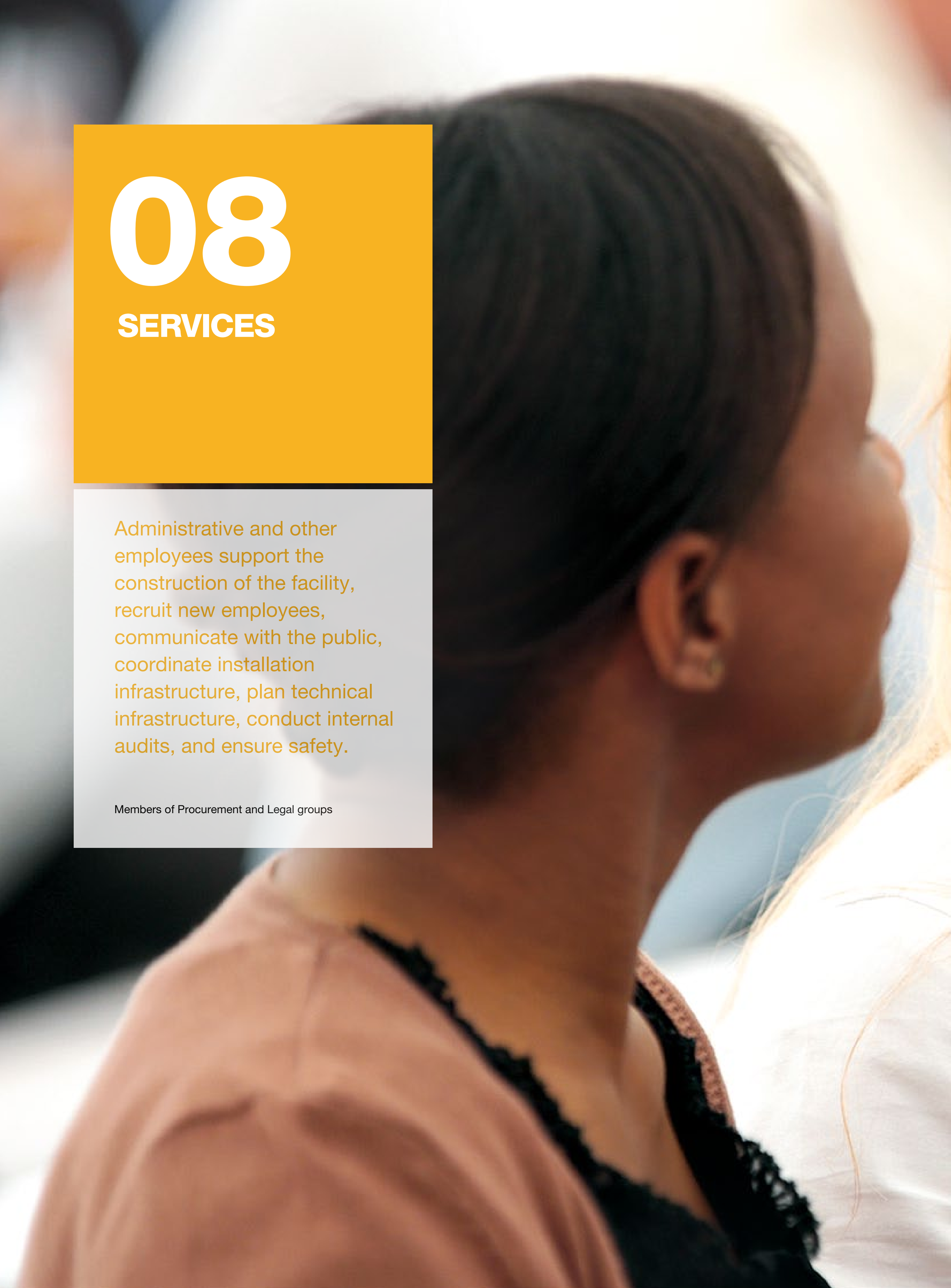
User community data-handling requirements were reviewed during a one-day follow-up meeting to the Karabo workshop organized with the DataXpress user consortium.

Outlook for 2014

The integration and exploitation of Karabo will be a key activity in 2014. Essentially, all synchronization and readout electronic systems are now available, and the coming year will be used for integration and performance testing. Rollout of test stands and startup of SASE1 tunnel systems are important targets for control.

In the coming year, tests of data management solutions will continue. A significant test of DAQ and control will start when the first ¼ Mpx LPD detector test stand starts operation. Tests of data catalogue services based on existing tools, such as those used at the Linac Coherent Light Source (LCLS) at SLAC National Accelerator Laboratory in Menlo Park, California, should conclude. ■

Group members
(left to right) Luis Maia, Kerstin Weger, Mayank Kumar, Hamed Sotoudi Namin, Djelloul Boukhelef, Jorge Elizondo (IT), Christopher Youngman (group leader), Manfred Knaack (IT), Bruno Fernandes, Kryzsztof Wrona (IT/WP76), Gabriele Giambartolomei, Martin Teichmann, Burkhard Heisen, Sergey Esenov, Janusz Szuba, Jörn Reifschläger, Andrea Parenti, Jan Tolkiehn, Patrick Geßler (WP75/WP76), Olivier Batindek (intern, not shown), Nicola Coppola (not shown), Iryna Kozlova (not shown), Bartosz Poljancewicz (IT, not shown), Amin Tarhani (intern, not shown), and Auguste Youdjeu (intern, not shown)



08

SERVICES

Administrative and other employees support the construction of the facility, recruit new employees, communicate with the public, coordinate installation infrastructure, plan technical infrastructure, conduct internal audits, and ensure safety.

Members of Procurement and Legal groups

ADMINISTRATIVE SERVICES

The European XFEL administration fulfils an enabling role in the company. The members of the administration provide the necessary resources for the construction of the European XFEL facility. They recruit highly qualified staff from all over the world and purchase needed goods and services, from copy paper 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 four groups: Finance and Controlling, Human Resources (see next article), Legal, and Procurement. Altogether, these groups have around 20 staff members—that is, about 10% of the total European XFEL staff. While in previous years the administration was characterized by staff buildup and recruitment, 2013 was a year of continuity.

Finance and Controlling

The financial resources of the company are managed by the Finance group. The activities include not only all financial transactions, such as the payment of invoices, salaries, and so on, but also 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 ensuring proper 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 was the case in previous years, in 2013, external auditors issued an unconditional certification for the annual statement 2012.

Cost controlling of a complex project like the European XFEL is a big challenge. It is a joint effort involving all groups within the company. This effort is coordinated by the Controlling group. The project has a budget of around 1.15 billion euro (in 2005 value). Given that the construction of the facility means working at the frontier of technology, a high level of uncertainty has to be met through a high level of flexibility in project controlling. Adding another layer of complexity is the high number of international partners, many of which contribute a large fraction of their share to the project in kind. The Controlling group issues regular cost reports and forecasts that help the management board as well as all group leaders, who are responsible for their group's budget, to proactively oversee the project.

Figure 1 From left to right, members of the Finance, Secretariat, and Legal groups

Legal

The Legal group is in constant communication not only with the other administrative groups but also with 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, agreements with the user consortia, and the accession of new shareholders.

Both the secretary and vice-secretary of the European XFEL Council are members of the Legal group. 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

For the Procurement group, 2013 was another year of significant projects and achievements. During the year, a total of 18 public tenders were successfully awarded. Some more public calls for tender were placed before the year ended and are still in progress.

Public calls for tender, which cover big single purchases, are only one part of the activities of the Procurement group. In total, the group processed over 1300 purchase requests in 2013, an increase of 30% compared to 2012. The value of the goods and services purchased amounted to 9.6 million euro (M€), excluding civil construction. An electronic procurement tool, called Simple System, which was introduced in 2012 for small purchases, proved to be very efficient. The number of orders issued through Simple System increased by more than 80% to over 650 orders.

Procurement for civil construction activities, supported by seconded staff from Deutsches Elektronen-Synchrotron (DESY), was very brisk during 2013, with orders issued for a total value of around 13 M€. Orders were placed for some of the future above-ground buildings on the Schenefeld campus: the tunnel distribution buildings, Halls 2–4 (XHE 2–4); a district heating transfer station; and the central electrical and pumping station (XHPSC). Tender procedures for the construction of media channels were successfully performed as well as further construction site–related work. The last big tender procedure, opened in December 2013, was for the civil construction work for the future headquarters building (XHQ) in Schenefeld. Construction activities are expected to start in spring 2014.

Thanks to intensive negotiations, well-executed public tenders, and constant comparison of prices on quotations handed in with purchase requests, the Procurement group was able to achieve considerable cost reductions throughout the year.

The Procurement group worked intensively on the introduction of a comprehensive e-procurement system. The system will be implemented to make the complete process of purchasing—from the moment the purchase request is completed, through the complete approval process, all the way to placing the final order—faster, more efficient, and more effective in 2014. During 2013, the group customized the system. It plans to go live with the new tool in spring 2014 for use by all employees.

Preparing for user operation

Although the end of the construction phase and the start of user operation of the European XFEL facility are still a few years away, administrative preparations for this transition are long under way. As European XFEL will become the responsible operator of the facility, administrative procedures involving public authorities have to be carried out that require a considerable amount of lead time. Internal preparations for the operation phase—such as developing staffing plans and a preliminary budget—have already begun.

In this context, a User Office will be established as a new administrative group in 2014. The members of this group will be the future contact persons for European XFEL users. They will also organize the beamtime application procedures. ■

INTERNAL AUDIT

In the fourth quarter of 2013, an internal auditor was recruited. The auditor established the framework for conducting audits within European XFEL, analysed the company, and developed an audit programme with the areas to be audited in 2014.

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

As in previous years, the HR group focused on building up the staff of European XFEL. In addition, the group helped integrate new employees and build teams as well as adjust processes to accommodate the new works council.

Continuing to grow

As in previous years, 2013 was characterized by a steady increase in the size of our workforce. This year, the number of employees, students, and guests grew from 163 to 202 (+24%). Fifty-two signed contracts resulted in a net growth of 39 people compared to the previous year.

During the year, 1755 applications (+526, or + 43%) were processed.

Recruitment activities for the year proved suitable and efficient. Almost all recruitment goals were reached. The one exception was the share of female employees (25%). However, this share corresponded exactly to the share of female applicants. Also, the share of female scientists (16%) was slightly higher than the share of female applicants (15%).

To test the efficiency of non-traditional recruitment activities, the HR group, in collaboration with members of various work packages, successfully took part in two events to attract young scientists and engineers. During the “Job Vector Career Day” in Düsseldorf, the group made a presentation about working at European XFEL and talked to roughly 100 potential candidates. The HR group collaborated with the Hamburg University of Technology (TUHH) and invited 15 students to European XFEL for a “Going for Careers Day”, introducing them to our work packages and job offers. These activities proved especially useful in attracting potential interns and student assistants.

As in previous years, 2013 was characterized by a steady increase in the size of our workforce. This year, the number of employees, students, and guests grew from 163 to 202.

Integrating new employees

A core activity during the buildup phase is the integration of the new employees into their new working environment. Equally important is the integration of families into their new city or country of residence.

Material support, such as reimbursing international relocation costs, facilitates integration, but “welcome activities” comprise much more:

- Arranging travel
- Preparing visa and residence permit applications
- Handling regulatory affairs
- Providing support in social matters (insurance and statutory benefits)
- Assisting in relocation
- Assisting in school and kindergarten matters
- Holding informative meetings (for example, about German income tax and our pension fund)
- Providing language courses (German, technical English)
- Supporting double employment
- Holding monthly staff meetings
- Hosting integration events (twice a year, one with families)
- Providing information about the “Hamburg Welcome Club”, a community for expatriates with the objective of social and cultural acclimatization

European XFEL participates in the competition “Diversity. Growth. Wealth.” (*“Vielfalt. Wachstum. Wohlstand.”*), organized by the Federal Ministry of Economics and Energy (BMWi), which recognizes exemplary integration efforts for international employees. In 2013, BMWi shortlisted the company for consideration as one of the 10 most exemplary employers in Germany.

> A core activity during the buildup phase is the integration of the new employees into their new working environment. Equally important is the integration of families into their new city or country of residence.

Figure 1 HR officer (left) greeting a new employee

Setting up professional training and language courses

By offering a wide range of professional training opportunities, European XFEL explicitly focused on the development of teams and individuals. Several work packages conducted team training sessions and workshops. The events focused on teaching individuals to work together to achieve common goals, and also improved the communication and collaborative culture of the participating teams.

To provide another way to help our international staff integrate, the HR group organized in-house German language courses on the levels A1, A2, B1, B2, and C1 for an initial 12-month period. These courses were financed by the German Federal Administration for Migration and Refugees (BAMF) and were led by the Hamburg Adult Education Centre. The demand exceeded the expectations of the HR group by far. In 2013, the courses were attended by 40 employees and 7 dependents. Next year, participation is expected to be even higher. In addition, the company partially subsidized external German language courses.

Coordinating works agreements

The European XFEL Works Council, which was founded and elected in spring 2012, launched all of its legally defined processes in 2013. The extension of many administrative procedures to accommodate the works council was coordinated by the HR group.

In 2013, European XFEL concluded several works agreements with the works council, including:

- “Objectives, feedback, and incentive pay process” agreement, which describes how employee objectives are set, achievement is evaluated, feedback is provided, and incentive pay is determined
- “Occupational health and safety (OHS) regulations” agreement, which provides a framework for our safety organization and helps to provide a safe working environment for all employees and visitors
- IT application agreements:
  - Pool4Tool procurement system
  - Atlatos travel management tool

In the course of the year, the legally mandated monthly meetings between the managing directors and the works council, as well as the four general assemblies of the works council, were conducted in a good and constructive atmosphere.

Upgrading employment contracts

For legal reasons, it proved very useful to switch the basis for employment contracts from the “European XFEL Staff Rules” to the collective agreement “TVöD (Bund)”. This change required the company to draft, explain, and sign a new employment contract with every single employee (at the time, 143 employees). Diligent planning and comprehensive information dissemination enabled the HR group to complete this transaction successfully by the end of March. ■

PRESS AND PUBLIC RELATIONS

To communicate the objectives and progress of the new research facility—and to ensure its long-term acceptance locally, nationally, and internationally—it is essential to provide open, comprehensive, and clearly understandable information to the public. The Press and Public Relations (PR) group serves as the interface between the public and European XFEL.

Objectives

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

- Sustaining and improving regional, national, and international press and other media coverage of the European XFEL project (Figure 1)
- Maintaining and further improving communication through the European XFEL website (www.xfel.eu), social media, flyers, brochures, posters, and annual reports
- 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

In addition, the PR group represents European XFEL at selected events, manages corporate identity, and develops communication concepts for the company. Until spring 2013, the group leader represented European XFEL in the coordination and international affairs working groups of EIROforum, a partnership between eight of Europe's largest intergovernmental research organizations.

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

Accomplishments

The PR group in 2013 implemented the following communications measures, among others:

- Published news releases, press releases, and newsletters
- Organized more than 60 guided tours of the European XFEL construction sites for 850 visitors, including scientists, journalists, politicians, students, and other stakeholders
- Produced and published the *European XFEL Annual Report 2012*
- Organized a celebration marking the end of underground civil construction, with more than 300 participants and guests from politics, academia, administration, and business, and updated a film covering the highlights of the construction project for the event (Figure 2)
- Published a new brochure on the project, its implementation, and its scientific objectives
- Contributed to the PR activities of EIROforum (*Science in School* and other brochures)
- Represented European XFEL with a booth at the physics festival Highlights der Physik in Wuppertal, Germany
- Hosted the science ministers of Poland and Russia, among other high-ranking politicians, at European XFEL
- Supported scientific events, such as the 2013 European XFEL Users' Meeting and the CORPES[13] conference, with news and photo coverage, website presence, posters, and merchandising items
- Participated in a working group—which included European XFEL Administrative Director Claudia Burger, representatives of the cities of Schenefeld and Hamburg, the district of Pinneberg, and the project company Projektgesellschaft Norderelbe—to realize a feasibility study for a visitor centre at the European XFEL Schenefeld site
- Produced a number of new merchandising items, such as polo shirts, rain covers for bike seats, and thermoses with the European XFEL design
- Organized the participation of European XFEL at the Hamburg Night of Science on the Deutsches Elektronen-Synchrotron (DESY) campus in Bahrenfeld—an event attracting 18000 visitors to an exhibition with experiments, demonstrations, film programmes, and tunnel tours, presented by 71 employees from both organizations (Figure 3)

Figure 2 The group invited a cellist for musical improvisation as part of the tunnel tour for guests at the celebration of the completion of underground construction in June.

Figure 3 The group organized European XFEL's exhibit during the Hamburg Night of Science on the DESY campus, which attracted thousands of visitors.

Neighbourhood work

Throughout civil construction of the European XFEL (2009–2015), 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 office informs these long-term neighbours about upcoming construction work through specially designed flyers and brochures, as well as through email and postings on the European XFEL website, phone calls, and even personal visits.

At the end of 2011, civil construction work for the 2 km long accelerator tunnel was concluded. In 2013, local residents near the tunnel route at times reported noise and vibrations from the tunnel. The neighbourhood office responded quickly, posting notices in the area. It also resolved an additional complaint about a spotlight.

In February, the office made a formal presentation to the neighbourhood group "Borner Runde" about next steps of civil construction on the Osdorfer Born site and conducted a discussion about environmental measures being taken by European XFEL and DESY. The office posted notices informing residents about the progress of construction.

The PR group regularly takes part in the weekly DESY construction group meeting to be able to inform neighbours and the public about the state of the construction project and the extent and duration of any potential inconveniences. In addition, the group continuously updates a construction calendar on the European XFEL homepage. ■

PHOTON SYSTEMS PROJECT OFFICE

Formerly known as the Technical Coordination (TC) group at European XFEL, the Photon Systems Project Office (PSPO) group is coordinating the installation of beamline components in the photon tunnels, coordinating the installation of scientific instruments and infrastructure in the experiment hall, ensuring the CAD integration of the various computer models of the facility’s components, and setting up a company-wide risk management system.

Joint TC team and the PSPO group

The complexity of the European XFEL project arises from its size and from the profusion of interfaces between the different components, which are planned and built by many scientific and technical groups worldwide. These groups collaborate within a work package structure that does not follow hierarchical principles. A joint Technical Coordination (TC) team at European XFEL and Deutsches Elektronen-Synchrotron (DESY), which recruits its members from the PSPO group at European XFEL and from DESY, does not have direct line responsibility but nevertheless acts as the prime systems integrator for the construction of the European XFEL facility.

In the TC team, the PSPO group focuses on the photon beamline installations in the tunnels and the scientific instruments in the experiment hall. In addition to its role within TC, the PSPO group also performs risk management for the European XFEL project.

The PSPO group focuses on the photon beamline installations in the tunnels and the scientific instruments in the experiment hall and performs risk management for the entire project.

Buildup of the PSPO group

At the end of 2012, it was decided to restructure the TC group at European XFEL into PSPO and two other groups: Central Instruments Engineering (see Chapter 6, “Scientific instruments and equipment”) and Technical Services (see Chapter 8, “Services”). This change of organization and tasks involved a reorganization of personnel and the need to quickly build up the PSPO group. In 2013, the group added four members: Konrad Piórecki, assistant to the risk coordinator; Gerd Wellenreuther, section coordinator for the experiment hall; Uschi Conta, documentation assistant; and Niko Saaristo, CAD integration engineer.

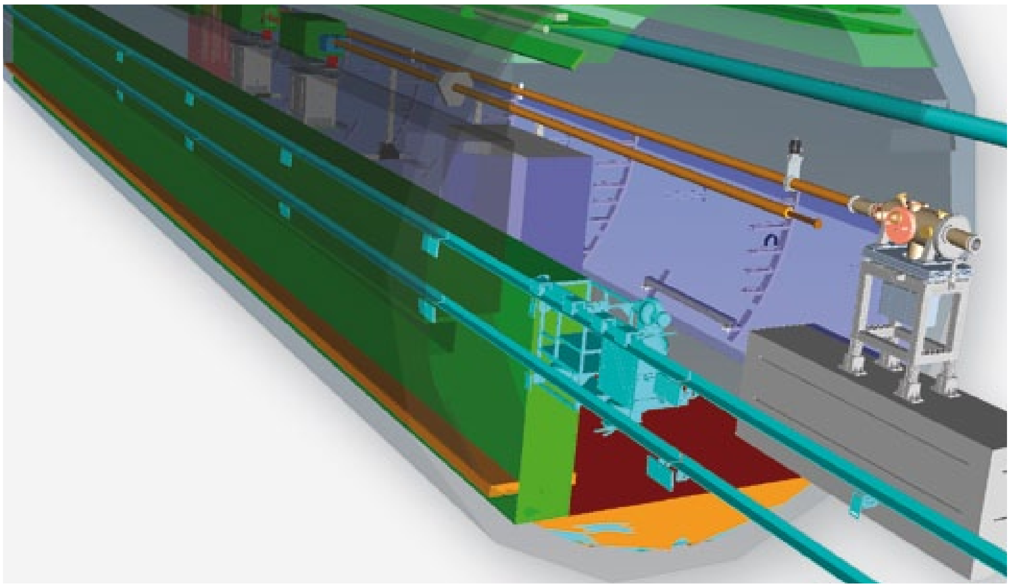


Figure 1 View of the XTD2 tunnel with photon and electron beamlines

Planning and infrastructure installations in the photon tunnels

In 2013, infrastructure installation started in the photon tunnels. It came close to completion in the second undulator tunnel (XTD2, Figure 1), which will accommodate the SASE1 undulators. Consequently, a prototype installation of the photon beam transport pipe could be set up in order to check interfaces and procedures. This prototype installation helps greatly in verifying the planning assumptions and procedures for the complete installation of the three SASE beamlines (Figure 2), which will start in the spring of 2014 and extend well into 2016.

Planning of instruments and infrastructure in the experiment hall

It is a major challenge to accommodate the complex space, access, stability, practicability, and cost requirements of the free-electron laser instruments in the experiment hall in Schenefeld. Difficulties also arise from the need for large independent optical laser and electronics installations in each experiment area.

While, in 2012, the outer boundaries of the instrument hutches in the experiment hall were fixed and agreed on, the focus in 2013 shifted to the infrastructure installations, which need to satisfy very complex requirements. These installations will occupy significant space and are closely intertwined with the design of the hutches themselves. Two external planning companies were hired to provide engineering know-how and planning resources. As a result, planning progressed rapidly. The respective tendering processes started with the concrete radiation protection enclosure for the High Energy Density Physics (HED) instrument in the south-west corner of the hall. The hutches for the SASE1 instruments Single Particles, Clusters, and Biomolecules (SPB) and Femtosecond X-Ray Experiments (FXE), as well as the respective optical lasers, are scheduled to be tendered early in 2014.

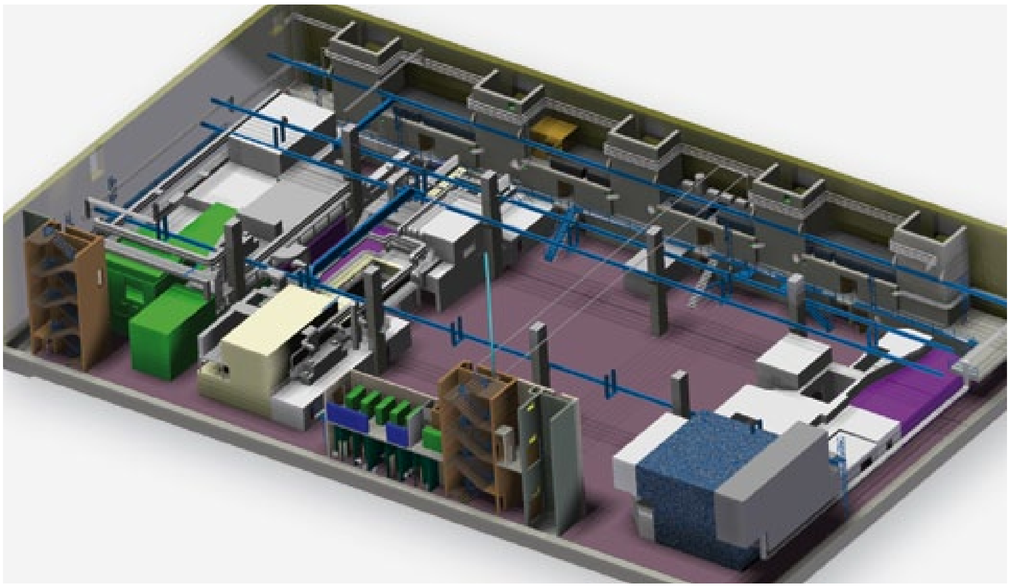


Figure 2 View of the SASE1 and SASE3 areas with their infrastructure on the left, SASE2 on the right

CAD integration

One of the tasks of the PSPO group is CAD integration, which contributes to assuring 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 contributing partners in the project to provide workable computer models of the respective components. Due to the size and complexity of the facility, strict standards for these models have to be defined and followed if the resulting integrated models are to remain manageable. Within the European XFEL project, a standard was defined early on for simplified placeholder models. This standard, which was based on the legacy CAD program I-DEAS, served well during the conceptual design phase. However, I-DEAS was found unsuitable for the more detailed engineering design integration phase. Hence, in 2013, the PSPO group developed guidelines for the integration models to be used during the engineering design phase in the photon tunnels and in the experiment hall. These guidelines, which are based on the Solid Edge program by Siemens PLM Software (Plano, Texas, USA), are currently in full use for the planning of the experiment hall and are partially in use for the detailed planning of the photon tunnel installations.

Risk management

The European XFEL Management Board has introduced a risk management system to identify and monitor risks that might threaten the company’s existence and, hence, the timely and economical completion of the European XFEL project. To implement the risk management system, the management board set up a risk committee and appointed a risk coordinator.

The risk coordinator implements the risk management system and related decisions by management, regularly collects risk reports from the different organizational units, and compiles a consolidated risk report. The risk coordinator is supported by an assistant.

The risk committee is in charge of further developing the risk management system and adopts the risk reports provided by the risk coordinator. It also advises on measures to reduce risks as suggested by the risk owners for decision by the management board. The risk committee is composed of the administrative director (chairperson), one scientific director as management board representative, the safety officer, the head of Finance and Controlling, and the risk coordinator and assistant.

In 2013, two risk reports were prepared and submitted to the European XFEL Management Board, Administrative and Finance Committee (AFC), and Council.

Outlook for 2014

The year 2014 will bring major challenges with the startup of installations in the photon tunnels and in the experiment hall. The first of these activities will be the construction of the radiation protection enclosure for the HED instrument in February. This will be followed by the first installations in the SASE1 beamline. By the end of the year, construction of the first hutches for the SASE1 instruments in the experiment hall should have started. This rapid succession of complex interdependent activities requires careful planning and monitoring that systematically tests the preparations made in previous years. ■

Group members
(left to right) Gerd Wellenreuther, Konrad Piórecki, Niko Saaristo, Uschi Conta, Tobias Haas (group leader), and Sabine Cunis

TECHNICAL SERVICES

Given the increasing amount of work required to plan and realize the technical infrastructure of the user-related parts of the facility, specifically on the Schenefeld campus, the European XFEL Management Board decided to establish the Technical Services (TS) group. In 2013, the group began planning the technical infrastructure, provision of district heating, and safety infrastructure for the facility.

Group responsibilities

The group leader, Bruno Becker-de Mos, joined European XFEL in August and got to work building up the TS group and optimizing the plans for the user laboratories and hutches.

The TS group's responsibilities include:

- Supporting and advising the technical and scientific work packages in designing the technical equipment needed for the laboratory rooms and instrument hutches
- Managing external consultant companies responsible for the planning of the technical laboratory layout and equipment
- Preparing, processing, and evaluating, together with the Procurement group, the calls for tender for technical and engineering support
- Setting up and running electrical and mechanical workshops
- Managing the facility (heating supply, air conditioning, technical building infrastructure, janitorial services, contracts, and so on)
- Maintaining technical infrastructure for users and staff in the operation phase of the facility, including support of and collaboration with the international user community and the hall crew
- Ensuring the day-to-day technical operation of the standard facility infrastructure

In 2013, the Technical Services group focused on planning the technical infrastructure of the laboratory and office building and the experiment hall, preparing for the provision of district heating, and helping with the definition of safety infrastructure.

Planning XHQ, XHEXP1, heating, and safety infrastructure

In 2013, the TS group focused on preparing for the construction of the technical infrastructure of the laboratory and office building (XHQ, Figure 1) and the experiment hall (XHEXP1), preparing for the provision of district heating, and, together with the Safety and Radiation Protection group, helping with the definition of the safety infrastructure.

For XHQ, the draft and execution planning of the concrete shell were finished and the call for tender was published shortly before the end of the year.

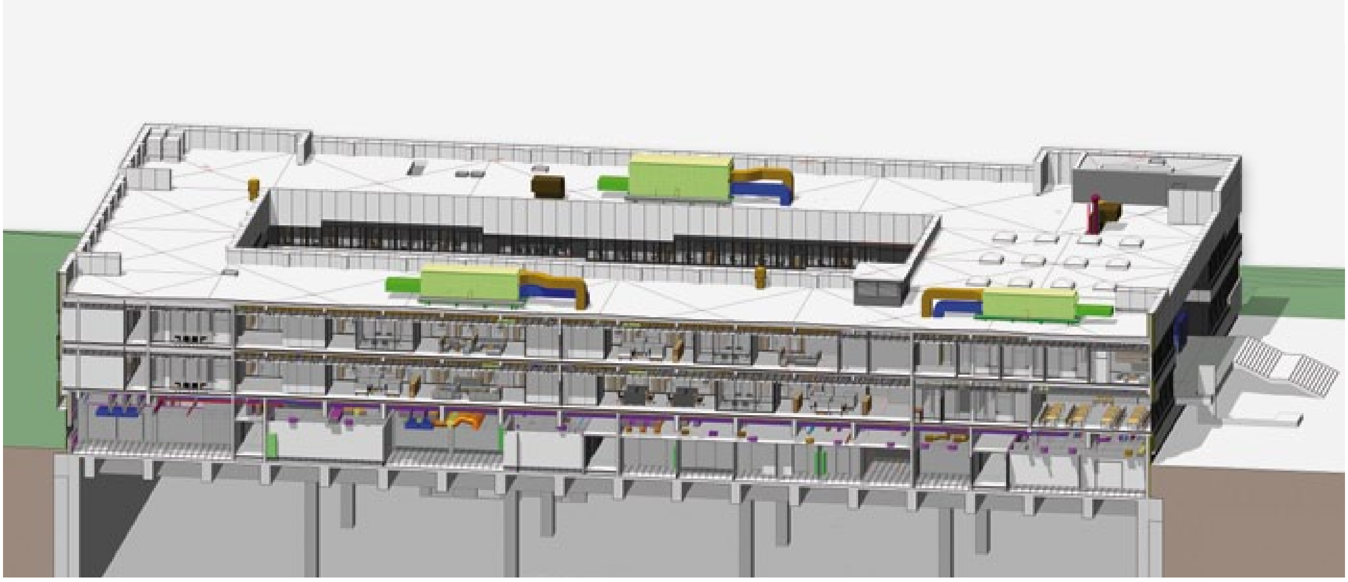


Figure 1 Cross-section of the headquarters building (XHQ). The execution planning for XHQ was finalized and a call for tender was sent out in 2013.

For XHEXP1, the draft planning of the experiment hutches for the six scientific instruments was conducted in close collaboration with the European XFEL Photon Systems Project Office (PSPO) group, the Safety and Radiation Protection (SRP) group, and external planning offices. The call for tender for the heavy concrete enclosure of the High Energy Density Physics (HED) instrument (Figure 2) at the SASE2 beamline was issued in December.

A team of two technicians supports the scientific and technical groups as they prepare to set up test equipment. They presently work in the workshops at DESY and thus benefit from the machine park available there.

The facility management team has continued day-to-day support for the temporary offices at Albert-Einstein-Ring 17 and 19, the civil construction office modules at the Schenefeld site, the temporary laboratories in the HERA South underground hall, and the European XFEL undulator and laser laboratories on the DESY campus.

In addition, the district-heating connection for the Osdorfer Born site and the transport via tunnel to the Schenefeld campus was prepared.

Together with the European XFEL Safety and Radiation Protection group, the overall safety concepts for the various buildings as well as the overall access scheme to the campus were reviewed in view of the preparation for their implementation.

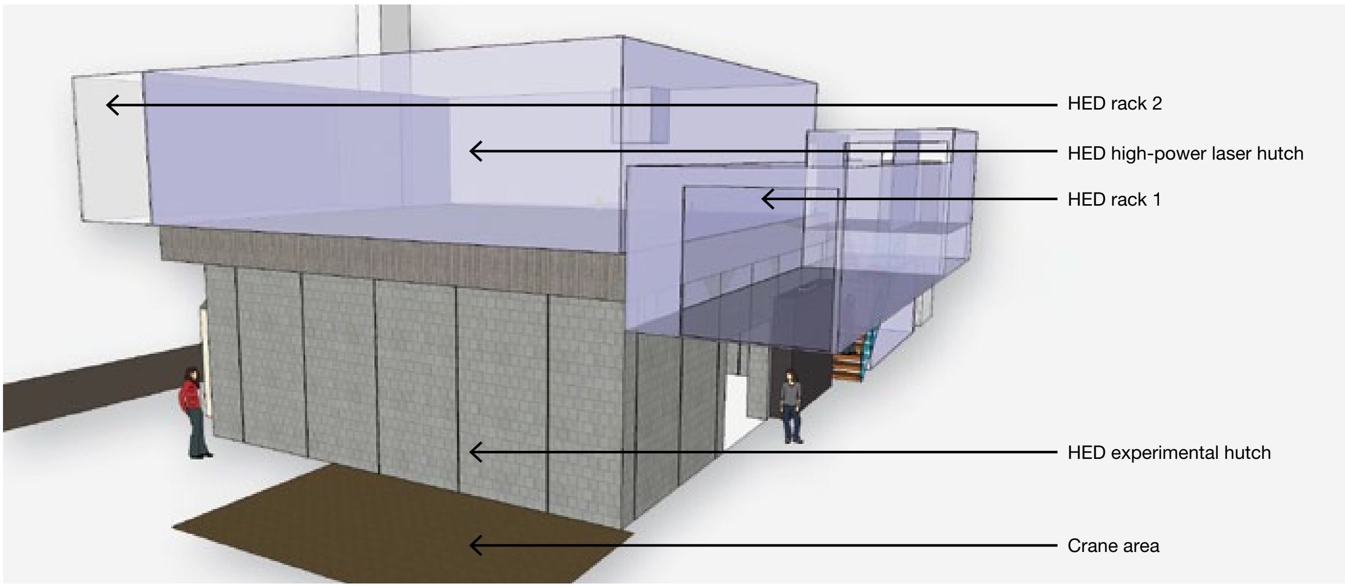


Figure 2 3D model of the enclosure for the HED instrument

Together with the European XFEL Safety and Radiation Protection group, the overall safety concepts for the various buildings, especially XHQ, as well as the overall access scheme to the campus were reviewed in view of the preparation for their implementation.

Outlook for 2014

In early 2014, the planning for the technical laboratory infrastructure for XHQ will be completed. At the same time, work will begin on the district-heating connection for the Osdorfer Born site. In addition, planning for the gate at the Schenefeld campus (XHGATE) and the central workshop and stockroom (XHWS) will be made. The *Zuwendungsverfahren Bau* process, a procedure according to the German rules for financing and constructing large infrastructures in the public sector, will be recorded for both buildings.

During the year, the TS group plans to establish a workshop container. This effort will include purchasing a lathe and a milling machine for the mechanical workshop and adding a third precision machinist to the team.

In addition, the TS group will oversee the preparations for construction of all hutches for SASE1 to SASE3 instruments and supervise tender procedures for non-technical portions of the hutches—including the walls and ceilings, structural parts, and vibration dampening measures—as well as other interior construction activities. The same applies to the technical infrastructure.

Finally, together with the Safety and Radiation Protection group, the TS group will develop access concepts.

To fulfil these tasks, the TS group plans to hire an electrical engineer, a civil engineer, a building services engineer, and a building automation engineer. ■

Group members
(left to right) Süleyman Arslan, Marco Schrage, Bruno Becker-de Mos (group leader), Uschi Conta, Jan Oliver Kirsch, Bernd Meier, Hrovje Kristic, and Carola Schulz (not shown)

SAFETY AND RADIATION PROTECTION

To ensure a safe and healthy work environment for all staff and guests at the European XFEL, the Safety and Radiation Protection (SRP) group assists and advises management and employees on German health and safety laws and practices.

SRP group

The SRP group leader, Sigrid Kozielski, reports directly to the administrative director, Claudia Burger, who is responsible for safety and radiation protection at the company. Kozielski acts as radiation protection officer and biological safety officer for European XFEL. Since April 2013, she also acts as biological safety officer for Deutsches Elektronen-Synchrotron (DESY).

Sabrina Scherz is the content management assistant in charge of updating the safety information and of organizing safety training.

In September 2013, Eric Boyd joined the SRP group as radiation protection officer. He works closely with the radiation protection group at DESY, focusing on the radiation shielding requirements in the future experiment hall on the Schenefeld campus. Starting in 2014, Boyd will also work in the fields of laser protection, electrical safety, and personnel safety systems.

Within each physical work area currently used by European XFEL, safety representatives have been nominated by the management board and trained. This includes the laser safety officers who were nominated from each laser laboratory. Laser safety officers and safety representatives work closely with the SRP group. In 2014, new X-ray equipment will be built in house by the Detector Development group. For this reason, more radiation protection officers will be trained and certified in 2014.

Medical Service

Medical Service is run by the DESY company doctor, Katharina Bünz. Together with the SRP group, Medical Service developed a health and safety questionnaire to improve the medical service at the company. The questionnaire provides information about possible hazards at the workplace to ensure appropriate medical consultations and examinations.

Safety monitoring and training

The SRP group visits and monitors workplaces. These visits ensure that the work risk assessments are up to date and that all personnel protective measures and equipment are in place. Inspection tours on the DESY campus are organized together with the DESY safety group.

The SRP group offers safety training for various safety hazards and emergency procedures (for example, first-aid training, fire extinguisher training, and laser safety training) in English and in German. General safety training for new staff and guests is conducted at the beginning of each month. The group is also preparing solutions for web-based training during the operation phase.

In 2013, employees and guests participated in two sessions of hands-on fire extinguisher training provided by the DESY safety group. This training will be offered again in 2014. To encourage preventive healthcare, the SRP group organized in-house eye relaxation training, which was provided by our accident insurer Unfallkasse Nord (Kiel, Germany) in German and English. The training was well received. Similar training is planned for 2014.

Due to increasing numbers of employees, new volunteers were trained as first-aiders to fulfil the requirements of German regulations and our accident insurer and increase the overall emergency preparedness of the staff. All employees conducting experiments in radiation protection–controlled areas of host institutes—such as BESSY II in Berlin and SACLA in Japan—took part in mandatory radiation protection training.

Safety planning and cooperation

The SRP group provides advice and assists in the planning of the facilities and buildings on the future Schenefeld campus—particularly for the new headquarters, the experiment hall, and the gate house where the emergency control centre will be located. Emergency response services will be set up in collaboration with the DESY technical emergency service and the local fire brigades to ensure a smooth and safe start of operations in 2017.

The SRP group is also responsible for radiation protection matters not related to the operation of the European XFEL, such as the handling of radioactive sources and operation of X-ray equipment for X-ray detector development and calibration. The radiation protection officer, Eric Boyd, will work closely with the nominated and certified DESY radiation protection officers for the facility, especially with regards to shielding requirements and personnel safety systems.

> The SRP group visits and monitors workplaces. These visits ensure that the work risk assessments are up to date and that all personnel protective measures and equipment are in place.

Starting in 2014, DESY and European XFEL will prepare a radiation protection organization concept for the commissioning and operation phase. The planning of the future safety organization at the Schenefeld campus will also be further intensified. The interfaces between DESY and European XFEL for safety and radiation protection responsibilities and services will be further defined.

Another important point is the implementation of an access management system to ensure safe access to the sites, laboratories, and experiment stations in underground areas. This access control should ensure that employees and guests are adequately trained in safety and emergency procedures before they start working.

In addition to working with the safety and radiation protection groups at DESY, the SRP group is in close contact with the safety groups of other research facilities, in particular members of EIROforum, a partnership of the eight largest intergovernmental scientific research organizations in Europe. In May 2013, the SRP group attended the International Technical Safety Forum (ITSF) Conference in May 2013 held in Grenoble, France. ■

Radiation protection organization

Claudia Burger (responsible person for radiation protection)
Thomas Tschentscher (radiation protection commissioner)
Sigrid Kozielski (radiation protection officer)
Joachim Schulz (deputy radiation protection officer)

Group members
(left to right) Sigrid Kozielski (group leader), Eric Boyd, and Sabrina Scherz

09

SCIENTIFIC RECORD

Participation in the Users' Meeting reached a new record, and other meetings and workshops organized by European XFEL also demonstrated keen interest in the new facility. The number of publications by European XFEL scientists continued to rise.

Part of the audience at the 2013 Users' Meeting

EUROPEAN XFEL USERS’ MEETING

23–25 January 2013
Deutsches Elektronen-Synchrotron (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 seventh meeting, the number of participants again broke the record from the previous year: there were approximately 800 attendees, up from about 680 in 2012. The programme included talks, several workshops, a satellite meeting on photon diagnostics, a special session on X-ray free-electron laser (X-ray FEL) instrumentation, and a poster session with over 300 posters. Participants discussed details of the European XFEL project and recent updates within the field of photon science. More than 45 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
- Instrument design developments and advances
- Selected science applications
- Current developments in the field of X-ray FEL facilities
- Job opportunities at European XFEL

Figure 1 Participants of the 7th European XFEL Users’ Meeting

FIRST RACIRI SUMMER SCHOOL ON ADVANCED MATERIALS DESIGN AT X-RAY AND NEUTRON SOURCES

17–25 August 2013
Peterhof (St. Petersburg), Russia

Jointly organized by leading research organizations from Russia, Sweden, and Germany, the first RACIRI Summer School featured lectures from representatives from operating and upcoming X-ray and neutron sources in each of these countries, as well as scientists from other universities and laboratories around the world. The summer school originated from a cooperation between the Röntgen-Ångstrom-Cluster (RAC), a partnership between Germany and Sweden, and the Ioffe-Röntgen-Institute (IRI), a partnership between Germany and the Russian Federation. Attended by 80 participants, mostly graduate students from the three organizing countries, the summer school included a welcome speech from European XFEL Scientific Director and RACIRI Scientific Committee Chair Serguei Molodtsov as well as a lecture from European XFEL Managing Director Massimo Altarelli. The focus of the first iteration of this summer school was to strengthen the students' knowledge of advanced materials design and to develop an interest in related facilities, including new light sources such as European XFEL in Germany, European Spallation Source and Max IV in Sweden, and PIK in Russia.

Figure 2 Attendees of the RACIRI Summer School in front of the Saints Peter and Paul Cathedral in Peterhof

WORKSHOPS

22–25 April 2013

2nd 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. The specific emphasis was on installation and integration aspects.

2–5 June 2013

Kick Off Meeting for the Helmholtz International Beamline for Extreme Fields (HIBEF) at the European XFEL

Organized by DESY, supported by the High Energy Density Physics (HED) group at European XFEL

This workshop served as the founding meeting for the HIBEF user consortium (UC). The consortium is coordinated by Helmholtz-Zentrum Dresden-Rossendorf (HZDR), Germany, and DESY. During the workshop, the group established the organization of the HIBEF UC and discussed potential in-kind contributions of the member institutions of the UC, as well as synergies with other European XFEL UCs.

29 July – 2 August 2013

International Workshop on Strong Correlations and Angle-Resolved Photoemission Spectroscopy (CORPES^{13})

Organized by European XFEL on the DESY campus, Hamburg, Germany

Held every second year, the workshop focuses on angle-resolved photoemission spectroscopy studies and methods involving correlated electron materials, such as superconductors, Kondo systems, and others. This was the fifth CORPES meeting and the first hosted by European XFEL. It featured two poster sessions and numerous talks on spectroscopic investigations of correlated electron materials, the many-body theory of correlated electrons in solids, the photoemission process, advances in photoemission techniques, and relations to other techniques in photon science. ■

SEMINARS

22 January 2013
Soft X-ray optical systems for the future NGLS in Berkeley
Tony Warwick, Advanced Light Source (ALS), Lawrence Berkeley National Laboratory (LBNL), Berkeley, California

18 February 2013
Studying biological assemblies with optical tweezers
Ulrich Bockelmann, Laboratoire de Nanobiophysique, École Supérieure de Physique et de Chimie Industrielles de la Ville de Paris (ESPCI ParisTech), Paris, France

1 March 2013
Lessons learned in building the LCLS
Persis Drell, SLAC National Accelerator Laboratory, Menlo Park, California

12 March 2013
Economic effects of basic research infrastructure
Michael Neumann, European XFEL, Hamburg, Germany

18 April 2013
Laboratory astrophysics needs: the case of X-ray astronomy
Jörn Wilms, Dr. Karl Remeis-Sternwarte, Astronomisches Institut der Friedrich-Alexander-Universität Erlangen-Nürnberg, Bamberg, Germany

3 May 2013
X-ray spectroscopy in very high magnetic fields
Cornelius Strohm, European Synchrotron Radiation Facility (ESRF), Grenoble, France

23 May 2013
Ultrafast nonthermal processes in FEL irradiated solids
Nikita Medvedev, Center for Free-Electron Laser Science (CFEL), Deutsches Elektronen-Synchrotron (DESY), Hamburg, Germany

7 June 2013
High-repetition rate laser pump / X-ray probe experiments at the APS
Eric Dufresne, Advanced Photon Source (APS), Argonne National Laboratory (ANL), Argonne, Illinois

1 July 2013
Current status of the PAL-XFEL project
In Soo Ko, Pohang University of Science and Technology (POSTECH), Pohang, Republic of Korea

14 November 2013
Watching ultrafast photo-induced non-adiabatic transformations in molecular switches and DNA building blocks
Friedrich Temps, Institute of Physical Chemistry, Kiel University (CAU), Germany

29 November 2013
Studies on ablation and surface modification by soft X-ray laser and XUV FEL beams
Sergey Pikuz, Joint Institute for High Temperatures of the Russian Academy of Sciences (JIHT RAS), Moscow, Russia

6 December 2013
Design and performance of the APS superconducting undulator
Efim Gluskin, Advanced Photon Source (APS), Argonne National Laboratory (ANL), Argonne, Illinois

16 December 2013
The study of core and valence excitations in molecules by stimulated Raman multidimensional broad band X-ray spectroscopy
Shaul Mukamel, University of California, Irvine, California

LECTURE SERIES

Femtochemistry, Photosynthesis, and Catalysis

Continuing the winter semester, which began in October 2012, this lecture series covered contemporary problems in chemical physics, with a particular emphasis on catalytic and light-conversion schemes. Both theoretical and experimental aspects were treated, making use of the entire range of contemporary techniques. The series, which addressed graduate students, including the participants of the different graduate schools for excellence, as well as faculty and staff members of the various Hamburg institutes, was organized by the Femtosecond X-Ray Experiments (FXE) instrument group at European XFEL.

10 January 2013
Fundamental light-induced processes of technological relevance: from molecules to nanomaterials
Nicola Armaroli, Institute for Organic Synthesis and Photoreactivity (ISOF), National Research Council (CNR), Bologna, Italy

17 January 2013
Unravelling the mysteries of solar nanocells using synchrotron radiation and laser technique
Wendy Flavell, The Photon Science Institute, University of Manchester, United Kingdom

24 January 2013
Ultrafast structural dynamics in ionic materials mapped by femtosecond X-ray powder diffraction
Thomas Elsaesser, Max Born Institute for Nonlinear Optics and Short Pulse Spectroscopy (MBI), Berlin, Germany

13 February 2013

Probing catalysis using X-rays: From artificial photosynthesis to ultrafast surface chemistry

Anders Nilsson, SLAC National Accelerator Laboratory, Menlo Park, California, and Stanford University, Stanford, California

15 February 2013

First-row transition metal-based chromophores for solar energy conversion: Fundamental issues and applications

James McCusker, Michigan State University, East Lansing, Michigan ■

European XFEL Science Lecture Series
Winter Semester 2012/13

European XFEL

FEMTOCHEMISTRY · PHOTOSYNTHESIS AND CATALYSIS

Lecture schedule:

Andreas Hauser

Stefan Lochbrunner

Jeroen van Bokhoven

Jacques Moser

Serena DeBeer

Ivano Tavernelli

Leif Hammarström

Paul van Loosdrecht

Coen de Graaf

Nicola Armaroli

Wendy Flavell

Villy Sundström

James McCusker

Thomas Elsässer

Anders Nilsson

Organization and contact

www.xfel.eu/lecture-series

Figure 1 Announcement for the lecture series "Femtochemistry, Photosynthesis, and Catalysis"

PUBLICATIONS

JOURNALS

AMO science at the FLASH and European XFEL free-electron laser facilities
J. Feldhaus, M. Krikunova, M. Meyer, Th. Möller, R. Moshammer, A. Rudenko,
Th. Tschentscher, J. Ullrich
J. Phys. B **46** (2013) 16, 164002
doi:10.1088/0953-4075/46/16/164002

Discovery of 505-million-year old chitin in the basal demosponge *Vauxia gracilenta*
H. Ehrlich, J. Keith Rigby, J.P. Botting, M.V. Tsurkan, C. Werner, P. Schwille, Z. Petrášek,
A. Pisera, P. Simon, V.N. Sivkov, D.V. Vyalikh, S.L. Molodtsov, D. Kurek, M. Kammer,
S. Hunoldt, R. Born, D. Stawski, A. Steinhof, V.V. Bazhenov, T. Geisler
Scientific Reports **3** (2013), 3497
doi:10.1038/srep03497

Experimental set-up and procedures for the investigation of XUV free electron laser interactions with solids
R. Sobierajski, M. Jurek, J. Chalupský, J. Krzywinski, T. Burian, S. Dastjani Farahani,
V. Hájková, M. Harmand, L. Juha, D. Klinger, R.A. Loch, C. Ozkan, J.B. Pełka,
K. Sokolowski-Tinten, H. Sinn, S. Toleikis, K. Tiedtke, T. Tschentscher, H. Wabnitz,
J. Gaudind
JINST **8** (2013), P02010
doi:10.1088/1748-0221/8/02/P02010

Femtosecond x-ray absorption spectroscopy at a hard x-ray free electron laser: Application to spin crossover dynamics
H.T. Lemke, Ch. Bressler , L.X. Chen, D.M. Fritz, K.J. Gaffney, A. Galler, W. Gawelda,
K. Haldrup, R.W. Hartsock, H. Ihee, J. Kim, K.H. Kim, J.H. Lee, M.M. Nielsen, A.B. Stickrath,
W. Zhang, D. Zhu, M. Cammarata
J. Phys. Chem. A **117** (2013), 735–740
doi:10.1021/jp312559h

Interference in the angular distribution of photoelectrons in superimposed XUV and optical laser fields
S. Düsterer, L. Rading, P. Johnsson, A. Rouzée, A. Hundertmark, M.J.J. Vrakking,
P. Radcliffe, M. Meyer, A.K. Kazansky, N.M. Kabachnik
J. Phys. B **46** (2013), 164026
doi:10.1088/0953-4075/46/16/164026

Interplay of Dirac fermions and heavy quasiparticles in solids
M. Höppner, S. Seiro, A. Chikina, A. Fedorov, M. Güttler, S. Danzenbächer, A. Generalov,
K. Kummer, S. Patil, S.L. Molodtsov, Y. Kucherenko, C. Geibel, V.N. Strocov, M. Shi,
M. Radovic, T. Schmitt, C. Laubschat, D.V. Vyalikh
Nat. Comm. **4** (2013), 1646
doi:10.1038/ncomms2654

Investigation of damage induced by intense femtosecond XUV pulses in silicon crystals by means of white beam synchrotron section topography
W. Wierzchowski, K. Wieteska, D. Klinger, R. Sobierajski, J.B. Pelka, D. Żymierska, T. Balcer, J. Chalupský, J. Gaudin, V. Hájková, T. Burian, A.J. Gleeson, L. Juha, H. Sinn, D. Sobota, K. Tiedtke, S. Toleikis, T. Tschentscher, L. Vyšín, H. Wabnitz, C. Paulmann
Radiation Physics and Chemistry **93** (2013), 99–103
doi:10.1016/j.radphyschem.2013.04.025

Isotopically resolved photoelectron imaging unravels complex atomic autoionization dynamics by two-color resonant ionization
P. O'Keeffe, E.V. Gryzlova, D. Cubaynes, G.A. Garcia, L. Nahon, A.N. Grum-Grzhimailo, M. Meyer
Phys. Rev. Lett. **111** (2013), 243002
doi:10.1103/PhysRevLett.111.243002

Joint European XFEL and DESY Photon Science Users' Meeting 2013
W. Laasch, Th. Tschentscher
Synchrotron Radiation News **26** (2013) 3, 45–48
doi:10.1080/08940886.2013.791220

Natively Inhibited Trypanosoma brucei Cathepsin B Structure Determined by Using an X-ray Laser
L. Redecke, K. Nass, D.P. DePonte, T.A. White, D. Rehders, A. Barty, F. Stellato, M. Liang, T.R.M. Barends, S. Boutet, G.J. Williams, M. Messerschmidt, M.M. Seibert, A. Aquila, D. Arnlund, S. Bajt, T. Barth, M.J. Bogan, C. Caleman, T.-C. Chao, R.B. Doak, H. Fleckenstein, M. Frank, R. Fromme, L. Galli, I. Grotjohann, M.S. Hunter, L.C. Johansson, S. Kassemeyer, G. Katona, R.A. Kirian, R. Koopmann, Ch. Kupitz, L. Lomb, A.V. Martin, S. Mogk, R. Neutz, R.L. Shoeman, J. Steinbrener, N. Timneanu, D. Wang, U. Weierstall, N.A. Zatsepin, J.C.H. Spence, P. Fromme, I. Schlichting, M. Duszenko, Ch. Betzel, H.N. Chapman
Science **339** (2013) 6116, 227–230
doi:10.1126/science.1229663

Non-dipole effects in the angular distribution of photoelectrons in sequential two-photon double ionization: argon and neon
E.V. Gryzlova, A.N. Grum-Grzhimailo, S.I. Strakhova, M. Meyer
J. Phys. B: At. Mol. Opt. Phys. **46** (2013), 164014
doi:10.1088/0953-4075/46/16/164014

Performance of an LPD prototype detector at MHz frame rates under Synchrotron and FEL radiation
A. Koch, M. Hart, T. Nicholls, C. Angelsen, J. Coughlan, M. French, S. Hauf, M. Kuster, J. Sztuk-Dambietz, M. Turcato, G.A. Carini, M. Chollet, S.C. Herrmann, H.T. Lemke, S. Nelson, S. Song, M. Weaver, D. Zhu, A. Meents, P. Fischer
15th International Workshop on Radiation Imaging Detectors, IWORID, Paris, France, 23–27 June 2013
JINST **8** (2013), C11001
doi:10.1088/1748-0221/8/11/C11001

Photon energy dependence of graphitization threshold for diamond irradiated with an intense XUV FEL pulse
J. Gaudin, N. Medvedev, J. Chalupský, T. Burian, S. Dastjani-Farahani, V. Hájková, M. Harmand, H.O. Jeschke, L. Juha, M. Jurek, D. Klinger, J. Krzywinski, R.A. Loch, S. Moeller, M. Nagasono, C. Ozkan, K. Saksl, H. Sinn, R. Sobierajski, P. Sovák, S. Toleikis, K. Tiedtke, M. Toufarová, T. Tschentscher, V. Vorlíček, L. Vyšín, H. Wabnitz, B. Ziaja
Phys. Rev. B **88** (2013), 060101(R)
doi:10.1103/PhysRevB.88.060101

Real-Time Manifestation of Strongly Coupled Spin and Charge Order Parameters in Stripe-Ordered $La_{1.75}Sr_{0.25}NiO_4$ Nickelate Crystals Using Time-Resolved Resonant X-Ray Diffraction
Y.D. Chuang, W.S. Lee, Y.F. Kung, A.P. Sorini, B. Moritz, R.G. Moore, L. Patthey, M. Trigo, D.H. Lu, P.S. Kirchmann, M. Yi, O. Krupin, M. Langner, Y. Zhu, S.Y. Zhou, D.A. Reis, N. Huse, J.S. Robinson, R.A. Kaindl, R.W. Schoenlein, S.L. Johnson, M. Först, D. Doering, P. Denes, W.F. Schlotter, J.J. Turner, T. Sasagawa, Z. Hussain, Z.X. Shen, T.P. Devereaux
Phys. Rev. Lett. **110**, (2013), 127404
doi:10.1103/PhysRevLett.110.127404

Sensing the wavefront of x-ray free-electron lasers using aerosol spheres
N.D. Loh, D. Starodub, L. Lomb, C.Y. Hampton, A.V. Martin, R.G. Sierra, A. Barty, A. Aquila, J. Schulz, J. Steinbrener, R.L. Shoeman, S. Kassemeyer, Ch. Bostedt, J. Bozek, S.W. Epp, B. Erk, R. Hartmann, D. Rolles, A. Rudenko, B. Rudek, L. Foucar, N. Kimmel, G. Weidenspointner, G. Hauser, P. Holl, E. Pedersoli, M. Liang, M.S. Hunter, L. Gumprecht, N. Coppola, C. Wunderer, H. Graafsma, F.R.N.C. Maia, T. Ekeberg, M. Hantke, H. Fleckenstein, H. Hirsemann, K. Nass, T.A. White, H.J. Tobias, G.R. Farquar, W.H. Benner, S. Hau-Riege, Ch. Reich, A. Hartmann, H. Soltau, S. Marchesini, S. Bajt, M. Barthelmess, L. Strueder, J. Ullrich, Ph. Bucksbaum, M. Frank, I. Schlichting, H.N. Chapman, M.J. Bogan
Optics Express **21** (2013) 10, 12385–12394
doi:10.1364/OE.21.012385

Solution of the phase problem for coherent scattering from a disordered system of identical particles
R.P. Kurta, R. Dronyak, M. Altarelli, E. Weckert. I.A. Vartanyant
New J. Phys. **15** (2013) 013059
doi:10.1088/1367-2630/15/1/013059

Speed limit of the insulator–metal transition in magnetite
S. de Jong, R. Kukreja, C. Trabant, N. Pontius, C.F. Chang, T. Kachel, M. Beye, F. Sorgenfrei, C.H. Back, B. Bräuer, W.F. Schlotter, J.J. Turner, O. Krupin, M. Doehler, D. Zhu, M.A. Hossain, A.O. Scherz, D. Fausti, F. Novelli, M. Esposito, W.S. Lee, Y.D. Chuang, D.H. Lu, R.G. Moore, M. Yi, M. Trigo, P. Kirchmann, L. Pathey, M.S. Golden, M. Buchholz, P. Metcalf, F. Parmigiani, W. Wurth, A. Föhlisch, C. Schüßler-Langeheine, H. A. Dürr
Nature Materials **12** (2013), 882
doi:10.1038/nmat3718

The beat in laser-accelerated ion beams
M. Schnürer, A.A. Andreev, F. Abicht, J. Bränzel, Ch. Koschitzki, K. Yu. Platonov, G. Priebe, W. Sandner
Phys. Plasmas **20** (2013), 103102
doi:10.1063/1.4824115

Toward Highlighting the Ultrafast Electron Transfer Dynamics at the Optically Dark Sites of Photocatalysts
S.E. Canton, X. Zhang, J. Zhang, T.B. van Driel, K.S. Kjaer, K. Haldrup, P. Chabera, T. Harlang, K. Suarez-Alcantra, Y. Liu, J. Pérez, A. Bordage, M. Pápai, G. Vankó, G. Jennings, C.A. Kutz, M. Rovezzi, P. Glatzel, G. Smolentsev, J. Uhlig, A.O. Dohn, M. Christensen, A. Galler, W. Gawelda, Ch. Bressler, H.T. Lemke, K.B. Møller, M.M. Nielsen, R. Lomoth, K. Wärnmark, V. Sundström
J. Phys. Chem. Lett. **4** (2013), 1972–1976
doi:10.1021/jz401016h

Toward unsupervised single-shot diffractive imaging of heterogeneous particles using X-ray free-electron lasers
H. Joo Park, N.D. Loh, R.G. Sierra, C.Y. Hampton, D. Starodub, A.V. Martin, A. Barty, A. Aquila, J. Schulz, J. Steinbrener, R.L. Shoeman, L. Lomb, S. Kassemeyer, Ch. Bostedt, J. Bozek, S.W. Epp, B. Erk, R. Hartmann, D. Rolles, A. Rudenko, B. Rudek, L. Foucar, N. Kimmel, G. Weidenspointner, G. Hauser, P. Holl, E. Pedersoli, M. Liang, M.S. Hunter, L. Gumprecht, N. Coppola, C. Wunderer, H. Graafsma, F.R.N.C. Maia, T. Ekeberg, M. Hantke, H. Fleckenstein, H. Hirsemann, K. Nass, H.J. Tobias, G.R. Farquar, W.H. Benner, S. Hau-Riege, Ch. Reich, A. Hartmann, H. Soltau, S. Marchesini, S. Bajt, M. Barthelmess, L. Strueder, J. Ullrich, P. Bucksbaum, M. Frank, I. Schlichting, H.N. Chapman, M.J. Bogan, V. Elser
Optics Express **21** (2013) 23, 28729–28742
doi:10.1364/OE.21.028729

Versatility of a hard X-ray Kirkpatrick-Baez focus characterized by ptychography
K. Giewekemeyer, R.N. Wilke, M. Osterhoff, M. Bartels, S. Kalbfleisch, T. Salditt
J. Synchrotron Rad. **20** (2013) 490−497
doi:10.1107/S0909049513005372

X-Ray Cross-Correlation Analysis of Disordered Ensembles of Particles: Potentials and Limitations
R.P. Kurta, M. Altarelli, I.A. Vartanyants
Advances in Condensed Matter Physics **2013** (2013), 959835
doi:10.1155/2013/959835

REPORTS

Conceptual Design Report: Scientific Instrument High Energy Density Physics (HED)
M. Nakatsutsumi, Th. Tschentscher
Technical Report (2013)
XFEL.EU TR-2013-003
doi:10.3204/XFEL.EU/TR-2013-003

Conceptual Design Report: Scientific Instrument Spectroscopy and Coherent Scattering (SCS)
A. Scherz, O. Krupin
Technical Report (2013)
XFEL.EU TR-2013-006
doi:10.3204/XFEL.EU/TR-2013-006

Conceptual Design Report: Undulator Control Systems
A. Beckmann, S. Karabekyan, J. Pflüger
Technical Report (2013)
XFEL.EU TR-2013-001
doi:10.3204/XFEL.EU/TR-2013-001

Detector Geometries for Coherent X-Ray Diffractive Imaging at the SPB Instrument
K. Giewekemeyer, M. Turcato, A.P. Mancuso
Technical Report (2013)
XFEL.EU TR-2013-007
doi:10.3204/XFEL.EU/TR-2013-007

Estimates of the Fluorescence-Induced Backscattered Dose for the LPD Detector
S. Hauf, A. Koch
Technical Report (2013)
XFEL.EU TR-2013-002
doi:10.3204/XFEL.EU/TR-2013-002

European XFEL Post-TDR Description
W. Decking, T. Limberg
Technical Note (2013)
XFEL.EU TN-2013-004-01

Extension of SASE bandwidth up to 2% as a way to increase the efficiency of protein structure determination by x-ray nanocrystallography at the European XFEL
S. Serkez, V. Kocharyan, E. Saldin, I. Zagorodnov, G. Geloni, O. Yefanov
Red Report (2013)
DESY 13-109
arXiv:1306.4830

Grating monochromator for soft X-ray self-seeding the European XFEL
S. Serkez, G. Geloni, V. Kocharyan, E. Saldin
DESY 13-040
arXiv:1303.1392

Nonlinear undulator tapering in conventional SASE regime at baseline electron beam parameters as a way to optimize the radiation characteristics of the European XFEL
S. Serkez, V. Kocharyan, E. Saldin, I. Zagorodnov, G. Geloni
Red Report (2013)
DESY 13-162
arXiv:1309.3149

Proposal for a scheme to generate 10 TW-level femtosecond x-ray pulses for imaging single protein molecules at the European XFEL
S. Serkez, V. Kocharyan, E. Saldin, I. Zagorodnov, G. Geloni, O. Yefanov
Red Report (2013)
DESY 13-101
arXiv:1306.0804

Proposal to generate 10 TW level femtosecond x-ray pulses from a baseline undulator in conventional SASE regime at the European XFEL
S. Serkez, V. Kocharyan, E. Saldin, I. Zagorodnov, G. Geloni
Red Report (2013)
DESY 13-138
arXiv:1308.0448

Purified SASE undulator configuration to enhance the performance of the soft x-ray beamline at the European XFEL
S. Serkez, V. Kocharyan, E. Saldin, I. Zagorodnov, G. Geloni
Red Report (2013)
DESY 13-135
arXiv:1308.0172

Technical Design Report: Scientific Instrument Materials Imaging and Dynamics (MID)
A. Madsen, J. Hallmann, T. Roth, G. Ansaldi
Technical Report (2013)
XFEL.EU TR-2013-005
doi:10.3204/XFEL.EU/TR-2013-005

Technical Design Report: Scientific Instrument Single Particles, Clusters, and Biomolecules (SPB)
A.P. Mancuso, A. Aquila, G. Borchers, K. Giewekemeyer, N. Reimers
Technical Report (2013)
XFEL.EU TR-2013-004
doi:10.3204/XFEL.EU/TR-2013-004

Vacuum Control System for the Photon Beamlines
T. Korsch
Technical Note (2013)
XFEL.EU TN-2013-005-01

Wake monochromator in asymmetric and symmetric Bragg and Laue geometry for self-seeding the European X-ray FEL
G. Geloni, V. Kocharyan, E. Saldin, S. Serkez, M. Tolkiehn
DESY 13-013
arXiv:1301.7621

CONTRIBUTIONS TO CONFERENCE PROCEEDINGS

A case study of novel X-ray Optics for FEL sources
J. Rehanek, F. Schäfers, H. Löchel, A. Firsov, J. Grünert, W. Freund, C. Ozkan, S. Molodtsov, A. Erko
11th International Conference on Synchrotron Radiation Instrumentation (SRI2012), Lyon, France, 9–13 July 2012
J. Phys.: Conf. Ser. 425, 052013 (2013)
doi:10.1088/1742-6596/425/5/052013

A Proof-of-Principle Study of a Synchronous Movement of an Undulator Array Using an EtherCAT Fieldbus at European XFEL
S. Karabekyan, A. Beckmann, J. Pflüger, M. Yakopov
14th International Conference on Accelerator & Large Experimental Physics Control Systems, San Francisco, California, 6–11 October 2013
ICALEPCS2013, THPPC095 (2013)
ISBN: 978-3-95450-139-7

Analysis of magnetic properties of the European XFEL undulator prototype
S. Tomin, N. Smolyakov, G. Geloni, J. Pflueger, Y. Li
11th International Conference on Synchrotron Radiation Instrumentation (SRI2012), Lyon, France, 9–13 July 2012
J. Phys.: Conf. Ser. 425, 032003 (2013)
doi:10.1088/1742-6596/425/3/032003

Automated Verification Environment for TwinCAT PLC Programs
A. Beckmann
14th International Conference on Accelerator & Large Experimental Physics Control Systems, San Francisco, California, 6–11 October 2013
ICALEPCS2013, MOPPC082 (2013)
ISBN: 978-3-95450-139-7

Breakdown Localization Studies on the SwissFEL C-band Test Structures
J. Klavins, S. Dementjevs, U. Locans, L. Stingelin, M. Wohlmuther, R. Zennaro, N. Shipman, F. Le Pimpec
4th International Particle Accelerator Conference, Shanghai, China, 12–17 May 2013
Proceedings of IPAC2013, WEPFI058 (2013)
ISBN: 978-3-95450-122-9

Characterizing the focus of a multilayer coated off-axis parabola for FLASH beam at λ = 4.3 nm
A.F.G. Leontowich, A. Aquila, F. Stellato, R. Bean, H. Fleckenstein, M. Prasciolu, M. Liang, D.P. DePonte, A. Barty, F. Wang, J. Andreasson, J. Hajdu, H.N. Chapman, S. Bajt
SPIE Optics + Optoelectronics, Damage to VUV, EUV, and X-ray Optics IV; and EUV and X-ray Optics: Synergy between Laboratory and Space III, Prague, Czech Republic, 15 April 2013
Proc. SPIE 8777, 87770T (2013)
doi:10.1117/12.2022403

Control Using Beckhoff Distributed Rail Systems at the European XFEL
N. Coppola, J. Tolkiehn, C. Youngman
14th International Conference on Accelerator & Large Experimental Physics Control Systems, San Francisco, California, 6–11 October 2013
ICALEPCS2013, TUPPC046 (2013)
ISBN: 978-3-95450-139-7

Design of soft x-ray gratings for free electron lasers: from specification to characterization
M. Vannoni, D. La Civita, R. Follath, L. Samoylova, F. Siewert, H. Sinn
SPIE Optical Metrology, 2013: Modeling Aspects in Optical Metrology IV, Munich, Germany, 13 May 2013
Proc. SPIE 8789, 878916 (2013)
doi:10.1117/12.2020520

Detector Development for the European XFEL: Requirements and Status
A. Koch, M. Kuster, J. Sztuk-Dambietz, M. Turcato
11th International Conference on Synchrotron Radiation Instrumentation (SRI2012), Lyon, France, 9–13 July 2012
J. Phys.: Conf. Ser. 425, 062013 (2013)
doi:10.1088/1742-6596/425/6/062013

Development status of the X-ray beam diagnostics devices for the commissioning and user operation of the European XFEL
J. Grünert, J. Buck, W. Freund, C. Ozkan, S. Molodtsov
J. Phys.: Conf. Ser. 425, 072004 (2013)
doi:10.1088/1742-6596/425/7/072004

Electron motion in a 3-D undulator magnetic field
N. Smolyakov, S. Tomin, G. Geloni
11th International Conference on Synchrotron Radiation Instrumentation (SRI2012), Lyon, France, 9–13 July 2012
J. Phys.: Conf. Ser. 425, 032023 (2013)
doi:10.1088/1742-6596/425/3/032023

Electronics Developments for High Speed Data Throughput and Processing
C. Youngman, B. Fernandes, P. Gessler, J. Coughlan, E. Motuk, M. Zimmer
14th International Conference on Accelerator & Large Experimental Physics Control Systems, San Francisco, California, 6–11 October 2013
ICALEPCS2013, TUPPC086 (2013)
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Electron trajectories in a three-dimensional undulator magnetic field
N. Smolyakov, S. Tomin, G.A. Geloni
4th International Particle Accelerator Conference, Shanghai, China, 12–17 May 2013
Proceedings of IPAC2013, WEPWA044 (2013)
ISBN: 978-3-95450-122-9

High power femtosecond 1030nm burst-mode front-end and pre-amplifier for the European XFEL pump-probe laser development
M. Kellert, K. Kruse, M. Pergament, G. Kulcsar, T. Mans, M.J. Lederer
European Conference on Lasers and Electro-Optics (CLEO Europe) 2013, International Quantum Electronics Conference, Munich, Germany, 12–16 May 2013
Optical Society of America, CA_P_23 (2013)
ISBN: 978-1-4799-0594-2

High Level FPGA Programming Framework Based on Simulink
B. Fernandes, P. Gessler, C. Youngman
14th International Conference on Accelerator & Large Experimental Physics Control Systems, San Francisco, California, 6–11 October 2013
ICALEPCS2013, TUPPC087 (2013)
ISBN: 978-3-95450-139-7

High power Yb:CALGO multi-crystal oscillator
A.-L. Calendron, M. Lederer, H. Cankaya, F. Kaertner
European Conference on Lasers and Electro-Optics (CLEO Europe) 2013, International Quantum Electronics Conference, Munich, Germany, 12–16 May 2013
Optical Society of America, CA_4_3 (2013)
ISBN: 978-1-4799-0594-2

Karabo: An Integrated Software Framework Combining Control, Data Management, and Scientific Computing Tasks
B.C. Heisen, D. Boukhelef, S.G. Esenov, S. Hauf, I. Kozlova, L.G. Maia, A. Parenti, J. Szuba, K. Weger, K. Wrona, C. Youngman
14th International Conference on Accelerator & Large Experimental Physics Control Systems, San Francisco, California, 6–11 October 2013
ICALEPCS2013, FRCOAAB02 (2013)
ISBN: 978-3-95450-139-7

Results from single shot grazing incidence hard x-ray damage measurements conducted at the SACLA FEL
A. Aquila, C. Ozkan, R. Sobierajski, V. Hájková, T. Burian, J. Chalupsky, L. Juha, M. Störmer, H. Ohashi, T. Koyama, K. Tono, Y. Inubushi, M. Yabashi, H. Sinn, Th. Tschentscher, A.P. Mancuso, J. Gaudin
SPIE Optics + Optoelectronics, Damage to VUV, EUV, and X-ray Optics IV; and EUV and X-ray Optics: Synergy between Laboratory and Space III, Prague, Czech Republic, 15 April 2013
Proc. SPIE 8777, 87770H (2013)
doi:10.1117/12.2017725

Sample refreshment schemes for high repetition rate FEL experiments
J. Schulz, S. Bari, J. Buck, Ch. Uetrecht
SPIE Optics + Optoelectronics, Advances in X-ray Free-Electron Lasers II: Instrumentation, Prague, Czech Republic, 18 April 2013
Proc. SPIE 8778, 87780T (2013)
doi:10.1117/12.2019754

Software Development for High Speed Data Recording and Processing
D. Boukhelef, J. Szuba, K. Wrona, C. Youngman
14th International Conference on Accelerator & Large Experimental Physics Control Systems, San Francisco, California, 6–11 October 2013
ICALEPCS2013, TUPPC045 (2013)
ISBN: 978-3-95450-139-7

Spontaneous radiation calculations for the European XFEL
I. Agapov, G.A. Geloni, O.V. Chubar, M. Scheer, M. Titze, N. Smolyakov, S. Tomin
4th International Particle Accelerator Conference, Shanghai, China, 12–17 May 2013
Proceedings of IPAC2013, TUPEA007 (2013)
ISBN: 978-3-95450-122-9

Status of detector development for the European XFEL
J. Sztuk-Dambietz, S. Hauf, A. Koch, M. Kuster, M. Turcato
SPIE Optics + Optoelectronics, Advances in X-ray Free-Electron Lasers II: Instrumentation Prague, Czech Republic, 3 May 2013
Proc. SPIE 8778, 87780U (2013)
doi:10.1117/12.2020773

Theoretical Basis of Photon Spectroscopies
M. Altarelli
Magnetism and Synchrotron Radiation: Towards the Fourth Generation Light Sources: Proceedings of the 6th International School “Synchrotron Radiation and Magnetism”, Mittelwihr, France, 14–19 October 2013
Springer Proceedings in Physics 151 (2013)
doi:10.1007/978-3-319-03032-6_3 ■

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