European XFEL

ANNUAL REPORT

European X-Ray Free-Electron Laser Facility GmbH

2016

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

2016

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European X-Ray
Free-Electron Laser
Facility GmbH

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Left to right Serguei Molodtsov, Robert Feidenhans'l, Andreas S. Schwarz, Claudia Burger, and Thomas Tschentscher

Opposite Blue illuminated photon tunnel

Dear Readers,

It is our pleasure to inform you about the status and progress of the European XFEL in 2016—the last year before scientific experiments start and hence a year that was particularly critical to the success and future of the European XFEL. Although much still needs to be done—finalizing and installing a myriad of large and small components, laying and connecting many cables, installing air conditioning, and so on—we eagerly await the moment the first lasing is achieved, the first sample irradiated, and the first photons collected on one of the brand-new detectors.

The excitement in the user community is huge, as evidenced by the large attendance of more than 1000 registered attendees at the European XFEL and DESY Photon Science Users' Meetings in January 2016. We were also happy to welcome our future users to the two user workshops, held in November and December with the specific purpose of preparing the user community for the first scientific proposals in 2017.

Acting as the "heart" of the European XFEL, the accelerator will provide the electrons required for the undulators to deliver photons to the vacuum tubes and beamlines that serve as the "arteries" of the facility. Without blood, no oxygen and no life; without electrons, no photons and no science. Therefore, the timely manufacturing and installation of the accelerator was essential. It was a relief to all of us that all 100 superconducting modules could be delivered and 96 installed in 2016.

In October, the start of commissioning was celebrated in presence of international guests with a large event held on the new European XFEL campus in Schenefeld that received broad media coverage all over the world. It was a great day that marked the end of the challenges we had faced to complete the many sophisticated components of the accelerator.

After the commissioning of the accelerator started, we suffered a setback when a helium exhaust line fell down during pressure tests. Fortunately, no one was hurt and most of the damage was quickly repaired, so commissioning could resume after a few weeks. Before Christmas, the cooldown of the accelerator was started. The realization and startup of the accelerator are the responsibility of the international Accelerator Consortium led by DESY, which coordinated the work extremely well and exhibited impressive motivation. As in previous years, they did a tremendous job in 2016 and continue to work hard to achieve first lasing. Congratulations to the Accelerator Consortium and the accelerator team!

In 2016, the company left its previous premises at Albert-Einstein-Ring and moved into its headquarters on the Schenefeld Campus. The move went very swiftly and smoothly on the third weekend of June. The almost seamless transition was made possible thanks to the dedicated efforts of the European XFEL groups that prepared and organized the move as well as the active cooperation of all the other staff members who participated.

Installation of the SASE1 and SASE3 undulators was mostly completed at the end of the year, the photon tunnels quickly equipped with optics, vacuum components, and diagnostic devices. Considerable progress has also been achieved in the experiment hall, where hutch construction continued and the installation of the first instruments began. Construction, component assembly, calibration, and testing of all instruments—including the sample environments, optical lasers, and detectors—also successfully continued in 2016. The systems for controlling the facility's components and processing and analysing the huge data flow that is expected from user experiments have made progress as well. Our theoreticians continue to push the boundaries of what is possible in X-ray free-electron laser experiments. But a significant amount of work still has to be done in 2017 before we welcome the first users, probably in September.

We would like to extend our heartfelt thanks to all of the European XFEL and DESY staff in the scientific, technical and administrative groups for their hard and enthusiastic work in 2016. We also thank all in-kind contributors who have delivered essential components to the European XFEL, without which the realization of the facility would not have been possible. And we would like to thank the European XFEL Council for its continued support as well as the different advisory committees for their dedicated and continued work and contributions.

Very special thanks from the European XFEL Management Board and staff goes to Massimo Altarelli, managing director and chairman of the management board until 31 December 2016. Massimo put his heart and soul into completing the European XFEL from the day he started at DESY in 2006. He invested 10 years of his life into the dream of constructing the world's most powerful X-ray free-electron laser. He was the first employee at European XFEL. When he retired, more than 300 highly motivated staff members were working in Schenefeld and more than 250 at DESY in Hamburg-Bahrenfeld to complete his dream.

Massimo's achievements were celebrated in December 2016 with a surprise party that included many speeches from friends and colleagues, young and old, from his entire career. The festivities would not have been complete without music, good food, and wine, and even Italian songs from Massimo's favourite football team. He greatly deserved his farewell party. Without him, the European XFEL would not be what it is today.

Thank you very much, Massimo.

Robert Feidenhans'l

Claudia Burger

Managing Directors

Serguei Molodtsov

Andreas S. Schwarz

Thomas Tschentscher

Scientific Directors

Martin Meedom Nielsen

Dear Readers,

The year 2016 was marked by many important milestones and events. This was also reflected in the work of the European XFEL Council, which represents the shareholders of the European XFEL. The council monitors the status of the project through reports by the European XFEL Council Chairman, Management Board, Administrative and Finance Committee (AFC), Machine Advisory Committee (MAC), and Scientific Advisory Committee (SAC) and sets the strategic direction for the facility by deciding on issues concerning staff, legal matters, in-kind contributions, and project management, as well as financial and organizational matters. The council met three times in 2016 and additionally made two decisions by written procedure.

Some milestones included festive occasions. Notably, European XFEL moved into its new headquarters in Schenefeld and officially inaugurated the building in a ceremony attended by representatives from international political, ministerial, and scientific societies.

In 2016, the installation of the linear accelerator was completed, essentially as foreseen in the updated construction plans. The accelerator modules were assembled in France as part of the activities of the Accelerator Consortium. This consortium illustrates the international dimensions of the European XFEL, with partners from 17 institutions in 8 countries, and is a testament to international collaboration overcoming scientific, technical, and administrative challenges to build the world's leading electron accelerator. This achievement made it possible to celebrate the start of the commissioning of the facility in October. At the ceremony, a high-level delegation with representatives from the international community, federal ministries, and the German states of Schleswig-Holstein and Hamburg collectively tightened the last flange in the vacuum system of the first beamline that will lead the X-rays to the scientific instruments in 2017.

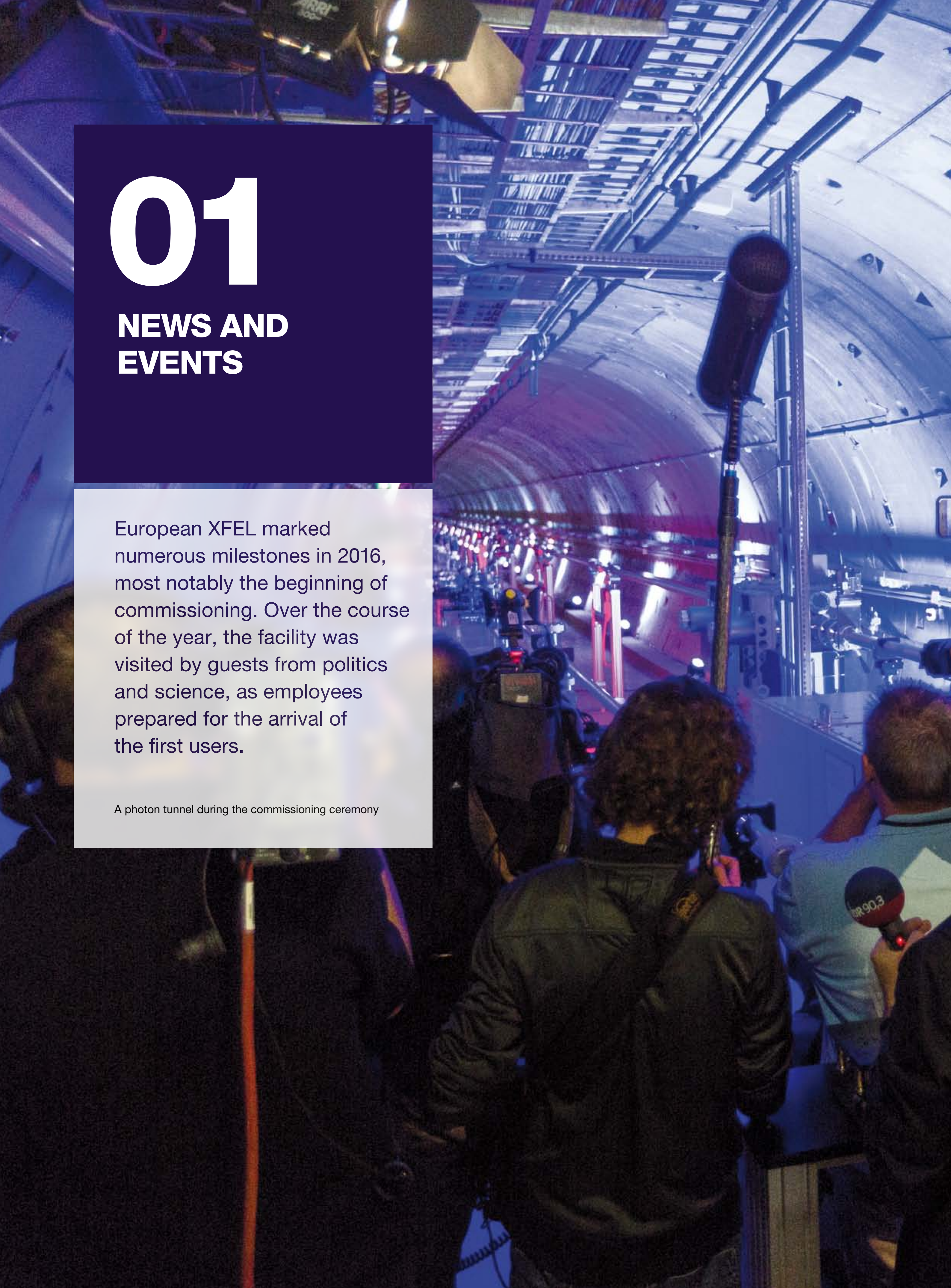
European XFEL is open to new members from the international community. We have already progressed very far in the negotiations with the United Kingdom, and in connection with the council meeting in November, we were honoured to receive a high-level visit from the Vice Premier of the People's Republic of China at European XFEL and DESY.

In 2016, the term of Massimo Altarelli as managing director and chairman of the management board ended. Massimo led the European XFEL from its founding years to its current state as a world-class facility nearing completion. On behalf of the council, I would like to take this opportunity to say a sincere thank you and extend our appreciation to Massimo for his long and dedicated commitment to the European XFEL.

Following the work of an international search and selection committee, the council unanimously appointed Robert Feidenhans'l as the new European XFEL Managing Director and Chairman of the Management Board. He has great experience as an X-ray scientist and as a scientific leader. He has been involved in the European XFEL project since the early days, and the representatives of the member countries were convinced that Robert is an excellent match for the position. We are sure he is the right person to steer the European XFEL in its transition from construction to operation as a world-leading facility for X-ray science that will enable breakthroughs in many different fields of research.

Martin Meedom Nielsen

Chairman of the European XFEL Council



01 NEWS AND EVENTS

European XFEL marked numerous milestones in 2016, most notably the beginning of commissioning. Over the course of the year, the facility was visited by guests from politics and science, as employees prepared for the arrival of the first users.

A photon tunnel during the commissioning ceremony

January 2016

29 January

Users' Meeting: Scientists look towards operation

In late January over 1000 scientists from around the world come to Hamburg for the European XFEL and DESY Photon Science Users' Meeting.

European XFEL Managing Director Prof. Massimo Altarelli gives an overview of the facility while DESY accelerator scientist Winfried Decking discusses the first electrons accelerated in the facility's injector and the strong push to complete the linear accelerator. The groups responsible for developing and constructing the six scientific instruments present the instruments' current status and potential day-one experimental capabilities. The European XFEL User Office showcases services to users provided at European XFEL, in particular the plans for the first call for proposals.

Once more, a special focus is placed on young scientists, with European XFEL providing bursaries for 34 graduate students or young researchers with recently awarded doctorates from 11 countries.

February/March 2016

24 February

Council Chairman and Vice Chairman confirmed in office

The European XFEL Council confirms its current chairman and vice chairman in office. Both Chairman Prof. Martin Meedom Nielsen and Vice Chairman Prof. Lars Börjesson will serve additional two-year terms as of 1 July 2016. They were appointed to their positions in 2014.

1 March

All segments of first light-generating system installed

The installation of the 35 segments of the first of three undulators is completed. Each of the three undulators is up to 210 m long and will produce X-ray laser light exceeding the intensity of conventional X-ray sources by a billion times.

This first completed undulator will generate X-rays that will be used for structural biology and ultrafast chemistry experiments.

April/May 2016

28 April

Girls' Day 2016: Kids get their hands on science

Fourteen girls and two boys get the chance to try out some of the basic technical work that supports a big science facility, while also meeting scientists and engineers and touring lab sites. Stimulating interest in science is an important objective of European XFEL.

3 May

World's most precise mirror arrives in Hamburg

A 95 cm long mirror that is more precise than any other yet built is delivered. The mirror is superflat and does not deviate from its surface specification by more than one nanometre, or a billionth of a metre. It is the first of several of its kind required for the European XFEL. The long research and development process involved institutes and companies in Japan, France, Italy, and Germany. Mirrors of this series will be used to deflect the X-rays by up to a few tenths of a degree into either of the two scientific instruments at the end of each photon tunnel in the experiment hall.

June 2016

29 June
Inauguration of Schenefeld headquarters

European XFEL reaches a major milestone: the inauguration of the new headquarters in Schenefeld. Guests from politics, administration, and the diplomatic corps; the European XFEL Council; and employees from European XFEL and DESY celebrate the event.

Schleswig-Holstein Economic Affairs and Technology Minister Reinhard Meyer states that European cutting-edge research now has a new home in Northern Germany. He looks forward to welcoming scientists from around the world. Prof. Ludmila Ogorodova, Deputy Minister of Education and Science of the Russian Federation, regards the successful cooperation during the realization of the European XFEL project as proof that, even in the world of today's difficult political realities, science continues to be a viable area for mutually beneficial and constructive international cooperation.

Managing Director Prof. Massimo Altarelli thanks everyone involved in the construction and says the facility comes closer to the start of operation every day.

July 2016

25 July
Electron injector exceeds expectations

DESY successfully concludes seven months of tests of the first section of the particle accelerator for the European XFEL—a huge success for the accelerator team and its international partners. The 40 m long electron injector performs distinctly better than expected. Ten times every second, it produces a train of up to 2700 short bunches of electrons of outstanding quality. After the tests, the injector goes offline to be connected to the main accelerator. Apart from DESY and European XFEL, institutes, research centres, and universities in France, Italy, Poland, Russia, Spain, Sweden, and Switzerland are involved in the injector.

July/August 2016

28 July
Polish contribution successfully completed

At the successful conclusion of the Polish contribution to the construction of the European XFEL, a delegation including Prof. Maciej Chorowski, Director of the Polish National Centre for Research and Development (NCBiR), visits DESY and European XFEL. The Polish in-kind contribution is one of the most important in the construction of the superconducting linear accelerator. Over the past years, in addition to assembly of components, around 50 Polish scientists have performed intensive tests of individual components and complete accelerator modules prior to their installation in the European XFEL tunnel.

3 August
Schleswig-Holstein Minister President Albig visits European XFEL

Minister President Torsten Albig, the head of the government of the German state of Schleswig-Holstein, visits the European XFEL research campus in Schenefeld. Albig says he is sure that the experiments at the European XFEL will positively affect our lives and the lives of our children.

September 2016

23 September
Campus roads named after outstanding scientists

European XFEL names three roads on its newly inaugurated research campus after major scientists whose contributions charted new paths in knowledge of the natural world: Rosalind Franklin, Bjørn Wiik, and Evgraf Fedorov.

26 September
Superconducting part of the accelerator ready

The next important milestone in the construction of the European XFEL is reached: The 1.7 km long superconducting linear accelerator is installed in the tunnel. It will accelerate bunches of free electrons flying at near-light speed to the extremely high energy of 17.5 GeV.

Responsible for the construction of the accelerator is an international consortium of 17 research institutes under the leadership of DESY.

October 2016

2 October
Robert Feidenhans'l appointed Chairman of the Management Board

Prof. Robert Feidenhans'l is appointed as the new Chairman of the Management Board of the European XFEL GmbH. The X-ray physicist, aged 58, is head of the Niels Bohr Institute at the University of Copenhagen, Denmark. Feidenhans'l will join European XFEL as of 1 January 2017. His predecessor, Prof. Massimo Altarelli, who has been at the head of the non-profit company since it was founded in 2009, will retire at the age of 68 in December. Altarelli states that he is delighted to see the European XFEL in excellent hands and is sure that Feidenhans'l will lead the facility to outstanding success in its operation phase.

6 October
Start of commissioning

European XFEL begins the commissioning of the 3.4 km long underground X-ray laser. Around 350 guests from politics, administration, and the diplomatic corps as well as scientists from around the world and employees of European XFEL and DESY celebrate this big milestone on the new research facility's campus in Schenefeld. In the underground tunnel near the experiment hall, representatives of the partner countries mount an approximately 2 m long beamline tube, one of the final still-missing pieces of the starting configuration of the X-ray laser. The commissioning will take place in the next few months.

The Polish Vice Minister for Science and Education, Dr. Piotr Dardziński, states that this is an important day for the advancement of science and that the commissioning of the European XFEL is great news for many researchers in Europe and beyond.

October/November 2016

25 October
European XFEL brings Düpenau back to nature

After restoration funded and coordinated by European XFEL, the stream Düpenau in the vicinity of the X-ray laser's site has renewed natural banks and associated wetlands. The renaturation activities are part of the compensation measures for the construction of the facility. European XFEL has also planted trees and shrubs, making the site an attractive place for local nature to thrive.

10 November
European XFEL to build guest house and canteen in 2017

European XFEL announces that, in 2017, it will build a canteen and guest house on its new campus in Schenefeld. The single-level canteen building, with about 150 dining spaces, will be located near the entrance of the campus. The 50–60 room guest house will be built on the southern part of the campus.

November 2016

24 November
Chinese Vice Premier visits European XFEL and DESY

As part of her visit to Germany, the Chinese Vice Premier Liu Yandong comes to DESY and European XFEL, accompanied by high-ranking government officials of the People's Republic of China. The Vice Premier visits the Accelerator Module Test Facility (AMTF) and the European XFEL accelerator tunnel. She also meets with Chinese scientists and guest researchers working at DESY and European XFEL.

Saying that she is deeply impressed by the research with cutting-edge technology at DESY and European XFEL, Liu stresses that she is highly interested in fostering and extending the scientific partnership, exchanging ideas, and training young scientists.

Prof. Massimo Altarelli emphasizes the successful cooperation with China, such as in the field of development and manufacturing of the undulators, in the construction of the accelerator, or in pursuing scientific questions.

December 2016

19 December
Optical laser for experiments with atomic-scale measurements

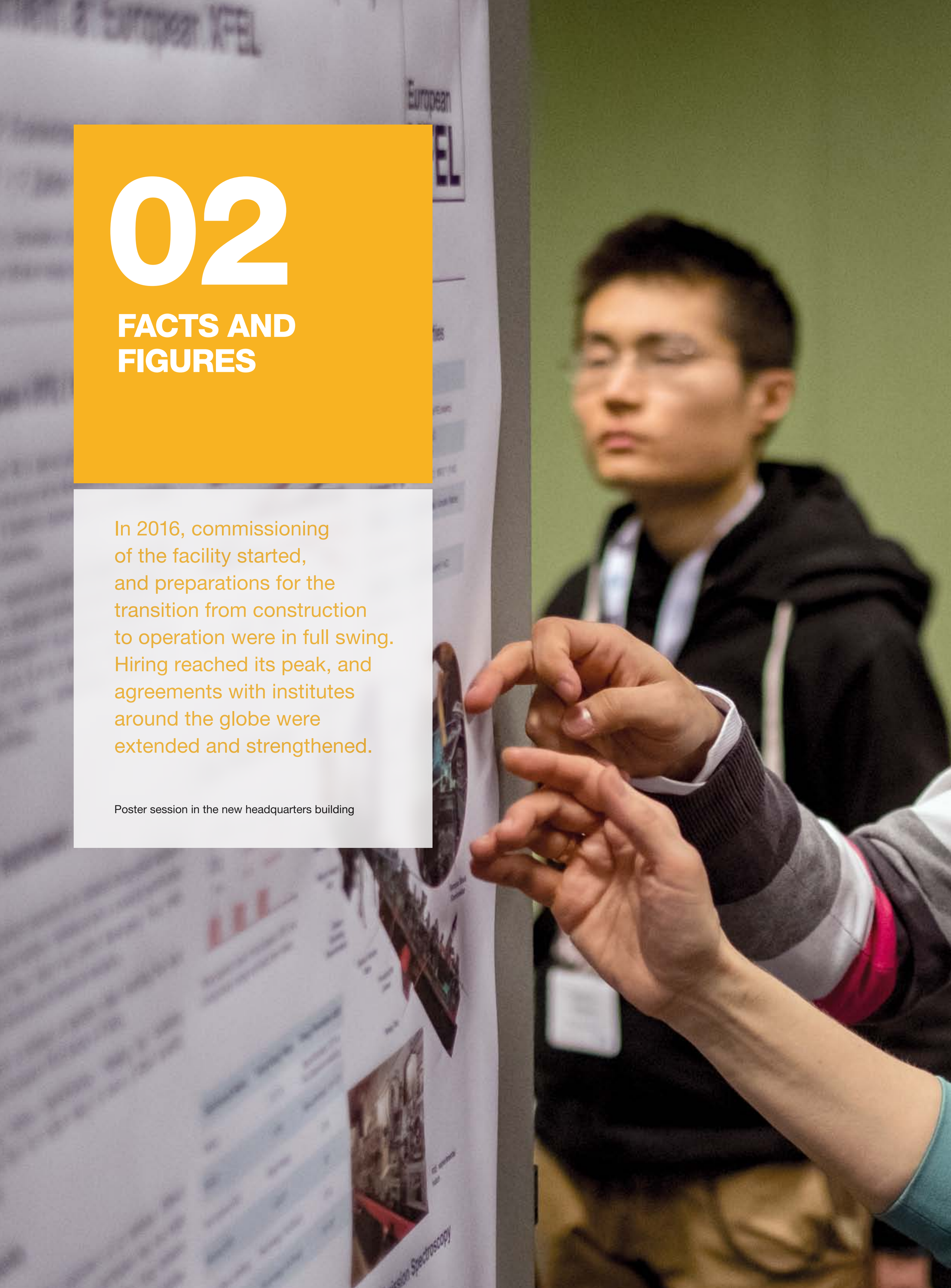
A research team at European XFEL completes development of a high-power pulsed optical laser that is synchronized with the European XFEL pulses and tuneable in both wavelength and pulse duration to the needs of each of the six different experiments. According to the Optical Lasers group leader Dr. Max J. Lederer, the laser is unique because it matches the burst emission pattern of the European XFEL and enables experiments at the highest possible pulse rate of the X-ray laser.

20 December
Scientists prepare for the big debut of the first two instruments

To prepare for their first experiments, a total of 100 scientists from around the world attend the SPB/SFX and FXE early user workshops. The workshops provide a first opportunity for scientists to understand what would be possible for the initial experiments, for which they work on the first proposals.

02
FACTS AND FIGURES

In 2016, commissioning of the facility started, and preparations for the transition from construction to operation were in full swing. Hiring reached its peak, and agreements with institutes around the globe were extended and strengthened.



Poster session in the new headquarters building

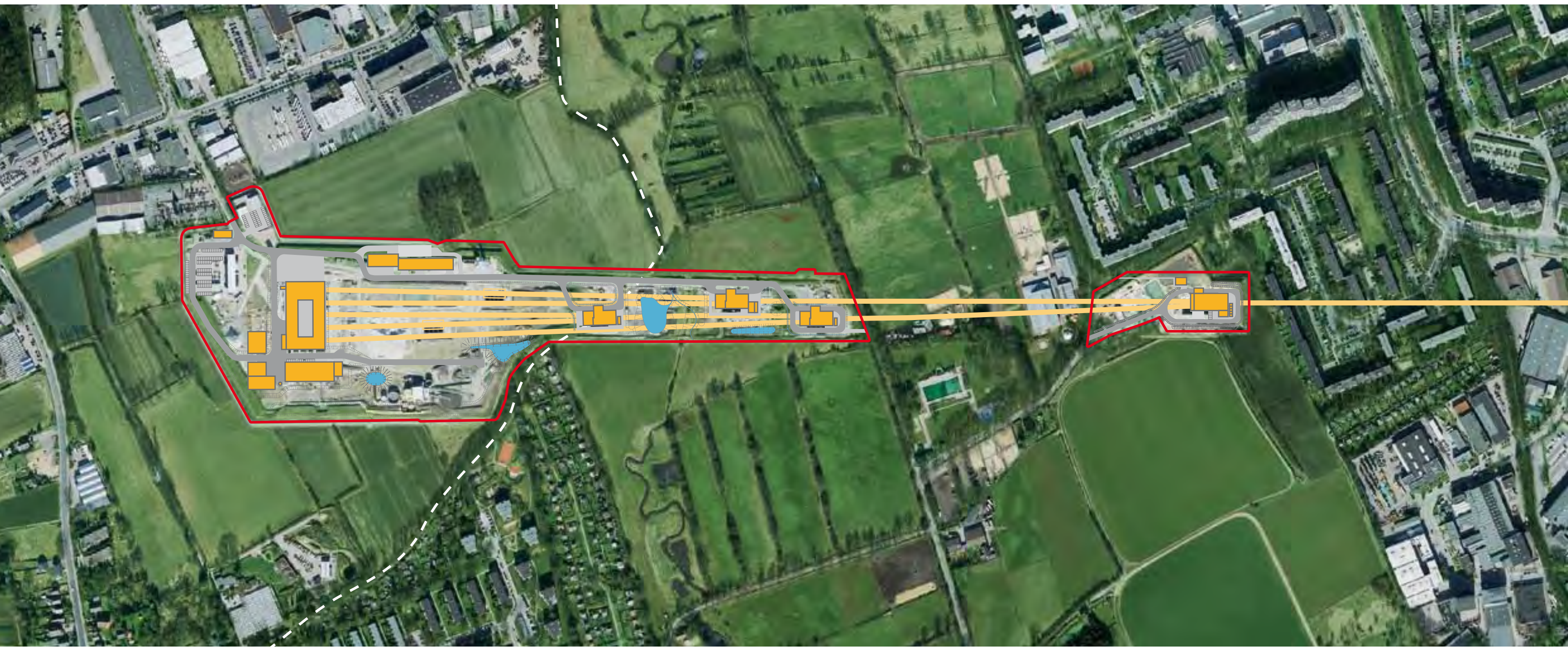


Figure 1 Aerial view of the European XFEL facility. **Left to right** Schenefeld, Osdorfer Born, and DESY-Bahrenfeld sites.

AT A GLANCE

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

Brilliant X-ray flashes for new research opportunities

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

The European XFEL is 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 runs from the DESY research centre in Hamburg to the town of Schenefeld in the German federal state of Schleswig-Holstein (Figure 1). The new facility comprises three sites: the DESY-Bahrenfeld site with the injector complex, the Osdorfer Born site with one distribution shaft, and the Schenefeld campus site, which hosts the underground experiment hall with a large laboratory and office building on top. The latter serves as the company headquarters.

European XFEL GmbH

As of December 2016, 11 countries are participating in the European XFEL project: Denmark, France, Germany, Hungary, Italy, Poland, Russia, Slovakia, Spain, Sweden, and Switzerland. In December 2014, the United Kingdom stated its intention to join the European XFEL as the twelfth member state. The international partners have entrusted the construction and operation of the facility to the non-profit European X-Ray Free-Electron Laser Facility GmbH, which was established in October 2009 as a limited liability company under German law. The facility is a joint effort of many partners. The company cooperates closely with its largest shareholder, DESY, a research centre of the Helmholtz Association, and with other organizations worldwide. When user operation starts in 2017, European XFEL will employ more than 300 people.

Construction costs

Construction of the European XFEL facility started in early 2009. Commissioning started in 2016. User operation with three beamlines and six instruments will start in the second half of 2017.

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

STAFF

In 2016, the European XFEL workforce of employees, students, and guests grew from 278 to 337 (+21%).

The number of employees increased as follows:

- Scientists: 156 (+33)
- Engineers: 88 (+5)
- Technical staff: 43 (+12)
- Administrative staff: 50 (+9)

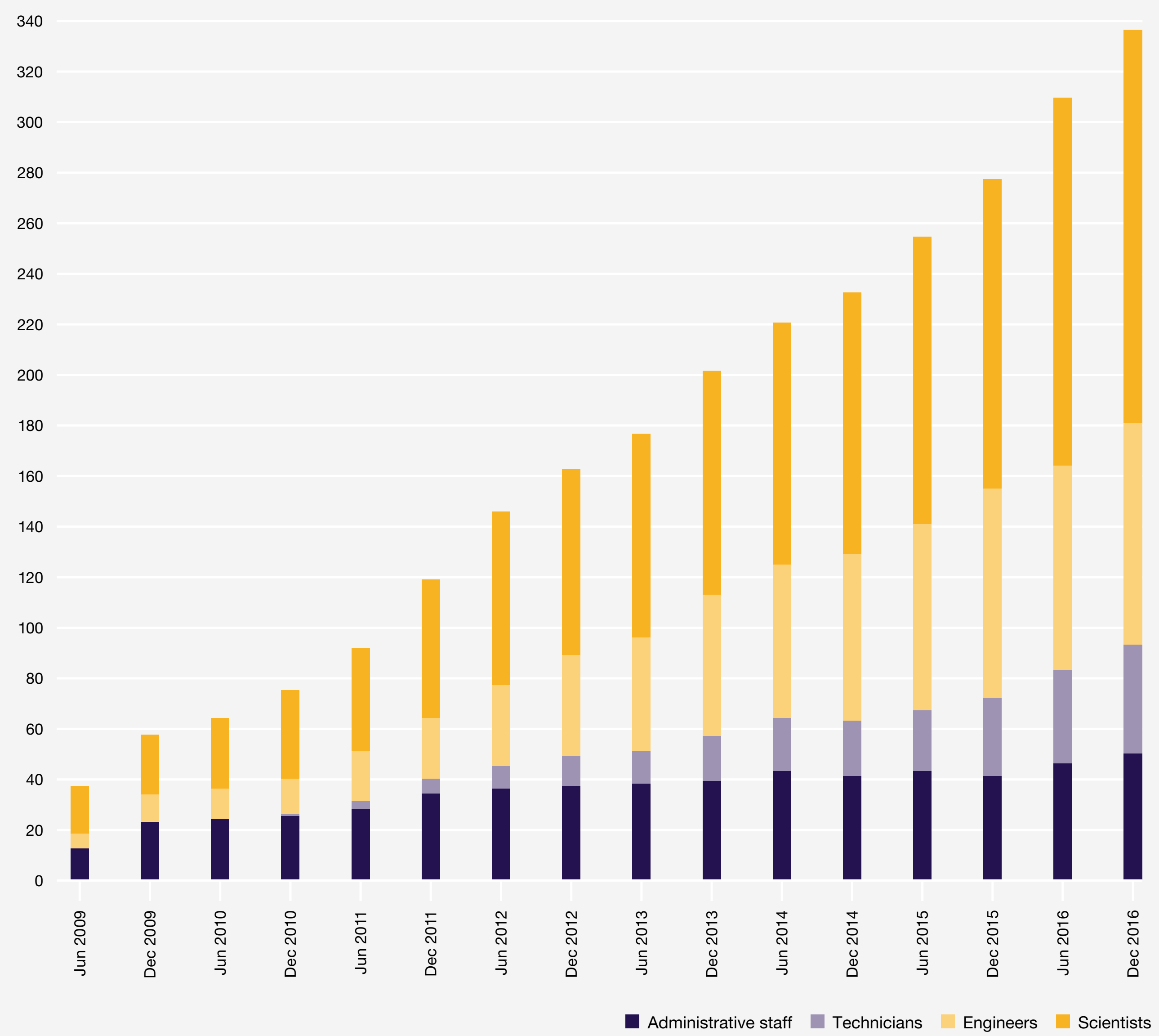
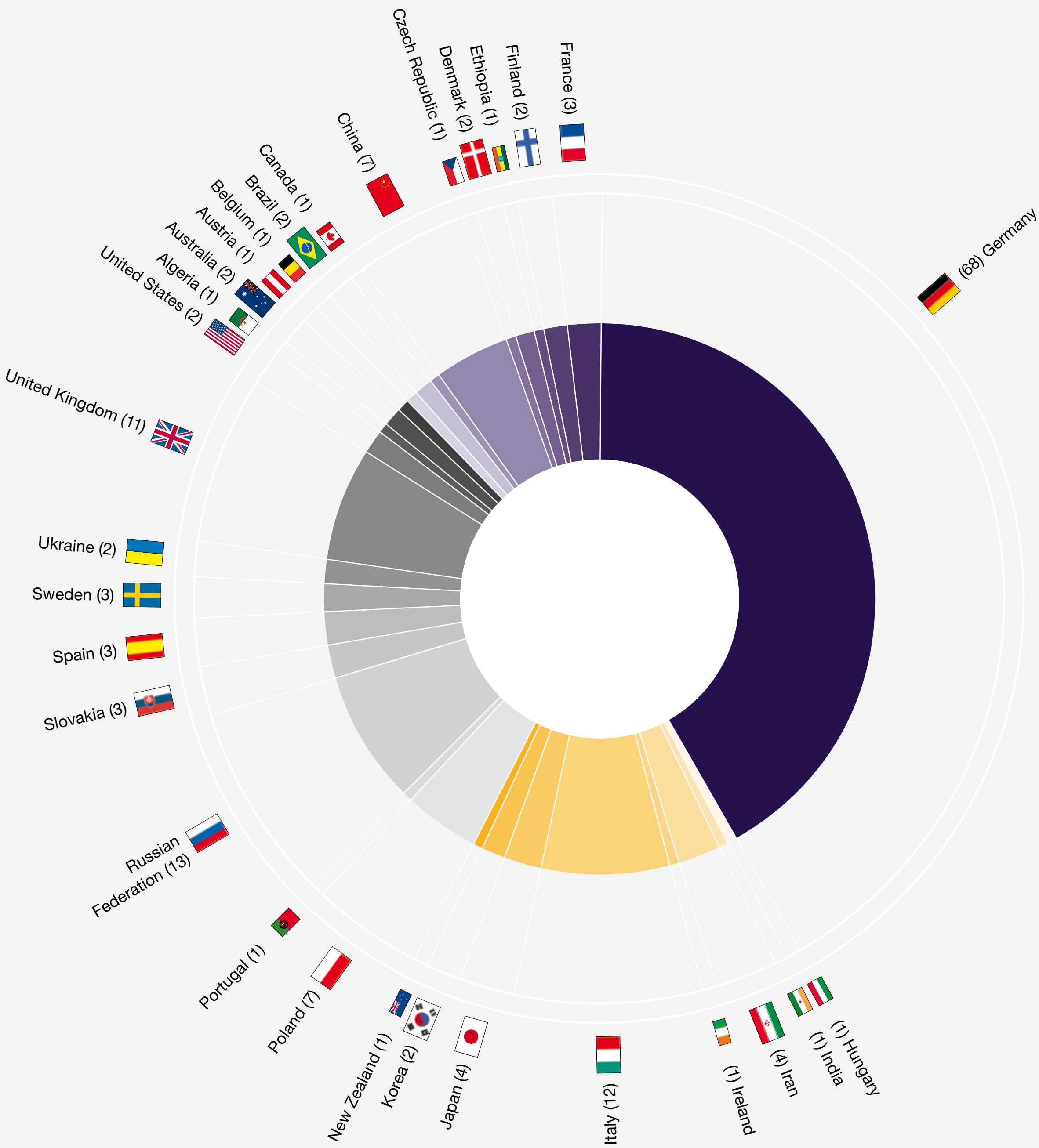
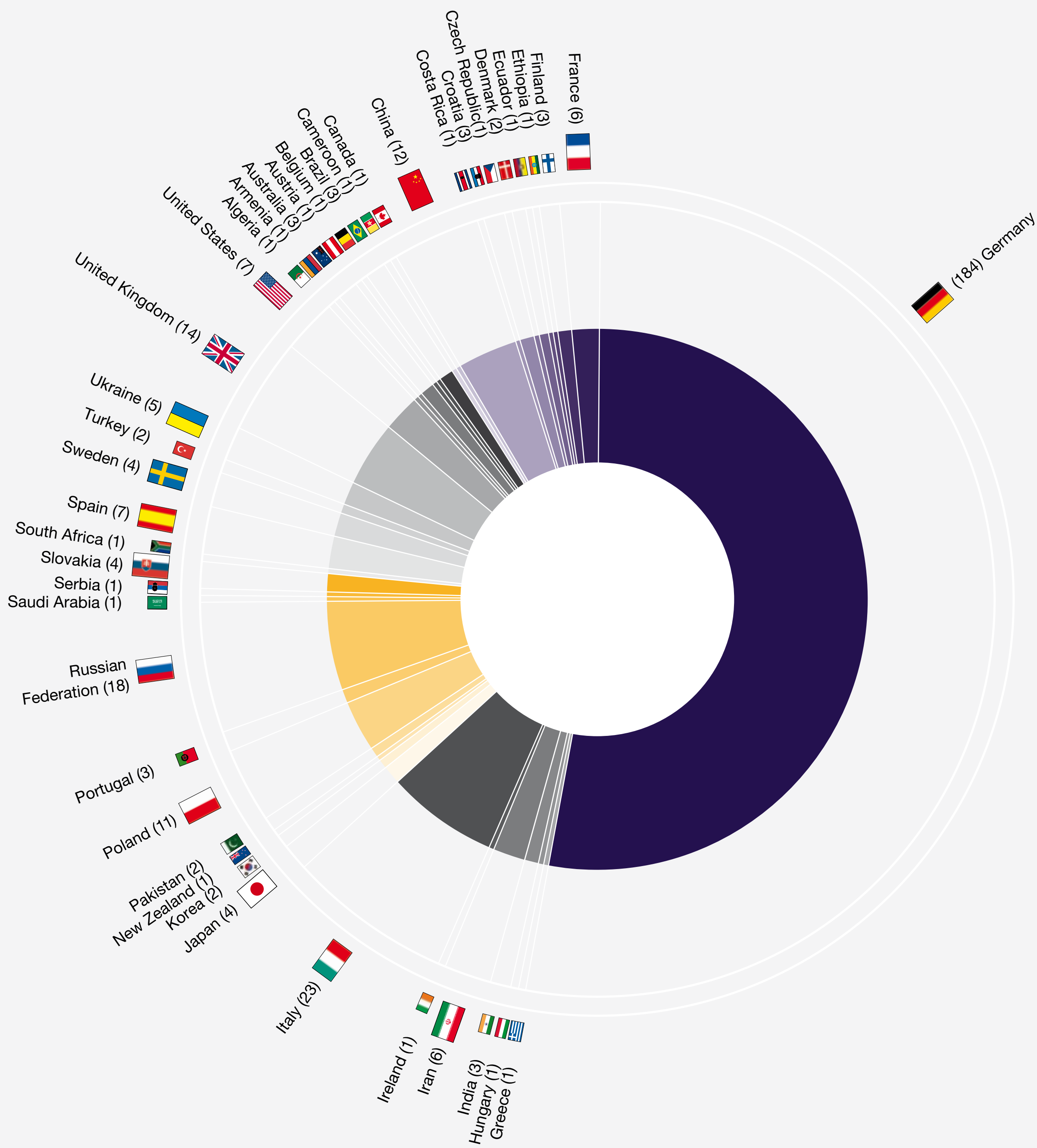


Figure 1 Overall growth in the number of employees, students, and guests (2009–2016)



Germany: 42%
Other countries: 58%
30 nationalities

Figure 2 Nationalities of scientific staff



Germany: 53%
Other countries: 47%
41 nationalities

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

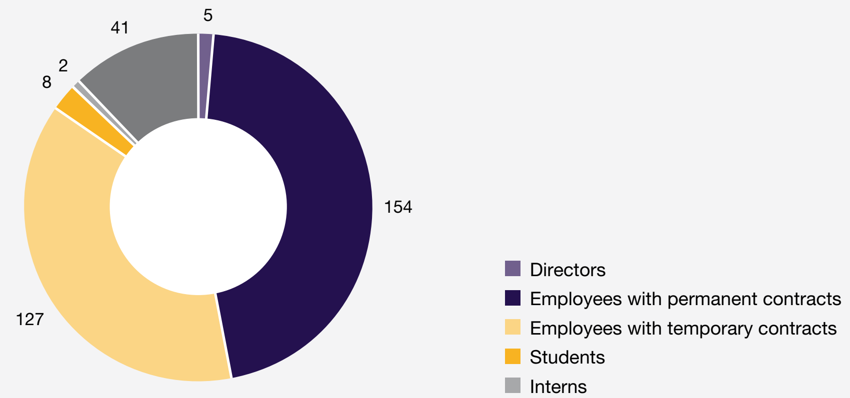


Figure 4 Contractual status of staff (2016)

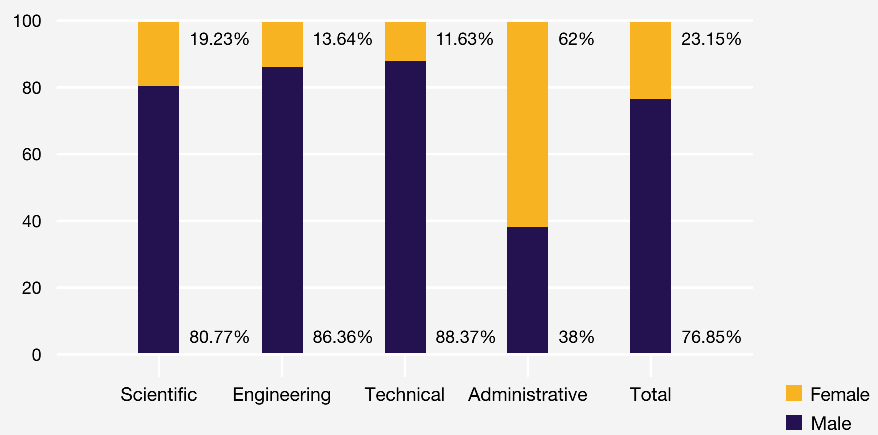


Figure 5 Gender of staff by work area (2016)

The share of international employees increased slightly:

- Total staff: 53% (-2% from 2015) from Germany, 47% from other countries
- Scientific staff: 42% (-3% from 2015) from Germany, 58% from other countries

A total of 41 (+5 from 2015) nationalities are now represented within the company.

At the end of 2016, 23% (+1%) of all employees and 19% (+2%) of scientists employed at European XFEL were female.

The average employee age was slightly below 39 (38.7), nearly unchanged from the previous year.

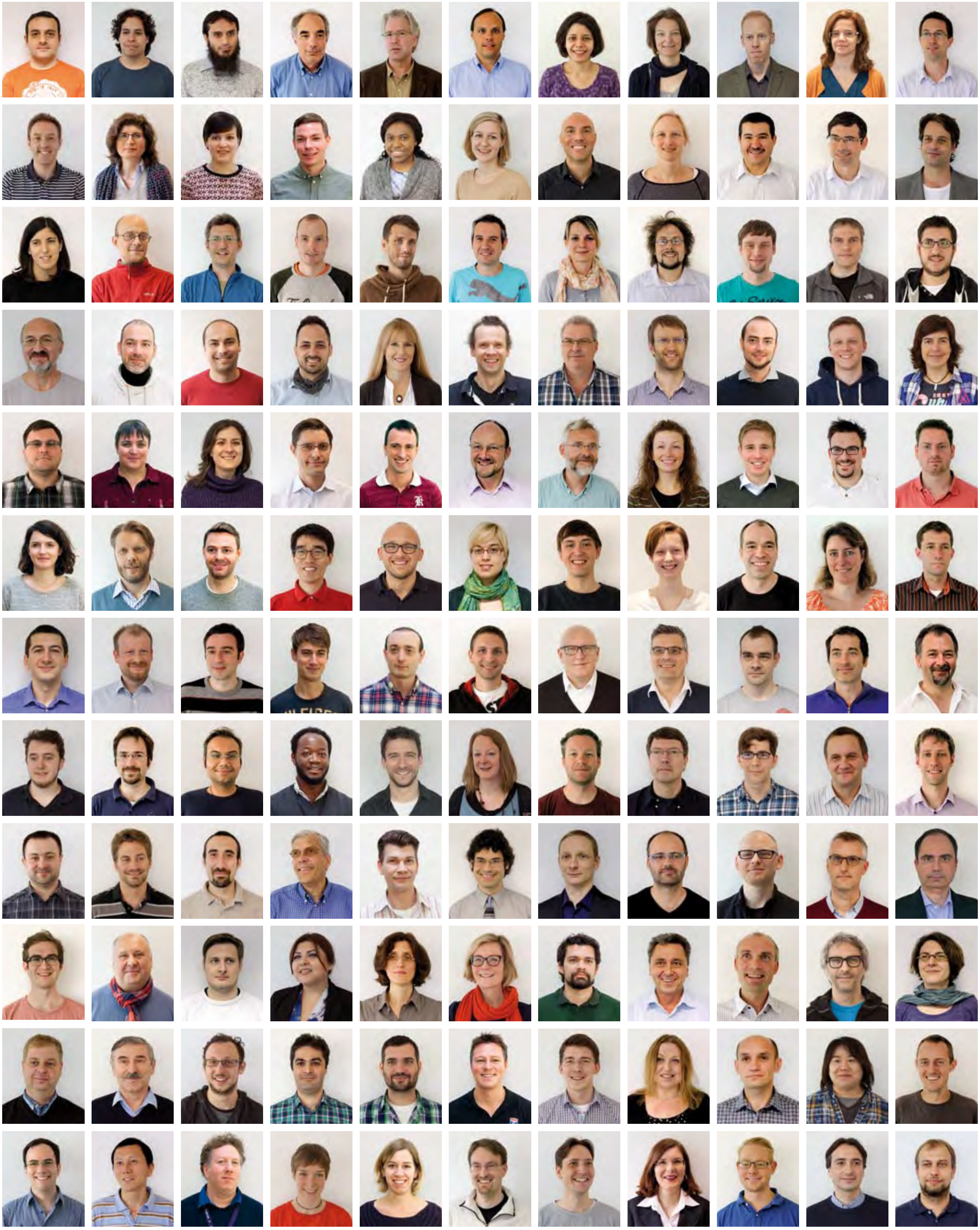
Staff of European XFEL as of 31 December 2016

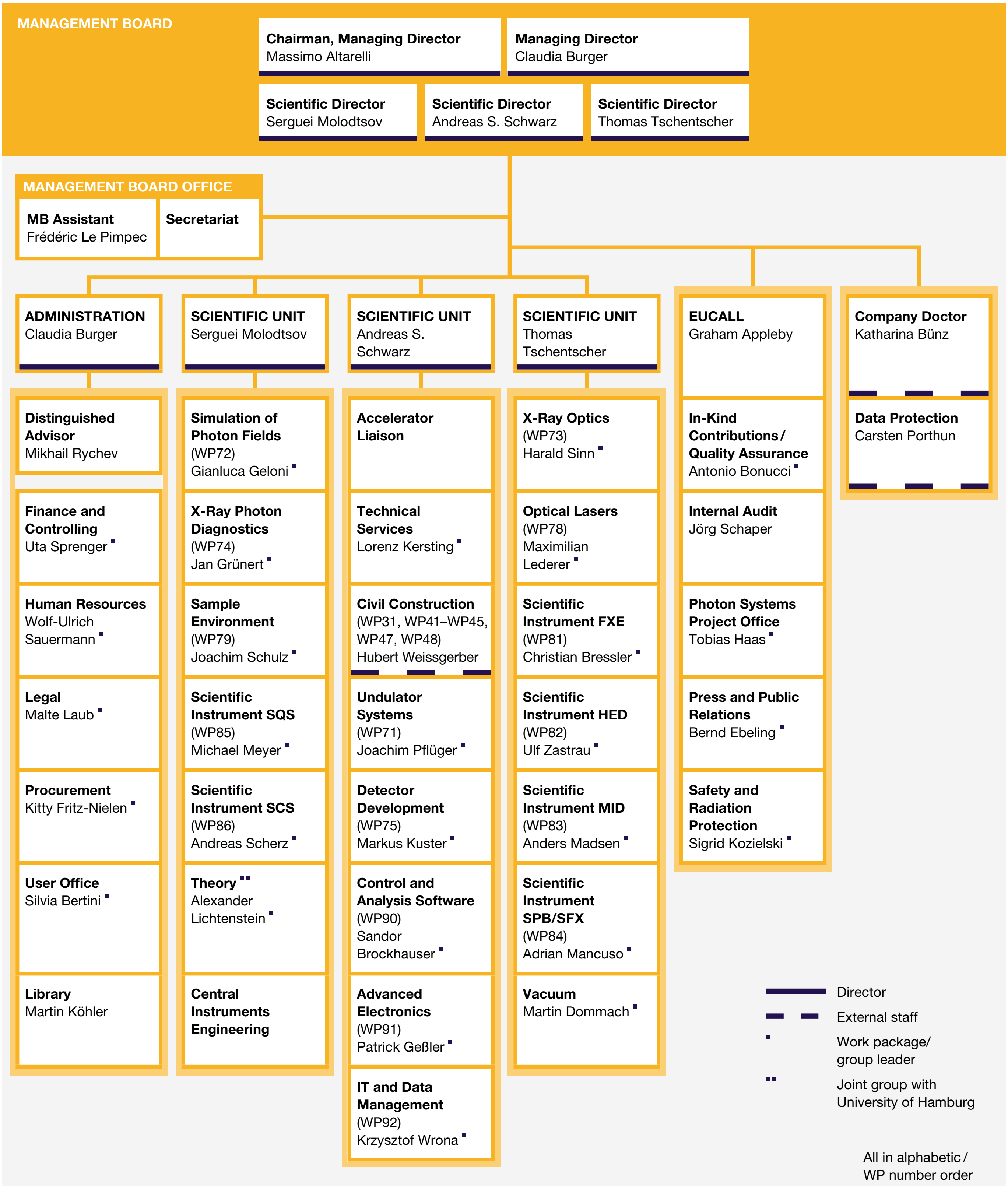
Abeghyan, Suren
Ahmed, Awais
Altarelli, Massimo
Alves Lima, Frederico
Ament, Kurt
Ansaldi, Gabriele
Ansari, Zunaira
Appel, Karen
Appleby, Graham
Aresté, Mónica
Arnold, Mathias
Arslan, Süleyman
Assefa, Tadesse Abebaw
Babies, Frank
Bagha-Shanjani, Majid
Ballak, Kai-Erik
Bamaga, Hazem
Baranašić, Bernard
Bartmann, Alexander
Bartsch, Tobias
Batchelor, Lewis
Baumann, Thomas
Bean, Richard
Bertini, Silvia
Biedermann, Nicole
Boehme, Elizabeth
Bondar, Valerii
Bonucci, Antonio
Bösenberg, Ulrike
Boukhelef, Djelloul
Boyd, Eric
Bressler, Christian
Britz, Alexander
Brockhauser, Sandor
Broers, Carsten
Brüggmann, Ulf
Burger, Claudia
Carley, Robert
Conta, Uschi
Coppola, Nicola
Cunis, Sabine
Da Costa Pereira, Maria Helena
De Fanis, Alberto
Deiter, Carsten
Delitz, Jan Torben
Delmas, Elisa
Derevianko, Illia
Di Felice, Massimiliano
Dickert, Bianca
Dietrich, Arthur
Dietrich, Florian
Dietze, Thomas
Dommach, Martin
Donato, Mattia
Dong, Xiaohao
Dörner, Katerina
Ebeling, Bernd
Eder, Catherine Ann
Ehsan, Wajid
Eidam, Janni
Eilers, Janna Mina
Ekmedzic, Marko
Elizondo, Jorge
Emmerich, Ralf
Emons, Moritz
Engelmann, Oleg
Englisch, Uwe
Esenov, Sergey
Feldmann, Thomas
Ferreira Maia, Luís Goncalo
Filippakopoulos, Kimon
Finze, Denis
Flammer, Meike
Flucke, Gero
Fobian, Michael
Fortmann-Grote, Carsten
Frank, Alexander
Frankenberger, Paul
Freijo Martín, Idoia
Freund, Wolfgang
Freyermuth, Tobias
Fritz, Mareike
Fritz-Nielen, Kitty
Galler, Andreas
Gawelda, Wojciech
Geloni, Gianluca
Gembalies, Imke
Gerasimova, Natalia
Gertz, René
Geßler, Patrick
Giewekemeyer, Klaus
Göde, Sebastian
Gorelov, Evgeny
Goretzky, Birgit
Göries, Dennis
Graceffa, Rita
Grünert, Jan
Grychtol, Patrik
Guhlmann, Florian
Haas, Tobias
Hagitte, Magdalena
Hagitte, Martin C.
Hallmann, Jörg
Hauf, Steffen
Heeßel, Gabriela
Heisen, Burkhard
Hemati, Shahin
Hickin, David
Holz, Christian
Ilchen, Markus
Ivicic, Kristina
Izquierdo, Manuel
Januschek, Friederike
Jezynski, Tomasz
Kane, Daniel
Karabekyan, Suren
Kaukher, Alexander
Kellert, Martin
Kelsey, Oliver
Kern, Elsa
Kersting, Lorenz
Khakhulin, Dmitry
Kim, Chan
Kirsch, Jan
Kist, Birthe
Kitel, Matthäus
Klačková, Ivana
Knaack, Manfred
Kniehl, Sandra
Knoll, Martin
Koch, Andreas
Köhler, Martin
Kohlstrunk, Nicole
Kondraschew, Alexander
Konôpková, Zuzana
Korsch, Timo
Köster, Janice Elaine
Kozielski, Sigrid Susanne
Kristic, Hrvoje
Kruse, Kai
Kujala, Naresh
Kurta, Ruslan
Kuster, Markus
La Civita, Daniele
Ladiges, Daniel
Laksman, Joakim
Lang, Philipp-Michael
Lange, Torsten
Laub, Malte
Le Guyader, Loïc
Le Pimpec, Frédéric
Lederer, Maximilian Josef
Lemcke, Felix
Li, Yuhui
Liebel, Henrik
Liu, Jia
López Morillo, Luis
Lorenzen, Kristina
Lu, Wei
Madsen, Anders
Malso, Michael
Mancuso, Adrian
Manetti, Maurizio
Manning, Bradley Jacob
Martens, Eike-Christian
Mau, Daniel
Mazza, Tommaso
McBride, Emma Elizabeth
Meger-Farshad, Danuta
Mekinda, Léonce
Mercadier, Laurent

Mergen, Julia
Meyer, Michael
Meyn, Frederik
Mills, Grant
Molodtsov, Serguei
Montesino Pouzols, Federico
Moore, James
Mulá Mathews, Gabriella
Münnich, Astrid
Nakatsutsumi, Motoaki
Neumann, Maik
Nidhi, Sneha
Osterland, Christiane
Ovcharenko, Yevheniy
Pahl, Deike
Pallas, Florent
Palmer, Guido
Parenti, Andrea
Parlicki, Patryk
Pergament, Mikhail
Pflüger, Joachim
Piergrossi, Joseph
Piórecki, Konrad
Planas Carbonell, Marc
Poljancewicz, Bartosz
Poppe, Frank
Porro, Matteo
Preißkorn, Florian
Previtali, Gianpietro
Priebe, Gerd
Prollius, Michael
Raab, Natascha
Reifschläger, Jörn
Reimers, Nadja
Reiser, Mario
Rio, Benoit
Risch, Johannes
Rodrigues Fernandes, Bruno Jesus
Ropers, Dennis
Roth, Thomas
Round, Adam
Rüscher, Jan Christoph
Rüter, Tonn
Rychev, Mikhail
Saaristo, Niko
Saffari, Pouneh
Samoylova, Liubov
Sander, Marieke
Santos, Hugo
Sauermann, Wolf-Ulrich
Schaper, Jörg
Scherz, Andreas
Scherz, Sabrina
Schlappa, Justine
Schlee, Stephan A.
Schmidt, Andreas
Schmitt, Rüdiger
Schneider, Phil
Schön, Torsten
Schrage, Marco
Schulz, Carola
Schulz, Joachim
Schulz, Sebastian
Schwarz, Andreas S.
Serkez, Svitozar
Shie, Halimah
Sikorski, Marcin
Silenzi, Alessandro
Sinn, Harald
Sleziona, Vivien
Sorin, Alexander
Sotoudi Namin, Hamed
Sprenger, Uta
Stawniczy, Andrew
Sukharnikov, Konstantin
Sztuk-Dambietz, Jolanta
Szuba, Janusz
Tanikawa, Takanori
Tebah, Wolfgang Azipon
Teichmann, Martin
Thiel, Florian
Thorpe, Ian
Thute, Prasad
Tolkiehn, Jan
Tomin, Sergey
Trapp, Antje
Tschentscher, Thomas
Turcato, Monica
van Hees, Brunhilde
Vannoni, Maurizio
Venkatesan, Sandhya
Villanueva Guerrero, José
Violante, Adriano
Wang, Jinxiong
Watts, David
Weger, Kerstin
Wegner, Ulrike
Weidenspointner, Georg
Weinhausen, Britta
Wellenreuther, Gerd
Wiggins, John
Winterhoff, Gundel
Wißmann, Laurens
Wittmaack, Frederike
Wolff Fabris, Frederik
Wrona, Krzysztof
Wu, Peggy
Wünschel, Mark
Xie, Wenji
Yakopov, Mikhail
Yang, Fan
Yaroslavtsev, Alexander
Youngman, Christopher
Zach, Juri
Zalden, Peter
Zastrau, Ulf
Zhang, Haiou
Ziolkowski, Pawel
Zozulya, Alexey

Guests of European XFEL as of 31 December 2016

Achner, Alexander
Baehtz, Carsten
Bahns, Immo
Bielecki, Johan
Bömer, Christina
Brun, Bernd
Chen, Bolun
Diez, Michael
Falk, Torben
Flade, Marco
Fomin, Evgeny
Fridlyanov, Maxim
Hadian Jazi, Marjan
Han, Huijong
Kabachnik, Nikolay
Kadek, Alan
Kallio, Juha
Kjellsson, Ludvig
Kursula, Inari
Li, Peng
Liebetrau, Andreas
Mehrjoo, Masoud
Messerschmidt, Marc
Mikes, Ladislav
Morgenroth, Wolfgang
Norden, Andreas
Pelka, Alexander
Pieper, Wolfgang
Pogan, Ronja
Rafipoor, Amir Jones
Sato, Tokushi
Sayar, Sonay
Schulze, Volkmar
Smirnov, Petr
Sperling, Philipp
Stäps, Christoph
Stern, Stephan
Toncian, Toma
Uetrecht, Charlotte
Vagovič, Patrik
Wei, Tao





Organization of the European X-Ray Free-Electron Laser Facility GmbH (December 2016)

BUDGET

The overall budget for the construction phase of the European XFEL project amounts to around 1.22 billion euro (2005 value). Forty-five percent of the project volume is contributed in kind by the various partners. The remaining fraction, amounting to more than 0.8 billion euro (current value), is contributed in cash to the company by its shareholders and associated partners. At the end of 2016, as the construction of the European XFEL progresses, more than 80% of the total cash budget has been spent.

The council decides on the annual budget available to cover all project expenses during the corresponding year. The total European XFEL payment budget in 2016 amounted to 142.5 million euro (M€).

Major activities

One major activity in 2016 was “Machine and technical infrastructure”, with a budget of 61.5 M€ (43%). Within this activity, 17 M€ was devoted to civil construction, mainly the finalization of the construction of the headquarters building (XHQ) in Schenefeld, and another 22 M€ was used for the technical infrastructure of XHQ and the experiment hall. For the other major activity, “Beamlines and experiments”, the payment budget was 57.2 M€ (40%). Of this, the largest fraction, 44.3 M€, was spent on capital investment. In addition, the commissioning started, with a budget of 16.6 M€.

The overall budget for the construction phase amounts to around 1.22 billion euro. Forty-five percent of the project volume is contributed in kind by the various partners.

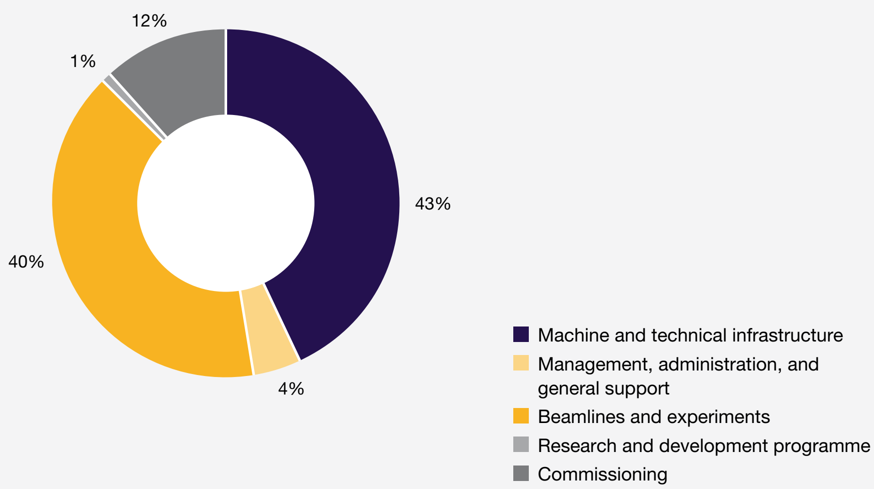


Figure 1 Payments by major activity in 2016

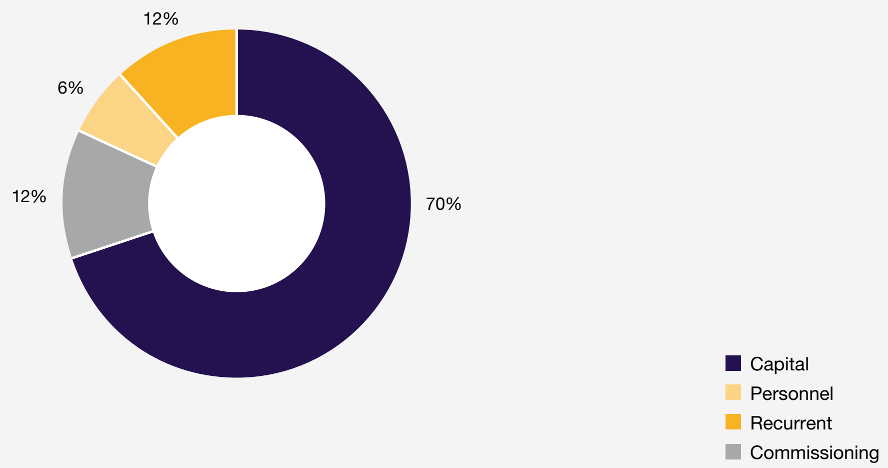


Figure 2 Payments by budget items in 2016

Budget items

The overwhelming portion (70%) of the 2016 payment budget was related to capital investment. This trend will continue during the remaining construction phase of the facility, as the biggest share of the project expenses are related to capital investment, with personnel and recurrent cost being of only subordinate importance.

Outlook for 2017

For the budget year 2017, an annual payment budget of 145.7 M€ was approved. As the operation phase will start in 2017, the budget already includes operation costs.

SHAREHOLDERS

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

Shareholders of the European XFEL GmbH (December 2016)	
Denmark	DASTI (Danish Agency for Science, Technology and Innovation)
France	CEA (Commissariat à l'Énergie Atomique et aux Énergies Alternatives) CNRS (Centre National de la Recherche Scientifique)
Germany	DESY (Deutsches Elektronen-Synchrotron)
Hungary	NRDI Office (National Research, Development and Innovation Office)
Poland	NCBJ (National Centre for Nuclear Research)
Russia	NRC KI (National Research Centre "Kurchatov Institute")
Slovakia	Slovak Republic
Sweden	Swedish Research Council (Vetenskapsrådet)
Switzerland	Swiss Confederation

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

ORGANS AND COMMITTEES

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

European XFEL Council	
Chairman	Martin Meedom Nielsen (DTU, Kongens Lyngby)
Vice Chairman	Lars Börjesson (Chalmers University of Technology, Gothenburg)
Delegates	
Denmark	Robert Feidenhans'l (University of Copenhagen) until 31 December 2016, Anders Kjær (DASTI, Copenhagen) until 31 October 2016, and Morten Scharff (DASTI, Copenhagen) since 1 November 2016
France	Maria Faury (CEA, Paris) and Amina Taleb-Ibrahimi (CNRS, Paris)
Germany	Helmut Dosch (DESY, Hamburg) and Beatrix Vierkorn-Rudolph (BMBF, Bonn)
Hungary	Dénes Lajos Nagy (Wigner Research Centre for Physics, Hungarian Academy of Sciences, Budapest)
Poland	Grzegorz Wrochna (NCBJ, Otwock-Świerk)
Russia	Mikhail Kovalchuk (NRC KI, Moscow), Andrey Svinarenko (JSC RUSNANO, Moscow) until 30 June 2016, and Sergey Salikhov (Ministry of Education and Science, Moscow) since 1 July 2016
Slovakia	Karel Saksl (Institute of Materials Research, SAS, Košice) and Pavol Sovák (P.J. Šafárik University, Košice)
Sweden	Johan Holmberg (Swedish Research Council, Stockholm) and Ingmar Persson (Swedish University of Agricultural Sciences, Uppsala) since 1 May 2016
Switzerland	Bruno Moor (State Secretariat for Education, Research and Innovation, Bern) and Gabriel Aeppli (PSI, Villigen)

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

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

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

European XFEL Management Board	
Chairman	Massimo Altarelli until 31 December 2016; Robert Feidenhans'l as of 1 January 2017
Administrative Director	Claudia Burger
Scientific Director	Serguei Molodtsov
Scientific Director	Andreas S. Schwarz
Scientific Director	Thomas Tschentscher

Advisory committees support European XFEL in various matters: Administrative and Finance Committee, Machine Advisory Committee, Scientific Advisory Committee, In-Kind Review Committee, Detector Advisory Committee, Laser Advisory Committee, and Data Management Committee.

Administrative and Finance Committee (AFC)	
Chairman	Leif Eriksson (Swedish Research Council, Stockholm) until May 2016, Xavier Reymond (State Secretariat for Education, Research and Innovation, Bern) since May 2016
Delegates	
Denmark	Anders Kjær (DASTI, Copenhagen) until November 2016, Morten Scharff (DASTI, Copenhagen) since November 2016, and Troels Rasmussen (DASTI, Copenhagen)
France	Salah Dib (CEA, Paris) and Laurent Pinon (CNRS, Paris)
Germany	Michael Budke (BMBF, Bonn) and Christian Harringa (DESY, Hamburg)
Hungary	Barbara Tóth-Vizkelety (NRDI Office, Budapest)
Poland	Zbigniew Gołębiewski (NCBJ, Otwock-Świerk)
Russia	Aleksandr Lvovskii (JSC RUSNANO, Moscow) until June 2016 and Valeriy Nosik (NRC KI, Moscow)
Slovakia	Pavol Sovák (P.J. Šafárik University, Košice) and Lukáš Zendulka (Ministry of Education, Science, Research and Sport) since April 2016
Sweden	Inger Andersson (Swedish University of Agricultural Sciences, Uppsala) and Katrin Brandt (Swedish Research Council, Stockholm)
Switzerland	Peter Allenspach (PSI, Villigen) and Xavier Reymond (State Secretariat for Education, Research and Innovation, Bern) until May 2016
Secretary	
	Uta Sprenger (European XFEL, Schenefeld, Germany)
Vice Secretary	
	Deike Pahl (European XFEL, Schenefeld, Germany)

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

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

Scientific Advisory Committee (SAC)	
Chairman	Stefan Eisebitt (MBI, Berlin, Germany)
Members	
	Rafael Abela (PSI, Villigen, Switzerland)
	Olga A. Olekseeva (IC RAS, Moscow, Russia) since 27 June 2016
	Patrick Audebert (LULI, École Polytechnique, Palaiseau, France) until 28 October 2016
	Mike Dunne (SLAC, Menlo Park, California, USA)
	Guillaume Fiquet (IMPMC, Paris, France) since 29 October 2016
	Gerhard Grübel (DESY, Hamburg, Germany)
	Maya Kiskinova (Elettra Sincrotrone Trieste, Italy)
	Inari Kursula (University of Oulu, Finland; CSSB, Hamburg, Germany)

Scientific Advisory Committee (SAC)	
	Anders Nilsson (Stockholm University, Sweden)
	Natalia Novikova (IC RAS, Moscow, Russia) until 26 June 2016
	Keith Nugent (La Trobe University, Melbourne, Australia)
	Christoph Quitmann (MAX-lab, Lund, Sweden)
	Ian Robinson (UCL, London, UK)
	Ilme Schlichting (MPI for Medical Research, Heidelberg, Germany)
	David Stuart (University of Oxford and Diamond Synchrotron, Oxfordshire, UK)
	Linda Young (ANL, Argonne, Illinois, USA)
Secretary	
	Gianluca Geloni (European XFEL, Schenefeld, Germany)

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

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

Data Management Committee (DMC)	
Chairman	Amedeo Perazzo (SLAC, Menlo Park, California, USA)
Members	
	Mikael Gast (BMBF, Bonn, Germany)
	Andy Götz (ESRF, Grenoble, France)
	David Quarrie (LBNL (retired), Berkeley, California, USA)
	Nick Rees (Square Kilometre Array, Cheshire, UK)
	David Stuart (University of Oxford and Diamond Light Source, Oxfordshire, UK)
	Vasily Velikhov (NRC KI, Moscow, Russia)
	Grzegorz Wrochna (NCBJ, Otwock-Świerk)

COOPERATION

European XFEL has established an extensive international research network with partners around the world. Cooperation and partnership agreements with research organizations serve to further advance X-ray laser science and help scientists to prepare for the unique research opportunities at the new facility. In 2016, European XFEL signed a cooperation agreement with the University of Siegen in Germany and extended an existing agreement with CLPU in Spain.

Cooperations with research institutions

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Technological Institute for Superhard and Novel Carbon Materials

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

Turkish Accelerator Center

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

"Umbrella" Federated Identity Management System

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

UCL

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

University of Hamburg

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

University of Milan

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

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

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

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

CREMLIN
The project Connecting Russian and European Measures for Large-scale Research Infrastructures (CREMLIN) will improve and strengthen the relations and networks between European and Russian research infrastructures at scientific and at research policy level. CREMLIN will enhance science cooperation between six Russian megascience facilities and European infrastructures, develop research policies involving all relevant stakeholders from science and policy with respect to the EU and the Russian Federation, and establish an effective exchange platform of findings and results within Russian megascience projects while stimulating and ensuring mutual learning across various disciplines and European and Russian communities. CREMLIN began in October 2015 and encompasses 13 European research infrastructures and 6 Russian megascience facilities. CREMLIN has received funding from the EU Horizon 2020 research and innovation programme under grant agreement No. 654166.

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

EUCALL

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

Memberships in research cooperations

Development and Use of Accelerator-Driven Photon Sources

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

EIROforum

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

Hard X-ray FEL collaboration

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

Physics on Accelerators and Reactors of Western Europe

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

USER CONSORTIA

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

- The **Integrated Biology Infrastructure Life-Science Facility at the European XFEL (XBI)** is a proposal for an integrated structural biology infrastructure—including laboratory space, sample characterization technique, and operation staff—in the headquarters building (XHQ). The consortium already provided the infrastructure for the corresponding area in the XHQ laboratory floor that was installed and commissioned. The first phase of dedicated equipment acquisition has started and some of the devices are already installed in the laboratories. Current members are Arizona State University, EMBL, Uppsala University, the University of Oulu, the UHH and University Hospital Eppendorf, and the Slovak Academy of Sciences.

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

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

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

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

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

SHORT HISTORY OF EUROPEAN XFEL

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

1980–1984

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

1992

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

1997

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

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

2000

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

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

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

2001

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

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

2002

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

2003

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

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

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

2004

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

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

2005

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

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

2006

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

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

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

2007

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

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

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

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

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

2008

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

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

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

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

2009

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

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

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

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

2010

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

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

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

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

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

2011

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

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

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

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

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

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

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

2012

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

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

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

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

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

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

2013

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

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

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

2014

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

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

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

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

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

2015

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

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

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

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

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

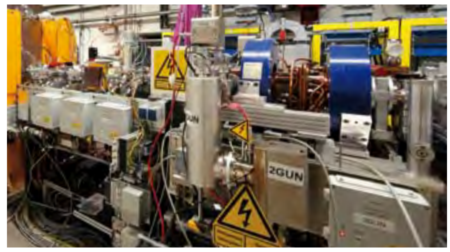


Figure 15 The European XFEL electron injector in December 2015

2016

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

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

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

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

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

Figure 16 Start of commissioning on 6 October 2016

03

FACILITY

In June 2016, European XFEL staff members moved to their workspaces on the new research campus in Schnefeld. In parallel, technical installations continued and further auxiliary buildings were built and planned.

Aerial view of the Schenefeld research campus

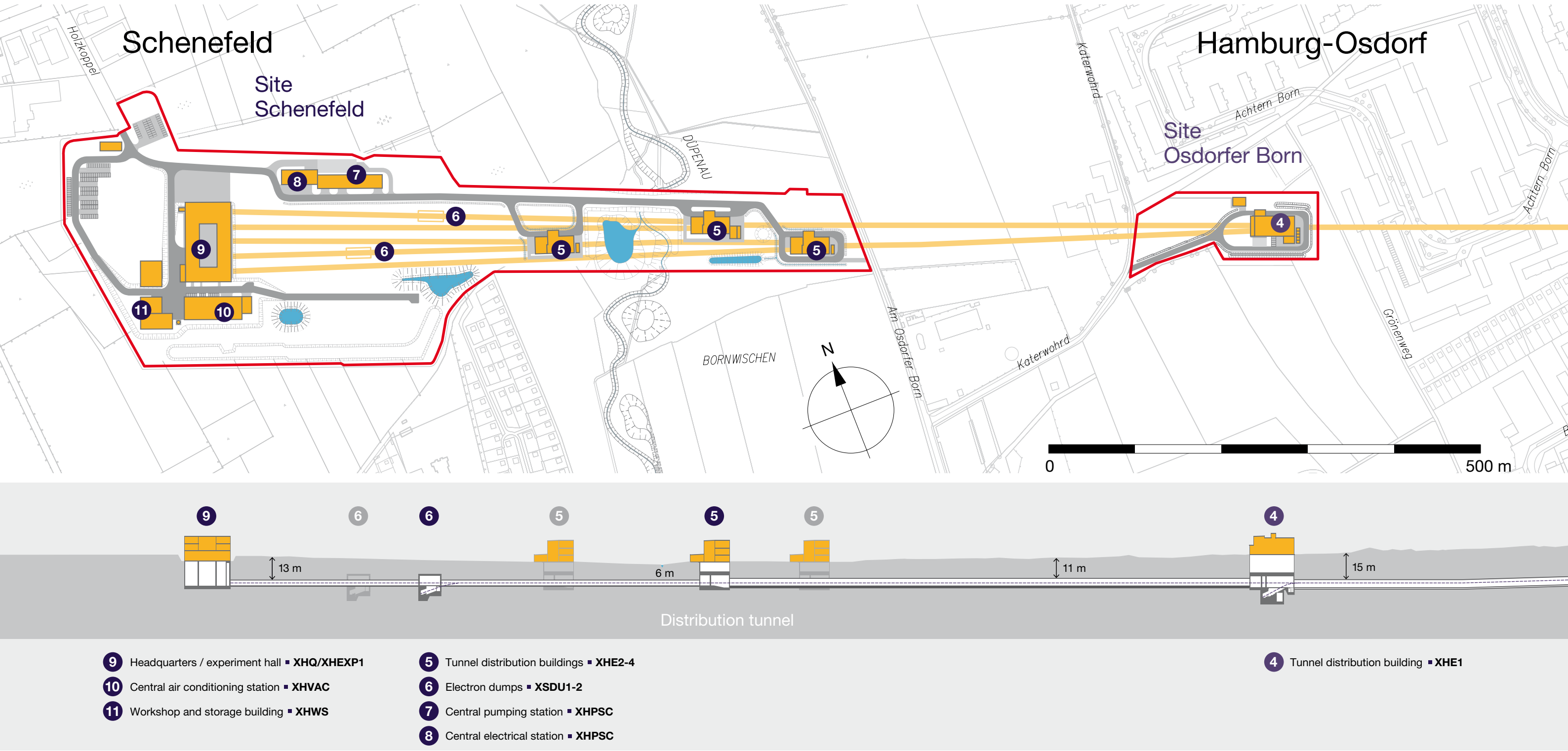


Figure 1 Layout of the European XFEL facility

CIVIL CONSTRUCTION

In 2016, most civil construction work focused on completing the headquarters building on the Schenefeld research campus, which was inaugurated in June. A new entrance building was completed, construction of a workshop and storage building was started, and planning of a canteen and guesthouse was initiated. Landscape works and infrastructure installations continue on the Schenefeld campus.

Overview

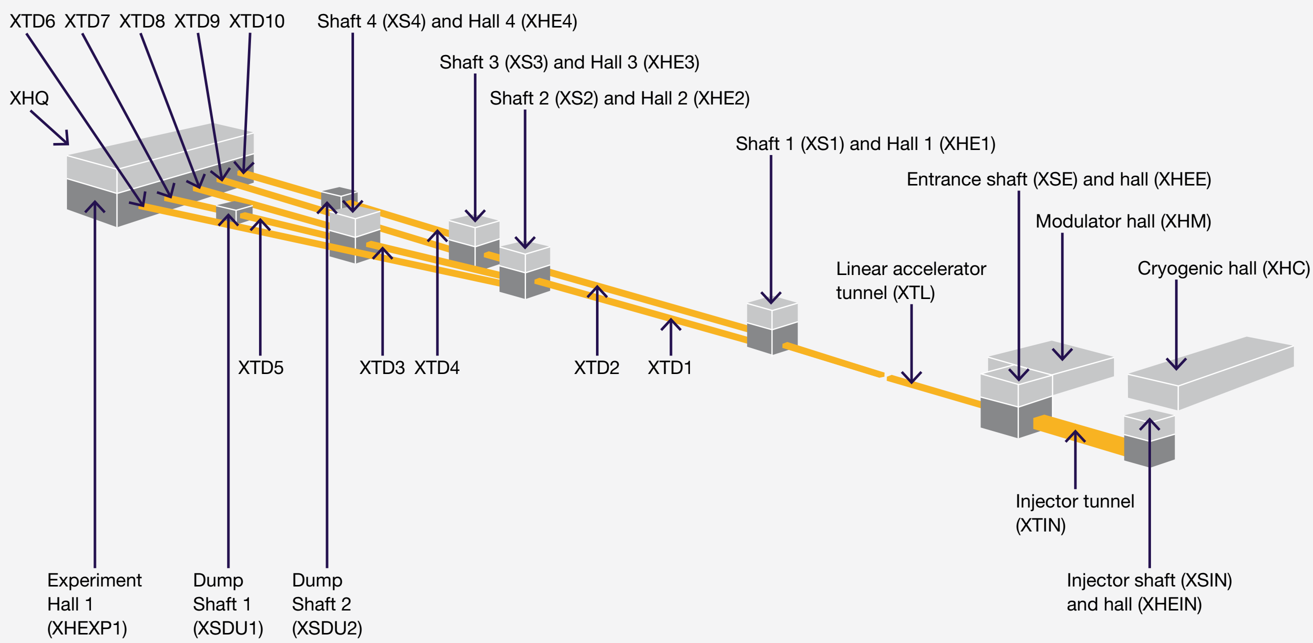
The overall layout of the European XFEL facility is shown in Figure 1. The top view indicates the dimensions and the placement in the surrounding area. The side cross-sectional view shows the ground profile and the various shaft buildings. The facility is approximately 3.4 km long and stretches from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

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

Status—December 2016

On the DESY-Bahrenfeld and Osdorfer Born sites, the civil construction work was completed in 2015, and the surface buildings and shafts were then turned over to the scientists for installation of the hardware needed to operate the facility.

In 2016, most activities concentrated on the Schenefeld campus site. Moving from east to west, the landscaping and infrastructure work was pushed forward and the road connecting the campus to the street Holzkoppel was completed. The civil construction and technical installation work in XHQ proceeded well. The building was finished in spring so the European XFEL staff could move from their premises in Albert-Einstein-Ring to the Schenefeld campus in June. The construction of the entrance building (XHGATE) was finished, and the building is now being used. Planning of the workshop and storage building (XHWS) was finished, and construction started.



Type	Building		
X = XFEL	C = Cryo (cooling)	EE = Entrance hall of entrance shaft	L = Linear accelerator
H = Hall	D = Distribution (switchyard tunnel)	EXP = Experiment	M = Modulator
S = Shaft	DU = Dump (beam absorber)	HQ = Headquarters	
T = Tunnel	E = Entrance	IN = Injector	

Figure 2 Buildings of the European XFEL facility

The buildings for the headquarters, for electrical power, and for air conditioning are finished and functional.

DESY-Bahrenfeld and Osdorfer Born sites

The civil construction work on the DESY-Bahrenfeld and Osdorfer Born sites is finished. The access halls for the injector (XHEIN) and the linear accelerator (XHEE) on the DESY-Bahrenfeld site and the access hall on the Osdorfer Born site (XHE1) are now being used to install the technical infrastructure and components needed for the linear accelerator and the SASE1 and SASE2 undulators. The only remaining work concerns the realization of the environmental compensation measures as prescribed in the plan approval documents (for example, the planting of bushes and trees).

Figure 3 Aerial view of the Schenefeld site (August 2016)

Schenefeld campus

Figure 3 shows an aerial view of the Schenefeld campus in August 2016. The access halls (XHE2–4) can be seen in the back towards the Osdorfer Born site. The large building in the foreground (XHQ) contains the laboratory complex for the facility on the ground floor and the offices on the first and second floor. The power building (XHPSC) is visible to the left of Figure 3 in the centre, and the building providing the air conditioning for the entire facility (XHVAC) can be seen to the right of XHQ. All these buildings are finished and are now functional. XHWS will be erected on the free space next to XHVAC. The small building in the lower left corner of Figure 3 is XHGATE.

The infrastructure work (water pipes, power lines, district heating, and so on) is finished, as is the road connecting the campus to the street Holzkoppel.

Figure 4 Inauguration of the headquarters building (XHQ) on 29 June 2016

A large part of the activities on the Schenefeld campus focused on XHQ. Many trades worked in parallel to complete the building, which was finally available for the European XFEL staff in early summer 2016. The company moved from Albert-Einstein-Ring to XHQ on 17–19 June. The inauguration of the building was celebrated with many external guests on 29 June (Figure 4).

In parallel to this work, the construction of XHGATE was finished, and the gatekeeper crew moved in. Figure 5 shows XHGATE shortly afterwards.

The planning for XHWS was finished, and construction of the building, which is located next to XHVAC, started in autumn. The work is expected to be finished in early summer 2017.

Construction of the entrance building was finished, and the gatekeeper crew moved in. Planning for the workshop and storage building was finished and construction started in autumn. Two very important buildings, the canteen and the guest house, are in the planning stage, and their construction will start in late spring 2017.

Two additional, very important buildings are in the planning stage: the canteen (XHC) for guests and staff and the guest house (XHG) for the many scientists who are expected to come to Schenefeld once the facility is in operation.

Figure 5 Entrance building (XHGATE)

Summary and forecast

In 2016, all essential milestones in civil construction were met. Costs for civil construction overall remained within the budget ceiling foreseen for the year.

In 2017, most of the work will focus on finalizing the construction of XHWS. Construction of XHC and XHG is planned to start in late spring, with completion scheduled for early summer 2018.

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

TECHNICAL SERVICES

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

Installation and commissioning

An ongoing task for the TS group throughout the year was supervising the commissioning of various technical installations in the new European XFEL headquarters building (XHQ), the experiment hall (XHEXP1), and the tunnels. Key aspects of the work were the start of operation of many heating, ventilation, and air conditioning systems as well as the ISO 6 classification of the cleanroom area located on the XHQ laboratory floor. In preparation for the company move, a daily challenge for the group was fixing major reported problems with installation.

Company move to Schenefeld

In the first half of 2016, the TS group focused on planning and preparing for the company move to Schenefeld, for which many preconditions had to be fulfilled, including approval by the authorities. The move took place on the third weekend of June. Over 3000 boxes and assorted items had to be moved to their new locations. The first official work day for the staff in XHQ was 20 June. Shortly after the successful move, the group partnered with a handyman service to handle tasks related to the daily business in a new office building.

Figure 1 Three-dimensional rendering of the canteen building

Building infrastructure installations and planning

The plan for the technical outfitting of the campus canteen (XHC, Figure 1) was improved during the year, and the legal procedure for financing and constructing public-sector infrastructures (*Zuwendungsverfahren Bau*) was initiated in December 2016.

XHC will offer seats for 150 people, and the kitchen will have the capacity to serve up to 450 meals during a given lunch period. Construction will start in 2017, and the canteen should be operational in summer 2018.

The Technical Services group influenced the design of the technical infrastructure of the guest house in order to meet the requirements of a new German energy-saving regulation.

The group also looked after the planning of the guest house (XHG) and especially influenced the design of the technical infrastructure in order to meet the requirements of a new German energy-saving regulation *Energieeinsparverordnung* (EnEV 2016). The building will be able to host up to 59 guests in 56 rooms. Out of six barrier-free rooms, three will be prepared specifically for wheelchair users. Construction is planned to start in summer 2017, and XHG should open its doors to guests in summer 2018.

Figure 2 Three-dimensional rendering of the XHG building

Figure 3 Three-dimensional rendering of the European XFEL plaza

Group members
Süleyman Arslan, Wolfgang Tebah Azipon (not shown), Tobias Bartsch, Bernd Brun (guest from RMN Ingenieure GmbH), Ulf Brüggmann, Uschi Conta, Ralf Emmerich (not shown), Oleg Engelmann, Christian Holz (not shown), Lorenz Kersting (group leader), Jan Oliver Kirsch, Alexander Kondraschew, Hrvoje Kristic, Michael Malso, Torsten Schön, Marco Schrage, Carola Schulz (Facility Management team leader), Christoph Stäps (guest from RMN Ingenieure GmbH, not shown), and Frederike Wittmaack (not shown)

Outlook for 2017

In early 2017, the TS group will support the civil construction for miscellaneous infrastructure projects to complete the European XFEL plaza in front of XHQ (Figure 3). The roofed bike stands and the lounge areas will be the focus of these activities.

The commissioning of and move into the new workshop and storage building (XHWS) in 2017 will require a major effort from a significant part of the group. Another challenge will be the transition from mainly construction duties to the day-to-day business of the operation phase.

Investments in equipment—such as machinery for the new workshop or additional forklifts—will be made in summer 2017. Another two technicians will be hired in early 2017.

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

04
IN-KIND CONTRIBUTIONS

A total of 22 institutes across Europe have contributed to the European XFEL's construction. The 1.7 km long superconducting linear accelerator was completed in 2016 with the help of the vast majority of these contributors.

Connecting modules in the linear accelerator


XM47
European XFEL
DESY
IN COLLABORATION WITH

IKC OVERVIEW

European XFEL shareholders contribute to construction costs in cash or in kind. In-kind contributions (IKCs) can take the form of component delivery, staff secondment, or both. To date, 79 IKCs by 22 institutes from 9 different countries are under way for a total of 585 million euro (M€).

Summary of 2016

Seventy-eight milestones were reached in 2016. Many milestones were part of the closing of the linear accelerator tunnel for cooldown and commissioning. All in-kind contributors supplying components for the cryomodules successfully completed their deliveries. In total, 103 assembled cryomodules were delivered, of which 97 are already installed in the injector and linear accelerator tunnels after characterization in the Accelerator Module Test Facility (AMTF) at DESY.

Overall contributions

In 2016, adjustments were made to the relative amounts of some IKCs. The total value of IKCs under way was approximately 585 M€, including contracts to Russian institutes (Table 1).

Abbreviation	Country	Number of IKCs	IKC value (k€)
DK	Denmark	2	4 087
FR	France	4	36 000
DE	Germany	36	429 447
IT	Italy	3	33 000
PL	Poland	5	19 131
RU	Russia	13	42 043
ES	Spain	4	8 330
SE	Sweden	10	4 948
CH	Switzerland	2	8 835
Total		**79**	**585 823**

Table 1 Projected IKC amounts by country (in 2005 prices) in thousands of euro (k€) as of December 2016

Countries contributing in kind

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

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

Some of the Russian IKCs were successfully completed in previous years (e.g. RU11 for Work Package 12, “Production and delivery of ‘warm’ magnets”, by NIIEFA; RU09 for Work Package 17, “Production and delivery of mechanical components and scintillators for the beam loss monitors”, by IHEP; RU17 for Work Package 12, “125 ‘warm’ magnets of type XQA”, by BINP; and RU25 for Work Package 12, “Production and delivery of 22 coil sets for XQK ‘warm’ magnets”, by BINP).

All in-kind contributors supplying components for the cryomodules successfully completed their deliveries. In total, 103 assembled cryomodules were delivered, of which 97 are already installed in the injector and linear accelerator tunnels.

The delivery of components foreseen in the other Russian contributions was nearly finalized in 2016:

- RU18 for Work Package 8, “Design, production and delivery of ‘cold’ vacuum components”, by BINP provided 106 pump lines and 848 coupler and cavity bellows.
- RU24 for Work Package 13, “Design, production and delivery of cryogenic equipment”, by BINP provided the injector feed and end cap, feed box, valve box, and transfer line.
- RU21 for Work Package 34, “Design, production and delivery of power supplies for corrector magnets”, by BINP provided more than 360 power supply units to be installed in the injector tunnel.

The final acceptance procedure for these deliveries is ongoing, in particular the last quality checks and the finalization of the related documentation.

Contributing institutes

As of December 2016, a total of 22 institutes are contributing in kind to the European XFEL facility (Table 2).

The progress of each of the 79 in-kind contributions is monitored through specific milestones defined in each contribution agreement. Seventy-eight milestones were completed and validated in 2016. In total, 385 milestones have been completed since the start of the project.

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

Table 2 Institutes contributing in kind to the European XFEL facility

IKRC recommendations

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

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

Allocations of IKCs

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

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

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

Milestone validation

The progress of each contribution is monitored through specific milestones, the criteria of achievement being detailed explicitly in the corresponding IKC agreement. Each milestone is connected to a crediting allotment for the shareholder or to the payment of an invoice in case of contracts with Russian institutes. The validation of milestones follows a specific procedure established in 2011.

Seventy-eight milestones were completed and validated in 2016. 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, 385 milestones have been completed since the start of the project. All related documentation is stored in a specific IKC database for future traceability.

Progress of IKCs

In 2016, the series production of IKC components for the accelerator complex was completed, along with assembly of the modules and their successful characterization.

In particular, the following items were installed in the modules:

- Superconducting cavities: 800
- Cryostats: 100
- Warm magnets: 715
- Cold magnets: 100

In total, 103 modules were delivered to DESY for final characterization and installation. Ninety-seven cryomodules were completely characterized at AMTF through the Polish contribution PL05 and installed in the tunnel for commissioning.

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

In 2016, all deliverables related to accelerator installation and preparation for beam commissioning were completed. Only a few of the IKCs that were successfully completed are highlighted below, in particular those where the quality assurance and asset management was documented in detail, allowing all related milestones to be credited.

The following IKCs, among others, were completed:

- **FR02, “Assembly of cavity strings”, and FR03, “Assembly of cryomodules”, for Work Package 3 and 9 by CEA**
  The final objective of FR02 and FR03 was the assembly of all the cryomodules for the injector and the cold (i.e. cryogenically cooled) linear accelerator of the European XFEL facility. In total, 103 accelerator modules were assembled: 3 pre-series modules (XM-3, XM-2, and XM-1) and 100 series modules (XM1 to XM100).

  The CEA IKCs included:

  - Supply of clean fastening hardware, aluminium gaskets, and copper seals (103 units)
  - Supply of magnetic shields for all superconducting cavities (824 units)
  - Supply of 2 K and 70 K superinsulation blankets for all accelerator modules (103 units)

- Assembly of all accelerator cryomodules (103 units), including assembly of RF couplers and cavity string in the ISO 4 cleanroom

The finished modules were shipped to DESY and tested in the AMTF through the Polish IKC PL05, “Test of niobium cavities and cryomodules in AMTF”, by IFJ-PAN. After the successful tests, 96 modules were installed in the accelerator tunnel and 1 module in the injector.

- **IT01, “Manufacturing of 320 niobium cavities, including helium tank”, and DE04, “Superconducting cavities”, for Work Package 4 by INFN and DESY, respectively**
The final objective of WP04 was to supply the accelerator’s superconducting cavities to be tested by Work Package 10 through the IKC PL05. The successfully tested cavities were then delivered to IRFU in Saclay, France, for cavity string and accelerator module assembly.

The production of superconducting accelerator cavities was based on DESY’s extensive experience gained through the TESLA linear collider R&D. More than 50 such cavities are in continuous operation at the FLASH FEL facility at DESY.

The altogether 800 cavities are the largest number ever used in one single accelerator installation. Cavity production and surface treatment techniques were performed according to the state of the art. The specification documents used for procurement needed to be carefully detailed since the final technology transfer from DESY and other laboratories to industry was a mandate of the European XFEL project.

The supply of accelerator cavities included:

- Procurement of all cavity material
- Quality control of all purchased material, such as scanning of niobium sheets
- Build-up of infrastructure in industry
- Complete mechanical fabrication of all cavities and helium tanks through industry
- Rough and final treatment of inner cavity surface, integration into helium tank, assembly of accessories, and shipment for performance check
- Continuous quality control during cavity production

The cavity production was contracted based on the determined specifications. Two vendors were selected in order to reduce the production risk: Ettore Zanon S.p.A. in Schio, Italy, and Research Instruments GmbH in Bergisch Gladbach, Germany. Together with

INFN (through IKC IT01), DESY coordinated and supervised both companies during the whole cavity production.

- **DE12, “Warm magnet system”, for Work Package 12 by DESY**
  The final objective of DE12 was to organize and supervise the production and manage the on-time delivery of the warm (i.e. not cryogenically cooled) magnet system according to the requirements of the Electron Beam Dynamics group (Work Package 16). The manufacturing of the warm magnets was allocated to NIIEFA (IKC RU11) and BINP (IKC RU17). A third contribution to Work Package 12 came from Manne Siegbahn Laboratory (MSL, now Stockholm University) in Sweden. MSL determined the magnetic axis of all quadrupole magnets (XQA) and transferred its position to reference balls fixed to the magnet yokes in a process called fiducialization. Work Package 12 was responsible for collecting all necessary information that was important for the magnet production, communicating this information to the institutes involved, informing the Accelerator Consortium and the European XFEL Management Board about production activities, and performing the final quality inspection of the magnets.

  According to the requirements of Work Package 16, magnet layouts were worked out and discussed with the different stakeholders from 2007 to 2010, after which a conceptual design report (CDR) was published. On the basis of the CDR, manufacturing drawings for the different magnet types were made. After the production readiness review was finished and the magnet types were accepted by the reviewers, the Russian institutes started production. The first magnet of type XQA was delivered to DESY in July 2012.

  After the magnets arrived at DESY, all magnet types except the XQA magnets underwent a functional test. For a subset of the magnets, measurements that were done in the Russian institutes were repeated as a final quality control. The magnets were provided for installation according to the facility installation plan.

- **DE21, “FEL concepts”, for Work Package 21 by DESY**
  The final objective of DE21 was to deliver the theoretical and numerical basis for the FEL layout of the European XFEL. It covered the reference design as well as proposals for future upgrades. As part of the European XFEL preparatory phase, the research group led by Mikhail Yurkov of DESY participated in the conceptual design of the complete facility. The purpose of the work was to provide information to users, envision possible upgrade scenarios, and support the planning for the commissioning and startup of the facility. Extensive simulations were needed as input for a database describing the radiation properties at the various working points of the facility. The underlying parameters and performance goals varied over the time of project execution, and the database had to be adjusted accordingly.

A commissioning strategy for SASE operation was established based on theoretical and numerical investigations, with the goal to define a robust and easy tuneable initial parameter space.

Ideas and visions for new FEL concepts were developed and followed up based on scientific and technological advances and upcoming user demands, for instance:

- Production of Fourier transform–limited X-ray pulses through self-seeding at the European XFEL
- Extension of self-seeding to hard X-rays > 10 keV as a way to increase user access at the European XFEL
- Self-seeding scheme for the soft X-ray line (SASE3) at the European XFEL
- Optimization of a dedicated bio-imaging beamline at the European XFEL
- Proposal to generate 10 TW–level femtosecond X-ray pulses from a baseline undulator in conventional SASE regime at the European XFEL
- Harmonic lasing in X-ray FELs
- Generation of attosecond soft X-ray pulses in a longitudinal space charge amplifier
- Possible operation of the European XFEL with ultralow-emittance beams
- Optical afterburner for an X-ray FEL as a tool for pump–probe experiments

- **ES03, "Power supplies for superconducting magnets", and DE34a, "Prototype development and series production of regulation electronics and of voltage measurement for the quench detection and feed through protection", for Work Package 34 by UPM and DESY, respectively**

DESY has many years of experience in developing, supervising fabrication in external companies, and operating magnet power supplies for both warm and superconducting magnets. In the former HERA accelerator at DESY in Hamburg, around 1000 power supplies were in operation for 17 years. The corresponding regulators and power parts were developed at DESY. In the ensuing years, these types of power supply were continuously improved.

For the PETRA III project, new digital regulation boards were developed and manufactured for the main magnets and the correction (steering) magnets. Developments also included power parts for the corrector magnets. About 600 power supplies are in operation in PETRA III today, showing good performance. These power supplies formed the basis for further developments at UPM.

UPM designed, produced, and delivered 240 power supplies integrated in a specific crate, each of them including:

- Power board with built-in redundancy
- Quench detection system
- Energy dump unit
- Measuring devices
- Appropriate documentation

The controller, including the digital regulation and control software, was provided by DESY. The deliverables consisted of 250 digital regulation boards of PETRA III–type and 260 voltage measurement boards, including the prototyping phase.

- **PL05, "Tests of cavities and cryomodules in the AMTF hall", for Work Package 10 by IFJ-PAN**
  To produce cryomodules according to European XFEL specifications, it was crucial to perform tests of the individual cavities and of the complete cryomodules.

  After manufacturing, the niobium cavities were individually tested before being assembled and integrated into the cryomodules. IFJ-PAN provided and trained the personnel required to perform these tests.

  After their assembly in Saclay, the cryomodules were individually tested at AMTF before being transported and installed in the accelerator tunnel. IFJ-PAN provided and trained the personnel required to perform these tests.

  The tests done on the series of 840 cavities included (among other things):

  - Transport of the cavities (supported by DESY)
  - Cavity storage issues at AMTF
  - Incoming visual and RF inspection of the cavities
  - Installation or dismounting of the cavities in or from vertical insert
  - Leak check of the connection in the vertical insert, mass spectrometry of the cavities (supported by DESY)
  - Installation or dismounting of vacuum, RF, and temperature sensor connections to or from vertical cryostat
  - Cryogenic operations including their automation (supported by cryoplant operator)
  - RF low-power acceptance test (supported by DESY)
  - Outgoing inspection of the cavities

The tests done on the series of 103 cryomodules included, among other things:

- Upgrade of the cavity measurement procedure (LabView), data transfer to database, and service manual (supported by DESY)
- Transport of the modules (supported by DESY)
- Cryomodule storage issues at AMTF
- Incoming inspection of the cryomodules
- Installation or dismounting of the cryomodules in or from the test stand, including cryomodule alignment, waveguide connections, cables for the coupler interlock, coupler tuning, cavity tuner and piezo controls, magnet current leads, process pipes and beamline, isolation of the process pipes with multilayer insulation, and thermal shield and sliding muff installation
- Leak check of the isolation vacuum, beam vacuum, coupler vacuum, and process pipes of the cryomodules on the test stand
- Cryogenic operations, including their automation (supported by cryoplant operator)
- Warm coupler conditioning, fundamental- and higher-order-mode spectrum RF measurements, *Q* load adjustment and measurement, cold coupler conditioning, cavity frequency adjustment, cold cavity performance test, and tuner and piezo test (supported by DESY)
- Cryogenic loss and heat load measurements (supported by DESY)
- Outgoing inspection of the cryomodules

The most important achievement was the shortening of the test duration without losing reliable information on the quality of the tested modules. The modification implemented in June 2015 was worked out in close collaboration with experts from DESY and IFJ-PAN. This modification enabled the completion of the cryomodule tests in August 2016.

- **IT03, “Cavities and cryomodule for the third-harmonic system”, and DE46, “High-power RF system, magnet, diagnostics, and vacuum accessories for the third-harmonic system”, for Work Package 46, by INFN and DESY, respectively**
The third-harmonic RF system of the European XFEL provides the RF linearization capability needed at the injector stage to minimize the bunch tails produced during the bunch compression stages and to recover the nominal peak bunch current. The final objective of Work Package 46 was to collaborate with the European XFEL beam dynamics working groups at DESY on the examination and definition of the beam dynamics requirements of the European XFEL third-harmonic section system and to design, engineer, procure, and install all its components, with tasks divided between INFN and DESY.

Starting in 2002, a four-cavity module operating at 3.9 GHz was designed, fabricated, tested, and assembled at Fermilab in the USA as part of the TESLA Technology Collaboration (TTC) activities of

DESY and Fermilab. The other parts of the 3.9 GHz section in FLASH, such as the high-power RF system and the RF controls, were provided by DESY. The FLASH third-harmonic section served as the prototype for the European XFEL third-harmonic system.

The DESY contribution to the European XFEL third-harmonic system started in summer 2007 with the preparation of a call for tender for fabrication of 3.9 GHz prototype accelerating structures, based on the Fermilab 3.9 GHz cavity design. In fall 2007, INFN took over the supervision of the fabrication and the vertical testing of these prototype cavities in order to provide the basis for the production and verification of the series components of the European XFEL system.

INFN designed and procured the European XFEL third-harmonic module and cavities (including cold vertical testing in the INFN LASA facility in Milano) as part of the Italian IKC IT03. DESY contributed the other parts of the third-harmonic section (e.g. the power couplers, the coupler vacuum line, the high-power RF system, and the RF controls), and the infrastructure not available at INFN (e.g. equipment for the non-destructive testing of niobium sheets, a power RF station for coupler conditioning, a horizontal cavity test stand, the cleanroom infrastructure for the cavity string assembly, the module assembly infrastructure, and the module test stand).

The European XFEL third-harmonic system was installed in the underground injector complex in September 2015 and commissioned and operated above its nominal requirements during the injector run from January to July 2016.

Photos of activities going on in 2016 at the collaborating institutes are shown in Figures 1–8.

Figure 1 Installation of Osdorfer Born beam dump (IKC DE20 by DESY)

Figure 2 Installation of the last accelerator module in L1, the first section of the linear accelerator (IKCs DE33 and DE03 by DESY, FR02 and FR03 by CEA). Many other institutions contributed components for the modules, such as power couplers (IKC FR01 by CNRS), vacuum lines, and cold vacuum parts (IKC RU18 by BINP).

Figure 3 Feedcap in L1, the first section of the linear acclerator (IKCs DE33 and DE13 by DESY, RU24 by BINP)

Figure 4 RF station, klystron (IKC DE01 by DESY)

Figure 5 Electron injector. The commissioning of the injector was successfully completed in 2015 (IKC DECO by DESY).

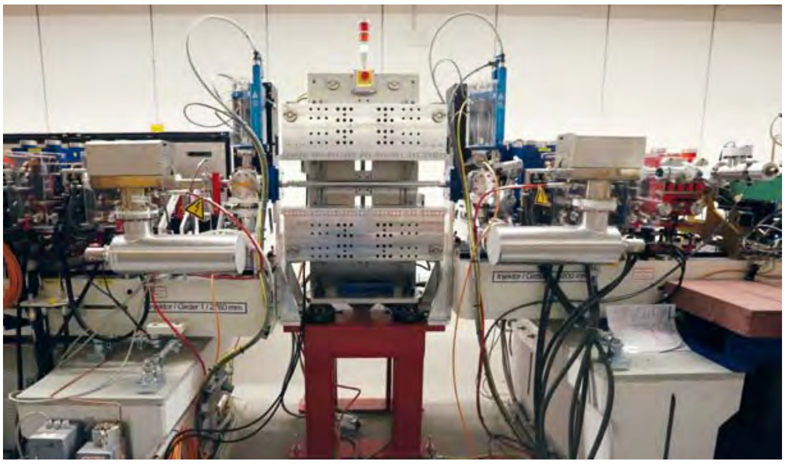


Figure 6 Installation of injector laser heater system (IKC SE03 by UU)

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

Figure 8 Preparation and RF conditioning of power couplers at LAL (IKC FR01 by CNRS). The optimization of the process in 2015 and 2016 allowed treatment of up to 12 couplers per week

Outlook for 2017

In 2017, a large number of milestones should be achieved in the ongoing IKCs. The commissioning of the linear accelerator will be finished, and the first lasing and the first experiments are expected to be carried out.

Group member
Antonio Bonucci

ACCELERATOR CONSORTIUM

The linear accelerator complex of the European XFEL and its comprehensive infrastructure are being constructed by an international Accelerator Consortium of 17 European research institutes under the leadership of DESY. In 2016, installation in the main linear accelerator tunnel was finished, and the superconducting part of the accelerator was cooled down in order for operation to start at the beginning of January 2017. Installation work in the other tunnel sections continued. By mid-2016, the injector commissioning, which had begun at the end of 2015, was successfully completed, with all performance goals reached.

Progress in 2016

The accelerator complex of the European XFEL consists of the 40 m long injector, the 1.3 km long cold (that is, cryogenically cooled) main linear accelerator with altogether 96 superconducting accelerator modules, and about 3.3 km of warm (that is, not cryogenically cooled) beamlines used to transport the electron beam either between successive linear accelerator sections or to the undulators.

The section in the 2 km long main linear accelerator tunnel (XTL) was completed in 2016, and its commissioning started with the cooldown of the superconducting modules. The injector was operated for seven months before it was shut down to finalize the connection of the cryogenic systems.

Linear accelerator installation completed

The production of accelerator modules at CEA in Saclay, France, was concluded with the delivery of Module XM100 at the end of July 2016. For schedule reasons and because a few modules needed sophisticated repair, it was decided to stop the tunnel installation after 96 series modules. This decision was supported by the fact that the excellent performance of the installed 96 modules guarantees an energy reach already well above the European XFEL specification of 17.5 GeV.

The main accelerator in XTL consists of nine cryogenic strings (CS), typically comprising 12 modules with eight cavities each. Only CS1 consists of four modules, which accelerate the electron beam to the intermediate energy needed in the first bunch compressor. As a consequence of the reduction to 96 modules, CS9 includes only eight modules. For the initial commissioning, CS8 and CS9 will remain inactive, as the technical commissioning of CS8 requires some final preparations scheduled for early 2017. Installation of CS9, which

Figure 1 View along the 80 modules of the linear accelerator section L3 in the XTL tunnel. Underneath the accelerator is a standard RF power station supplying four accelerator modules, followed by shielded electronic cabinets housing a variety of systems.

suffered an incident during a pressure test of a helium exhaust line just prior to the first cooldown, will be finished in extended maintenance periods. Most of the damage along CS9 was repaired in late fall 2016, but the RF waveguide distribution required the procurement of replacement parts. Nevertheless, operation of all cryogenic strings including CS8 will allow a beam energy of 17.5 GeV to be reached in summer 2017.

Following the module installation, the remaining RF power stations—consisting of pulse transformer, klystron, and waveguide distribution system—were installed. In addition, electronic cabinets housing low-level RF controls, electron beam diagnostics, and vacuum and cryogenic controls were positioned underneath the linear accelerator sections. Downstream of the cold linear accelerator, the last beamline components were installed, including beamline magnets, vacuum chambers with pumps, kicker magnets to distribute the beam to the different downstream tunnels, and electron beam diagnostics. With the cabling of all the components, work in XTL was finished by fall 2016.

In December 2016, the cryogenic system was fully commissioned and the first cooldown of the accelerator started. The thorough assembly and installation of the accelerator modules, cryogenic boxes, and transfer lines paid off: neither vacuum leaks nor cold leaks (that is, helium leaks opening at cold temperatures) were found, which constitutes an excellent basis for the future long-term operation of the linear accelerator.

The superconducting accelerator of the European XFEL can accelerate bunch trains of 2700 electron bunches at a repetition rate of 10 Hz. This mode was successfully established in the injector.

Injector performance goals reached

The 40 m long injector is the first section of the accelerator. All the members of the Accelerator Consortium contributed to its construction. As the injector comprises almost all subsystems that are also present in the other parts of the accelerator, its commissioning and operation not only posed various electron beam dynamics challenges but also served as an extensive system test.

With the round-the-clock routine operation of the first two superconducting accelerator modules—a standard 1.3 GHz module and a 3.9 GHz higher-harmonic module used to manipulate the longitudinal beam shape—the commissioning team gained valuable experience for the commissioning of the other 96 modules now installed in the tunnel. The geometric properties of the 3.9 GHz system, in particular, proved to be very sensitive to slight variations in helium pressure, and de-tuning was often observed before a change in pressure was registered in the cryogenic system itself. To resolve the issue, suitable pressure sensors in the main linear accelerator will be included in the regulation loops.

The interplay between the two RF systems and their combined effect on the electron beam can be observed with the help of a transverse deflecting system. To this end, a transverse RF field is applied along the length of the electron bunch, giving the head and the tail of the bunch different transverse offsets. The energy spread along the bunch can then be observed on a screen after a spectrometer dipole. By adjusting the amplitude and phase of the RF systems with respect to each other, the energy spread can be minimized.

As a measure of the beam phase space volume, the emittance is one of the most important electron beam parameters. It is determined in the injector by means of a sequence of four consecutive beam imaging screens mounted about 4 mm off the nominal beam trajectory. Using fast kicker magnets, individual bunches can be steered onto the screens. This system allows a fast and almost non-invasive emittance measurement even along a bunch train. After careful tuning of the injector parameters, the target value of <1 mm mrad was routinely observed.

The superconducting accelerator can accelerate bunch trains of 2700 electron bunches at a repetition rate of 10 Hz. This mode was successfully established in the injector, entailing the use of the 4 kW high-power beam absorber at the end of the injector. In total, a beam charge of about 3 C was produced during the injector commissioning—that is, about the same order of magnitude as the SLAC X-ray FEL LCLS has produced so far since its startup in 2009.

Transition to user operation

The year 2017 will be extremely busy and exciting for the Accelerator Consortium. The technical commissioning of the European XFEL accelerator will lead to the operation of the world's largest superconducting linear accelerator. Under the leadership of DESY, beam commissioning will begin, with the goal to observe first lasing in the SASE1 undulator by early summer.

05

PHOTON BEAM SYSTEMS

In 2016, scientists completed installation of the first two X-ray generating undulators. Beamlines, optics, and diagnostics were also set up. Simulations helped to develop schemes for improved X-ray generation and new possibilities for experiments.

Installing a mirror cradle in a vacuum chamber

UNDULATOR SYSTEMS

The European XFEL will include three undulator systems—periodic magnetic structures in which the electrons will generate ultrabrilliant pulses of X-ray radiation. Each of the hard X-ray systems, SASE1 and SASE2, will be more than 200 m long and comprise 35 undulator segments with a period length of 40 mm. The soft X-ray system, SASE3, will be about 120 m long and contain 21 segments with a period length of 68 mm. The Undulator Systems group is responsible for organizing the production, installing, and commissioning these systems in close cooperation with the Accelerator Consortium. Future responsibilities of the group will include the development of new types of light sources, for example to generate light with variable polarization.

Progress in 2016

In 2016, the focus was on SASE1 and SASE3. All hardware components within the responsibility of the group, such as undulator segments, quadrupole movers, and phase shifters, were installed. In parallel, all components required for SASE2 were made ready for installation. The control systems for SASE1 and SASE3 were commissioned, enabling the two undulator systems to be controlled remotely. The air conditioning systems were installed. As of December 2016, this includes the enclosures for SASE1 and SASE3 and the air conditioning devices for all three undulator systems.

To satisfy the demand for circularly polarized light in the VUV range from 0.2 to 5 nm covered by SASE3, a collaboration with SwissFEL was launched to investigate the use of helical undulators for generating circularly polarized radiation at the SASE3 beamlines.

Figure 1 SASE1 undulator system in the XTD2 tunnel (spring 2016)

SASE1, SASE2, and SASE3

Figure 2 SASE1 undulator system after installation of the air conditioning system (September 2016)

The main objective in 2016 was the installation of the SASE1 and SASE3 undulator systems in the tunnels. Figures 1 and 2 give an impression of the progress achieved: Figure 1 shows an upstream view along the SASE1 system after the installation of the undulator segments in spring 2016.

Figure 2 shows another upstream view taken in September after the installation of the air conditioning system. The air conditioning unit, which can be seen in the foreground, provides an air flow of 36 000 m^3/h stabilized to 0.1°C/24 h into the enclosure. The air direction is opposite to the beam direction. The panels that extend from the top of the enclosure to the floor isolate the undulator hermetically from the rest of the tunnel. They can be removed for undulator maintenance and access.

During the summer, the SASE3 system was installed and completed in a very similar fashion.

In parallel to the hardware installation in SASE1 and SASE3, undulator segments, phase shifters, and quadrupole movers were wired and connected to the local control nodes. After installation of the fibre connection to the balcony room in the experiment hall, the central control node was installed and software commissioning started. Currently, SASE1 and SASE3 can be remotely controlled using the DOOCS accelerator control system. For safety reasons, however, gap motion is still blocked.

In December 2016, mechanical commissioning of the SASE1 undulator system started. The wooden safety covers, which protect the magnet structures during installation and which are still present in Figure 1, were removed, and the vacuum chambers were precision-aligned to the gap. The gaps of all segments can now reach the minimum value of 10 000 ± 0.001 mm (Figure 3). This is the first step to full remote gap control. The next steps will include the adjustment of the limit switches and hard stops, the installation of the online dosimetry system, and finally the installation of the air coil correctors.

In the course of the year, all hardware components needed for SASE2 were prepared. The last undulator segments were re-measured by September. For the alignment in the tunnels, the magnetic centres of the phase shifters were transfer measured to geometric fiducials, and the quadrupole movers were prepared. Everything is now ready for installation.

Figure 3 First undulator segment, U40-X069-K029, in Cell 3 closed to the minimum gap of 10 mm

Helical afterburner

There is a strong demand for circularly polarized radiation at the SASE3 beamlines, which could not be covered in the baseline scope of the European XFEL. For this reason, a collaboration with SwissFEL was initiated. The present idea is to build four 2 m long segments based on the APPLE-X design being developed at SwissFEL for their Athos beamline. Using the pre-bunched electron beam of SASE3, these four segments together will work as one coherent radiator in a configuration also called “afterburner”.

Figure 4 Two metre long APPLE-X undulator adapted to match the SASE3 undulator system

Modifications are necessary to meet the European XFEL requirements: photon ranges need to be matched by proper choice of device parameters, and compatibility with the European XFEL accelerator, electron optics, and tunnel geometry needs to be guaranteed. Figure 4 shows a first sketch of a SwissFEL APPLE-X undulator matched to European XFEL needs.

The parameters of the SASE3 APPLE-X system will be chosen such that the following conditions are fulfilled:

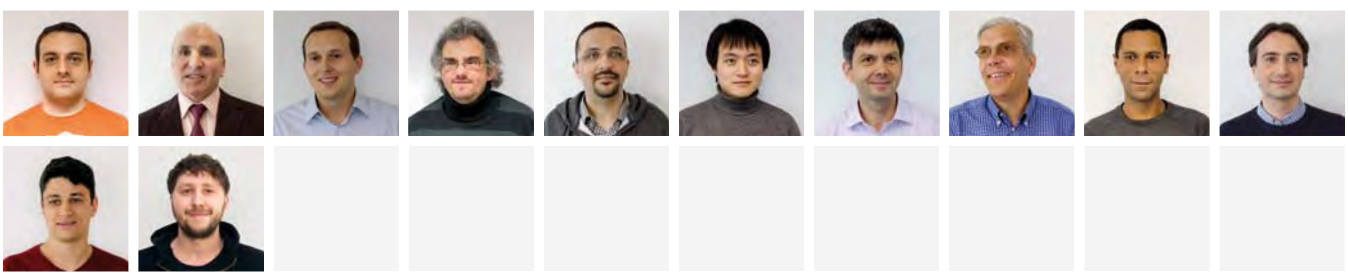
- The afterburner must cover the full photon energy range of SASE3. This is equivalent to covering the full SASE3 operational *K* range from 4 to 9.
- Full polarization control is required in the operational range:
  - Right and left circular polarization
  - Linear polarization with a polarization angle selectable between +90° and -90°

These requirements form the basis for the magnetic design. A detailed design report is being prepared.

Outlook for 2017

In 2017, the group will focus on achieving the ready-for-beam status one by one for all three undulator systems and continue to develop the helical afterburner:

- **SASE1**
  The SASE1 system is most advanced and close to completion. The commissioning of the undulator hardware will continue. By the end of January 2017, the system will be fully operational and ready for beam.
- **SASE3**
  The SASE3 schedule follows the one of SASE1 with a time difference of several months. Some final safety installations inside the air conditioning enclosure, which are mandatory for operation with beam, are planned for January 2017. Hardware commissioning as described above for SASE1 is due to start immediately afterwards. SASE3 is expected to be ready for beam in March 2017.
- **SASE2**
  The status of SASE2 corresponds to the one of SASE1 about one year ago. However, the experience made with SASE1 and SASE3 will significantly speed up installation, so SASE2 is expected to be ready for beam by June 2017.
- **Helical afterburner**
  A mechanical design for the SASE3 afterburner segment will be developed and tested on a prototype that will be built together with SwissFEL. The aim is to have a conceptual design for the whole afterburner, including the modifications for electron beam, ready in 2017.



Group members
Suren Abeghyan, Majid Bagha-Shanjani, Karl-Heinz Berndgen (until April 2016, not shown), Georg Deron (until September 2016), Uwe Englisch, Efim Gluskin (guest, from September until December 2016, not shown), Bora Ketenoglu (guest, from June until July 2016), Peng Li (guest, not shown), Yuhui Li, Florian Preißkorn (not shown), Tao Wei (guest, not shown), Suren Karabekyan, Joachim Pflüger (group leader), Marc Viehweger (until April 2016), Frederik Wolff-Fabris, Mikhail Yakopov, and Marc Wünschel

SIMULATION OF PHOTON FIELDS

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

Progress in 2016

In its baseline SASE mode of operation, the European XFEL will produce linearly polarized pulses of X-rays with typically poor longitudinal coherence and a pulse duration depending on the characteristics of the electron beam. The SPF group investigates cost-effective ways to complement the SASE mode with advanced FEL schemes in order to best fulfil user requirements. In 2016, activities of the group members and their collaborators focused on the generation of radiation with controllable and stable polarization properties, the realization of multicolour pulses at the SASE3 undulator, and the production of attosecond-class X-ray pulses. The group also continued to help with the development of the hard X-ray self-seeding (HXRSS) setup to be installed at SASE2 and started to investigate external seeding options. Finally, the SPF group advanced the development of the OCELOT simulation software and used it in optimization studies at FLASH.

Collaborations

The SPF group continued to benefit from collaborations with Vitali Kocharyan and Evgeni Saldin as well as Ilya Agapov, Martin Dohlus, and Igor Zagorodnov at DESY. In addition, the group started to cooperate with Guangyao Feng and Aram Kalaydzhyan, also at DESY. Nicolay Smolyakov, Boris Krasnopolskiy, and Evgeny Fomin at the NRC KI synchrotron contributed to the group efforts supported by the EDYN EMRAD project, which is jointly funded by BMBF and the Russian Ministry of Science and Education in the context of the Ioffe–Röntgen Institute (IRI). In 2016, Svitozar Serkez and Takanori Tanikawa joined the SPF group.

Polarization control

Using the FEL simulation code Genesis and the in-house software OCELOT, SPF group members Gianluca Geloni and Svitozar Serkez, together with collaborators from DESY, confirmed that a combination of inverse tapering and short helical radiators would provide pulses with a high and stable degree of circular polarization at SASE3. They also showed that residual linearly polarized background radiation might be further blocked or strongly defocused, so as not to disturb sensitive experiments, using the X-ray optics following the undulators [1].

Two-colour pulses

Together with the SCS and SQS groups, Geloni and Serkez continued to work on a method for obtaining double FEL pulses with different frequencies and tuneable delay to be used in pump–probe experiments. In this scheme, two different parts of the SASE3 undulator are tuned to different wavelengths, generating pulses with different colours, while a magnetic chicane, to be installed between the two parts, provides a variable delay.

Attosecond pulses

The minimal duration of the X-ray pulses produced by the European XFEL in SASE mode amounts to a few femtoseconds. Together with collaborators from DESY and with the support of the Optical Lasers and Undulator Systems groups, Geloni and Serkez worked on methods for reducing the pulse duration down to the attosecond level, the timescale of electron dynamics. The collaboration investigated different methods based on introducing modulations of the electron beam energy or density at visible-to-infrared wavelengths, in order to decrease the FEL pulse duration and allow for timing the X-ray pulse and the pump pulse with attosecond-level accuracy.

HXRSS at SASE2

Geloni and Serkez further supported the developments of the HXRSS project at SASE2, which is unfolding within a larger international collaboration. The design is based on a two-chicane scheme that promises, together with post-saturation tapering, nearly Fourier-limited X-ray pulses with a several times higher brightness. The chicanes are designed to also be used for two-colour generation and ultrashort radiation pulse measurements.

External seeding

In the soft X-ray region, external laser seeding (ELS) techniques can provide nearly Fourier-limited FEL pulses with virtually no influence of the stochastic properties of shot noise (Figure 1).

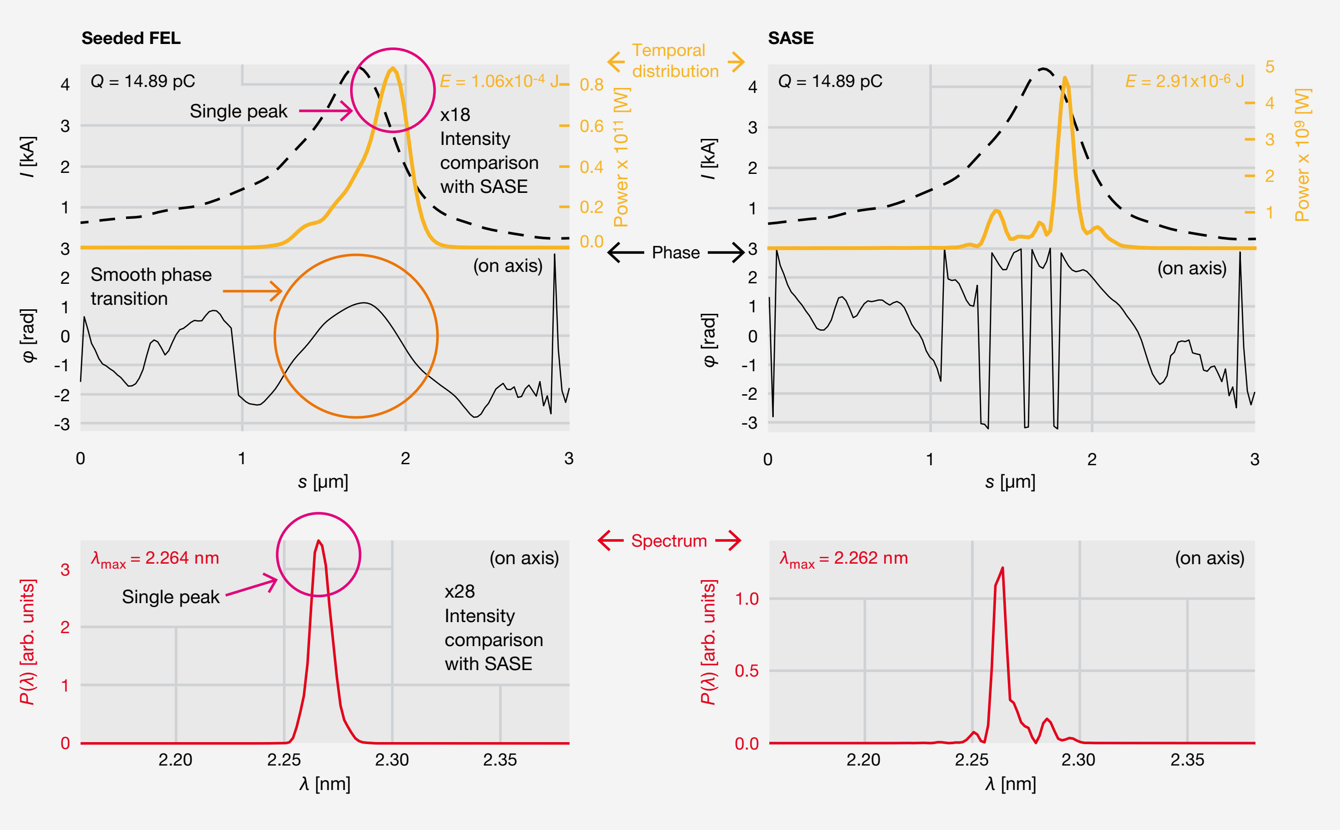


Figure 1 Comparison of electron beam and radiation properties from SASE and HHG seeding at SASE3 at a wavelength of 2.26 nm
(*Q*: electron bunch charge; *I*: electron current; *φ*: radiation phase; *P*: spectrum; *λ*: wavelength; and *s*: longitudinal position inside the bunch)

In the spectral range where external seed lasers are available, ELS techniques can generate stable radiation pulses naturally synchronized to an external laser. Group members Geloni and Tanikawa started to investigate the feasibility of ELS techniques at high repetition rate and high electron beam energy at the European XFEL. Preliminary results indicate that a direct high-harmonic generation (HHG) seeding scheme will be available around the water window region, while the production of pulses with higher photon energies by means of HHG seeding becomes challenging because of insufficient seed laser power.
For the production of fully coherent pulses with higher photon energies, other ELS schemes, such as high-gain harmonic generation (HGHG) and echo-enabled harmonic generation (EEHG), are currently being investigated.

Software developments

Since 2011, the SPF group has been developing the software toolkit OCELOT in collaboration with DESY, NRC KI and, recently, SLAC, for designing and operating FEL- and storage-ring-based light sources.

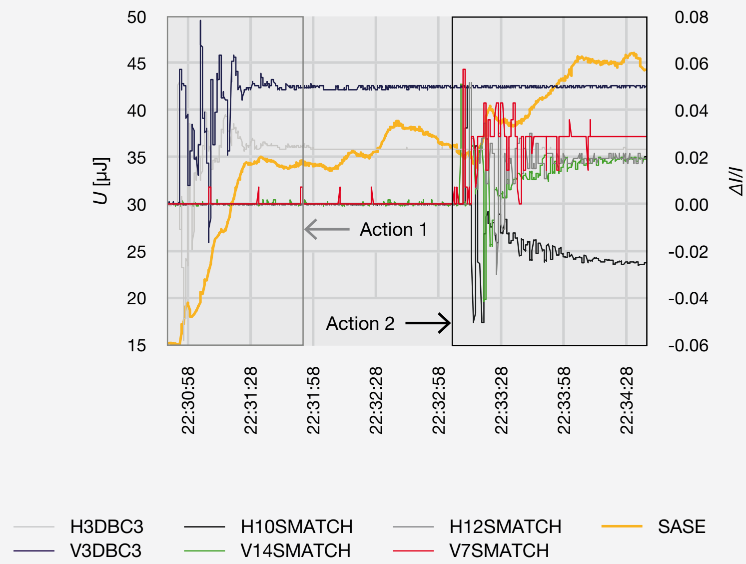


Figure 2 Example of automatic SASE tuning at FLASH at a wavelength of 10.4 nm. The orange line shows the behaviour of the SASE pulse energy, the other lines refer to the current in vertical ("V") and horizontal ("H") correctors. (*U*: X-ray pulse energy; *I*: corrector current)

OCELOT includes four main modules: electron beam dynamics, spontaneous emission, FEL simulations with an interface to the FEL code Genesis, and online machine control and optimization. These modules can be used independently or together to build complex physical models. The development of OCELOT is supported by the EDYN EMRAD project.

Group member Sergey Tomin advanced the beam dynamics module to include collective effects in collaboration with Martin Dohlus and Igor Zagorodnov at DESY, while Evgeny Fomin from the NRC KI synchrotron developed a multi-objective genetic algorithm (MOGA) for optimization purposes. Serkez continued to develop the Genesis pre- and post-processor module. The SPF group and its partners also used OCELOT for optimizing the SASE pulse energy at FLASH (Figure 2) and for increasing the injection efficiency at the Siberia-1 storage ring of NRC KI [2].

Outlook for 2017

In 2017, the SPF group will continue previous collaborations and further develop software both in house and in the framework of the EDYN EMRAD project. The group members will advance their studies on new schemes for the production of X-ray pulses with special characteristics. They will also be involved in the commissioning of the European XFEL, where they expect to gain useful insight into the machine operation and to provide online optimization by exploiting OCELOT and their previous experience at FLASH. ■

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THEORY

The Theory group focuses on the development and application of novel theoretical approaches and tools to support and advance research at the European XFEL. The group develops theory and software and performs simulations to facilitate spectroscopic and scattering X-ray studies at FELs. Part of the Theory group is based at UHH.

Progress in 2016

In 2016, the members of the Theory group and their collaborators studied the electronic spectra of correlated materials and the nanoscale structure of complex objects.

In collaboration with Adrian Mancuso of the SPB/SFX group, Jeffrey Donatelli and Peter Zwart of LBNL, and Chun Hong Yoon and Andrew Aquila of LCLS, group member Ruslan Kurta advanced the development of novel techniques for single-particle imaging. Kurta also proposed a multiple-wavelength resonant fluctuation X-ray scattering (FXS) approach for the element-specific imaging of nanoscale objects in random ensembles [1]. In cooperation with the group of Ivan Vartaniants at DESY, Kurta participated in the development and application of cross-correlation approaches for structural studies of advanced materials. Together with Manuel Izquierdo of the SCS group, group member Evgeny Gorelov worked on the accurate description of spin state transition in $LaCoO_3$ and investigated the role of surface effects.

Members of the Theory group and their collaborators studied the electronic spectra of correlated materials and the nanoscale structure of complex objects. They advanced development of novel techniques for single-particle imaging and worked on the accurate description of spin state transition in $LaCoO_3$.

The Theory group also established several new collaborations. Together with Samed Halilov of the University of Massachusetts in Lowell, USA, the group started to work on the development and application of theoretical methods for the interpretation of surface-sensitive X-ray photoelectron spectroscopy experiments. Another new collaboration, with Alexander Guda of the Southern Federal University in Rostov, Russia, and Carlo Lamberti of the University of Torino in Italy, is devoted to the study of catalytic processes by means of X-ray emission spectroscopy. Finally, together with Wilfried Wurth of FLASH at DESY, the Theory group aims to describe ultrafast metal–insulator transition in magnetite.

The group continued existing collaborations, with Martin Eckstein of MPI for the Structure and Dynamics of Matter in Hamburg, Germany, and Viktor Valmispild of UHH on out-of-equilibrium many-body methods, and with Andreas Scherz of the SCS group on demagnetization dynamics in FeRh.

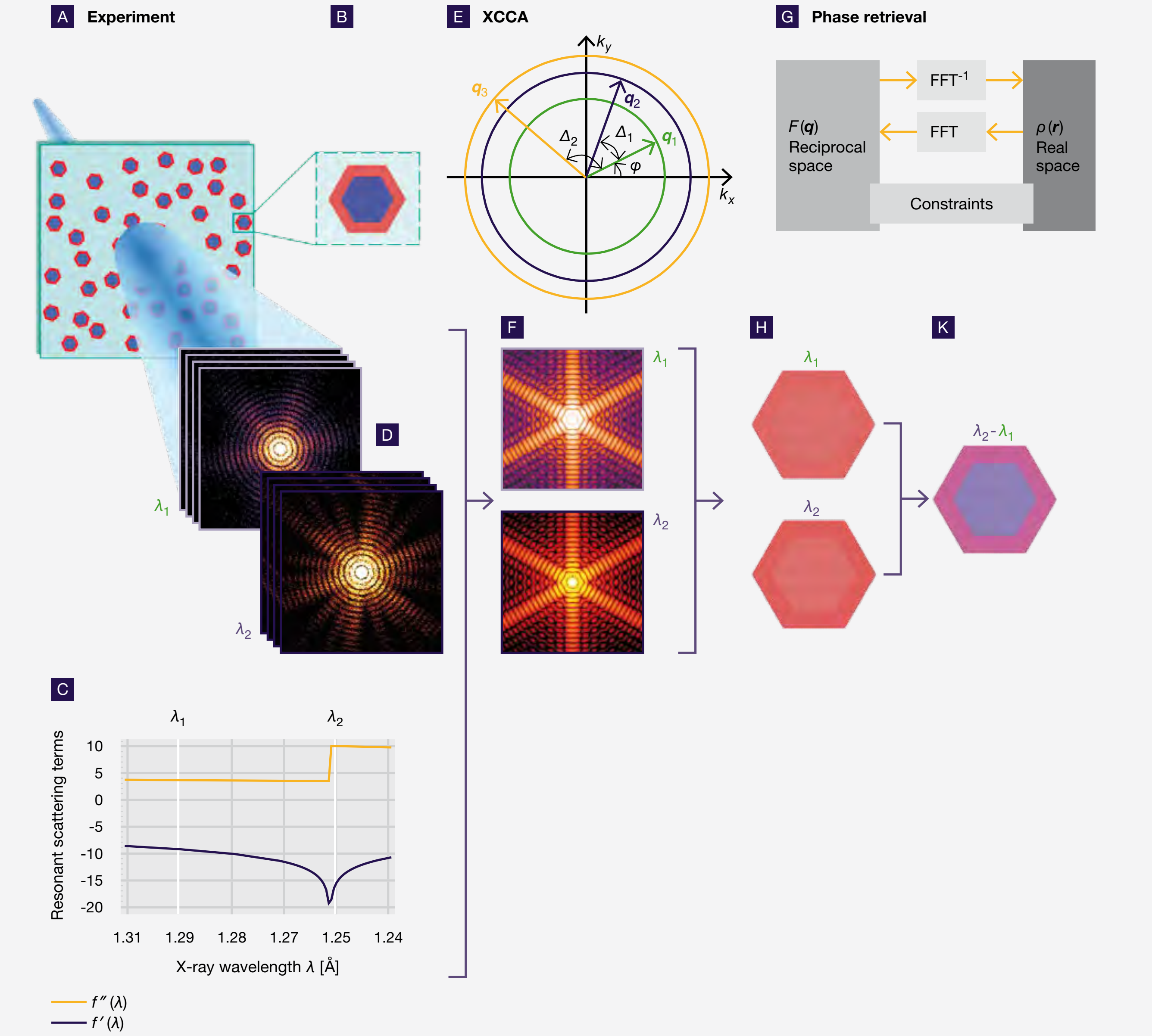

Figure 1 Workflow of the multiple-wavelength resonant FXS approach. In the experiment (A), X-ray scattering is measured from a sample composed of identical objects (B) at two different wavelengths λ_1 and λ_2 near the resonant value for a chemical species of interest (C). The resulting two sets of diffraction patterns (D) are treated separately by XCCA (E) to recover the scattered intensity distributions (F) corresponding to a single object. The recovered intensities (F) are inverted using the iterative phase retrieval technique (G) to produce images of the object (H) measured at two distinct energies. The sought elemental distribution (K) is determined from the difference of the two object images (H). Reproduced from [1]. (FFT: fast Fourier transform; FFT^{-1}: inverse fast Fourier transform)

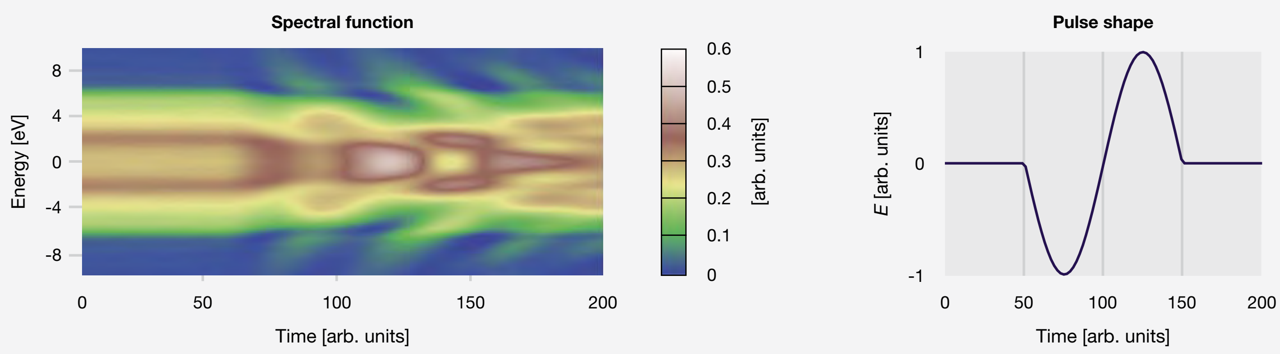

Figure 2 Modelling changes in the electronic structure of an anisotropic two-dimensional lattice of correlated sites under the influence of a strong single-cycle electromagnetic pulse.
Left Time-resolved density of states of the anisotropic two-dimensional Hubbard model.
Right Amplitude of the electric field during the pulse. (*E*: electric field)

Single-particle imaging

The imaging of single particles remains one of the most important challenges at modern X-ray FELs. The limited resolution of the reconstructed biological samples demonstrated so far demands further theoretical and experimental efforts to establish single-particle imaging techniques at these novel light sources. This is the aim of the international Single Particle Imaging (SPI) initiative, which was launched in 2015. Within this collaboration, the Theory group, together with Donatelli and Zwart from LBNL, is developing a novel imaging technique based on X-ray cross-correlation analysis (XCCA) of the scattered intensities and on the multi-tiered iterative phasing algorithm. The application of this technique enabled *ab initio* reconstructions of nanoscale virus structures measured at LCLS, allowing the resolution of structural features that are hardly accessible by conventional approaches.

Multiple-wavelength fluctuation X-ray scattering

The multiple-wavelength FXS approach developed by the Theory group extends the possibilities of resonant imaging [1]. It enables the recovery of the elemental distribution within individual objects of a disordered system composed of reproducible nanoscale objects with short positional and rotational relaxation times (Figure 1). The approach might be especially advantageous for structural studies at X-ray FELs, particularly when reasonable X-ray data cannot be measured from a single weakly scattering particle before it is destroyed.

X-ray spectroscopy of correlated materials

Adopting the Korringa–Kohn–Rostoker (KKR) method and the recently developed realistic many-body cluster approach, the Theory group performed calculations of photoelectron spectra and layer-resolved X-ray absorption spectra for low-index surfaces of catalytically active perovskite $LaCoO_3$. The results will provide insights into the physics of spin state transition and the catalytic activity of $LaCoO_3$ [2]. This work is being done with the SCS group. The developed methods were further applied to other materials, for example to the metal–organic framework CPO-27-Ni and to magnetite (Fe_3O_4). The first results show that the rich physics of correlated materials can be understood by using many-body realistic computational approaches for interpreting spectroscopic experimental data.

Non-equilibrium correlated systems in strong electric fields

Using the recently developed microscopic approach to non-equilibrium many-body dynamics of the generic Hubbard model, the Theory group studied the response of correlated materials to strong ultrashort electromagnetic pulses. In particular, the group investigated changes in the electronic structure of an anisotropic two-dimensional lattice under the influence of a strong single-cycle electromagnetic pulse (Figure 2).

In the framework of its collaboration with the SCS group, the Theory group studied the demagnetization process in FeRh during pump–probe experiments. Calculations of the demagnetization rate were performed for different magnetic phases in the presence of the pump pulse using the time-dependent density functional theory approach. This technique allows electron dynamics in correlated materials to be modelled in the presence of an electromagnetic pulse.

Outlook for 2017

In 2017, the Theory group will continue its research within the existing projects and collaborations. Kurta will go on working on the development and application of advanced approaches for scattering and imaging experiments at X-ray FELs. As a member of a collaborative effort formed during the SPB/SFX early user workshop in 2016, Kurta will apply these novel approaches in the first single-particle imaging experiments at the SPB/SFX instrument. Gorelov will continue existing collaborations with the SCS group focusing on the theoretical description of spectroscopic experiments. The development of a multi-orbital fluctuation exchange impurity solver will provide the possibility to treat realistic material-specific models in the framework of out-of-equilibrium dynamical mean-field theory, with the aim of describing the interaction of correlated materials and strong light pulses with temporal resolution. ■

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X-RAY OPTICS

The X-Ray Optics group is responsible for the X-ray optics in the photon tunnels, including the development of mirror systems, monochromators, and further beamline elements, such as shutters, slits, and collimators. In 2016, the mechanical setup of the X-ray beam transport for the SASE1 undulator beamline was completed, and most elements of the SASE3 beam transport were installed.

Progress in 2016

Together with the Vacuum group, the X-Ray Photon Diagnostics group, and various DESY groups, the X-Ray Optics group completed the SASE1 photon transport systems in the tunnels XTD2 and XTD9 and nearly finished the photon transport systems for the SASE3 beamline in XTD10.

A major milestone for the X-Ray Optics group was the completion and characterization of the first long mirror with a profile accuracy of ±1 nm in early 2016. As the year went on, the company JTEC Corporation in Japan delivered nine more flat and two curved mirrors with similar profile accuracy. The X-Ray Optics group is also involved in the technical commissioning of the European XFEL, which officially started on 6 October.

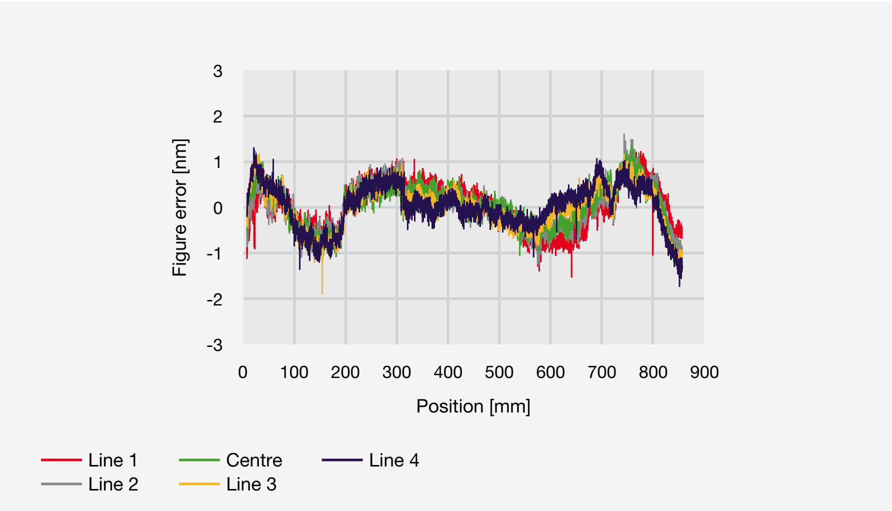

Figure 1 First super-polished mirror delivered by JTEC Corporation in April 2016.
Left The mirror being placed for measurements in the group's interferometer after polishing.
Right Measurement of hight profile errors (performed by JTEC).

The company FMB Feinwerk- und Meßtechnik in Germany delivered and installed the large soft X-ray monochromator for the SASE3 beamline in XTD10. As of December 2016, almost all other X-ray optical components are on site as well and installed (photon beam loss monitors, shutters, slits, and beam dumps). Some last components of serial productions for SASE2 are in their final production or testing phase at the vendors' sites (shutters for the MID instrument, two mirror chambers for SASE2, and some of the collimators). The detailed design of the SASE2 beamline was completed for XTD6 and is nearing completion for XTD1, the last tunnel section of the SASE2 photon beam transport system.

Group member Liubov Samoylova and coworkers continued the development of the WavePropaGator (WPG) software package. It allows the entire beamline optics to be modelled in a wave-optical approach, including optics errors obtained from metrology measurements [1].

Compared to the well-established mirrors used for synchrotron radiation, specifications on polishing errors are about a factor of 10 more stringent, with a maximum deviation from the theoretical shape in the range of ±1 nm over the entire length of the mirror.

Changes to the group

Immo Bahns joined the X-Ray Optics group in 2016 as a Ph.D. student in collaboration with the group of Jörg Rossbach from UHH. The goal of his thesis is to develop a suitable optics scheme for diamond reflectors for an X-ray FEL oscillator. Vivien Sleziona joined the X-Ray Optics group as a student assistant working with Xiaohao Dong, providing substantial support to the hard X-ray monochromator project. Valerija Music finished her bachelor thesis on X-ray mirror benders (UHH) [2], and Mahadi Umar Jidda completed his master thesis on programmable logic controllers on mirror systems (University of Applied Sciences Bremerhaven).

Super-polished X-ray mirrors

Among the key components required to deliver a high-quality X-ray beam to the instruments are X-ray mirrors with an extreme surface finish. Compared to the well-established mirrors used for synchrotron radiation, specifications on polishing errors are about a factor of 10 more stringent, with a maximum deviation from the theoretical shape in the range of ±1 nm over the entire length of the mirror. Figure 1 shows the first mirror produced by JTEC Corporation that achieved this precision. As shown in the graph, the deviation from the ideal flat

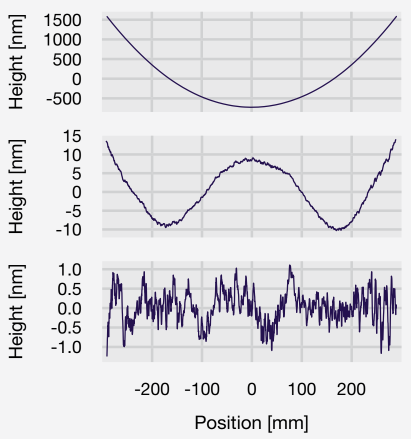

Figure 2 Height profile measurements of pre-mirror for the soft X-ray monochromator.
Top Overall shape showing the focusing ellipse.
Middle Residual shape after subtracting the ellipse, showing the influence of support points.
Bottom Measured shape error after subtraction of deformations expected from mirror mounts.

surface of a side-deflecting mirror is shown on five stripes of 850 mm length within the optical aperture of 20 mm width.

Figure 2 shows the metrology of a vertically focusing mirror for the soft X-ray monochromator measured by group members Maurizio Vannoni and Idoia Freijo Martín with the Fizeau interferometer in the European XFEL metrology laboratory. The top panel shows the overall curvature of 17.5 km that is required for the desired focusing effect. Subtracting the theoretical focusing ellipse from the measured profile yields a W-like shape with an amplitude of 20 nm (middle panel). This shape results from deformation at the support points, which are located about ±180 mm from the centre, during the production process. These points were chosen such that they match the support geometry in the monochromator chamber. Because the metrology measurement is done in side-facing geometry, these deformations are visible. They match the predictions made using finite-element calculations. After subtracting the theoretical shape of the support deformation, the remaining error is again on the order of ±1 nm (bottom panel).

New type of soft X-ray monochromator

During the technical design phase of the SASE3 beam transport, the X-Ray Optics group developed a new scheme for a diffraction-limited plane-grating monochromator. On the one hand, the goal was to stay close to the diffraction limit so the pulse stretching would remain as close as possible to the Heisenberg limit related to the energy resolution. On the other hand, the monochromator optics was optimized to handle large energies of up to 10 mJ per photon pulse. As a result, the dimensions of pre-mirrors and gratings need to be large (substrate lengths of more than 0.5 m) and the specification for shape errors and ruling comparable to the precision of the beam transport mirrors (such as the pre-mirror shown in Figure 2).

A severe problem to overcome was the mechanical stability of the grating mounts. Three long and heavy gratings are mounted on a common cradle that has to scan over a range of several degrees and, at the same time, guarantee a mechanical stability not exceeding the polishing accuracy of the optics of about 50 nrad rms. Group member Daniele La Civita conducted a series of vibration measurements to check this critical parameter. At the production site of FMB Feinwerk- und Meßtechnik, the observed vibration level was around 200 nrad rms, even during quiet periods in the night. The causes identified were the floor mount, the ground vibrations at the site, and some small mechanical and assembling issues.

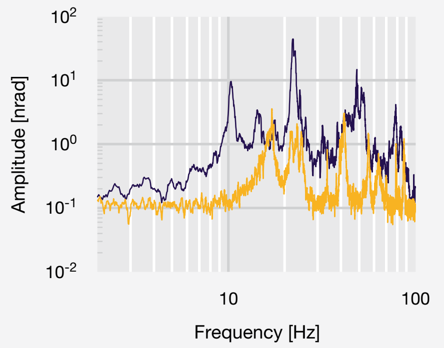

Figure 3 New diffraction-limited plane-grating monochromator.
Top Measured angular vibrations of the grating cradle. The purple curve shows a measurement at the production site, yielding an overall averaged vibration level of 200 nrad rms. After some corrections of the mechanics and installation in XTD10, the vibration level was reduced to 40 nrad rms (orange curve).
Bottom Soft X-ray monochromator shortly after installation in XTD10.

After some modifications, vibration measurements at the device's final destination on an epoxy-grouted base plate in XTD10 revealed a mechanical stability of the grating cradle of 40 nrad rms (Figure 3).

Outlook for 2017

In 2017, commissioning of the SASE1 and SASE3 photon beam transport systems will begin as soon as the first X-rays will be produced. This is a prerequisite for starting the commissioning of the first scientific instruments by the middle of the year and later the European XFEL user programme. The SASE2 beam transport system will be built up and technically commissioned. ■

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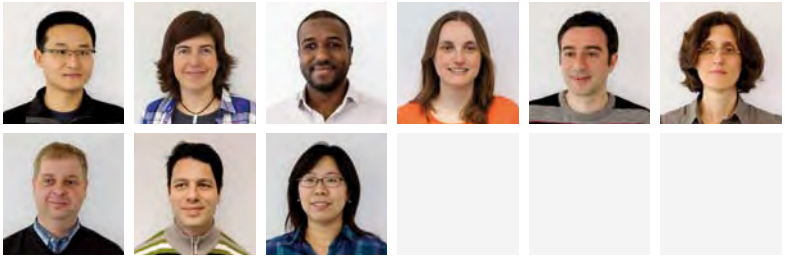


Group members
Immo Bahns (student, not shown), Xiaohao Dong, Idoia Freijo Martín, Natalia Gerasimova (not shown), Mahadi Umar Jidda (student, until June 2016), Nicole Kohlstrunk, Daniele La Civita, Liubov Samoylova, Harald Sinn (group leader), Vivien Sleziona (student assistant, not shown), Petr Smirnov (guest, not shown), Antje Trapp (not shown), Maurizio Vannoni, and Fan Yang

VACUUM

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

Changes to the group

In 2016, three group members left the Vacuum group to face new challenges within European XFEL. Two technicians, Frederik Meyn and Denis Finze, were hired in early 2016. Massimiliano di Felice moved from the X-Ray Optics group to the Vacuum group in July, and Benoit Rio started as a mechatronic technician at the end of November. Two students joined the group in 2016: Atula Poduval wrote her master thesis on pressure control for a gas injection system, and Phil Schneider started his engineering internship in October.

In 2016, the group finished the installation of all the ultrahigh-vacuum components for the SASE1 photon beam transport. The electronic racks were equipped with all necessary control hardware, and the wiring of many components to the control system was carried out in order to allow operation of the beamline in spring 2017.

Progress in 2016

In 2016, the Vacuum group mainly concentrated on finalizing the installation of the vacuum beam transport system for the SASE1 undulator in the tunnels XTD2 and XTD9, starting the SASE3 installation in XTD10, and preparing for the SASE2 vacuum system assembly. Significant progress was made on the assembly of the SASE3 gas attenuator system.

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

The SASE1 vacuum control system was wired up, and the group started to define the vacuum interlock and the graphical user interface to the control software.

Figure 1 Electrical installation work in XTD9. Components of the differential pumping units are being connected to their controllers, which are placed inside the electronics racks below the beam pipe.

Beam transport installation

In 2016, the Vacuum group finished the installation of all the ultrahigh-vacuum (UHV) components for the SASE1 photon beam transport inside XTD2 and XTD9.

The SASE1 electronics racks were equipped with all necessary control hardware. The wiring of many beamline components to the control system was carried out in 2016 (Figure 1) in order to allow operation of the SASE1 beamline in spring 2017. Afterwards, the Vacuum group, in collaboration with the Advanced Electronics group, started testing the individual electronic devices in the tunnels, before they were added to the programmable logic controller loop. As of December 2016, commissioning of the control system and implementation into Karabo, the European XFEL control and analysis software framework, are ongoing.

SASE3 gas attenuator

The SASE3 gas attenuator will enable an accurate variation of the beam intensity without modification of the undulator configuration, by introducing a defined gas pressure into the gas cell of the attenuator. As of December 2016, all the necessary components are being installed into their final position in XTD10. Special efforts have been made to exhaustively fiducialize and align the device's clear-out 20 mm diameter aperture system. The almost 38 m long beamline sector occupied by the gas attenuator is expected to be ready for full technical commissioning by the end of February 2017.

Figure 2 SASE3 gas attenuator installed in XTD10 (January 2017)

Differential pumping systems

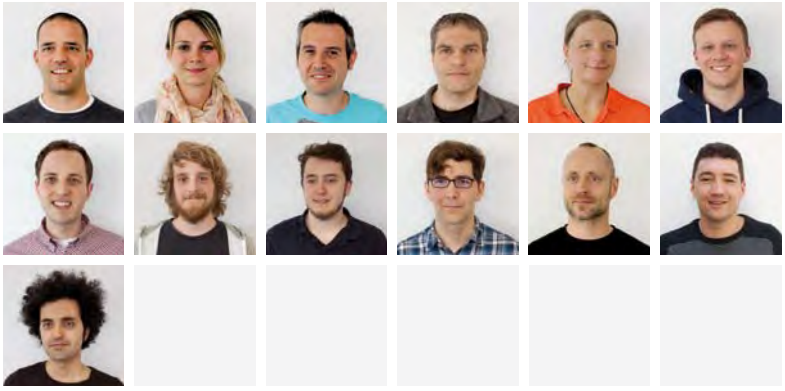
Following up on the previously deployed differential pumping systems for noble gases, the two standard modules foreseen in XTD10 were successfully installed. As of December 2016, the customized versions of the girder-mounted design (known as "ceiling-hanging" and "bridge" versions) to be installed in XTD1 are being produced. They are expected to be technically commissioned, put in place, and aligned in their final positions by May 2017.

Scientific instrument support

In addition to its activities relating to the photon tunnel beamline components, the Vacuum group in 2016 intensified its close collaboration with the instrument groups. The group generated the vacuum-related calculation reports required prior to the detailed design of the specific systems, for example for the UHV beam transport lines for the SPB/SFX, SQS, and HED instruments, for the centralized and remote fore-vacuum system of SPB/SFX, and so on. The Vacuum group also guided the instrument groups through the procurement process, assisted with technical commissioning, supervised tests, and supported them during the assembly of these systems.

Outlook for 2017

In 2017, the Vacuum group will concentrate on finalizing the vacuum beam transport systems in the underground tunnels. It will implement and commission the vacuum control systems in collaboration with the X-Ray Optics, Advanced Electronics, and Control and Analysis Software groups. It will also continue to provide vacuum-related support to the instrument groups. ■



Group members
Alexander Bartmann (until May 2016), Bianca Dickert, Massimiliano Di Felice, Martin Dommach (group leader), Janni Eidam, Denis Finze (not shown), Paul Frankenberger (until October 2016), Timo Korsch (until October 2016), Henrik Liebel (student), Eike-Christian Martens, Frederik Meyn, Maik Neumann, Atula Poduval (student, from April until October 2016, not shown), Benoit Rio, Phil Schneider (student, not shown), and Raúl Villanueva Guerrero

X-RAY PHOTON DIAGNOSTICS

The X-Ray Photon Diagnostics group is responsible for designing, constructing, commissioning, and operating the diagnostic devices that will monitor the X-ray photon pulses generated by the European XFEL. In 2016, the group installed sensitive diagnostic equipment in the tunnels served by the SASE1 and SASE3 undulators, cabled and technically commissioned the SASE1 installations without beam, and installed much of the diagnostic infrastructure in all the photon tunnels.

Changes to the group

After several years of developing a photoelectron spectrometer (PES), Jens Buck left the group in June 2016. His successor, Joakim Laksman, joined the group in mid-December. He will relaunch efforts towards gas-based diagnostics together with a second new physicist arriving in January 2017, who will focus on the X-ray gas monitor (XGM), the main gas-based diagnostic device. Two electrical technicians joined the group in March and November through leased labour for assembling electronic creates and confecting and installing cables in the tunnels. In November, the group began to transfer electrical workplaces from the HERA South laboratories to the new laboratories in the European XFEL headquarters building (XHQ) in Schenefeld.

Figure 1 First fully installed and cabled XGM at SASE1 in the XTD2 tunnel. The picture shows the local electronics between the pillars, the cabling of the chambers, and the customized rare-gas supply panel on the lower left.

Figure 2 Final hanging construction of the differential pumping stages that separate the XGM from the PES in SASE3. The bridge crosses over an electronics rack.

Figure 3 HIREX crystal chamber installed at its final location in XTD9

Gas-based online diagnostics

In early 2016, the group received all the remaining XGM units provided by DESY. These devices are challenging to install, as they require continuous ultrahigh-vacuum operation. Over the year, three of them were fully assembled with their local infrastructure and installed in the SASE1 and SASE3 tunnels (Figure 1). The SASE1 XGMs were equipped with their complicated cabling and their control and data acquisition electronics, and their commissioning without beam started. In the SASE2 tunnel XTD1, a massive steel structure was erected to rigidly support the XGM in its elevated position. High stability is required because the XGMs will provide beam position monitoring at 10 μm accuracy in addition to the absolutely calibrated pulse-to-pulse intensity measurement.

An extensive rare-gas supply system required for online diagnostic devices was built into all the photon tunnels by the company Dräger. In total, more than 5 km of pipes connect gas cabinets outside the tunnels with eight devices in different tunnels, providing each of them with four highly pure gases (krypton, argon, xenon, and nitrogen). Custom-tailored panels for gas selection were installed at each device.

The differential pumping stages (Figure 2), which will separate the XGM from the PES, were successfully tested at the HERA South labs: when injecting argon at 7×10^{-6} mbar at one end, its partial pressure at the other end was only 5×10^{-8} mbar, and when injecting xenon at 10^{-5} mbar at one end, the contamination on the other side was always lower than 10^{-11} mbar.

Invasive diagnostics

Further activities in 2016 included the high-resolution hard X-ray (HIREX) single-shot spectrometer, which comprises two main vacuum chambers. The HIREX spectrometer was built by the company AXILON and delivered to European XFEL in September, where the X-Ray Photon Diagnostics group tested it and equipped it with additional essential parts. Wolfgang Freund designed and installed its complicated beryllium window dome, and Naresh Kujala procured and installed the fragile diamond gratings and the fixed-radius bent silicon crystals. Finally, in December, the HIREX spectrometer was transported to its final location within the SASE1 branch in XTD9 (Figure 3).

Four diagnostic imagers were manufactured and delivered to European XFEL in 2016. At the end of the year, installation was finished in SASE1 and ongoing in XTD10. Eight of a total of 25 imagers are now installed.

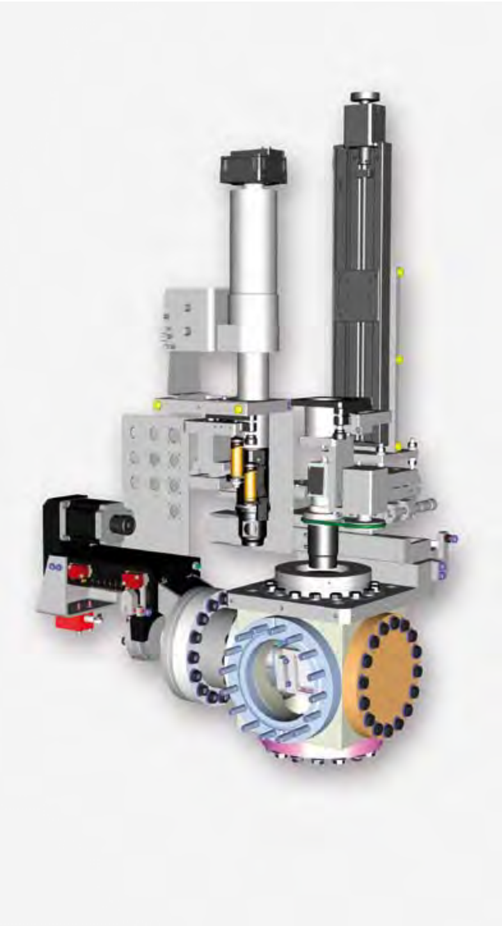


Figure 4 CAD model of the exit slit imager

Critical components of the imagers, regarding radiation hardness and time response, are scintillating screens. Cameras are critical for single-pulse detection. The group addressed these issues by collaborating with different companies and institutes: Applied Diamond in the USA for diamond screens, Fraunhofer IKTS in Germany for YAG screens, and LCLS for scintillating screen tests with the help of the European XFEL MID group. Group member Andreas Koch carried out high-speed camera tests with the support of the Optical Lasers group. The camera tests allowed the finalization of the design of the latest imager development, the exit slit imager (Figure 4). Two such imagers are now being fabricated at an external company. They will be placed in XTD10 in the focal plane of the SASE3 monochromator, allowing the alignment of the photon beam and the investigation of its spectral properties. These imagers have high-speed shutters based on multichannel plates (MCPs) that enable single X-ray pulses to be isolated out of the 4.5 MHz pulse train.

The group also completed and installed the *K* monochromator (Figure 5) and the MCP detector in SASE3. As of December 2016, technical commissioning and control system implementation are in progress.

PES, THz streaking, and diamond detectors

In May 2016, a paper [1] was published with important results from experiments at LCLS in 2015 where the PES was successfully used for the first time for X-ray FEL polarization control. Another related paper on machine learning for prediction of X-ray FEL pulse properties was submitted for publication.

In May, a paper was published with important results from experiments where the photoelectron spectrometer was successfully used for the first time for X-ray FEL polarization control.

Group member Jia Liu participated in THz streaking measurements during FLASH short-pulse operation and obtained encouraging results, measuring X-ray pulses down to 10 fs. He published a technical note on THz streaking–based pulse length measurement at the SQS instrument. In this report [2], efficient laser-based THz generation and characterization, temporal resolution of THz streaking, and corresponding requirements are demonstrated. Meanwhile, Liu tested laser-based THz generation using the pump–probe laser of the Optical Lasers group together with colleagues from several other European XFEL groups. They achieved promising THz output for diagnostic and future THz pump–probe experiments. A small cryostat for cooling the THz crystal has been designed and will be commissioned soon. Liu finalized the

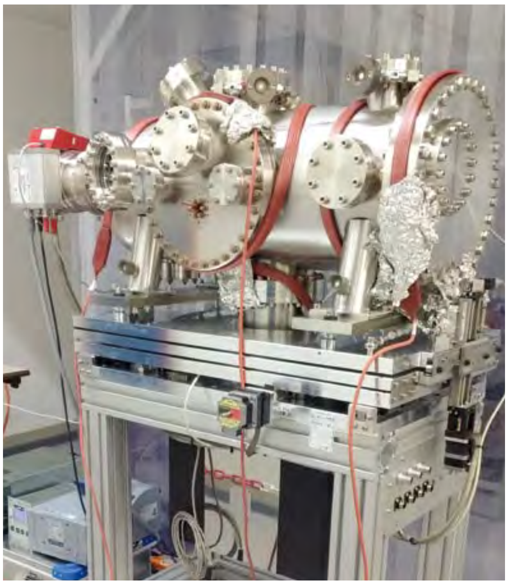


Figure 5 *K* monochromator for SASE3 ready for bake-out, a process that prepares the device for vacuum operation. It was installed in XTD10 in October 2016.

technical design of the photon arrival time monitor for the SPB/SFX instrument. Procurement of parts is ongoing.

Wolfgang Freund and Jan Grünert continued their development of diamond detectors. In collaboration with the MID group and external institutes, several prototypes with different electrode materials were studied at LCLS. Thomas Roth from MID is preparing the results for publication.

Outlook for 2017

Next year will be challenging for the X-Ray Photon Diagnostics group, with several milestones ahead. The completion of the SASE1 and SASE3 installations and their technical commissioning in the first quarter of the year will be followed by the installation of all the SASE2 systems in the second quarter. At the same time, the group will commission the SASE1 systems with photon beam and offer diagnostics support for the first lasing of the European XFEL. Later in the year, commissioning will follow in SASE3 and SASE2. Towards the end of 2017, the group will gradually move from construction and installation work to commissioning of the installed systems. These activities will continue in 2018 in parallel with the exploration of the machine parameter space until full performance is achieved. ■

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J. Liu
XFEL.EU TN-2015-002-01 (2016)

Group members
Jens Buck (until June 2016), Florian Dietrich, Torben Falk (not shown), Wolfgang Freund, Jan Grünert (group leader), Andreas Koch, Naresh Kujala, Joakim Laksman, Jia Liu, Sascha Lübbe (until October 2016, not shown), Marc Planas, Johannes Risch (not shown), and Sonay Sayar (not shown)

PHOTON SYSTEMS PROJECT OFFICE

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

Changes to the group

At the beginning of 2016, Mónica Aresté joined the group as project-planning assistant. Her task is to help plan and coordinate the electronics design, production, and installation as well as related cabling activities. Three student assistants spent a significant amount of time in the group, helping with photo documentation of project progress and with writing minutes. Two positions within the group that became vacant at the end of the year will have to be filled as quickly as possible in view of the current critical project phase.

Installation and commissioning in the photon tunnels

In 2016, component installations made further progress in the northern photon tunnels (XTD2, XTD4, XTD9, and XTD10). Installation work in the SASE1 beamline tunnels XTD2 and XTD9 is almost complete, with activities now focusing on the commissioning of the installed components. In November 2016, a 70 m long contiguous vacuum section was put into operation, including integration into the European XFEL control software framework Karabo. In December,

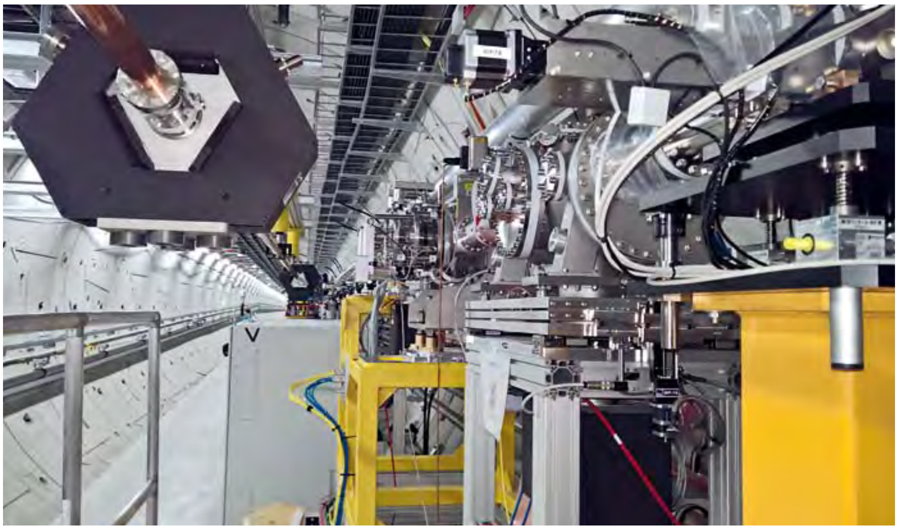


Figure 1 Electron beamline (left) and photon beamline (right) in the tunnel XTD2

the 35 SASE1 undulator segments installed in XTD2 were successfully closed for the first time to their nominal minimal gap of 10 mm. In the coming months, the rest of the installations will be put into operation so all the northern tunnels can be closed in spring 2017 in preparation for the first electron beam from the accelerator.

Infrastructure installations in the southern tunnels proceeded with some delays. At the end of the year, they were largely complete with some smaller activities still to be done. After power and air conditioning became available, the ambient humidity and temperature in the tunnels finally reached the specified values. Component installations started, albeit slowly, as resources were largely bound to activities in the northern tunnels and the accelerator tunnel. Installation in the photon tunnels picked up momentum in the last quarter of the year, when some of the resources bound in the accelerator tunnel were freed with the closing of this tunnel and the subsequent cooldown of the accelerator. As of December 2016, installation of the electron beamline along the SASE2 branch is roughly 75% complete, whereas most of the photon beamline still needs to be installed.

Planning of hutches and infrastructure in the experiment hall

In 2016, the PSPO group focused on planning and supervising the construction of hutches and their infrastructure in the experiment hall, as many activities had to be carried out simultaneously. Civil construction and infrastructure installation were completed in the SASE1 instrument area, while construction activities proceeded in the SASE2 and SASE3 areas. In the SASE3 area, these activities suffered a major setback when a challenge to a tender for air conditioning installation resulted in a six-month delay for these works. The delay affected other infrastructure installations due to the high level of integration.

Figure 2 Completed SASE1 hutches in the experiment hall

Based on the experience gained during SASE1 construction, the PSPO group decided to restructure the key milestones for the hutches and their infrastructure in such a way as to grant the instrument groups earlier access to their hutches, allowing construction work and instrument installation to go on in parallel to some degree. The goal is to recover some of the time lost during hutch construction. The SASE3 hutches are planned to be handed over to the instrument groups in summer 2017, the SASE2 hutches in spring 2018.

Electronics and cable planning

Activities relating to the integration of electronics, the cabling, and the corresponding commissioning with software are grouped in three lots: the first lot comprises all network-type cables together with electronics racks, the second lot all electronics crates for controlling and monitoring instrument components, and the third lot all cables connected to the control crates. The three lots are strongly interdependent and require a close collaboration of various groups within European XFEL as well as several external contractors and in-kind contributors.

Thanks to the strict adherence of all project partners to the standards set for externally provided models, the group was able to continuously maintain and upgrade the existing CAD model of the experiment hall, ensuring that it contains up-to-date information about all existing and planned installations.

Figure 3 Rack room of the FXE instrument

The first lot was successfully tendered for SASE1 and SASE3. In SASE1, the contractor completed the work. For SASE3, installation will start in early 2017. For SASE2, the documentation has been prepared, with tendering scheduled for early 2017. For the second lot, the engineering documentation is being done in house, while the production is being carried out as an in-kind contribution from NCBJ in Poland. As of December 2016, the engineering for all crates in SASE1 is finished and the crates have been produced and delivered. For SASE3, about one quarter of the engineering has been done and production has started. For SASE2, the instrument groups have delivered a good fraction of the required documentation but the work can only proceed when SASE3 is finished, which is currently expected in July 2017.

CAD integration

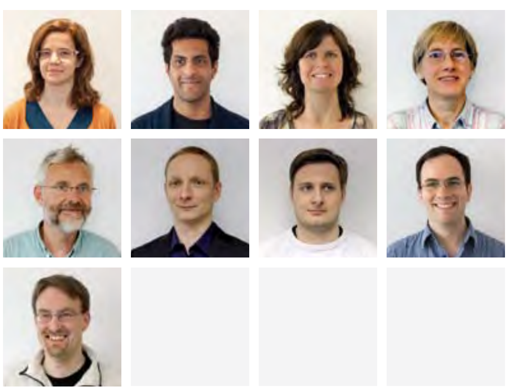
One of the tasks of the PSPO group is CAD integration, which helps assure the compatibility of all interfaces and forms the basis for identifying spatial conflicts of components within the facility. Thanks to the strict adherence of all project partners to the standards set for externally provided models, the PSPO group was able to continuously maintain and upgrade the existing CAD model of the experiment hall, ensuring that it contains up-to-date information about all existing and planned installations and that it can be used as the main reference for all installation activities.

Instrument installation planning

The PSPO group provides extensive support to the instrument groups with installation planning and has set up installation schedules for all six instruments and the lasers. These schedules properly account for all required resources. PSPO also maintains an infrastructure master schedule that accounts for civil construction and infrastructure installations. Progress of the instrument installation activities is monitored on a bi-weekly basis in coordination meetings, using excerpts from the master plan valid for a period of three months. These three-month views are compared to the actual progress and imminent activities, and the master plan is then updated wherever necessary. Thus, an up-to-date schedule is available at all times.

Risk management

Currently, the PSPO group is tracking several hundred risks in its risk catalogue. Two risk reports with the most salient entries were prepared in 2016 and submitted to the European XFEL Management Board, Administrative and Finance Committee (AFC), and Council. To reduce the administrative effort associated with risk management and maintenance and to involve more project members directly in the risk collection process, PSPO is currently investigating different software systems to support this activity.



Group members
Mónica Aresté, Lakshman Badami (intern from February until April), Uschi Conta, Sabine Cunis, Tobias Haas (group leader), Alexandru Ivanov (intern until February, not shown), Konrad Piórecki, Niko Saaristo, Adriano Violante, Gerd Wellenreuther, and Frederike Wittmaack (intern from July until October, temporary assistant from October, not shown)

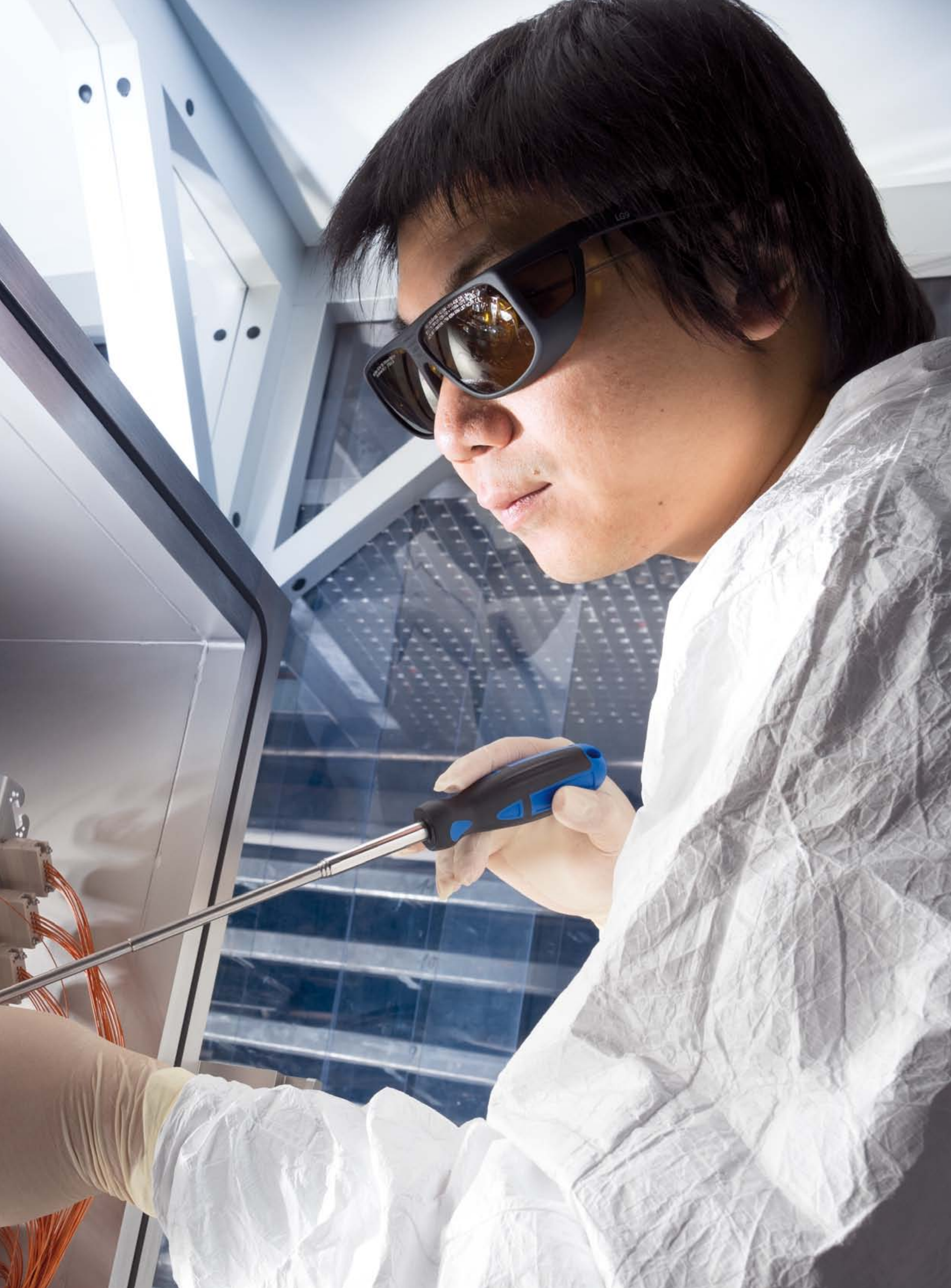
Outlook for 2017

The high level of installation activities reached in 2016 in the photon tunnels and in the experiment hall will be maintained for some time in 2017. The SASE1, SASE2, and SASE3 photon beamlines in the tunnels should be completed and the tunnels closed for operation with beam. In the experiment hall, construction of hutches and their infrastructure will be completed for the SASE2 and SASE3 areas. Some of these activities will extend into 2018. Instrument installation will proceed in parallel in all three areas. In addition, complex interdependent commissioning activities both with and without beam need to be coordinated and monitored. This rapid succession of involved activities will only subside towards the end of 2017, when both SASE1 and SASE3 should be in operation while SASE2 should be nearing completion. ■

06 SCIENTIFIC INSTRUMENTS AND EQUIPMENT

In 2016, installation of the first two instruments in the experiment hall began. Specialized components for the instruments were developed further, user laboratories were equipped, and the pump–probe optical laser system for the first two instruments was finalized.

Checking alignment of an X-ray splitter



SCIENTIFIC INSTRUMENT FXE

The Femtosecond X-Ray Experiments (FXE) instrument will enable ultrafast pump–probe experiments on extremely short time scales—100 fs and below—for a broad scientific community. While the first components have already been installed, the FXE group is completing the design of a few remaining components in research campaigns using laboratory laser sources, synchrotron storage rings, and X-ray FEL sources. In addition, the group is engaged in a related research programme, primarily about understanding correlated electronic and structural dynamics occurring during photochemical reactions.

Progress in 2016

In 2016, most of the FXE instrument components were installed in the optical branch of the experiment hutch, including the high-power slit system, solid attenuators, beam imaging units, beryllium compound refractive lenses (CRLs), and others (Figure 1). Installations also included several vacuum components, as this section of the FXE instrument requires ultrahigh-vacuum conditions. The first vacuum section was closed and pumped down to the specified pressure in December 2016. In addition, the robot arm designed to hold the X-ray emission detector was mounted beneath the robot tower. Installation of the complete instrument cabling, including detector cables, data acquisition and timing cables, and stepper motor control cables, started in 2016 and was nearly completed by the end of the year.

The cables are connected to numerous electrical racks located inside a dedicated FXE rack hutch, which was built above the FXE experiment hutch. The motor control drivers and other electronic components are required to remotely operate the devices and detectors inside the experiment hutch. At the end of 2016, the electronic crates containing the motor drivers were about to be completed, and two-thirds of all the cables from the upstairs rack room to the downstairs experiment hutch had been routed, with the remainder due to be finished in early 2017. The remaining FXE infrastructure—the control room and laser hutch—also made very good progress, with installation scheduled to be completed at the beginning of 2017.

Changes to the group

Engineer Timo Korsch and technician Paul Frankenberger, formerly members of the Vacuum group, joined the FXE group in 2016 to enable the technical commissioning of the instrument. Together with Lewis Batchelor from the Central Instruments Engineering group, they cabled the CRL assembly for collimating the divergent X-ray beam in

Figure 1 Optical branch of the FXE instrument, consisting of the high-power slit system, solid attenuators, beam imaging units, and beryllium CRLs (from right to left along the direction of the beam). The orange robot arm that will hold the detector can be seen in the back (far left).

the XTD2 tunnel. Guest Ph.D. student Mads Laursen from the group of Martin Meedom Nielsen at DTU in Denmark started to integrate the FXE robot into Karabo. In addition, Peter Zalden, formerly a guest scientist in the group, became an FXE staff member in 2016, with a particular focus on solid-state science at the FXE instrument. He is also responsible for THz activities at the European XFEL. Frederico Alves Lima, who was hired from LNLS in Brazil, brings expertise required to commission the FXE instrument in a timely fashion, as well as know-how in bio-inspired molecular systems and resonant diffraction experiments. In December 2016, Ph.D. student Tadesse Abebaw Assefa passed his final exam at UHH by defending his thesis on “Tracking Chemical Reactions with Ultrafast X-ray Spectroscopic Techniques”, becoming the first Ph.D. graduate at European XFEL. The group congratulates him on this success (Figure 2).

In 2016, most of the FXE instrument components were installed in the optical branch of the experiment hutch.

Research activities

As in previous years, the FXE group carried out experiments at various synchrotron and X-ray FEL sources, participating for example in an experiment at LCLS, led by DTU, on the atomistic characterization of the active-site solvation dynamics of a model photocatalyst [1]. The results provide a key step towards understanding the dynamics involved in artificial photosynthesis. Further publications include the in-house development of a MHz-compatible data acquisition scheme [2].

Figure 2 Tadesse Abebaw Assefa, the first European XFEL Ph.D. graduate.
Left Scientific Director Thomas Tschentscher congratulates Assefa after his final Ph.D. exam.
Right Assefa preparing an experiment at PETRA III.

In April 2016, Sebastian Schulz, Andreas Galler, and Ph.D. student Michael Diez teamed up with colleagues at LCLS to measure the relative arrival time of femtosecond hard X-ray and optical laser pulses with few-femtosecond precision using a fast-flowing liquid sample. Such high-precision measurements are crucial for timing ultrafast experiments at the FXE instrument at MHz repetition rates. The results underline the success of the European Cluster of Advanced Laser Light Sources (EUCALL) project, for which Schulz provides important input.

Workshops

During the annual DESY Photon Science and European XFEL Users' Meeting in January 2016, the FXE group organized a joint PETRA III and European XFEL workshop entitled "From Picoseconds to Femtosecond X-Ray Experiments". The discussion about user needs for time-resolved X-ray studies at the different Hamburg light sources (PETRA III, FLASH, European XFEL, and lab-based X-ray tools) in combination with suitable laser laboratory infrastructure for preparing such studies triggered new ideas on how to further improve the available X-ray sources for a broader user community.

On 1–2 December, the FXE group organized another workshop for prospective users, which focused on the specific FXE operation conditions expected for early user experiments in September 2017. It addressed potential users intending to submit a proposal for an early user experiment at the FXE instrument in one of the first calls for proposals in 2017. The meeting provided opportunities for discussion and encouraged the creation of collaborations for the experiments.

Teaching and educational activities

During the summer semester 2016, Andreas Galler and Christian Bressler taught the course “Light–Matter Interactions: Atoms, Molecules, and (Non)Linear Optics” at UHH, with the support of guest lecturers Michael Meyer of the SQS and Ulf Zastrau of the HED instrument group. Bressler also received support from Zastrau for his lecture “How to read, understand and assess the quality of experimental publications”. Altogether, the FXE group members are very active on the Hamburg research scene: Dmitry Khakhulin, Sebastian Schulz, and Peter Zalden are associate members of CUI with Ph.D. students Christina Bömer, Alexander Britz, and Michael Diez, while Andreas Galler and Wojciech Gawelda are principal investigators at the IMPRS-UFAST graduate school.

Outlook for 2017

In 2017, the FXE group will complete the hardware installation and technical commissioning in the experiment hall, commission the instrument with the first X-ray beam, and prepare everything for early user operation in September 2017. The group will resume teaching activities at UHH during the summer semester in cooperation with the HED, SCS, and SQS groups. Experimental campaigns at APS, ESRF, HZDR, PETRA III, and SACLA will be carried out, besides completing the long-term FXE proposal at PETRA III on X-ray parametric down-conversion.

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

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J. Synch. Rad. **23**, 1409–1423 (2016)

SCIENTIFIC INSTRUMENT HED

The High Energy Density Science (HED) group designs, installs, and operates the HED scientific instrument—a unique platform combining hard X-ray FEL radiation with the capability to generate extreme states of matter. In 2016, the HED group finalized the mechanical and electrical design of the beamline components while supervising the construction activities.

Progress in 2016

In 2016, the HED group received beamline components and refined control requirements for the instrument. As of December 2016, the main vacuum chamber is almost ready, and contracts have been signed for the baseline X-ray detectors. Together with the Helmholtz International Beamline for Extreme Fields at the European XFEL (HIBEF) user consortium, the group has been defining the high-power lasers and approaching the user community for the design of novel experiments.

Changes to the group and the HIBEF user consortium

In 2016, several members joined HED: Zuzana Konôpková enhances the group's expertise in high-pressure science, Konstantin Sukharnikov contributes electrical engineering skills, and technician Thomas Feldmann runs the group's lab and assembles beamline components. Also joining were Humboldt Return Fellow Philipp Sperling and guest Wolfgang Morgenroth, who works through a BMBF project with the University of Frankfurt am Main in Germany. Toma Toncian joined the HIBEF user consortium as leading laser scientist.

Infrastructure, interaction chamber, and controls

Group member Andreas Schmidt supervised the HED and MID instrument planning. He identified the need for important modifications and integrated them into the instrument layout. By the end of 2016, all hutches except the HED laser bay were built. The contract for building the Interaction Chamber 1 (IC1), HED's primary vacuum vessel, was awarded to the company Toyama in Japan. Ian Thorpe verified the quality of the electron beam–welded aluminium vessel at a factory acceptance test in Japan (Figure 1). Sukharnikov gathered all necessary information about cameras, controllers, and motors in order to plan cables and racks, and ordered stages and positioning hexapods. The HED group received microscopes for target inspection and met with the Sample Environment group to design a sample changer. Feldmann and Schmidt started to equip the HED lab,

Figure 1 IC1 vacuum chamber during the factory acceptance test at Toyama in Japan

where the first delivered components for the HED beamline are stored, with infrastructure and tools.

X-ray beam transport, baseline detectors, lasers, and user workshops

Karen Appel coordinated the planning of the X-ray beam transport from the SASE2 undulators to the experiment area, including finalizing the design of the components in the photon tunnel, in the optics hutch, and in the experiment area. Thorpe designed the mechanical beamline components in the experiment hall. Both worked with guest scientist Bolun Chen of CAEP in China on the final design of the single-shot spectrometer, which is, as of December 2016, under construction in China. The vacuum vessel for the split and delay line, which is contributed by the University of Münster in Germany through a BMBF project, was installed in the tunnel. For the design of the beam dump and an X-ray window, Konôpková simulated the damage threshold of diamond in the X-ray beam. The group signed a contract with SLAC for ePIX X-ray detectors and obtained approval to purchase JUNGFRAU X-ray detectors from PSI in 2017.

Motoaki Nakatsutsumi finalized the layout of the pump–probe laser beam transport to IC1 in close cooperation with the Optical Lasers group. This includes the design of the photon arrival monitor and the beam cross-correlator that will be used to cross-correlate this laser with both the X-ray beam and the 100 TW short-pulse laser. Together with Gerd Priebe of the Optical Lasers group and Toma Toncian of HIBEF, he defined the specifications for two high-power lasers.

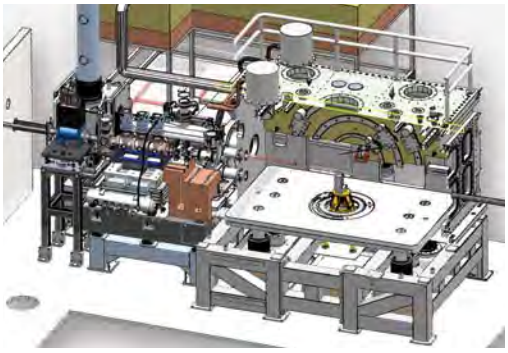

Figure 2 CAD representation of the primary HED interaction area. The X-ray beam enters from the left and passes through the X-ray and optical beam transport before entering IC1, the front wall of which is removed for a better view.

The contract for the 100 TW–class short-pulse laser was awarded to Amplitude Systemes in France. The design of the laser beam transport to the experiment area was finalized (Figure 2). Following an on-site visit of HIBEF and European XFEL scientists to STFC in the UK, final adjustments to the layout of the DiPOLE 100-X laser, a 100 J all-diode-pumped few-nanosecond laser, are being worked out.

The HED group and the HIBEF user consortium organized two user workshops to discuss concepts for experiments with diamond anvil cells (in January 2016 at DESY) and dynamic laser compression (in September 2016 at European XFEL). Two related conceptual design reports were written and will be published in early 2017. Konôpková prepared the integration of related HIBEF contributions such as the target delivery, the DiPOLE 100-X laser beam focusing, the diamond anvil cell setup, and a velocity interferometer system for any reflector (VISAR).

Conferences, research, and publications

In 2016, group members were involved in seven experiments (four as principal investigators) at LCLS, in one each at FLASH and SACLA, as well as in experiments at high-power laser facilities (Janus at LLNL and DRACO at HZDR) and at synchrotrons (PETRA III). The experiments focused on high-pressure mineralogy, X-ray scattering from laser-compressed matter, proton acceleration and instabilities in laser-irradiated cryogenic hydrogen, and optical properties of XUV-heated water.

Within the network of the international HED community, group members analysed data, drafted the results, and published several articles. In particular, Nakatsutsumi and others published a case study on femtosecond laser-generated HED states and how X-ray FELs can shed light on their spatio-temporal evolution [1]. Ulf Zastrau and others published a letter on the first spatially resolved X-ray scattering experiment on laser shock-compressed matter to be performed at an X-ray FEL [2]. Both publications address pioneering techniques that will improve the performance of the HED instrument.

Third-party funding and teaching

Together with external colleagues, Appel and Konôpková successfully applied to Deutsche Forschungsgemeinschaft (DFG) for funding of a research unit focusing on high-pressure Earth sciences. Sebastian Göde launched a development collaboration with HZDR for cryogenic jets experiments at high repetition rate. Zastrau co-lectured two courses at UHH and became a principal investigator in the IMPRS-UFAST graduate school. Nakatsutsumi prolonged his appointment with

Osaka University in Japan. Ph.D. student Nicole Biedermann performed experiments at PETRA III and received a conference poster award.

Outlook for 2017

In spring 2017, IC1 and the laser beam transport will be installed. In summer, all X-ray beamline components are expected to be installed after initial assembly in the HED lab. The first X-ray detectors will be delivered and tested. The University of Münster will provide the split and delay line required in the X-ray beam transport tunnel. In fall and winter, the HED group will commission the fully completed instrument without X-rays, depending on the timely delivery of the control racks.

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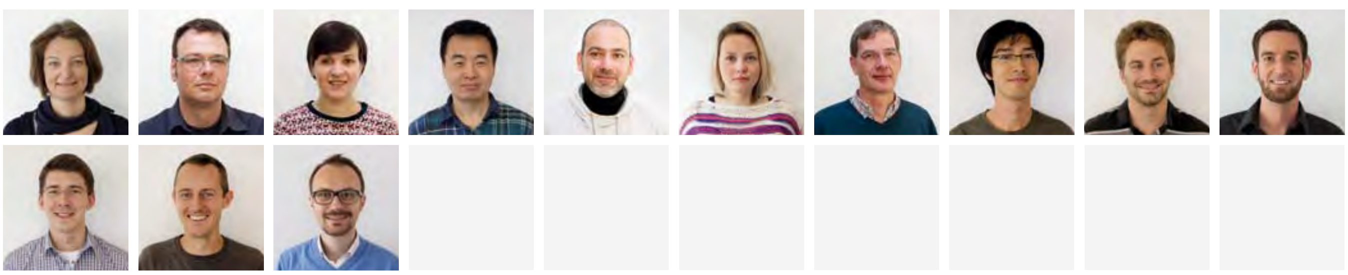


Group members
Karen Appel, Carsten Baehtz (guest, HIBEF coordinator), Nicole Biedermann (Ph.D. student, jointly with University of Potsdam), Bolun Chen (guest), Thomas Feldmann, Sebastian Göde (not shown), Zuzana Konôpková, Emma McBride (postdoc at LCLS, not shown), Wolfgang Morgenroth (guest), Motoaki Nakatsutsumi, Alexander Pelka (guest, HIBEF), Andreas Schmidt (jointly with MID), Philipp Sperling (not shown), Konstantin Sukharnikov, Ian Thorpe, and Ulf Zastrau (group leader)

SCIENTIFIC INSTRUMENT MID

The Materials Imaging and Dynamics (MID) group is responsible for building one of the scientific instruments of the European XFEL. The MID instrument will enable studies of structure and dynamics in condensed matter by means of X-ray scattering and imaging experiments on the nanoscale. Further areas of application are materials science and nanomaterials. In 2016, the group received and tested the first instrument components to be installed in the experiment hall. All major components are scheduled to arrive in 2017.

Progress in 2016

In 2016, the MID group worked with manufacturers and vendors to ensure that the stringent quality and arrival time requirements of all instrument components could be met. The group continued to build up laboratories and testing infrastructure in the HERA South hall and received the first components for technical commissioning. The group was also involved in several experiments at LCLS, ESRF, and PETRA III.

The MID group in 2016

A new scientist, Alexey Zozulya, joined the MID group in 2016. He will further strengthen the group's competence in beamline operation and X-ray optics. Furthermore, Alexander Bartmann joined the group as a vacuum technician. Mario Reiser started as a Ph.D. student in the framework of a collaboration with Christian Gutt from the University of Siegen in Germany to study the dynamics of condensed matter by advanced analysis of weak speckle patterns. Birthe Kist continues as a master student in the group, collaborating with Patrick Huber from TUHH with the aim of investigating the condensation and crystallization of gases in confinement at low temperatures.

The group continued to build up laboratories and testing infrastructure and received the first components for technical commissioning.

Instrument construction and testing

As of December 2016, a cryocooled double mirror system for the experiment hutch is being assembled at the vendor's site. The mirrors are polished deterministically to correct for gravitational sag, taking the special three-point support in the neutral plane into account, with the aim of getting a perfectly flat surface when mounted.

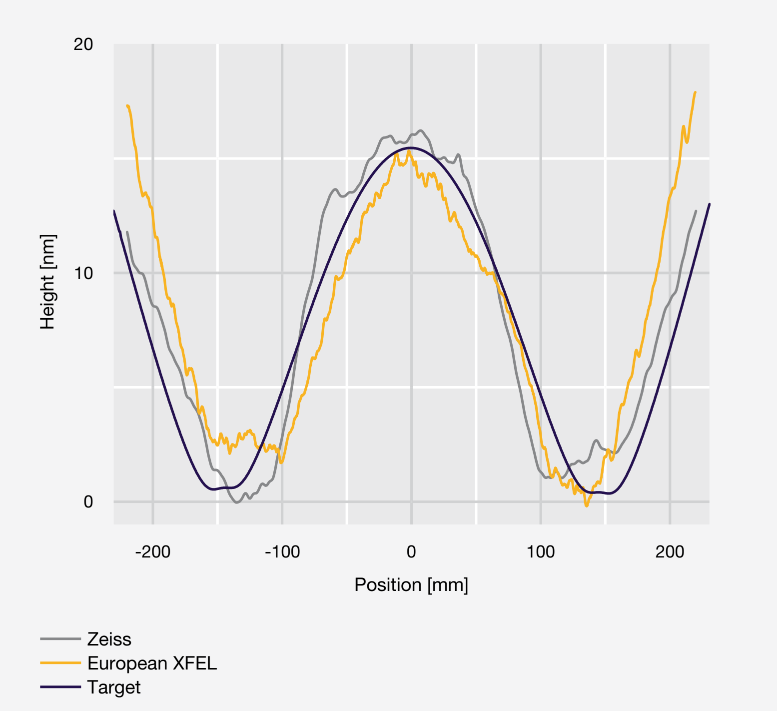
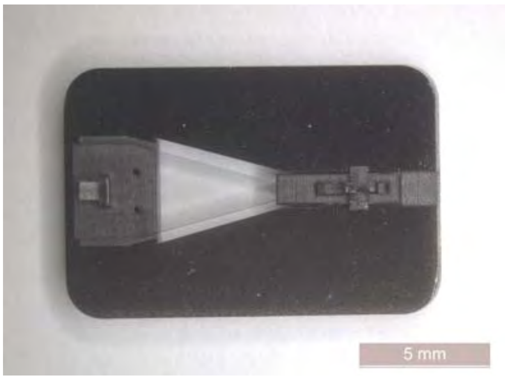


Figure 1 Average height variation over the 500 mm long silicon mirror. The “Target” curve indicates the shape required to compensate for the deformation the mirror will experience in the kinematic mount. The “Zeiss” and “European XFEL” measurements were obtained by laser interferometry.

The mirror profiles were measured in the European XFEL metrology laboratory with nanometre precision by Maurizio Vannoni and Idoja Freijo Martín of the X-Ray Optics group using a Fizeau interferometer in side-facing geometry (Figure 1). The difference between the required profile and the measured one is small enough to avoid any distortions of the X-ray beam reflecting off the mirror.

The differential pumping section, which is intended to separate the ultrahigh vacuum in the X-ray optics section from the less good vacuum conditions around the sample and further downstream, arrived at European XFEL in 2016 and underwent substantial testing of both vacuum and mechanics. It was the first item to be inspected for site acceptance tests and the MID group gained a lot of experience in the process, also because the MID cleanroom and laboratory facilities in the HERA South hall had to be upgraded accordingly. These facilities will be transferred to the new MID laboratories in the European XFEL headquarters building (XHQ) in 2017.

As of December 2016, the large X-ray Scattering and Imaging Setup (XSIS) is being manufactured at the vendor’s site. It comprises a large multipurpose sample chamber in which the interaction region will be located. XSIS also features a 10 m long detector arm that will host the Adaptive Gain Integrating Pixel Detector (AGIPD), an area detector specially developed for European XFEL, offering the possibility of acquiring image frames with one million pixels at 4.5 MHz repetition rate. The MID group plans to begin installation of XSIS in the experiment hutch in mid-2017 and get the setup operational before the end of the year.



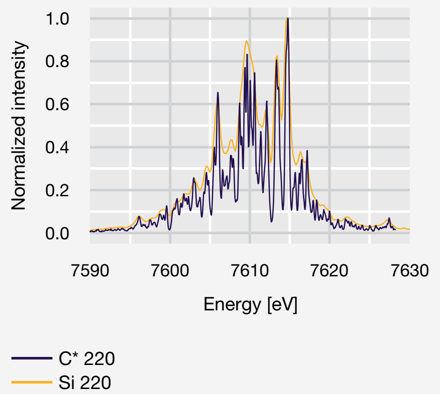


Figure 2 Testing a new dispersive spectrometer based on curved diamond crystals [1].
Top Photograph of a triangular diamond crystal mounted inside the mechanical bender.
Bottom Photon energy spectrum of a single LCLS pulse measured with the diamond bender (C* 220 reflection) and with a bent silicon (Si 220) crystal. Thanks to the minimum beam absorption by the thin diamond, a silicon spectrometer can be positioned downstream, allowing the spectrum of the exact same pulse to be measured with the two different crystals. Obviously, the resolution of the diamond spectrometer is much superior.

Research and development

In 2016, the MID group tested a novel dispersive spectrometer based on curved diamond crystals [1]. It allows high-resolution spectral characterization of every X-ray pulse, as the group demonstrated in a successful experiment at LCLS (Figure 2). Use of diamond optics whenever possible will be essential at the European XFEL due to the risk of ablation, but also due to the high repetition rate of pulses resulting in severe heat load on all optical components. To this end, the MID group, together with the X-Ray Optics group and the materials research facility FSBI TISNCM in Russia, initiated work on thin, semi-transparent, bent diamond crystals, which are grown with unprecedented crystalline quality and size at FSBI TISNCM. The group intends to incorporate spectrometers of this type into the MID instrument and use them during early beam commissioning.

The MID group, along with the X-Ray Photon Diagnostics group, the University of Augsburg in Germany, and others, also developed diamond-based transmission detectors that allow the photon flux to be measured for every pulse at a rate of 4.5 MHz without stopping the beam. Several of the new devices were tested at LCLS. Particularly, a device based on a thin diamond sensor (with over 90% transmission at 8 keV) and thin beryllium electrodes has shown good results and will be further developed and used at the MID instrument for non-invasive beam diagnostics.

Furthermore, the MID group participated in an investigation of the possibilities for implementing a high-resolution inelastic X-ray scattering (IXS) instrument at the European XFEL [2]. Because of the large number of pulses per second at the European XFEL, average-flux-limited techniques such as IXS become interesting to implement at X-ray FEL sources. The study found that potentially three orders of magnitude in flux density can be gained with a high-resolution IXS setup at European XFEL compared to APS or ESRF, and a possible design of both monochromator and spectrograph was outlined.

In 2016, the group tested a novel dispersive spectrometer based on curved diamond crystals. It allows high-resolution spectral characterization of every X-ray pulse.

Outlook for 2017

The MID group will continue to work together with manufacturers and receive and test instrument components in 2017. In parallel, the installation and integration of components in the experiment hall will begin as the hutches are handed over, which is currently planned for May 2017. The group's new XHQ laboratories will be inaugurated and the MID facilities in the HERA South hall shut down. The successful R&D programme will continue with experiments at X-ray sources around the world.

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SCIENTIFIC INSTRUMENT SCS

The Spectroscopy and Coherent Scattering (SCS) instrument will enable time-resolved X-ray scattering experiments to unravel the electronic and structural properties of condensed-matter systems in the smallest space–time dimensions. In 2016, the SCS group nearly completed the construction of the key instrument components and continued to test the instrumentation in the assembly lab. For the new laboratories in the headquarters building in Schenefeld, the SCS group procured a high-repetition-rate laser system providing a platform for in-house research and instrument development.

Progress in 2016

In 2016, the SCS group nearly completed the construction of SCS beamline components, and testing and debugging of device components advanced in the SCS assembly lab in the HERA South hall. The SASE3 hutch construction and infrastructure installation work in the experiment hall continued. As of December 2016, first instrument components are ready for installation in mid-2017, when it will be possible to move sensitive equipment into the SASE3 hutches. In preparation for instrument installation, floor anchors were placed and the experiment floor was made ready for the grouting of instrument supports.

Changes to the group

Mechanical engineer Alexander Sorin joined the group in 2016 to complement the SCS engineering skills, focusing on the mechanical integration of the FastCCD array detector. Student assistant Hazem Bamaga, a bachelor student in information engineering, supports the group with the assembly and cabling of device components. Laurent Mercadier, an experienced laser scientist and user of X-ray FEL facilities, teamed up with group member Robert Carley to work on the optical laser delivery and timing diagnostics of the SCS instrument.

Experiment stations and spectrometer

The forward-scattering fixed-target (FFT) experiment station was contracted to the company Toyama in Japan in spring 2016 (Figure 1) and will be delivered in March 2017. After installation at the SCS beamline, it will be equipped with sample environment, diagnostics, and detectors to enable X-ray absorption spectroscopy, small-angle X-ray scattering, and coherent diffractive imaging studies of condensed matter. The sample environment of the FFT experiment station

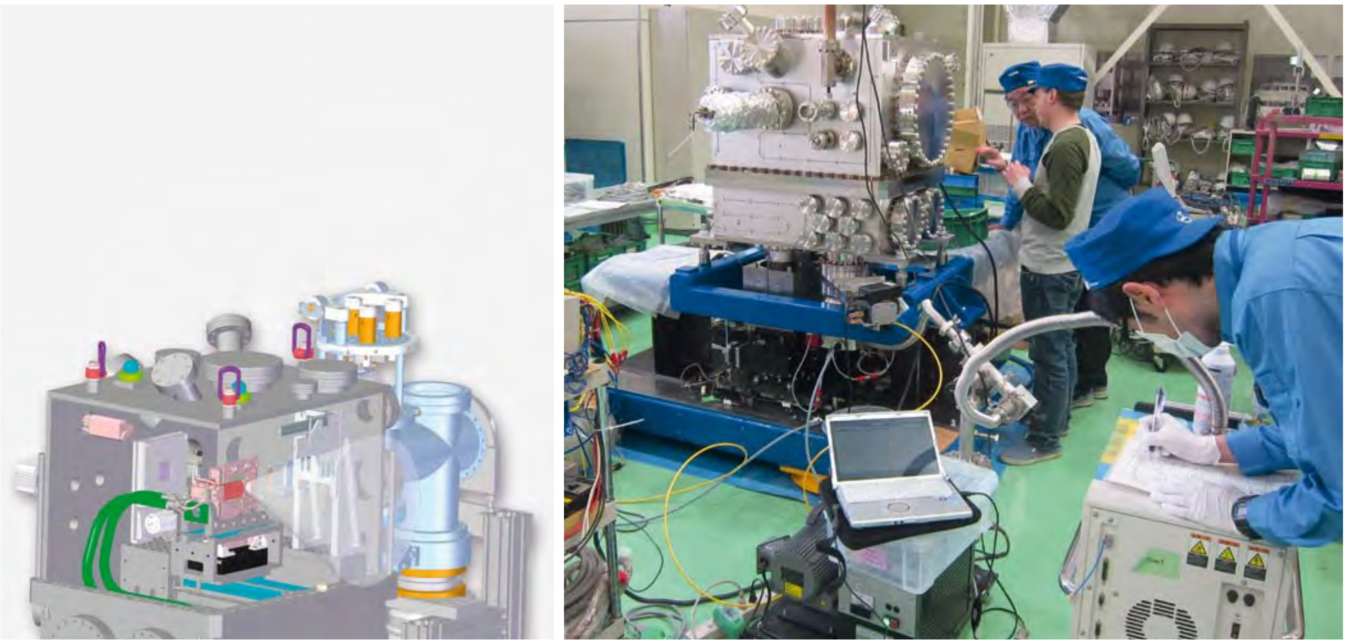

Figure 1 FFT experiment station.
Left CAD view of the sample environment and the X-ray scattering geometry.
Right Assembly and testing of the experiment station at the Toyama factory in Japan.

includes—but is not limited to—a fast sample scanner, a magnetic field, and an optical laser delivery system. THz beams and cryogenic sample temperatures will be provided in the next step.

In 2016, the Heisenberg Resonant Inelastic X-Ray Scattering (h-RIXS) user consortium completed the optics design of the h-RIXS spectrometer. The substrates for the spectrometer optics were ordered in November 2016, with the procurement of the two grating structures of 3000 lines/mm and 1000 lines/mm due to follow soon afterwards. The mechanical design and construction of the spectrometer will be outsourced to an external company after the specifications have been finalized. Installation of the device at the SCS beamline is planned for summer 2018. The capabilities at the SCS beamline allow for a continuous change of the scattering angle of the spectrometer during the experiments ($60° < 2\theta < 150°$), enabling studies of elementary excitations of condensed matter in the energy and momentum domain.

The continuous change in scattering angle is made possible by the high-precision floor in the SCS experiment hutch, which was installed in 2015 and allows very precise movements of heavy instrumentation floating on air cushions, as well as by the special capabilities of the X-ray resonant diffraction (XRD) baseline chamber, which will be endowed with a continuous-rotation flange. As of December 2016, the XRD chamber is under construction. It will be installed at the beamline in 2018 as the second SCS baseline experiment station.

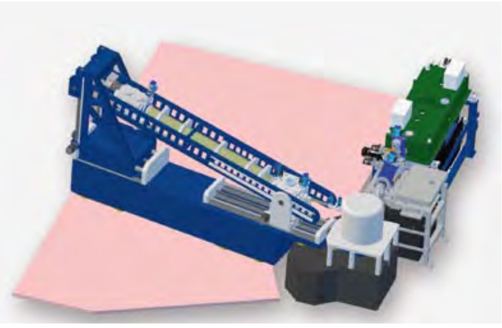

Figure 2 CAD model of the XRD chamber and the hRIXS spectrometer on the high-precision floor at the SCS instrument beamline

Research activities

For the new SCS laser laboratory in Schenefeld, which became available at the end of 2016, the group procured a highly reliable, stable, turn-key, high-repetition-rate femtosecond laser system to act as a platform on which a number of non-linear optical apparatuses can be built starting in March 2017. The laboratory will be used for femtosecond spectroscopy studies of materials, for in-house scientific research, and for further development of the main SCS instrument capabilities, such as THz generation and delivery.

Among the research activities of the group, Alexander Yaroslavtsev led a series of experimental campaigns at the BESSY II, ESRF, and SOLEIL synchrotron radiation facilities aiming to use angle-resolved photoemission spectroscopy and X-ray magnetic circular dichroism to more deeply investigate the electronic structure and magnetic properties of rare-earth transition metal pnictides of the form $RECo_2X_2$ (RE = rare-earth; X = P, As). These quasi two-dimensional materials, which are isostructural to the well-known ferropnictide high-temperature superconductors, provide a great opportunity to study the relationship between various electronic and magnetic properties and the strength of electron correlations. The subject of the studies was defined together with the group of Michael Shatruk from Florida State University in the USA, who also prepared the samples for the experiments. In a second step, the project aims at laser-induced transient doping of the system to control the magnetic state, which will be investigated by means of time-resolved optical reflectivity and X-ray absorption experiments in the laser laboratory and at the SCS instrument, respectively.

Publications

The SCS group published several articles in 2016, among them a photoelectron microscopy study of the surface electronic and spin properties of $LaCoO_3$ across the semiconductor-to-metal transition [1]. The second study was an experimental demonstration of the collective response of atoms to a resonantly tuned X-ray driving field leading to an earlier onset of non-linear light–matter interaction in condensed-matter systems compared to the single-atom response in the gas phase [2].

Outlook for 2017

In 2017, the SCS instrument hutch construction and infrastructure installation will continue in the experiment hall. The instrument components will be transferred to Schenefeld and installed in the experiment hutch when the major work of hutch infrastructure installation will be complete in mid-2017. While awaiting the start of instrument installation, the SCS group will further test equipment and advance the design, procurement, and assembly of instrument components foreseen for the second phase of instrument operation.

The SCS group will continue its in-house research and participate in several experimental campaigns at other facilities together with international collaborators. Under the direction of Justine Schlappa, the group will perform experiments at FERMI to explore opportunities for three-wave mixing studies between X-ray and optical frequencies on complex materials. The study will focus on the model material NiO, which is well characterized in both frequency domains. The experiments, which match the scientific profile of the SCS instrument on non-linear studies, will be performed in collaboration with the group of Giacomo Ghiringhelli from Politecnico di Milano in Italy.

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doi:10.1103/PhysRevLett.117.027401

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SCIENTIFIC INSTRUMENT SPB/SFX

The Single Particles, Clusters, and Biomolecules and Serial Femtosecond Crystallography (SPB/SFX) group is responsible for building a scientific instrument for structural investigations of crystalline and non-crystalline matter, in particular biological molecules. Major achievements in 2016 include the installation of key instrument components in the XTD9 tunnel, factory acceptance and on-site tests of much of the SPB/SFX instrumentation, as well as continued research and publications on instrumentation and imaging.

Summary of 2016

The first users are expected to arrive at the European XFEL in autumn 2017, and many of them will perform experiments at the SPB/SFX instrument. In preparation, the group completed the construction of most of the instrumentation for SPB/SFX and commenced installation—particularly of components in the XTD9 tunnel upstream of the hutches. At the end of 2016, an early users' workshop was held to communicate the possibilities for day-one experiments at SPB/SFX and foster collaboration in accessing the limited beamtime available in 2017. In parallel, the group continued its scientific activities, exploring the limits of single-particle imaging (SPI), performing experimental single-shot wavefront measurements, and advancing the simulation of complete photon-based experiments.

Expanding the group

To prepare for early experiments and user support in 2017, the SPB/SFX group was further expanded in 2016. Five scientists with a strong background in SPB/SFX-relevant fields joined the group: Marjan Hadian-Jazi, Grant Mills, Adam Round, Marcin Sikorski, and Britta Weinhausen. The mechanical technicians Felix Lemcke and Andrew Stawniczy strengthened the group's technical and engineering support, and Bradley Manning joined as the group's control engineer. A number of these new staff members are supported by financial contributions of the SFX user consortium.

Commencing installation

The mirror optical focusing systems are core components of the SPB/SFX instrument [1], providing not only the highest transmission but also the neatest focus possible across the envisaged photon energies. As of December 2016, two systems—designed in collaboration with

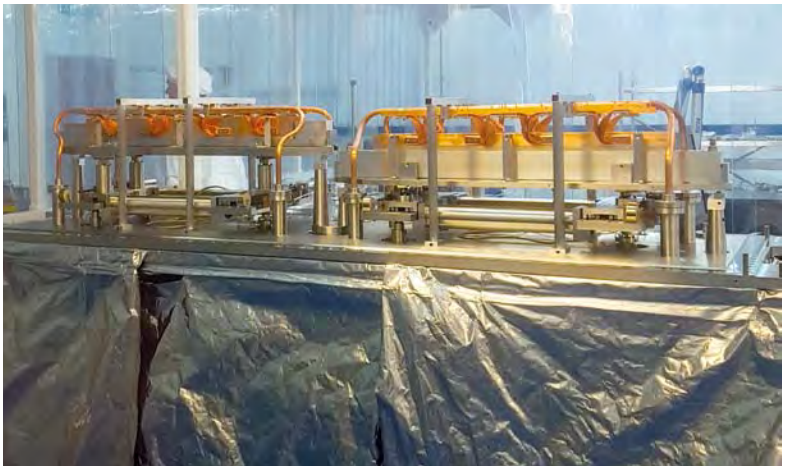

Figure 1 Mechanical support structure and cooling system for the SPB/SFX micrometre-scale mirror, photographed without vacuum chamber lid in the cleanroom of the manufacturer, FMB Oxford in the UK

the X-Ray Optics group to produce both a micrometre-scale and a 100 nm–scale focal spot across a photon energy range of 3 to 16 keV—are predominantly manufactured and in delivery. The systems consist of two major subsystems: the mechanics, cooling, and vacuum systems for the 1 m long mirrors and the super-polished mirrors themselves. The majority of the mirrors are being shipped to European XFEL, and all the mechanics are scheduled for delivery in January 2017 (Figure 1).

In preparation for users, the group completed the construction of most of the instrumentation for SPB/SFX and commenced installation.

However, the mirrors are expected to still be in metrology and coating phases when the X-ray FEL will start up. Therefore, an alternative focusing system based on compound refractive lenses was installed in XTD9 in 2016, including all the necessary lenses for focusing the day-one beam to a focal spot size of about 2.5 μm. Many other components were installed in XTD9 as well, including a pulse picker, which will allow the selection of a single train of X-ray FEL radiation.

The other major components of the instrument are the sample environment, the detection system, and their support structure. As of December 2016, the component support structure is in quality control and due for delivery in early 2017. The sample environment, which is a modular design accommodating a variety of methods of delivering sample into the beam, has largely been designed in collaboration with the Sample Environment group and ordered, with many components already in house or scheduled to arrive in

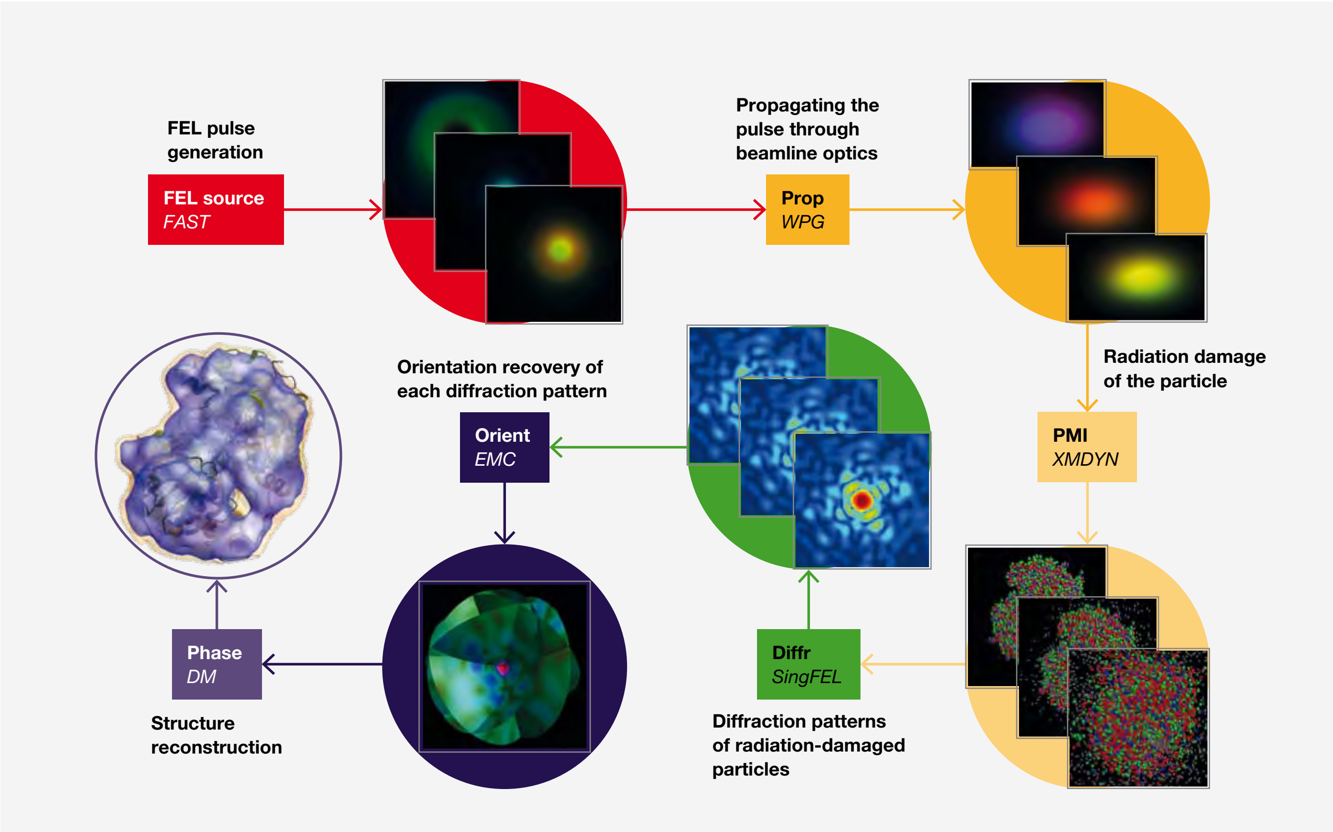

Figure 2 Flow diagram of the source-to-experiment simulation (simS2E) pipeline, from X-ray FEL pulse generation to electron density reconstruction. The **FEL source** module simulates the electron bunch that exits the undulators. The simulated electron bunch is then propagated through the beamline optics to the interaction point using the **Prop** module. The **PMI** module models the radiation damage of the protein sample when irradiated by the simulated laser pulse. The **Diffr** module simulates the time-averaged diffraction pattern of the radiation-damaged protein. The **Orient** module recovers the orientation of the individual diffraction patterns, and the **Phase** module solves the phase problem in order to recover the electron density. Figure first published in [2], where the individual software acronyms are also defined.

early 2017. The detector—the first 1 Mpx Adaptive Gain Integrating Pixel Detector (AGIPD) for the European XFEL—arrived at the laboratory of the Detector Development group on 21 December.

To communicate these capabilities and more, an early users' workshop was held on 28–29 November. About 100 participants from around the world were informed of the likely configuration of the instrument for early user experiments, the process to apply for beamtime, and how to form collaborations around experiment directions possible for day one.

Exploring single-particle imaging in simulation and experiment

In 2016, the group published a comprehensive simulation tool for SPI experiments (Figure 2) [2]. Group member Carsten Fortmann-Grote and collaborators are expanding this tool within the European Cluster

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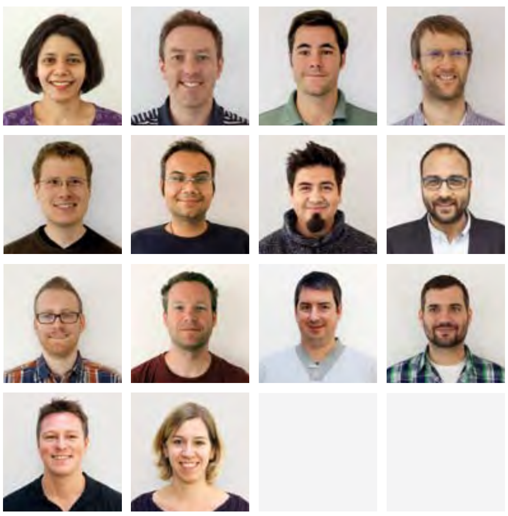

Group members
Zunaira Ansari (supported by SFX project, Wellcome Trust UK), Richard Bean, Gannon Borchers (until November 2016), Carsten Fortmann-Grote (supported by EUCALL project), Klaus Giewekemeyer, Marjan Hadian-Jazi (supported by SFX project, La Trobe University, Australia, not shown), Oliver Kelsey (not shown), Felix Lemcke (not shown), Masoud Mehrjoo (student, supported by CUI), Luis López Morillo (supported by SFX project, Wellcome Trust UK), Adrian Mancuso (group leader), Bradley Manning (supported by SFX project, Wellcome Trust UK), Marc Messerschmidt (supported by SFX project, BioXFEL Center, USA) Grant Mills (not shown), Steffen Raabe (supported by SFX project, DESY, until October 2016, not shown), Nadja Reimers (not shown), Adam Round, Tokushi Sato (supported by SFX project, DESY, not shown), Marcin Sikorski (not shown), Andrew Stawniczy (supported by SFX project, Wellcome Trust UK), Stephan Stern (supported by SFX project, DESY), Patrik Vagovič (supported by SFX project, DESY, not shown), and Britta Weinhausen

of Advanced Laser Light Sources (EUCALL) project, with the aim to generalize it to a wide class of X-ray and optical photon experiments. Using this broader simulation tool chain, a systematic study of the effect of X-ray pulse duration in X-ray FEL SPI experiments was performed, which is expected to be submitted for publication in March 2017.

To investigate the experimental limits of SPI, the group pursued two main efforts. First, group member Klaus Giewekemeyer and co-workers studied a model nanofabricated single-particle sample, using deliberately limited signal level. This study yielded insights into how low a signal may be to still produce a successful 3D reconstruction of the sample. Second, within the framework of the SPI project at LCLS, Ruslan Kurta of the Theory group, in collaboration with the SPB/SFX group and Jeffrey Donatelli and Peter Zwart at LBNL, developed an improved correlation analysis that can recover the 3D structure of a single virus from diffraction data collected at LCLS.

These various studies provide essential information about the feasibility of different SPI experiments. In particular, they allow the evaluation of usable signal-to-noise ratios and signal levels, the determination of ideal pulse durations, and perhaps the development of better algorithms for analysing the data.

To support this imaging research, doctoral student Masoud Mehrjoo has been performing studies on the wavefront properties of FEL beams using data collected at FLASH. The aim is to generalize analysis methods that characterize the wavefront of single FEL radiation pulses from measurements of the beam alone. Such measurements can be made simultaneously with SPI measurements, ultimately either allowing explicit use of the wavefront knowledge in imaging analysis, or at least providing another diagnostic tool for thresholding or rejecting data.

Outlook for 2017

Milestones for the SPB/SFX group in 2017 will include the installation of the remaining day-one components, the testing and commissioning of the instrument, as well as the transition to supporting early users and first experiments. Early in the year, the group will install the remainder of the day-one instrumentation in the SPB/SFX optics and experiment hutches. Commissioning is planned until summer, initially without and ultimately with the X-ray FEL beam. In the second half of the year, the group is looking forward to welcoming the first users to the instrument and supporting the first experiments—a true milestone for all involved!

SCIENTIFIC INSTRUMENT SQS

In 2016, the Small Quantum Systems (SQS) instrument group started assembling and testing different components of the X-ray FEL beam diagnostics section and of the spectrometers foreseen for the two experiment chambers of the SQS instrument, dedicated to the study of atomic-like quantum systems (AQS) and nano-size quantum systems (NQS), respectively. Research activities concentrated on two-colour experiments in atomic photoionization and on new experimental schemes based on controlling the spectral phase of XUV radiation.

Construction of the SQS instrument

In 2016, the SQS group was mainly involved in preparing various parts of the SQS instrument, including assembly, mechanical and electrical control, and tests of vacuum performance. In parallel, the infrastructure installation in the experiment hall by external companies was actively followed up to assure the instrument can be installed by summer 2017 at the latest. To make sure that this final task before the commissioning of the instrument is properly carried out, two new group members, a technician and a laser scientist, were hired in 2016.

Specific production steps were undertaken for the following components:

- **NQS chamber**
  The design of the NQS vacuum chamber and the associated electron and ion spectrometers was finalized (Figure 1). It provides the option to use the large Depleted P-Channel Field Effect Transistor (DEPFET) Sensor with Signal Compression (DSSC) imaging detector, which is being developed specially for the high repetition rate available at the European XFEL, or, for day-one operation, simpler multichannel plate (MCP)–based imaging detectors. The NQS chamber is dedicated to investigations on rare-gas and metal clusters as well as on larger nanoparticles and (bio-)molecules. The layout of the chamber will enable the use of different types of cluster sources and of a liquid-jet assembly, while keeping the possibility to also install specific user equipment later on.
- **Electron time-of-flight spectrometer**
  The first of six high-resolution electron time-of-flight spectrometers was assembled and successfully tested at PETRA III. These spectrometers are key components of the AQS experiment chamber. They enable spectroscopic studies requiring high kinetic energy resolution on core-excited atoms and molecules and allow the determination of the angular distribution of the emitted electrons. Test experiments confirmed the excellent overall performance of this home-built spectrometer and demonstrated its high kinetic

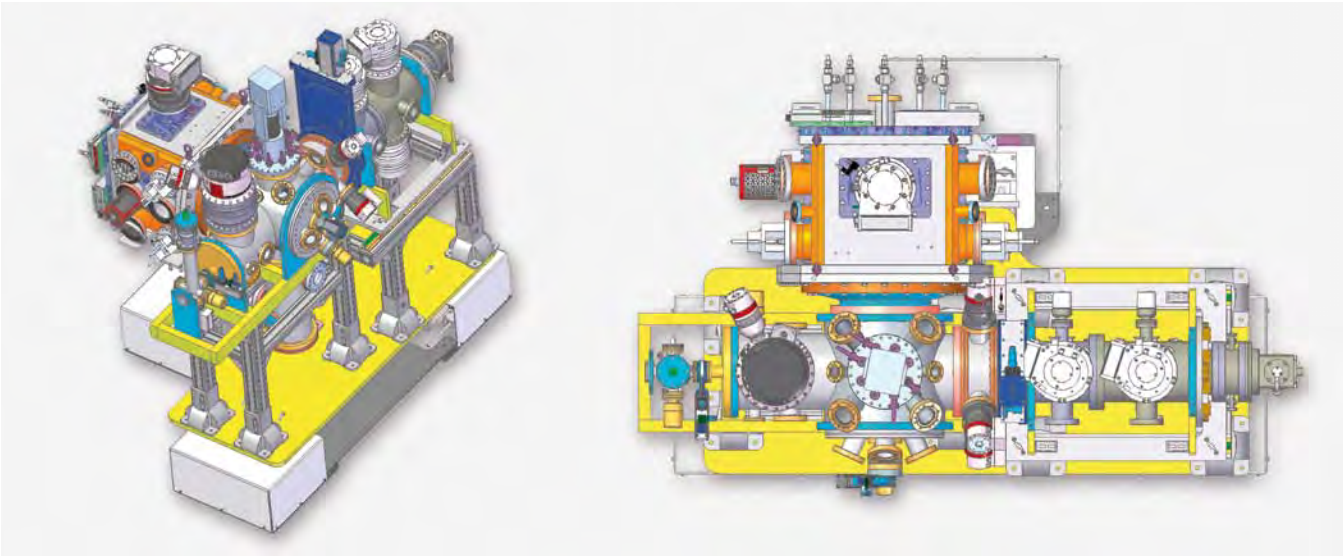

Figure 1 NQS experiment chamber in side view **(left)** and top view **(right)**, including a DSSC imaging detector, a cluster source, and electron and ion imaging spectrometers as baseline instrumentation

energy resolution, which reached values of $E/\Delta E$ = 10 000 for electrons of 800 eV kinetic energy, thereby matching the design values. Two additional spectrometers are under construction to complete the set of three spectrometers in the dipole plane—that is, perpendicular to the X-ray beam propagation direction—foreseen for first experiments in 2017. Three further spectrometers mounted out of the dipole plane are planned to be installed in early 2018.

- **Molecular beam setup**
  The atomic and molecular target gases will be introduced into the AQS chamber using a supersonic jet assembly composed of a high-pressure expansion chamber and appropriate skimmers and pinholes, which will enable the realization of a well-directed beam with negligibly small Doppler components. A new setup was successfully tested together with the electron time-of-flight spectrometers, showing that a sufficiently high target density can be achieved in the interaction region.
- **X-ray beam diagnostics**
  The position and the pulse energy of the X-ray FEL pulses will be analysed with dedicated diagnostic tools in front of the Kirkpatrick–Baez focusing optics and the experiment chambers. A gas monitor detector for precisely determining the number of FEL photons for each individual pulse and an FEL beam imager for visualizing the FEL beam position in the beamline were assembled and tested in the HERA South hall. Special care was taken to ensure that all electrical connections, in particular those for high-voltage supplies, work properly and that their parts are compatible with the ultrahigh-vacuum conditions envisaged for the entire instrument.

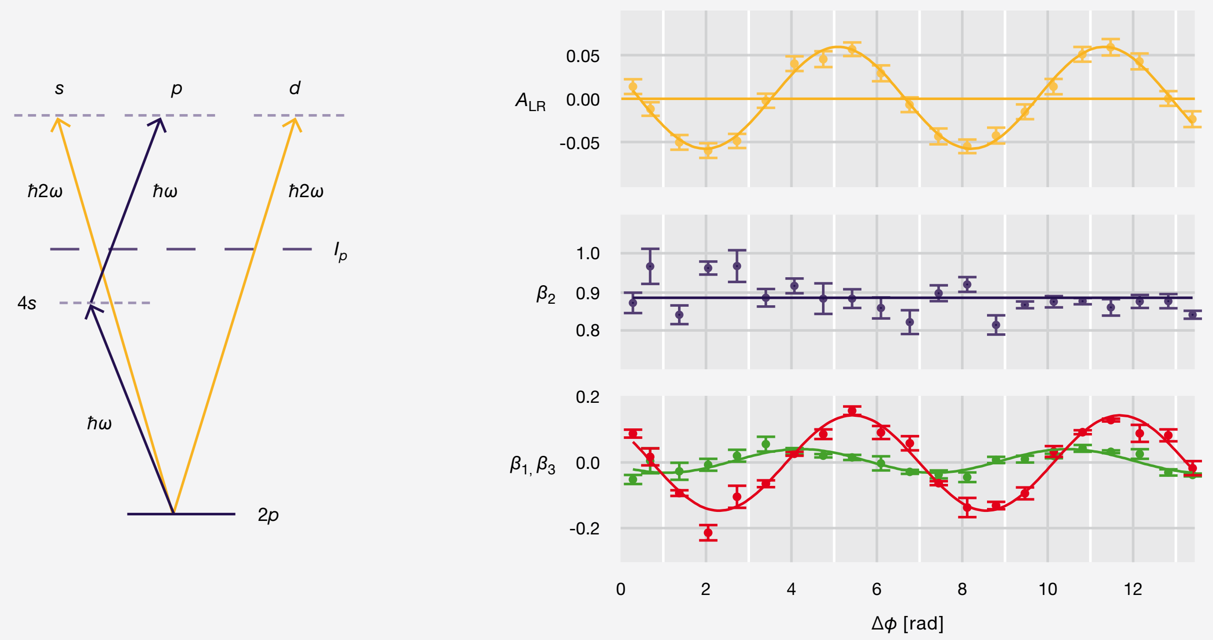

Figure 2 Control of the 2*p* photoionization in atomic neon by controlling the spectral phase of the XUV radiation.
Left Experimental scheme. A photoelectron may be ejected either as a *p* wave by a two-photon process (purple), or as an *s*+*d* wave by a one-photon process (orange). The intermediate 4*s* resonance in the two-photon pathway helps to bring the signal of both pathways on a similar level.
Right *Top:* Asymmetry parameter A_{LR} as a function of the relative delay $\Delta\phi$ between the spectral phases of the ω and 2ω radiation (orange markers) and a sinusoidal fit (orange solid line). *Middle and bottom*: β_1 (green), β_3 (red), and β_2 (purple) are the fit parameters for the angular distribution of the outgoing electrons. [2]

Research activities

The research activities of the SQS group in 2016 concentrated on experiments at the seeded XUV FEL FERMI in Italy.

One part of the measurements took advantage of the availability at FERMI of circularly polarized light. The combination with an intense and also circularly polarized optical laser enables the dynamics of the photoionization process—more precisely the relative contributions of the partial waves characterizing the outgoing electron—to be modified in a controlled way. The experiments, supported by a theoretical analysis, demonstrated this typical behaviour of photoionization in a strong dressing field for a simple two-photon process in the atomic prototype system helium [1].

The other part of the research activities, which was performed in close collaboration with groups from Italy, Germany, Russia, and the USA, explored a new control parameter for the XUV radiation, namely the spectral phase of the radiation pulses. In a proof-of-principle experiment [2], photons of wavelength ω were combined with photons of wavelength 2ω (Figure 2). By using a two-photon ionization process for the wavelength ω and a one-photon ionization for the second harmonic 2ω, electrons of the same kinetic energy are generated. The resulting electron angular distribution shows a clear asymmetry, which directly depends on the relative spectral phase between the two types of radiation.

These experiments demonstrated the perfect technical performance of the accelerator, enabling control of the FEL radiation with a precision and relative stability on a time scale of a few attoseconds. The achieved level of control opens up this ultrafast temporal domain for future scientific applications. Similar possibilities will be also explored for the European XFEL, but the challenges are even higher due to the much shorter wavelengths and thereby the much shorter time period for one optical cycle of the radiation.

Outlook for 2017

After completion of the infrastructure installation work by summer 2017, the SQS group will make every effort to finish the instrument installation in order to be ready to receive the first SASE3 photon beam in the SQS experiment hutch by the end of the year. The different components of the beamline and the three experiment chambers (AQS, NQS, and the reaction microscope SQS-REMI) will be prepared and characterized without beam at the beginning of the year. In parallel, the integration of the electronics and control units into the European XFEL control and analysis software framework Karabo will go on. Research activities will continue on a reduced level, focusing on specific topics related to molecular fragmentation dynamics and non-linear and dichroic phenomena in one- and two-photon ionization.

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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 2016, the group used their R&D laser system for various experiments aiming to expand the laser's wavelength capabilities. Stability tests and ongoing control system integration were another focus of activities. The engineering design of the laser systems was completed, and procurement for three pump–probe lasers was substantially advanced. Installation of the first system at the SASE1 undulator beamline started.

Optical lasers at European XFEL

Experiments at the six scientific instruments of the European XFEL require a dedicated, synchronized optical pump–probe laser. In total, three such laser systems will be installed to serve the six instruments, one at each experiment area (SASE1, SASE2, and SASE3). The specifications for the pump–probe laser were summarized from the science cases of the facility's instruments on the one hand and the peculiarities of the European XFEL emission on the other. The former typically lead to relatively standard specifications, such as ultrashort pulse durations ranging from a few optical cycles to several 100 fs, pulse energies of a few microjoule to millijoule, as well as different wavelengths—all depending on the scientific objectives. The European XFEL emission, however, is quite specific, owing to

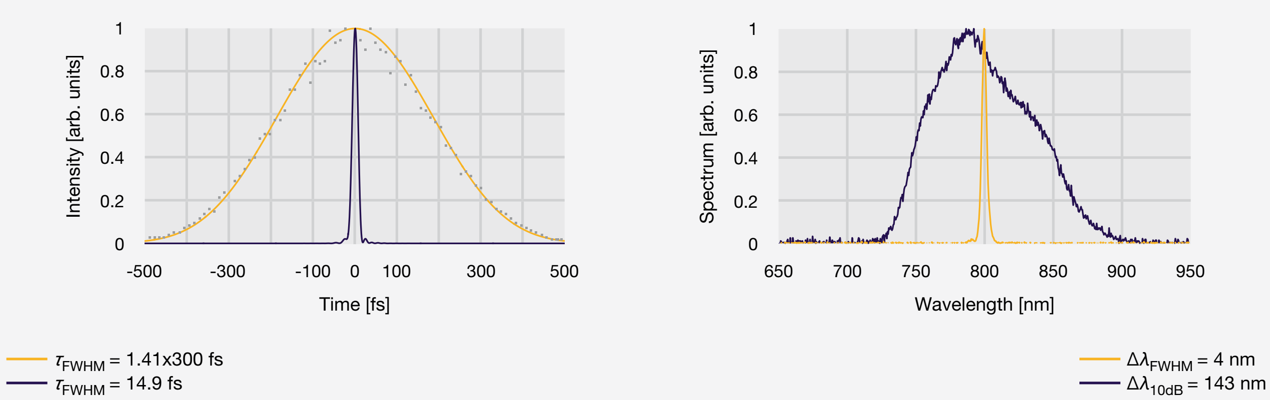

Figure 1 Characterization of amplified pulses at 100 kHz intra-burst repetition rate and 3.25 mJ single-pulse energy.
Left Blue curve: short-pulse mode, reconstructed pulse shape. Orange curve: long-pulse mode, autocorrelation.
Right Corresponding spectra, taken with an exposure time of 80 μs. (τ: pulse duration; λ: wavelength; $\Delta\lambda$: spectral width; FWHM: full width at half maximum; 10dB: at 10% of peak)

the burst mode operation of the accelerator: up to 27 000 X-ray femtosecond pulses per second are emitted in 10 Hz bursts of 600 µs duration and with up to 2700 pulses per burst—that is, the repetition rate is up to 4.5 MHz within the bursts, which the pump–probe laser needs to match.

Meeting all these requirements in combination is clearly outside the scope of today's off-the-shelf laser technology, hence the need for a dedicated development effort. Major results of this effort are presented in [1,2]. They include burst average powers of more than 300 W and single-pulse energies of up to 3 mJ at the 800 nm signal wave of a multistage non-collinear optical parametric amplifier (NOPA). Other features are the capability of producing pulses between <15 fs and 300 fs duration, which are close to the Fourier transform limit, and various schemes of wavelength conversion. As an example, Figure 1 shows the limits of achievable pulse durations together with corresponding spectra.

With the experimental R&D for the pump–probe laser complete, the Optical Lasers group finalized the engineering design of the laser system for the SASE1 laser room in the experiment hall. Procurement for all laser systems and other laser-related applications reached a very mature state by the end of the year. Similarly, the planning and construction of laser hutches advanced. The degree of completion of the SASE1 pump–probe laser hutch allowed the group to start installation and preliminary commissioning of components at the end of 2016. Figure 2 shows the 3D CAD model of the pump–probe laser for SASE1.

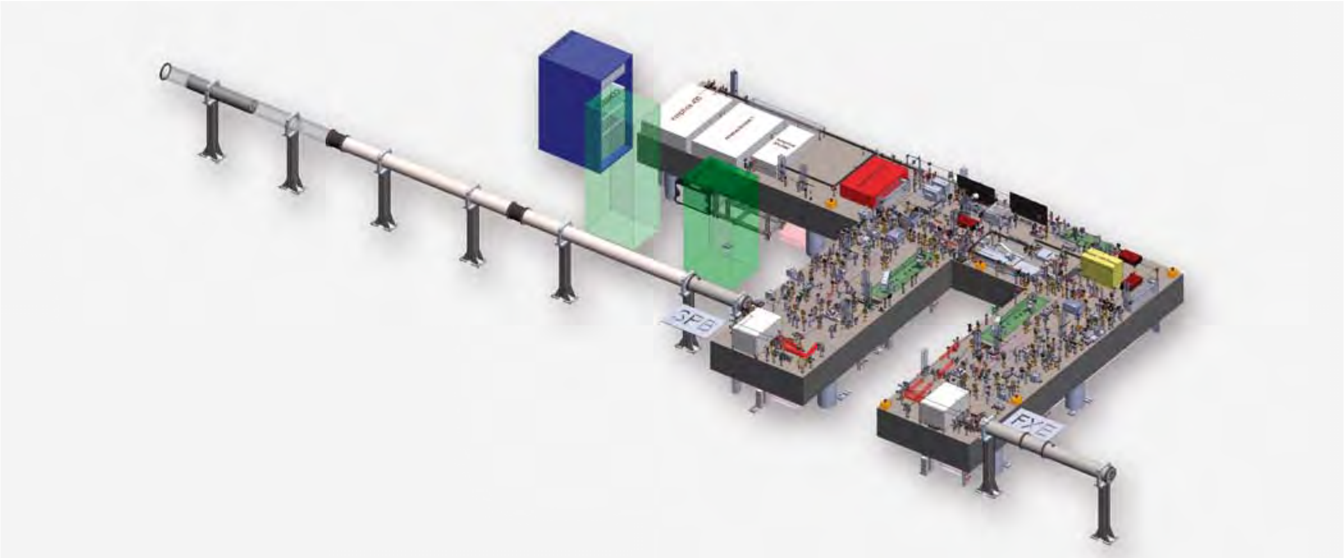

Figure 2 Three-dimensional CAD model of the pump–probe laser for SASE1 with beamlines to the FXE and SPB/SFX instruments

Further activities

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

The group also contributed to the laser integration at the HED instrument. This work is a joint effort with the HED group and the HIBEF user consortium, which will contribute a 100 TW ultrashort-pulse laser and a 100 J–class nanosecond laser to the instrument.

The joint European XFEL and DESY Laser Advisory Committee (LAC) convened in April 2016, explicitly endorsing the efforts and progress of the Optical Lasers group.

Outlook for 2017

Major tasks and activities of the Optical Lasers group in 2017 include:

- Pump–probe laser installation at SASE1 and start of installations at SASE2 and SASE3, as soon as the hutches are ready
- Ancillary experiments with the R&D pump–probe laser, including wavelength conversion, THz generation, and component testing
- Continued testing of the integration of the pump–probe laser into Karabo, the European XFEL control and analysis software framework
- Start of transport and installation of the prototype pump–probe laser into the R&D laboratory in the headquarters building (XHQ)
- Integration of staff contributed by HIBEF to gain hands-on experience with the installation and operation of 100 TW and 100 J lasers at various sites (HZDR in Germany and CLF at RAL in the UK)

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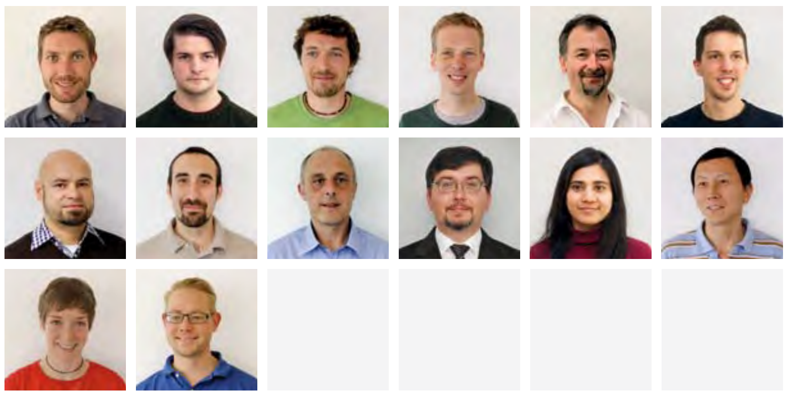


Group members
Moritz Emons, Tomasz Jezynski (not shown), Daniel Kane, Martin Kellert, Kai Kruse, Max Lederer (group leader), Florent Pallas, Guido Palmer, Mikhail Pergament, Gerd Priebe, Toma Toncian (permanent guest, HiBEF), Sandhya Venkatesan, Jinxiong Wang, Ulrike Wegner, and Laurens Wißmann

SAMPLE ENVIRONMENT

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

Progress in 2016

The Sample Environment group is responsible for the user laboratories in the European XFEL headquarters (XHQ) building. About 550 m^2 of biology laboratories and 200 m^2 of physics and chemistry laboratories for users were finished in 2016. The group took a leading role in preparing these rooms for user operation.

The group finalized the day-one sample environments for some of the scientific instruments, predominantly in the fields of liquid targets for biology, fast solid-sample exchange, and compact pulsed magnets.

Biology user support

In summer 2016, group member Kristina Lorenzen took on duties as biology laboratory manager, a position funded by the Integrated Biology Infrastructure Life-Science Facility at the European XFEL (XBI) user consortium and integrated into the Sample Environment group. User support and safety can now be coordinated collaboratively with the Sample Environment group, the instrument teams, and external partners.

In September, Katerina Dörner joined the Sample Environment group. Dörner is an expert in liquid-sample preparation for serial femtosecond crystallography, with a background in chemistry and biochemistry. In 2016, she started to equip the chemistry laboratory for user support and complete the liquid-jet nozzle fabrication facilities.

SPB/SFX sample environment

Coordinated by group leader Joachim Schulz, an expert team from MPI for Medical Research in Heidelberg, CFEL in Hamburg, and European XFEL finalized the technical design of the upstream sample environment for the SPB/SFX instrument. Group member Prasad Thute integrated the components into a CAD model, ensuring that all components can be used to their design specifications.

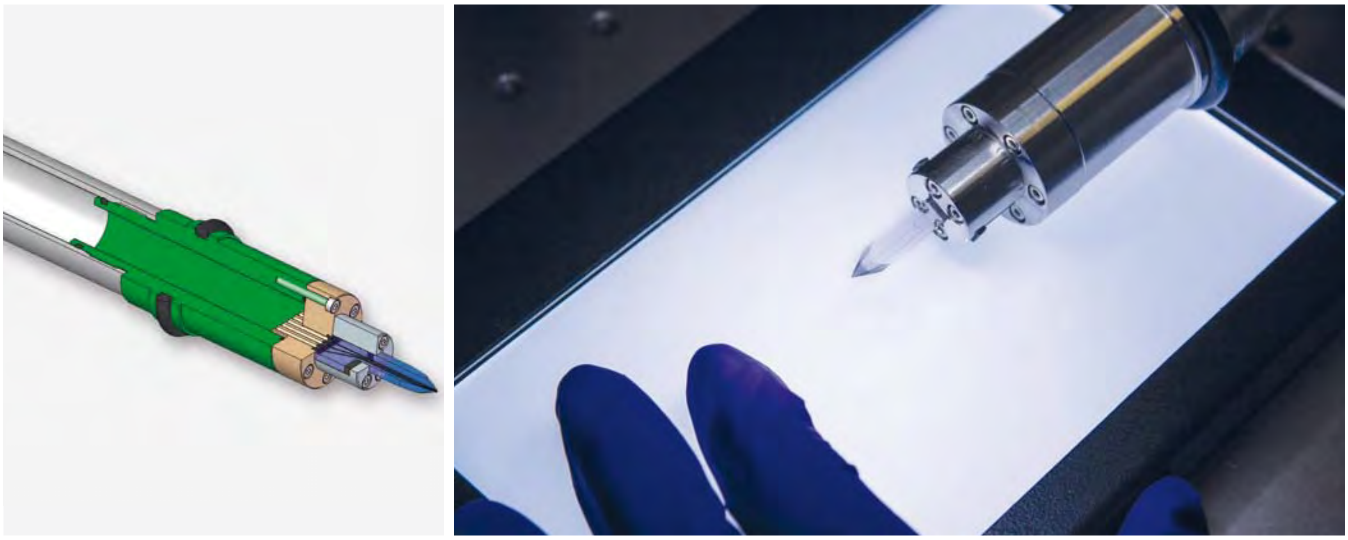


Figure 1 Dynamic gas virtual nozzle system based on microfluidic devices
Left Design study of the nozzle system
Right Photo of the nozzle system

In 2016, the Sample Environment group received the first components of the SPB/SFX sample environment: a sample changer with a temperature-controlled gas-free syringe system and a positioning hexapod for the liquid-jet catcher and fixed targets. All long-lead-time components have been ordered and will be delivered in early 2017.

The group prepared about 550 m^2 of biology laboratories and 200 m^2 of physics and chemistry laboratories for users. Day-one sample environments for some of the scientific instruments were also finished.

The Sample Environment group set up equipment for in-house nozzle production. In cooperation with external partners, the group explored new ways of producing nozzles. One focus is the integration of nozzles based on microfluidic devices into the European XFEL standard nozzle rod (Figure 1). Microfluidic devices can be produced reproducibly in large quantities and could lead to lower costs and better availability of standard nozzles for serial femtosecond crystallography. The group is also considering mixing jets and more complicated focusing schemes.

Magnetic fields

In November 2016, the Sample Environment group completed an experiment at PETRA III together with colleagues from the ESRF

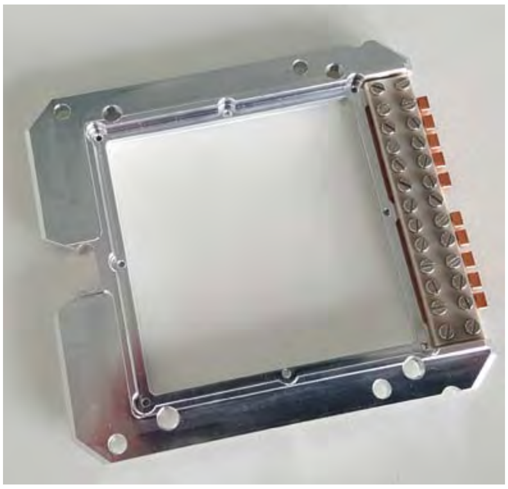


Figure 2 The SCS sample frame provides a 50 x 50 mm² active area for user samples. It features four places for fiducial marks and ten electric contacts for sensor integration. The same standard will be used for the MID instrument, whereas the other instruments will be provided with larger sample frames with 110 x 110 mm² active area.

Figure 3 First delivery for the SPB/SFX sample environment. Robert Shoeman (right, MPI for Medical Research in Heidelberg) explains the functions of the sample shaker and cooling unit to group member Matthäus Kitel in the new user laboratories.

Sample Environment group, using pulsed high magnetic fields for nuclear forward scattering on $CuFeO_2$ samples. Group member James Moore handed over a prototype direct-current electromagnet to the SCS instrument group for integration tests in their main experiment chamber. Furthermore, the Sample Environment group received and assembled 80% of the components for the pulsed coil prototype for the MID instrument.

Fast solid-sample scanners

Scanning solid-state samples or targets fixed on substrates is required at five of the six scientific instruments. In 2016, the Sample Environment group concentrated on building a fast solid-sample scanner prototype for the SCS instrument (Figure 2). This device will allow samples to be scanned reliably at the 10 Hz bunch train repetition rate of the European XFEL. A load–lock sample frame changer and a cartridge system to store up to eight sample frames in the vacuum chamber will allow fast automatic exchange of sample frames. The SCS instrument will predominantly examine surface targets and has the highest vacuum demands for solid-sample exchange.

Within the High Repetition Rate Sample Delivery (HIREP) work package of the European Cluster of Advanced Laser Light Sources (EUCALL) project, funded by the European Union, the Sample Environment group took a leading role in defining a standard sample frame for fixed targets at synchrotron light sources, high-power laser facilities, and FELs.

Preparation of user laboratories

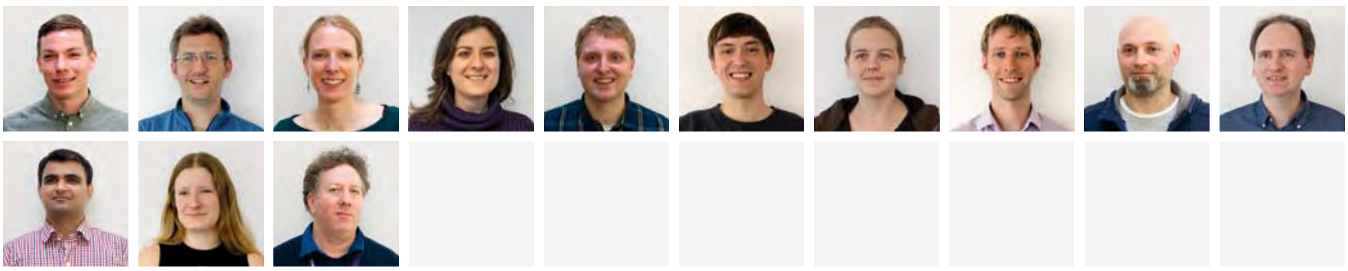
The Sample Environment group is responsible for equipping and operating about 200 m² of user sample preparation laboratories. Together with the XBI user consortium and the SPB/SFX instrument group, the group manages an additional 550 m² of biology laboratories. In autumn 2016, the construction companies handed the laboratories over to the Sample Environment group. As of December 2016, the greater part of the equipment has been moved from the preliminary group laboratories in Hamburg-Bahrenfeld to the new XHQ laboratories in Schenefeld (Figure 3).

Outlook for 2017

In 2017, the Sample Environment group will transform into a user support group. In the first half of the year, most activities will focus on getting ready for first user experiments. Together with in-house and external partners, group members will assemble and commission the day-one sample environment for SPB/SFX in the user laboratories.

The group will set up and test prototypes of the magnetic sample environment for MID, the fast solid-sample scanner for SCS, and new liquid-jet nozzle concepts for the FXE and SPB/SFX instruments. At the same time, the group will finalize the plans for equipping the user laboratories and prepare the laboratories for first users.

In the second half of the year, the Sample Environment group will take responsibility for laboratory user support. These activities will include instructing users on how to use in-house equipment efficiently and safely, assisting them in bringing their samples to the facility, and providing them with the necessary know-how and equipment to make their experiment successful.



Group members
Johan Bielecki (guest), Carsten Deiter, Elisa Delmas (not shown), Katerina Dörner, Rita Graceffa, Huijong Han (guest, not shown), Alan Kadek (guest), Matthäus Kitel, Inari Kursula (guest, not shown), Kristina Lorenzen, James Moore, Dennis Ropers, Joachim Schulz (group leader), Prasad Thute, Charlotte Uetrecht (guest), and David Watts

CENTRAL INSTRUMENTS ENGINEERING

The Central Instruments Engineering (CIE) team aims to coordinate, standardize, and implement common engineering projects of the six scientific instruments. In 2016, the CIE team delivered key day-one components for the SASE1 undulator beamline, produced critical electrical design documentation, and planned the cabling for the scientific instruments.

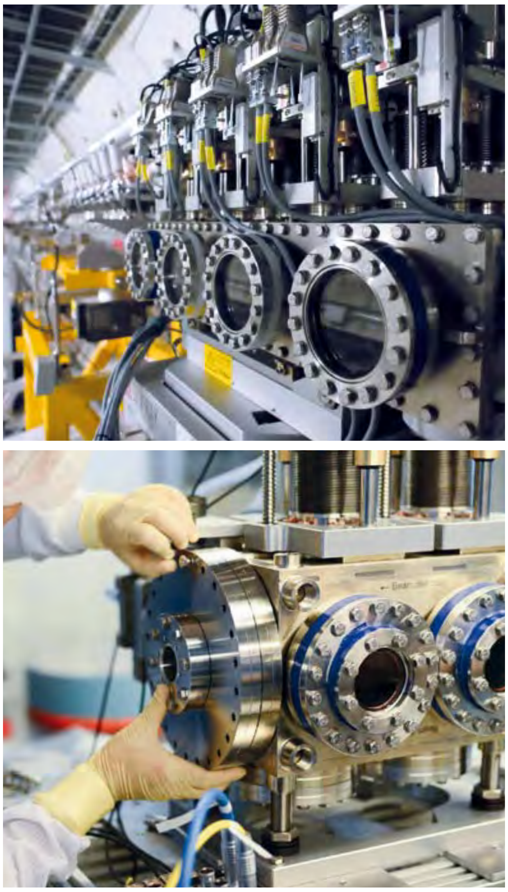


Figure 1 Activities coordinated by the CIE team.
Top Collimating the beryllium CRL system for the FXE instrument installed in the SASE1 XTD2 beamline.
Bottom Final assembly of a power slit for the optics hutch of the SPB/SFX instrument.

Progress in 2016

In 2016, the CIE team focussed on documentation using the ePlan software—a key tool for electrical design and planning—and the cable planning of the SASE1 instruments. In addition, the team delivered essential X-ray optic components and integrated them into the SASE1 beamline.

Changes to the team

In 2016, CIE increased its focus on electrical planning and cabling. As such, the part of the team responsible for these efforts was strengthened in order to meet the challenging electrical requirements of the instruments.

Coordinating instrumentation projects

In 2016, CIE coordinated several instrumentation projects in parallel, both in-house design solutions, such as the pulse picker for the SPB/SFX instrument, and subcontracted projects, such as the Danish in-kind contribution (IKC) DK02, “Components for the scientific instruments FXE, SPB, MID, and HED”. The IKC yielded three types of devices for use at each of the hard X-ray instruments: a collimating beryllium compound refractive lens (CRL) system for the FXE instrument (Figure 1 top), power slits (Figure 1 bottom), and a solid attenuator for the SPB/SFX instrument.

The integration of all three types of devices was completed for the SASE1 tunnel installations in 2016. These components will be vital for operation of the SPB/SFX and FXE instruments.

The team coordinated several instrumentation projects in parallel that will be vital for the operation of the SPB/SFX and FXE instruments.

Producing electrical designs using ePlan

The core task of the CIE ePlan team is to create documentation for the programmable logic controller (PLC) modules, document the instrument cabling up to the component connection boards, and prepare for the creation of TwinCAT control firmware using the ePlan documentation.

The ePlan documentation is key to successfully meeting the electrical requirements of the instruments. The ePlan designs form the basis for the production of PLC crates through the Polish IKC PL08 ("Production of programmable logic controller crates for six instruments") and for all the other suppliers of electrical components and cables. In addition, ePlan is an important tool for checking wiring schemes and producing accurate cable lists for external suppliers.

In 2016, the CIE team completed the ePlan documentation for the FXE instrument, resulting in approximately 22 PLCs produced and delivered. The firmware for these PLCs was written, and around 450 cables were defined and ordered, the majority of which was installed.

A significant part of the SPB/SFX ePlan design was defined and documented in 2016, with completion expected in March 2017 due to the much greater complexity of electrical installations at this instrument. In total, 2500 cables must be planned, ordered, and installed for SPB/SFX. As of December 2016, many of them have already been installed in the SPB/SFX rack rooms.

Outlook for 2017

In 2017, the IKC DK02 will be completed, resulting in the delivery of the remaining 14 components for the HED, MID, and SPB/SFX instruments. In-house production of fast shutters and beam stops for SPB/SFX and HED will be completed, and the CIE team will continue to support the commissioning of the instruments.

The ePlan designs will be finalized for SASE3, and to a large degree, for SASE2. Cable installation at SASE3 and SASE2 will start in summer and winter 2017, respectively.

In 2016, the estimated number of PLC modules needed for the instruments was increased. To meet this new production goal, the CIE team defined a required output of 20 ePlan designs per month. This higher output entails an increase in personnel working on this task. Thus, from 1 January 2017 on, there will be a new, temporary group called the Electrical Engineering Team (EET), comprising six ePlan experts and two cable planners.

Group members
Lewis Batchelor, Bernard Baranasic, Oliver Bieler (not shown), Marco Flade (not shown), Michael Fobian, Andreas Norden (not shown), Patryk Parlicki, Wolfgang Pieper, and Jörn Reifschläger

07

DETECTORS, CONTROLS, AND COMPUTING

In 2016, preparations for the calibration and commissioning of the detector systems were in full swing, devices enabling control of the scientific instruments were built, and the facility’s user portal was developed.

Inside the detector cleanroom in the HERA South laboratory

DETECTOR DEVELOPMENT

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

Progress in 2016

In 2016, the Detector Development group finalized the installation and commissioning of the detector calibration and test infrastructure for large 4.5 MHz 2D imaging detectors in the HERA South building [1]. As of December 2016, the laboratory environment is ready for the delivery of the first devices by external partners in early 2017 and the start of acceptance and performance tests.

By concentrating on detector commissioning, calibration activities, and establishing the structure for user operation, the group is preparing its transition from the European XFEL construction to operation phase. The group strengthened collaborations with scientific and technological partners to ensure that a continuous evolution of detector technology provides excellent conditions for facility users to stay at the forefront of science.

The detector calibration and test infrastructure is ready for the delivery of the first devices by external partners in early 2017.

The Detector Development group invested significant effort into developing data calibration methods and software in cooperation with external partners, with the primary goal of improving the scientific data quality. In parallel, activities focused on preparing, for example, detector GUIs in order to make the operation of complex detector systems as efficient and user-friendly as possible.

Changes to the group

Ludvig Kjellson from Uppsala University in Sweden joined the group as a Ph.D. student. During his thesis, he will focus on commissioning and performance optimization of a multichannel plate (MCP) detector to be implemented into a high-resolution spectrometer for the SQS instrument, all in collaboration with Jan Erik Rubensson from Uppsala

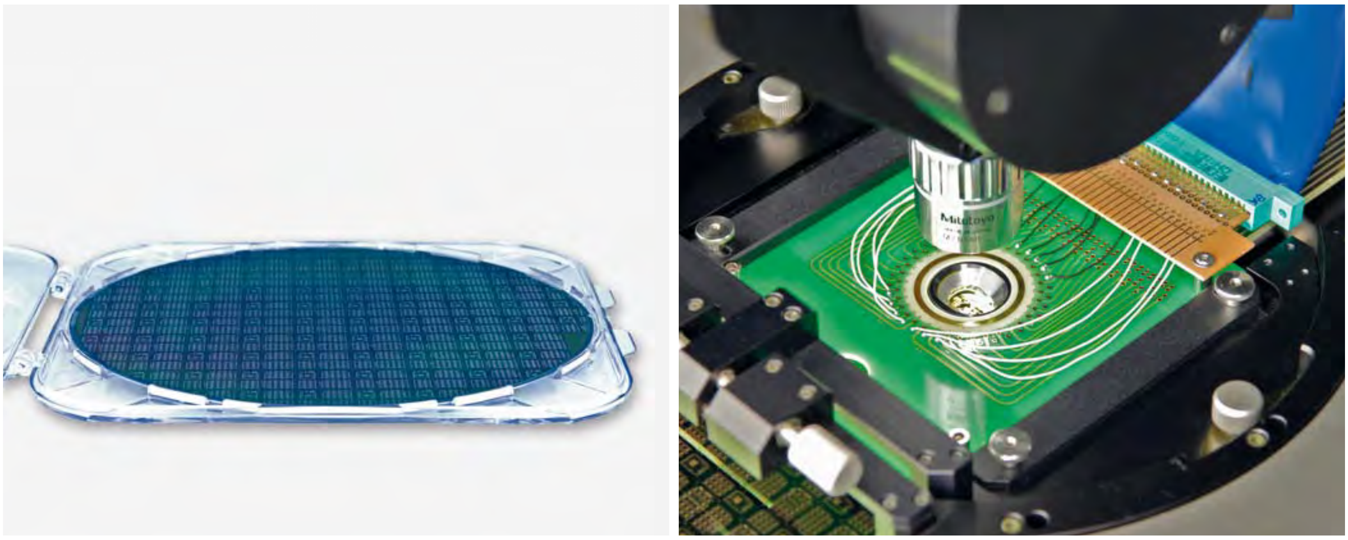


Figure 1 Feasibility demonstration of DEPFET sensor production with an industrial CMOS process.
Left First prototype active pixel sensors based on DEPFET technology, produced at a CMOS foundry on an eight-inch silicon wafer.
Right Semi-automated probe station for testing of DEPFET X-ray active pixel sensors.

University. Andreas Liebetrau provided substantial support to the group in electronics engineering, taking on responsibility for the installation, testing, and commissioning of detector power supply infrastructure. From October to December, Volkmar Schulze strengthened the group's technical capabilities by supporting the mechanical installation and commissioning of detector test infrastructure.

Delivery of first detectors

In May 2016, LBNL in Berkeley, USA, delivered the first low-speed imaging detector based on charge-coupled device (CCD) technology to European XFEL. The system successfully detected X-ray photons in the European XFEL detector laboratory, and group member Friederike Januschek and colleagues started to calibrate it, optimize its performance, and integrate it into the European XFEL data processing and control infrastructure.

The year 2016 was also very successful for the collaboration developing the Depleted P-Channel Field Effect Transistor (DEPFET) Sensor with Signal Compression (DSSC). The first DSSC detector prototype module equipped with a mini silicon drift detector (MiniSDD) sensor registered first X-ray photons at the low-energy photon beamline of PETRA III. In parallel, the collaboration started precision calibration measurements with small-scale prototype sensor modules at the proton beamline of Laboratorio di Tecniche Nucleari per i Beni Culturali in Sesto Fiorentino, Italy.

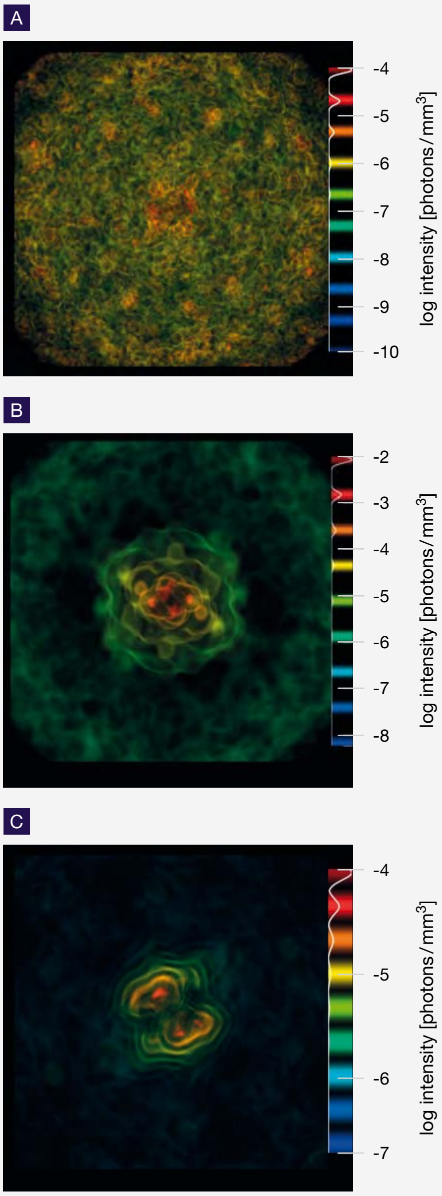


Figure 2 Simulated AGIPD images of 3D diffraction patterns of a nitrogenase iron protein (PDB 2nip) taken at 5 keV and oriented with the EMC algorithm.
Top Realistic detector in simple analysis: Substantial noise artefacts are visible in the oriented data prepared using a simple thresholding analysis.
Middle Ideal detector: The artefacts generated in the simple analysis become evident when comparing the result to oriented images resulting from an ideal, noiseless detector.
Bottom Realistic detector in probability-based analysis: A more complex probability-based thresholding analysis taking per-pixel noise and gain characteristics into account leads to a partial recovery of the scattering signal from detector noise.

The cooperation between PNSensor in Munich and Fraunhofer IMS in Duisburg, both in Germany, bore first fruits. The cooperation partners demonstrated the feasibility of producing DEPFET sensors at an industrial complementary metal oxide semiconductor (CMOS) foundry and tested the first DEPFET active pixel sensor prototypes (Figure 1). Based on this major success, the European XFEL Management Board approved the production of large-scale sensor modules in 2017.

Together with collaborators from RAL in the UK, group member Philipp Lang established a calibration concept for the full-scale Large Pixel Detector (LPD). The group members are awaiting delivery of the LPD to their detector laboratory in February 2017 for calibration, acceptance testing, and integration into the FXE experiment.

The Adaptive Gain Integrating Pixel Detector (AGIPD) collaboration launched the production of their second-generation application-specific integrated circuit (ASIC). This electronic circuit will replace the present ASIC of the 1 Mpx AGIPD foreseen for the SPB/SFX and MID instruments. First performance measurements indicate that the circuit will further improve the performance of the final camera. In parallel, members of the AGIPD collaboration integrated the first 1 Mpx detector system.

Another detector system received by the Detector Development group and presently being tested is a prototype MCP detector for the SQS instrument provided by Surface Concept in Germany.

The group also launched design studies aiming to prepare the next generation of detectors, in order to be able to provide detectors that match emerging scientific requirements. Figure 2 shows examples of a detector simulation that allows for accurate modelling of data degradation due to detector readout electronics effects and can give insight into expected experimental data quality and enhance subsequent data analysis.

Outlook for 2017

In 2017, the Detector Development group will primarily focus on putting the first 4.5 MHz large-area 2D imaging detectors into operation in the HERA South detector laboratory. Using the existing calibration and test infrastructure, group members will carry out acceptance tests of the megapixel AGIPD and LPD systems and validate their performance to assure that the first scientific objectives of the SPB/SFX, FXE, and MID instruments can be achieved. Finally, the tested systems will be installed at the instrument beamlines and commissioned. In addition, the group will prepare for first experiments and early user operation, for example by drafting detector and software documentation. ■

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S. Hauf, M. Donato, B.C. Heisen, M. Kuster, P.M. Lang, L. Maia, A. Münnich, T. Rüter, J. Sztuk, M. Turcato, K. Wrona
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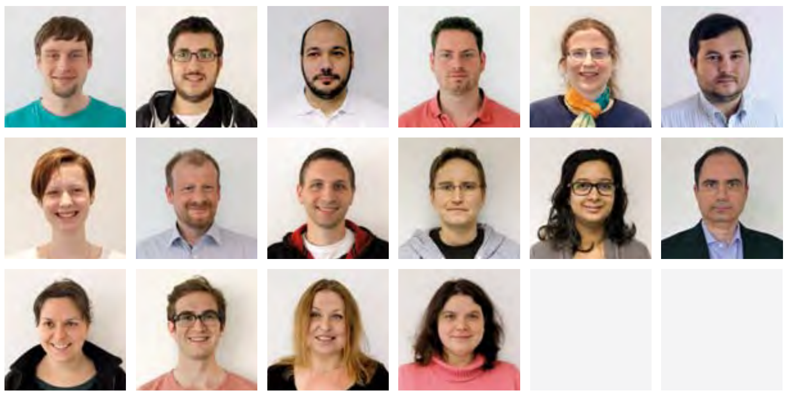

Group members
Thomas Dietze, Mattia Donato (student), Marko Ekmedžić, Steffen Hauf, Friederike Januschek, Alexander Kaukher, Ludvig Kjellsson (student, not shown), Ivana Klačková (student), Markus Kuster (group leader), Philipp Lang, Andreas Liebetrau (guest, not shown), Astrid Münnich, Sneha Nidhi (DSSC project), Matteo Porro (DSSC project), Natascha Raab, Tonn Rüter (student), Stephan Schlee (student, DSSC project, not shown), Rüdiger Schmitt (not shown), Volkmar Schulze (until December 2016, not shown), Jolanta Sztuk-Dambietz, Monica Turcato, and Georg Weidenspointner (DSSC project, not shown)

ADVANCED ELECTRONICS

The Advanced Electronics (AE) group is responsible for control and fast readout electronics required for automation, data acquisition, and data pre-processing at photon beamlines and instruments at the European XFEL. In 2016, the AE group focused on the production and preparation for installation of electronics required at the SASE1 instruments.

Large-scale production and automatic programming of control electronics

The scientific instruments at the European XFEL include complex systems, such as optical and laser systems as well as detectors and diagnostic devices, all of which require sophisticated vacuum setups, sensors, and motion control devices. With support from different groups and the Polish in-kind partner institute NCBJ, the first 100 programmable logic controller (PLC) modules were planned, designed, produced, tested, and prepared for installation at the FXE and SPB/SFX instruments (Figure 1). The programming of so many modules was only possible due to a specially developed programming framework and tools, which allow for automatic generation of the required firmware based on information exported from electrical CAD drawings and further input data. In 2016, the group members involved in this effort made significant progress in optimizing this procedure.

The first 100 programmable logic controller modules were planned, designed, produced, tested, and prepared for installation.

Transition to production, testing, and implementation

Two new group members helped with the transition from design and prototyping to production, testing, and installation. Janna Eilers joined the AE group as an experienced technician to support installing and testing of the electrical infrastructure and of sensitive control electronics. As a specialist in high-speed data transfer and processing, Awais Ahmed worked on testing and further optimizing important image and signal processing electronics. In addition, he collaborated with other institutes in the European Cluster of Advanced Laser Light Sources (EUCALL) project.

Demonstration of Train Builder system

For carrying out experiments, many diagnostic and detector systems are required. A special class of detectors involves

Figure 1 Storage of the tested PLC modules before installation in the instrument rack rooms. In 2016, more than 100 customized modules were produced and tested.

2D imaging detectors, which are capable of acquiring images at the facility repetition rate of 4.5 MHz. These detectors—including the Large Pixel Detector (LPD), the Adaptive Gain Integrating Pixel Detector (AGIPD), and the Depleted P-Channel Field Effect Transistor (DEPFET) Sensor with Signal Compression (DSSC)—produce about 10 GB of data per second. A system called Train Builder is required to receive, re-arrange, and distribute the acquired data in real time to multiple computer systems so that the image data can be stored and further processed. The development of this system was contracted to RAL. With the availability of the first ¼ Mpx LPD, the successful operation of the processing chain (including the LPD, control and synchronization electronics, Train Builder, and computers) was demonstrated. Besides the ¼ Mpx test setup, the first full 1 Mpx Train Builder system was produced, delivered, and tested.

Group members
Awais Ahmed, Frank Babies, Kai-Erik Ballak, Nicola Coppola, Janna Eilers (not shown), Bruno Fernandes, Tobias Freyermuth, Patrick Geßler (group leader), Daniel Mau (not shown), Hamed Sotoudi Namin, Jan Tolkiehn, Wenji Xie (student, not shown), and Juri Zach (student, not shown)

Outlook for 2017

In 2017, the AE group will focus on installation, testing, and commissioning support for control and data acquisition electronics and firmware. Furthermore, the group will provide support for the first experiments as well as optimizations based on gathered experience. ■

CONTROL AND ANALYSIS SOFTWARE

The CAS group is responsible for providing the experiment control and data analysis framework, Karabo, which covers all scientific instruments, photon beamlines, and laboratories at the European XFEL. In 2016, the group delivered Karabo 2, a new, consolidated version that will be used throughout the commissioning and operation phases of the facility.

Summary of 2016

During 2016, CAS contributed to the Vacuum Control Commissioning Taskforce by delivering the Karabo control system for the commissioning of the first vacuum sections of the SASE1 photon beam transport system. At the same time, a consolidated version of the Karabo framework was released as the base for the control system to be used during the commissioning phase of the European XFEL. In December, the group presented Karabo 2 to 60 participants from the detector, data acquisition, and scientific instrument groups, describing novel functionalities and new features at a one-day internal workshop.

CAS transitioned in 2016 from development to commissioning. The group was restructured and additional personnel were hired to ensure the proper level of support during the coming period, when further construction activities, instrument assembly, tunnel and instrument commissioning, and early experiments will be performed simultaneously.

Moving from development to commissioning

Figure 1 Setup of the central control room mock-up with the Karabo installation for commissioning several SASE1 vacuum sections

After successfully developing and releasing sequential updates to the Karabo framework in the previous year, the major goal in 2016 was to shift the focus from software development and support of test installations to preparation for commissioning of all photon beamlines and scientific instruments. Steffen Hauf of the Detector Development group temporarily joined the group as chief software architect and led the consolidation of development, resulting in the release of Karabo 2, which can now support the commissioning tasks with scaled-up performance and increased robustness.

The new group leader, Sandor Brockhauser, joined in May and started to restructure the group, putting more emphasis on support for commissioning. He introduced dedicated contact persons for the scientific instrument, detector development, and data acquisition groups, organized a deputy system to ensure the daily availability of contact persons, and began hiring additional personnel. He also introduced the Agile software development methodology in order to be able to quickly react to the changing priorities in implementation and optimally follow the wave of commissioning. In line with the changing focus, he designed a support structure for data analysis, opened new positions, and strengthened data analysis collaborations with key partners, such as the DataXpress user consortium.

Achievements in 2016

The CAS group achieved the major milestone of consolidating the Karabo framework. After long years of development, it was essential—before entering the commissioning phase—to review the actual status and release a version that reliably addressed all open issues required for scaling up the framework from simple test stands to a facility-wide installation. Hauf and group member Burkhard Heisen performed the analysis and designed the consolidation concept. Among others, new features include unified states, an alarm management system, a central configuration database, more efficient pipeline processing and broker communication, and data acquisition run control.

In preparation for commissioning, group members Andreas Beckmann and Alessandro Silenzi led the development of a simulation framework in Karabo that enables software integration tests and facilitates the control system development for complex instrumentation setups without requiring connection to real hardware. As a result of this framework, software bugs and inconsistencies in implementation can be discovered early, and the stability of even the initial control system releases can be guaranteed. To facilitate offline work, a central control room mock-up was installed. This setup provides the possibility of presenting the offline evolving control system before its first deployment for running the real vacuum system in the SASE1 tunnel. The mock-up contributed to the immediate success in commissioning the first vacuum sections in 2016. The achievements of the CAS group were presented in technical workshops and international conferences (e.g. [1]).

Outlook for 2017

In 2017, the CAS group will be involved in the commissioning of the photon beamline installations in the tunnels as well as the commissioning of all scientific instruments so they can take first beam and be prepared for early user experiments. While continued support will be provided for control system commissioning, as a part of the gradual change in focus towards operation and experiments, CAS will hire dedicated personnel to support data analysis integration into Karabo and to help users efficiently interpret the data they collect at the European XFEL. ■

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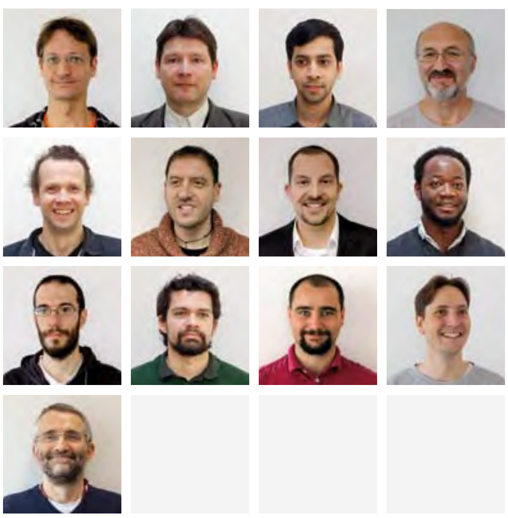


Group members
Andreas Beckmann (until July 2016), Valerii Bondar (not shown), Sandor Brockhauser (group leader), Wajid Ehsan, Sergey Esenov, Gero Flucke, Gabriele Giambartolomei (until September 2016), Dennis Göries (not shown), Burkhard Heisen, David Hickin (not shown), Léonce Mekinda, Andrea Parenti, Hugo Santos, Alessandro Silenzi, Martin Teichmann (not shown), Kerstin Weger (not shown), John Wiggins, and Christopher Youngman

IT AND DATA MANAGEMENT

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

Progress in 2016

In 2016, ITDM group members continued to deliver IT services to European XFEL staff members. The group also put into operation IT infrastructure and network in the SASE1 instrument area and SASE3 tunnels. All components of the data recording system for SASE1 were deployed, configured, and thoroughly tested. The first part of the offline data processing hardware was selected and purchased. Data storage hardware required for building the raw data repository for experiments was installed in the DESY data centre. The group provided further web applications and IT tools for managing experiment proposals, scheduling beamtime, and handling experiment data.

Changes to the group

The ITDM group hired a system engineer, Gianpetro Previtali, to manage computing and data storage resources. The collaboration with the DESY IT group was further strengthened by setting up specific data management projects. The formal collaboration agreement between European XFEL and DESY was prepared.

IT office infrastructure and support

The IT support to European XFEL staff members and guest scientists covered all aspects of IT for everyday work in offices and laboratories as well as dedicated projects from other work packages and administrative groups. A fully functioning office network and equipment for the meeting rooms in the new European XFEL headquarters building (XHQ) were delivered on time, helping to enable a smooth transition to the new location.

Data management system

A very important milestone reached at the end of 2016 was the deployment of the software for the User Portal to the European XFEL (UPEX). The UPEX software will be used from the beginning of 2017 for management of experiment proposals, the peer-review process, and instrument beamtime scheduling.

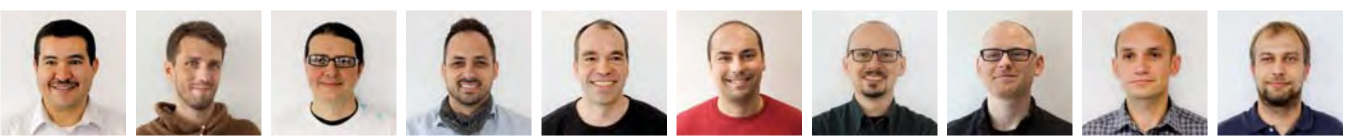
In 2016, the implementation of a data recording system continued, based on the achievements of previous years. After successful tests of the hardware and software allowing the full data rate to be recorded to online storage, the system was extended and connected to the DESY data centre. A dedicated long-distance InfiniBand network connection between the experiment hall and the data centre was established and successfully put into operation. This allowed for tight integration of online and offline resources, resulting in better utilization.

In 2016, the infrastructure of the DESY data centre was extended, allowing for the installation of the first hardware resources for European XFEL. Half of a 10 PB raw data repository, operated using dCache data management software, was deployed. At the same time, 1 PB of fast storage space, based on a high-performance clustered general parallel file system (GPFS), was set up and put into production. At the moment, it is heavily used for the simulation and analysis of data generated at other photon science facilities.

Outlook for 2017

In the coming year, the ITDM group will continue to provide IT services and add specific services that address the user community.

Installation of IT infrastructure required for operating scientific instruments and performing experiments in the SASE2 and SASE3 areas will continue. The full data acquisition chain—including run management, interactions with the metadata catalogue, and the raw data repository—will be used for the first time in real experiment conditions. ■



Group members
Djelloul Boukhelef, Illia Derevianko, Jorge Elizondo, Kimon Filippakopoulos, Manfred Knaack, Luis Maia, Maurizio Manetti, Federico Montesino Pouzols (from October until December 2016, not shown), Bartosz Poljancewicz, Gianpietro Previtali (not shown), Janusz Szuba, and Krzysztof Wrona (group leader)

08
SERVICES

Administrative and other employees support the facility, recruit staff, communicate with the public, conduct internal audits, ensure safety, and plan for welcoming future users. They also organize events and make arrangements for external visitors.

Many people collaborate to support the facility

ADMINISTRATIVE SERVICES

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

Composition of the administration

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

Finance and Controlling

The financial resources of the company are managed by the Finance group. The activities include all financial transactions, such as the payment of invoices and salaries, as well as liquidity management, based on the requirements of the project and the scheduled cash contributions by the different contracting parties funding the project. The Finance group is also in charge of bookkeeping and accounting in accordance with the applicable German accounting standards. The members of the Finance group deliver the annual financial statement of European XFEL and make sure that the company correctly fulfils all tax obligations. As in the previous years, external auditors issued an unconditional certification for the annual statement 2015.

Cost controlling of a complex project like the European XFEL with a budget of 1.22 billion euro (in 2005 value) is a big challenge. It is a joint effort involving all groups within the company and is coordinated by the Controlling group. Working at the frontier of technology means that a high level of uncertainty has to be met through high-level flexibility in project controlling. The high number of international partners, many of which contribute a large fraction of their share to the project in kind, further increases complexity. The Controlling group issues regular cost reports and forecasts to provide the management board as well as all group leaders with up-to-date financial information, anticipating probable developments and risks. To help prepare for the upcoming operation phase of the facility, the Controlling group developed an operation budget, in close collaboration with the management board and group leaders.

Legal

The Legal group supports the other administrative groups and the scientific work packages, giving legal advice on a wide range of subjects. In addition to drafting contracts with external partners, the Legal group is involved in activities such as administrative preparations for the transition to the operation phase. Given that European XFEL will become the responsible operator of the facility, administrative procedures have to be carried out that involve public authorities and considerable lead time.

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

Procurement

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

In 2016, the group processed 5408 purchase requests, an increase of 80% as compared to 2015. At the same time, they processed a total of 16 tender procedures covering purchases over 209 000 € and 104 procedures covering purchases over 30 000 €. The total value of the goods and services purchased amounted to 42.7 million euro (including civil construction).

For civil construction, supported by seconded staff from DESY, 240 purchase requests were processed, an increase of 60% as compared to 2015. For above-ground construction, orders were placed for the warehouse and workshop building (XHWS), among others. For below-ground construction, orders were mainly placed for the technical infrastructure of the hutches in the experiment hall.

In June 2016, the company moved to the new campus in Schenefeld, and the Procurement group was busy preparing related tender procedures. The move required a new logistics process, including goods receiving. The tasks and processes of the goods receiving department have been outsourced to a logistics service provider until XHWS is completed and put into operation. The new process was set up and introduced within the company, and the transition went smoothly and without disruptions.

European XFEL rarely buys off-the-shelf products, instead purchasing unique equipment or components. The X-Ray Scattering and Imaging Setup, a telescoping detector arm that is part of the MID instrument, is a good example of an extremely complex piece of equipment with a limited market. It took a considerable effort by the scientists and the Procurement group to find the best method of introducing the demand to the market in the form of a public tender, with the goal of reaching as many potential suppliers as possible.

In April 2016, the first set of the mirrors for the X-Ray Optics group arrived at our facility, and the metrology performed was highly satisfactory. These state-of-the-art mirrors required a worldwide-unique polishing method, performed by only one supplier located in Japan. The transport of these ultrapolished mirrors was a very delicate issue and involved a great deal of interaction between the Procurement group, the supplier in Japan, and the shipping companies in Japan and Germany.

In 2017, the Procurement group will prepare for the operation of the warehouse facilities and will continue to define, modify, and implement processes in response to changes in the laws and regulations regarding European and German public tender procedures, as well as to the continuous development of the European XFEL.

Introducing an ERP system

To facilitate the smooth and efficient operation of the facility and to further increase the transparency and availability of information for stakeholders, the company will implement an enterprise resource planning (ERP) system. The main objectives are to provide an integrated real-time view of core business processes, to track business resources, to share related data across the various groups, and to facilitate the information flow between all business functions. The timeframe for the implementation will likely extend to 2018, as careful preparation and optimization of business processes are crucial for the success of an ERP system.

Library

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

INTERNAL AUDIT

In 2016, the internal auditor conducted audits of administrative tasks and procedures and other relevant activities at European XFEL. Additionally, the internal auditor acts as the contact person for all questions related to the company anti-corruption policy.

The internal auditor verifies that employees comply with corporate rules and regulations as well as laws and decrees; that the company is making appropriate and economical use of funds; and that assets are properly safeguarded. The internal auditor thus has two core tasks. The first is to focus on the legality, propriety, and regularity of the implementation of the budget and to 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

In 2016, the HR group handled personnel matters related to the move to Schenefeld and split its focus between staff build-up and preparation for the operation phase.

Moving to Schenefeld

Beyond organizational and technical challenges, the move of the company from Hamburg to Schenefeld also included the transfer of legal employment status of all staff members, at the time encompassing 290 people, from the city–state of Hamburg to the state of Schleswig-Holstein. This transfer required the completion and implementation of a so-called social compensation plan, concluded with the works council to balance or reduce the financial burden on employees resulting from the change of premises. After comprehensive input from employees and the completion of a survey, final consultations between the HR group and the works council resulted in a works agreement, which was signed by the managing directors and the chairpersons of the works council on 4 April 2016. The subsequent implementation by the HR group proceeded smoothly and without any objection.

Continuing to grow

In 2016, the recruitment of staff likely reached its peak. Seventy-four new employees began work at European XFEL in the course of the year, and an additional five signed contracts to start in 2017. In 2016, the net number of employees, students, and guests grew from 278 to 337 (+21%). During this time, the HR group processed 1930 applications.

The recruitment activities once again proved to be efficient, and all job openings could be filled. The share of women among our scientists increased by 2%, to 19%. Nevertheless, the company seeks to further improve the gender balance among the scientists and engineers. The share of staff members from countries other than Germany increased slightly, to 47%. The share of international scientific staff amounts to 58%. Six percent of the employees with German citizenship were recruited from outside the country.

From staff build-up to operation phase measures

The transition from the build-up of staff to the operation phase will change the activities of the HR group. While setting up processes and tools as well as recruitment have formed the lion’s share of the work to date, organizational and development tasks will gain significant importance. Regulations and processes have to be developed for efficient user operation, including shift work, on-call duties, and other measures for the staff. The HR group provides legal and practical know-how and has to reconcile the needs of operation with the interests of the employees, who are represented by the works council, which, according to German labour law, has extensive authority in this respect, among others.

Leadership training and German classes

Our general and mandatory leadership training in 2015 was followed by individual coaching and group workshops in 2016. The main topics were leadership, organization, and communication in growing and highly heterogeneous teams.

In 2016, we were able to continue the popular in-house German language classes for employees and their dependants. The costs for the courses were shared between the company and the employees.

Providing equal opportunities

On 1 January 2016, the biennial mandate of the newly elected equal opportunities spokespersons (EOS), Meike Flammer from the Legal group and Motoaki Nakatsutsumi from the HED group, started. During the year, no complaints were reported and no requests for mediation were made.

In 2016, recruitment of staff likely reached its peak. Seventy-four new employees began work at European XFEL in the course of the year, and an additional five signed contracts to start in 2017.

In December, the EOS launched a survey about the perceived status of equal opportunities at the company considering especially the reconcilability of work and family. Results will be published and discussed in spring 2017. In December, a workshop for employees about legal backgrounds and practical issues regarding equal treatment and prevention of harassment was successfully performed.

Co-determination

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

At the end of 2015, the number of members of the works council fell below the legally required 9 people. Therefore, new elections had to be held in spring 2016.

The results represent the diversity of our staff:

- Female (4), male (5)
- Non-German (4), German (5)
- Scientists (5), engineers (1), technicians (1), administrative staff (2)

The new works council then elected Bartosz Poljancewicz as chairman and Kristina Lorenzen as vice chairwoman.

A cornerstone of this year’s collaboration with the works council was the completion of the works agreement “Hiring Guidelines / Recruitment Procedure”, which regulates and describes a fair, transparent, and efficient process.

Other regulation completed or discussed in 2016 included:

- Contract management software CONTRACT by otris software AG (signed 21 January 2016)
- Social compensation plan (signed 4 April 2016)
- Access regulation on the Schenefeld campus (ongoing)
- On-call duty (ongoing)
- Shift-work commissioning team (ongoing)
- Telecommuting (revision, ongoing)
- Vacation planning (ongoing)
- Occupational health and safety at work (OHS) management software (started)

PRESS AND PUBLIC RELATIONS

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

Objectives

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

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

Figure 1 Members of the press interview Massimo Altarelli (Managing Director until December 2016) during the ceremony for the start of commissioning.

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

Accomplishments

In 2016, the PR group implemented many communication measures, in particular:

- **Publications and training**
  Published news releases, press releases, and newsletters; compiled and distributed the monthly press review; produced and published the *European XFEL Annual Report 2015*; and offered media training for staff members.
- **New corporate design**
  In connection with the upcoming start of user operation, introduced a new corporate design for European XFEL to ensure that all communication media, such as brochures, posters, presentations, letterheads, websites, or social media, as well as business stationary and giveaways, follow a modern and coherent design. A central element of the new corporate design is the logo, which received a design refresh. Its white colour expresses openness and accessibility. The three elements of the logo that represent the accelerator tunnel (long blue bar), the photon tunnel (shorter blue bar) and the experiment hall (orange) now have a stronger emphasis. Figure 2 shows the old logo (left) and the refreshed logo (right) in comparison. The refreshed logo and the new corporate design are built on the existing elements, but they also illustrate the transition at European XFEL from construction site to operating research facility. Introduction of the new CD started in 2016 and will be continued in a step-by-step process that ensures that existing material can still be used and does not have to be discarded.
- **Website relaunch**
  Began a website relaunch, defining structure and layout, and developing modules together with an external agency. The new website will meet the requirements of an operating user facility with content focused on science communication and user information, as well as being technically state of the art, with responsive design for mobile devices. The relaunch, which is scheduled for the first half of 2017, will also be a last major step towards completing the introduction of the new corporate design.

Figure 2 The old logo (left) and the refreshed logo (right)

Figure 3 Merchandising items in the new corporate design

- **New brochures**
  Supplied a German version of the brochure *The European X-Ray Free-Electron Laser Facility and the Challenges of Our Time* and collaborated with the Polish shareholder to produce a Polish version. Print versions in English and Russian were already distributed in 2015.
- **New videos**
  Produced a new tunnel flight video exploring the underground structures of the European XFEL. An update done a few months later also included time-lapse compositions of the activities at the construction sites and in the experiment hall. The film can be viewed on the European XFEL YouTube channel and is available for download on the European XFEL media database (www.xfel.eu/mediabank).
- **Guided tours**
  Organized more than 90 guided tours for 1200 visitors of the European XFEL construction sites, including representatives from the diplomatic corps of different countries, scientists, journalists, politicians, PR specialists, students from universities and schools, and other stakeholders.
- **Internal events**
  Organized the inauguration event for the new European XFEL headquarters building in June and the Start of Commissioning event in October, each attended by 350–400 guests, as well as accompanying public relations work. Contributed significantly to the organization of the internal housewarming party in July and the farewell event for the retiring Chairman Massimo Altarelli. Supported other scientific, administrative, and construction events, such as the 2016 European XFEL Users' Meeting, early user workshops, numerous visits of VIPs to the facility, and a topping out event for the

SASE 1 hutches in the experiment hall, with news and photo coverage, posters, and merchandising items.

- **External events**
  Organized the participation of European XFEL at the Hamburg Day of Science on the University Hospital Eppendorf campus, an exhibition offering insights into fascinating research projects, lectures, film programmes, a science slam, numerous activities to join, and a science family programme. Organized the European XFEL booth at the physics festival *Highlights of Physics* in Ulm, Germany, which this year focused on the topic “Microcosm” and attracted more than 60 000 visitors. Organized European XFEL’s participation in the 2016 HSH Nordbank Run in Hamburg, which raised about 150 000 € for a children’s fund.
- **Visitor centre**
  Continued to participate in a working group—which included European XFEL Administrative Director Claudia Burger and representatives of the cities of Schenefeld and Hamburg and the district of Pinneberg—to support the construction and operation of a visitor centre at the European XFEL Schenefeld site. In 2016, an operation concept for the visitor centre was developed. In addition, first steps to develop a common concept for European XFEL and DESY visitor centres were taken together with DESY, and the results were compiled in a brochure and presentation.
- **EIROforum**
  Chaired the Communication group in EIROforum, a collaboration of eight major international research organizations in Europe, until the end of the European XFEL Chairmanship in June. Also contributed to the content, editing, and strategy of *Science in School*, the EIROforum journal for teachers.

Neighbourhood work

Throughout the civil construction of the European XFEL (since 2009), the PR group has placed 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. The office participates regularly in a working group focused on the Osdorfer and Schenefelder Feldmark landscape conservation areas, presenting the compensation measures being implemented by European XFEL, and maintains contacts with the local NABU nature conservation group. In November, the neighbourhood office conducted an information event for NABU members with a visit to the experiment hall and tunnel together with a discussion about the environmental compensation measures at a poster exhibition.

USER OFFICE

The User Office is coordinating user services and related administrative processes for the facility. After a preparatory phase, which started in 2014, the group focused on supporting the planned start of user operation in 2017, aiming to provide facility users with excellent service before, during, and after their experiments.

Preparing the first call for proposals

The Early User Experiment programme will provide selected users with the opportunity to perform experiments early in the operation phase of the European XFEL. The selection of the first early-user experiments will be based on scientific merit, as well as feasibility and safety considerations.

In 2016, the User Office focused on the finalization of tools and processes for the scientific review of proposals submitted in the framework of a call for the early operation allocation periods. In the same context, the User Office supported the European XFEL Management Board in setting up the first Proposal Review Panels and their terms of reference, stating rules of procedure and responsibilities for an efficient and transparent review process.

The fruitful collaboration with the IT and Data Management (ITDM) group continued in 2016. ITDM successfully finalized the proposal form and the corresponding submission workflow within the User Portal to the European XFEL (UPEX). Like many other facilities in Europe—including DESY, MAX-IV, and SOLEIL—European XFEL has chosen to stay in the Digital User Office software family, meaning it derives its basic functionalities from the user portal software in use at PSI.

The User Office focused on the finalization of tools and processes for the scientific review of proposals. In collaboration with the IT and Data Management group, the proposal form and corresponding submission workflow within the user portal UPEX were finalized.

At the end of 2016, the User Office supported the FXE and SPB/SFX instrument groups in organizing their first early user workshops. These workshops informed the user community about the specifications for these instruments in the early operation phase and aimed at fostering user collaborations in order to make efficient use of the available beamtime.

Getting ready for early operation users

In 2016, the European XFEL Council approved the construction of a canteen and a guest house on the European XFEL campus. The buildings are scheduled to open in 2018 and will allow the hosting of scientists participating in experiments on the campus, in most cases following a shiftwork scheme for a couple of days at a time. For the interim period, the User Office plans to support accommodation arrangements for experiment team members from outside the Hamburg area. Later, the User Office plans to provide assistance to these users for guest house or hotel reservations.

After the company moved to the Schenefeld campus in June 2016, the User Office, in cooperation with the Human Resources and Procurement groups, helped organize options for meals for staff and visitors. The resulting collaboration with a bakery service, local restaurants, and a food truck network will be useful for users as well, although not intended as a replacement for the future on-site canteen.

In April, the second meeting of the European User Offices was hosted at European XFEL. Experience and knowledge were exchanged on a number of issues.

In addition, the setup of a travel office within the User Office was initiated in 2016. Halimah Shie, who previously was responsible for travel in the Finance group, started to work as travel officer at the User Office, providing her experience to prepare a travel service infrastructure for users and to support building the necessary administrative framework.

As of December 2016, recruitment for two positons—for user travel and administrative support—is under way to complete the present staffing plans of the User Office.

Networking with other facilities

In April, the second meeting of the European User Offices was organized in cooperation with the user offices of DESY Photon Science and EMBL Hamburg, and hosted at European XFEL in Hamburg-Bahrenfeld.

Figure 1 Participants of the second meeting of European User Offices in Hamburg, 3–4 April 2016

About 20 large-scale research infrastructures and institutions (from France, Germany, Hungary, Italy, Poland, Spain, Sweden, Switzerland, and the UK including both internationally funded and national organizations) were represented by about 50 participants, mainly from user offices but also from scientific coordination, user portal, and IT groups. Experience and knowledge were exchanged on a number of issues connected to user services and user operation at synchrotrons, FELs, and neutron, muon, and laser facilities, and a further step in networking with other European user offices was reached. For the European XFEL User Office, hosting the meeting was a way to acknowledge the support from and the readiness to exchange information about user services within the European user office community.

Outlook for 2017

Next year will be the first in a series of extremely busy years for the User Office. After the first call for proposals in January 2017, a second call, involving further scientific instruments, is planned for later in the year. At the same time, the group will finalize several procedures and services related to user visits and experiments, in cooperation with other groups. In the second part of the year, the group will also prepare for the first early user experiments and user visits on the Schenefeld campus.



Group members
Silvia Bertini (group leader), Gabriela Heeßel, and Halimah Shie

SAFETY AND RADIATION PROTECTION

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

Organization

The SRP group supports and advises the management board, staff, and users on how to provide a safe and healthy working environment. The group includes two safety engineers, one of whom is a biological safety officer; one radiation protection officer; one safety technician; and one laser safety officer. The safety engineers are also trained radiation protection officers. The safety technician, René Gertz, and laser safety officer, Pouneh Saffari, started in 2016. In February 2017, a technical safety engineer will begin working in the group.

Members of the works council, the medical service, and the safety representatives of each research group, together with the administrative director, form the legally required work safety committee, which meets every three months. At these meetings, the SRP group informs committee members about safety topics, accident and incident reports, legal changes, day-to-day work, safety programmes, and safety monitoring tours.

Occupational safety

The SRP group offers laser and radiation protection training and organizes first aid, fire extinguishing, and crane operation training. General and experiment safety training for new staff and guests is conducted once a week, as is the practical training for self-rescuing devices required for tunnel access. All training is conducted in English and German.

In 2016, together with the Legal group, the SRP group finalized the annex to the DESY operation agreement related to occupational safety and emergency management. Internal roles and those of the group's partners were clarified, and responsibilities and services were further defined. According to the agreement, the SRP group and the DESY safety group will supervise all occupational safety aspects in their assigned areas of responsibility. The SRP group will be responsible for the Osdorfer Born site, the photon tunnels, and the Schenefeld campus, whereas the DESY safety group will look after the DESY-Bahrenfeld site and the accelerator tunnel.

The emergency control centre, located in the entrance building (XHGATE) on the Schenefeld campus, will be staffed by DESY Technical Emergency Service. In 2016, one fully trained colleague from DESY started to work in XHGATE, and staffing will gradually increase throughout 2017 and 2018. The crew in XHGATE is responsible for guarding the site and coordinating emergency calls to ensure that injured persons receive quick help. They also instruct firefighters in case the fire brigade is on site.

Together with the User Office, the SRP group established a workflow for the safety aspects of sample forms and experiment setups. The group also began preparing the online safety training for users, in consultation with the User Office and the IT and Data Management (ITDM) group.

The software for safety risk assessment was obtained from the accident insurer and installed at the end of 2016. This software is in English and German, and includes a hazardous substance registry.

A new laser safety officer, Pouneh Saffari, who started in March 2016, coordinates laser safety at European XFEL. This officer established an obligatory laser safety training programme for the Class 4 laser rooms, all of which are access-controlled. In addition, at the end of 2016, the SRP group published a laser safety policy, which describes the laser safety organization of the company and the preventive measures for safe laser operation.

The group offers laser and radiation protection training and organizes first aid, fire extinguishing, and crane operation training. General and experiment safety training for new staff and guests is conducted once a week, as is the practical training for self-rescuing devices required for tunnel access.

In May 2016, the International Technical Safety Forum (ITSF) for safety experts from large accelerator facilities worldwide was organized jointly with the DESY safety group on the DESY campus in Hamburg-Bahrenfeld. In October 2016, the seventh EIROforum Safety Meeting of safety engineers from all EIROforum members, organized by the SRP group, took take place on the European XFEL campus in Schenefeld. Both conferences provided the opportunity for the participating experts to discuss important safety issues, such as safety organization, crisis management, sustainability, and laser safety.

Radiation protection

The SRP group is also responsible for the handling of radioactive sources and the operation of X-ray equipment for detector development and calibration. In-house X-ray setups have been upgraded with new X-ray sources and larger testing chambers, which will be used to test larger detector prototypes for the experiments. The radiation protection officers were involved in the planning of the radiation protection hutches as well as the personnel safety system (PSS) for the scientific instruments in the experiment hall. The PSS is being developed and implemented by DESY as an in-kind contribution. The conceptual planning was carried out in close collaboration with the DESY radiation protection officers, who are responsible for the European XFEL accelerator. The overall radiation protection organization for the commissioning and operation phase was prepared together with the DESY radiation protection group. For the operation phase, four European XFEL radiation protection officers have been additionally certified in 2016 for working in facilities that generate ionizing radiation so they can assume responsibilities in the experiment hall and in the photon tunnels.

For access to radiation protection controlled areas of the accelerator area, an electronic personnel dosimetry system was procured that will be linked to the access control system.

Outlook for 2017

With the employment of a new safety engineer in February 2017, the planned number of seven group members will be reached. In the first half of 2017, a safety review with experts from European research facilities will take place in order to ensure that the tasks of the SRP group are well defined and that safe user operation is ensured.

The group will also continue to implement the access management system, together with its partners at DESY.

In 2017, the SRP group will continue to prepare more safety guidelines for the operation phase of the European XFEL facility. Together with the Technical Services (TS) group, the SRP group will closely examine electrical safety and machine safety, a task to be looked after by the group's new technical safety engineer.

The SRP group plans to start providing all safety training online, with participants required to pass a quiz at the end of each course. This training will be introduced in successive steps throughout the year, starting with the general and experiment safety training at the beginning of 2017, followed by safety training modules for access to the photon tunnels, the experiment hall, and research laboratories.

Safety risk assessments and instructions for all workplaces will continue, along with regular monitoring of all workplaces. In 2017, the SRP group will further intensify efforts to help group leaders assess and mitigate safety risks in their work areas.

Installation of the personnel dosimetry system will start at the beginning of 2017 at all access points to the accelerator area. The system will be ready with the start of operation in mid-2017, when European XFEL will become responsible for radiation protection.

With the start of the operation of the laboratories, the SRP group will establish a special waste management concept.

The SRP group will continue to develop the SRP webpages and safety guidelines that users will have to follow to submit their proposals for experiments at the European XFEL facility.

Safety team

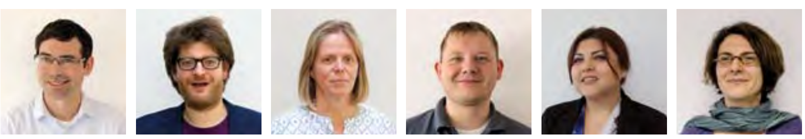
- Sigrid Kozielski (experimental safety and biological safety officer)
- Michael Prollius (experiment and general safety officer)
- Pouneh Saffari (laser safety officer)
- René Gertz (safety technician)
- Sabrina Scherz (assistant to the SRP group)

Radiation protection team

Responsible for radiation protection:
- Claudia Burger

Radiation protection commissioners:
- Sigrid Kozielski
- Thomas Tschentscher

Radiation protection officers:
- Eric Boyd
- Sigrid Kozielski
- Frédéric Le Pimpec
- Michael Prollius
- Joachim Schulz



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

09

SCIENTIFIC RECORD AND GLOSSARY

European XFEL maintains strong connections with the global scientific community, hosting workshops and engaging with future users from around the world at its annual Users' Meeting and other events.

Poster session at the 2016 Users' Meeting


XFEL
eltherm
Engineering

EUROPEAN XFEL USERS' MEETING

27–29 January 2016
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 tenth meeting, the number of participants broke the record from the previous year yet again: nearly 1000 scientists from around the world came to the full meeting. The programme included talks; several workshops; satellite meetings on time-resolved experiments at the FXE instrument, biology sample environments at X-ray FELs, photon beam diagnostics, and science at the HED instrument; and a poster session with more than 340 posters. Participants discussed details of the European XFEL project, future experiments, user consortia, and recent updates within the field of photon science. More than 30 students from around the world attended on travel grants disbursed by European XFEL.

The Users' Meeting focused on the following topics:

- Installation progress
- Plans for the start of commissioning and the first call for user experiment proposals
- Instrument design developments and advances
- Selected science applications
- Current developments and recent results in the field of X-ray FEL facilities

Figure 1 One of the talks at the 2016 European XFEL Users' Meeting

FOURTH RACIRI SUMMER SCHOOL ON CONVERGENT SCIENCE AND TECHNOLOGY FOR SOCIETY

21–28 August 2016
Repino, Russia

Jointly organized by leading research organizations from Russia, Sweden, and Germany, the fourth RACIRI Summer School featured lectures by representatives of operating and upcoming X-ray and neutron sources worldwide as well as scientists from universities and laboratories around the world. The summer school originated from 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 Russia. The fourth iteration of the summer school focused on the intersection between scientific research and the challenges of modern society. Lectures included presentations on new X-ray and neutron methodologies, studies of nanotechnology and functional materials, advancements in alternative power generation and energy storage materials, developments in biological research with X-rays and neutrons, and applications of X-ray and neutron studies to efforts to preserve and investigate cultural artefacts. Speakers included scientists from European XFEL and DESY in Germany, Uppsala University and Stockholm University in Sweden, and NRC KI and Moscow State University in Russia, among many others.

WORKSHOPS

5–6 April 2016
2nd Meeting of European User Offices
Organized by European XFEL, DESY Photon Science, and EMBL Hamburg
at European XFEL, Hamburg, Germany

This meeting brought together the user offices of several synchrotron, neutron, and FEL research facilities across Europe. Topics included recent developments in user administration at many research infrastructures, funding for user access, new and upgraded facilities, user portal IT developments, and possibilities for collaboration and mutual support.

12–14 September 2016
Dynamic Laser Compression Experiments at the HED instrument at European XFEL
Organized by the Helmholtz International Beamline for Extreme Fields (HIBEF) user consortium and European XFEL on the European XFEL Research Campus, Schenefeld, Germany

This workshop was intended for the HED instrument group to receive feedback from the international user community on selected scientific cases and their technical implementation at the upcoming HED instrument at European XFEL that will be in part funded through HIBEF.

During the workshop, a community-wide presentation and discussion of the concepts for shock and ramp compression experiments was conducted. Prior to this workshop, a conceptual design report (CDR) was drafted by a team of international authors, which served as a basis of discussion at the workshop. The workshop was held in conjunction with the HP4 workshop at DESY.

Figure 1 Attendees of the SPB/SFX early user workshop

14–16 September 2016
5th Joint Workshop on High Pressure, Planetary, and Plasma Physics (HP4)
Organized by European XFEL and DESY on the DESY campus, Hamburg, Germany

This workshop brings together researchers from different fields in the physical sciences to discuss the generation and diagnostics of extreme states of matter as appearing in the interior of planets, brown dwarfs, and stars. Participants discussed recent results and future experiments related to the evolution and structure of giant planet interiors, composition and internal geodynamics of solid planets, deep volatile cycles and exchange processes between geochemical reservoirs, the physics and chemistry of impact processes, phase transformations at extreme states of temperature and pressure, dynamic and ultrafast processes in strongly excited solids, and more.

28–29 November 2016
Early User Workshop for the SPB/SFX instrument
1–2 December 2016
Early User Workshop for the FXE instrument
Organized by European XFEL at the European XFEL Research Campus, Schenefeld, Germany

In preparation for the first call for experiment proposals in early 2017 and user operation later in the year, the SPB/SFX and FXE instrument groups each welcomed around 100 researchers to discuss day-one instrument parameters and initiate experiment collaborations. European XFEL scientists provided information about the overall setup, research possibilities, sample environment, optics, diagnostics, detectors, and data collection infrastructure for the two instruments. At breakout sessions that followed the initial presentations, attendees laid out concepts for possible experiment campaigns at the instrument. ■

Figure 2 One of the talks during the FXE early user workshop

SEMINARS

1 February 2016
Fluctuation X-ray scattering: updates and perspectives
Peter Zwart, LBNL, Berkeley, California, USA

3 March 2016
High resolution single molecule imaging by scanning probe and electron microscopy through preparative mass spectroscopy
Stephen Rauschenbach, MPI for Solid State Research, Stuttgart, Germany

15 July 2016
Combining the ultra-cold and the ultra-hot for laser-plasma proton acceleration
Daniele Margarone, ELI Beamlines, Dolní Břežany, Czechia

28 July 2016
External laser seeding possibilities at the European XFEL—preliminary results
Takanori Tanikawa, European XFEL, Schenefeld, Germany

26 August 2016
Intra-molecule motion analysis of functional proteins at single molecule level using synchrotron X-ray
Hiroshi Sekiguchi, JASRI, Sayo, Hyogo, Japan

20 September 2016
Cold and controlled molecules for XFEL experiments
Jochen Küpper, CFEL, DESY, and UHH, Hamburg, Germany

21 September 2016
Sample environments at the ESRF: pulsed high magnetic fields and more
Peter van den Linden, ESRF, Grenoble, France

4 October 2016
Ultra-fast solid to solid phase transition in diamond
Sven Toleikis, DESY, Hamburg, Germany

18 October 2016
Development of SR and FEL SCUs at the APS
Efim Gluskin, APS, ANL, Argonne, Illinois, USA

1 November 2016
Probing molecular electronic and nuclear dynamics in isolated molecules
Markus Guehr, University of Potsdam, Germany

17 November
THz-driven ultrafast spin-lattice scattering in metallic ferromagnets
Stefano Bonetti, Stockholm University, Sweden

13 December 2016
Ultrafast solid-state photoemission spectroscopy: from the extreme ultraviolet to hard X-rays
Kai Rossnagel, University of Kiel, Germany ■

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ANL
Argonne National Laboratory in Argonne, Illinois, USA

APS
Advanced Photon Source in Argonne, Illinois, USA

BESSY II
Berliner Elektronenspeicherring-Gesellschaft für Synchrotronstrahlung at Helmholtz-Zentrum Berlin in Germany

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

BMBF
German Federal Ministry of Education and Research

CAD
computer-aided design

CAEP
China Academy of Engineering Physics in Mianyang, Sichuan, China

CEA
Commissariat à l'Énergie Atomique et aux Énergies Alternatives in Saclay, France

CELLS
Consorcio para la Construcción, Equipamiento y Explotación del Laboratorio de Luz de Sincrotrón in Cerdanyola del Vallès, Spain

CFEL
Center for Free-Electron Laser Science in Hamburg, Germany

CIEMAT
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas in Madrid, Spain

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

CNRS
Centre National de la Recherche Scientifique in Orsay, France

CUI
Centre for Ultrafast Imaging in Hamburg, Germany

DESY
Deutsches Elektronen-Synchrotron in Hamburg and Zeuthen, Germany

DFG
Deutsche Forschungsgemeinschaft

DLR
German Aerospace Center

DOOCS
Distributed Object Oriented Control System

DTU
Technical University of Denmark

ESRF
European Synchrotron Radiation Facility in Grenoble, France

FEL
free-electron laser

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

FLASH
Free-Electron Laser in Hamburg at DESY in Germany

Fraunhofer IKTS
Fraunhofer Institute for Ceramic Technologies and Systems in Hermsdorf, Germany

Fraunhofer IMS
Fraunhofer Institute for Microelectronic Circuits and Systems in Duisberg, Germany

FSBI TISNCM
Technological Institute for Superhard and Novel Carbon Materials in Troitsk, Moscow, Russia

FXE
Femtosecond X-Ray Experiments [European XFEL instrument]

GUI
graphical user interface

HED
High Energy Density Science [European XFEL instrument]

HZB
Helmholtz-Zentrum Berlin (HZB) in Germany

HZDR
Helmholtz-Zentrum Dresden-Rossendorf in Germany

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

IMPMC
Institut de minéralogie, de physique des matériaux et de cosmochimie in Paris, France

IHEP
1. Institute of High Energy Physics in Protvino, Russia
2. Institute of High Energy Physics at the Chinese Academy of Sciences in Beijing, China

IMPRS-UFAST
International Max Planck Research School for Ultrafast Imaging and Structural Dynamics

INFN
Istituto Nazionale di Fisica Nucleare in Italy

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

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

JINR
Joint Institute for Nuclear Research in Dubna, Russia

LAL
Laboratoire de l'Accélérateur Linéaire in Orsay, France

LASA
Laboratorio Acceleratori e Superconduttività Applicata in Milan, Italy

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

LLNL
Lawrence Livermore National Laboratory in Livermore, California, USA

LNLS
Laboratório Nacional de Luz Síncrotron in Campinas, Brazil

LULI
Laboratoire pour l'Utilisation des Lasers Intenses in Paris, France

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

MID
Materials Imaging and Dynamics [European XFEL instrument]

MPI
Max Planck Institute

NCBJ
National Centre for Nuclear Research in Świerk, Poland

NIIEFA
D.V. Efremov Institute of Electrophysical Apparatus in St. Petersburg, Russia

NRC KI
National Research Centre “Kurchatov Institute” in Moscow, Russia

PETRA III
PETRA III at DESY in Hamburg, Germany

PSI
Paul Scherrer Institut in Villigen, Switzerland

RAL
Rutherford Appleton Laboratory in Oxfordshire, UK

RF
radiofrequency

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

SASE
self-amplified spontaneous emission

SCS
Spectroscopy and Coherent Scattering [European XFEL instrument]

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

SOLEIL
SOLEIL Synchrotron in Saint-Aubin, France

SPB/SFX
Single Particles, Clusters, and Biomolecules and Serial Femtosecond Crystallography [European XFEL instrument]

SQS
Small Quantum Systems [European XFEL instrument]

STFC
Science and Technology Facilities Council in Swindon, UK

SwissFEL
Swiss Free-Electron Laser at the Paul Scherrer Institut in Villigen, Switzerland

TU Dortmund
Technische Universität Dortmund in Germany

TUHH
Hamburg University of Technology

UCL
University College London in the UK

UHH
University of Hamburg in Germany

UPM
Universidad Politécnica de Madrid in Spain

VUV
vacuum ultraviolet radiation

WUT
Wrocław University of Technology in Poland

XUV
extreme ultraviolet radiation

YAG
yttrium aluminium garnet

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