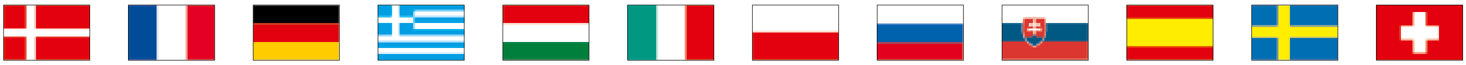
European
XFEL

ANNUAL REPORT

European X-Ray Free-Electron Laser Facility GmbH

2012

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



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CONTENTS

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

Dear Readers,

This annual report provides an overview of activities at European XFEL in 2012. Thanks to the continuing support of our shareholders and to the dedication and hard work of our staff and our collaborators in laboratories all over the world, we made significant progress towards completing the facility.

A highly visible and symbolic milestone was the completion of the tunnel boring work in June 2012. The 5.77 km long network of tunnels is now the centre of intense activities to install the infrastructure that will deliver power, signals, cryogenic fluids, and other resources to the accelerator, undulators, and photon beamlines. Considerable effort also went into defining the specifications and preparing for the tender of the remaining above-ground buildings, in particular the headquarters in Schenefeld. Located directly above the experiment hall, the headquarters will host one floor of laboratories for sample preparation, characterization, and R&D as well as two floors of offices.

The year 2012 was very important: we prepared and, in some cases, launched the series production for the vast amount of components required to build the European XFEL. For the 2 km long accelerator, in particular, but also for the electron beam transport systems and the undulators, many items entail the coordination and follow-up of a complex and tight production schedule. Important components, such as accelerator cavities, cryomodules, and undulator segments, have been contracted out to industry, either directly or by partners who contribute to the project in kind. Other components are being built directly by the partner institutes, some in huge quantities. This production commenced in 2012, and the first in-kind contributions from countries other than Germany were completed and delivered in the summer. In the fall, other successful contributions arrived. Most of these in-kind contributions were delivered to DESY, where they are being tested and integrated into the overall accelerator assembly.

In such a large and complex project, there are, of course, issues that prove to be more challenging than expected. As a result, maintaining the overall project schedule requires continuous effort. The European XFEL Management Board, Deutsches Elektronen-Synchrotron (DESY), which coordinates the Accelerator Consortium, and our international partners are working together very closely and with a remarkably constructive spirit to meet our goals.

We are particularly grateful that, during the past year, the increase of the financial pledges of most of our contracting parties has given the project a sound basis. Such support is especially appreciated in a time of severe budget constraints in all countries.

At the beginning of 2012, Claudia Burger replaced Karl Witte as managing and administrative director. Throughout the year, the administration has been consolidated and strengthened. With key administrative positions now filled, the company is well placed to manage and control the finances of such a complex international project, to run the many large calls for tender in an efficient and transparent manner, and to attract and retain talented people from many different countries. Recruitment activities are especially important to the project at this stage. European XFEL GmbH has grown from 119 employees at the end of 2011 to 163 at the end of 2012, with 28 nations represented. To grasp the true extent of the project, however, it is important to understand that many hundreds of scientists, engineers, and technicians at DESY and 20 other institutes in the participating countries are producing in-kind contributed components for the European XFEL.

The close involvement of our future user community continued in 2012, as demonstrated by the ever-growing attendance at our annual Users' Meeting, which we hosted jointly with the photon science division of DESY in January. In the course of the year, the community responded with great enthusiasm to our invitation to contribute to the scientific programme and to the experiment equipment of the facility within the user consortia programme, which opens up additional possibilities for further instruments and ancillary top-class facilities that will complement the scientific portfolio of the European XFEL.

The high scientific interest in our project was confirmed by the impressive participation in the “Science at FELs” conference, the world's first major international conference dedicated to science with X-ray free-electron lasers, which we organized together with DESY in July. The popularity of the workshop on self-seeding held at the conference underlined this interest. The self-seeding technique, which improves the quality and usefulness of X-ray pulses for science, was invented by Gianluca Geloni (European XFEL), Vitali Kocharyan (DESY), and Evgeny Saldin (DESY) in 2010, and successfully tested at the Linac Coherent Light Source (LCLS) at SLAC National Accelerator Laboratory in Menlo Park, California, in January 2012. We are especially proud that the 2012 Innovation Award on Synchrotron Radiation was conferred on the three inventors and Paul Emma of Lawrence Berkeley National Laboratory.

We wish to thank all those who contributed to the progress of the project—inside our company, on its supervisory and advisory committees, at the institutes collaborating with us, and in the science community at large. We hope that readers will find this annual report informative, interesting, and pleasant to read.

Massimo Altarelli

Claudia Burger

Managing Directors

Serguei Molodtsov

Andreas S. Schwarz

Thomas Tschentscher

Scientific Directors

FOREWORD BY THE EUROPEAN XFEL COUNCIL CHAIRMAN

Robert K. Feidenhans'l

Dear Readers,

As chairman of the European XFEL Council, it is a great pleasure for me to witness the tremendous activity at this stage of the construction phase. Every time I visit, I see new faces and meet more scientific pioneers who have joined the project; I hear about progress and accomplishments in the construction of buildings and accelerator components; I learn about new concepts in X-ray free-electron laser instrumentation; I get glimpses of new science frontiers that will be crossed in the coming years.

The European XFEL facility will be a magnet for scientists around the world, as demonstrated by the 2013 Users' Meeting. The big auditorium at Deutsches Elektronen-Synchrotron (DESY) was hardly large enough to host all the participants—even though there are still a few years to go before the facility will be commissioned and start operation. Notably, the auditorium was full of young students and postdocs—that is, the scientists who will exploit the full scientific potential of the facility in the decades to come. The enthusiasm was palpable. Matching activities are being carried out at the Center for Free-Electron Laser Science (CFEL), a cooperation of DESY, the Max Planck Society, and the University of Hamburg.

Together, European XFEL and DESY promise to form a unique, world-leading centre of photon science. Researchers at the Linac Coherent Light Source (LCLS) at SLAC National Accelerator Laboratory in the USA and the SPring-8 Angstrom Compact Free-Electron Laser (SACLA) in Japan are already performing excellent experiments in collaboration with their colleagues at European XFEL. Many of these novel scientific approaches will reach their full potential thanks to the high repetition rates of the European XFEL.

The technical developments presented at the Users' Meeting were overwhelming. Building the European XFEL is a technical challenge in many fields, of which the accelerator complex, the X-ray optics, the scientific instruments, the detectors, and the data handling and analysis systems are the most prominent examples. Many of these components, for instance the X-ray optics or X-ray detectors, have been improved to an extent never even dreamt of a decade ago. These developments will enable European XFEL to set new scientific and technological standards, leading to inventions that will give European industry a decisive edge in an increasingly competitive world.

The seeding of the X-ray laser, an idea originally invented by scientists from European XFEL and DESY, has been implemented at LCLS and has led to a much more brilliant X-ray beam than originally expected. One of the big issues for the European XFEL Council in 2013 will be to secure a seeding option to be implemented and offered to users at the European XFEL from day one.

In 2012, the European XFEL Council met three times. Its members took note of the reports by the European XFEL Council Chairman, Management Board, Administrative and Finance Committee (AFC), Machine Advisory Committee (MAC), and Scientific Advisory Committee (SAC). Furthermore, council members discussed and took decisions on a number of important topics, such as legal, financial, and organizational matters, user consortia, and in-kind contributions.

The coming years promise to be even more exciting. I encourage all European scientists and national governments to contribute to this project. Together, we can make the European XFEL an example of what Europe can accomplish in a joint effort.

Robert K. Feidenhans'l

Chairman of the European XFEL Council

01

NEWS AND EVENTS

In 2012, European XFEL completed the tunnel boring—a major milestone for the project. The first in-kind contributions for the X-ray laser were delivered from our partners, industrial production for key components picked up pace, and our scientists promoted XFEL science.

Tunnel boring machine AMELI in the final shaft

January 2012

1 January

New Managing and Administrative Director

Claudia Burger becomes the new Managing and Administrative Director of European XFEL. The economist was appointed in October 2011 by the European XFEL Council.

Previously, Burger was administrative managing director at ILS – Research Institute for Regional and Urban Development in Dortmund, Germany. At European XFEL, Burger joins the five-member management board and is responsible for human resources, procurement, and finance as well as safety issues. Her predecessor, Karl Witte, retired in December 2011.

25–27 January

680 scientists attend Users' Meeting

About 680 participants from 28 countries attend the sixth annual European XFEL and DESY Photon Science Users' Meeting in Hamburg. In a three-day programme jointly organized with Deutsches Elektronen-Synchrotron (DESY), future users as well as other interested scientists, students, staff, and stakeholders meet to discuss new developments at the world's largest and most sophisticated X-ray laser, European XFEL, and the DESY light sources FLASH, DORIS, and PETRA III.

Many young scientists—23 of whom received travel grants from European XFEL—are among the participants. The programme includes a number of workshops and satellite meetings as well as group meetings and a poster session with almost 300 posters.

February 2012

9 February

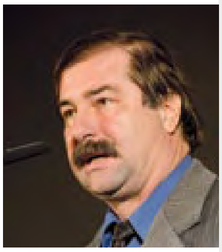
Council chair and vice-chair re-elected

The European XFEL Council re-elects Chairman Robert Feidenhans'l and Vice-Chairman Pavol Sovák for a second two-year term. The European XFEL Council is the supreme organ of the company, functioning as the shareholder assembly and deciding important issues of company policy.

Robert Feidenhans'l, head of the Niels Bohr Institute and professor of nanophysics at the University of Copenhagen, Denmark, is internationally recognized for developing new methods and X-ray techniques for the exploration of the nanoworld.

Pavol Sovák is a professor at P.J. Šafárik University in Košice, Slovak Republic. His research interests include studying the relationships between the structure and the magnetic properties of amorphous and nanocrystalline soft magnetic materials using transmission electron microscopy and X-ray techniques.

Robert Feidenhans'l



Pavol Sovák

May 2012

29 February

Accelerator tunnel construction completed

Construction of the more than 2 km long accelerator tunnel is completed. The construction company ARGE Tunnel XFEL officially hands over the tunnel to DESY, which serves as the building contractor on behalf of European XFEL.

In March, the Accelerator Consortium starts to equip the tunnel with infrastructure and security equipment, such as radio, lighting, cable trays, and smoke detectors. The last accelerator module is scheduled to be installed in May 2015, after which the accelerator will be tested for the first time.

Work on the accelerator tunnel started in January 2011, when the tunnel boring machine TULA began to dig its way from the Osdorfer Born site to the DESY-Bahrenfeld site. In July 2011, TULA reached its destination. The tunnel was then equipped with a floor made of concrete elements.

9 May

Hamburg’s deepest underground scientific workplace

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

The HERA South underground building complex stretches over eight storeys and is more than 25 m deep. At the centre of the complex is the 15 m high former experiment hall, which offers 2000 m^2 of test and laboratory area. The underground building includes many more rooms, which will now be used as laboratories.

In the HERA South hall, scientists and engineers are developing and testing equipment to guide and control the European XFEL X-ray beam, components for the scientific instruments, detectors, and information technology for data acquisition and processing.

22 May

Research facilities collaborate on data management and analysis

European XFEL, DESY, Forschungszentrum Jülich, Germany, and National Research Centre Kurchatov Institute (NRC KI) in Moscow, Russia, cooperate to develop new data management and data analysis solutions for large-scale scientific facilities. A Memorandum of Understanding is signed in Berlin during the closing event of the German–Russian Year of Education, Science, and Innovation 2011–2012.

Experiments at new large-scale research facilities, such as the European XFEL, produce enormous amounts of data, which need to be stored, maintained, and made available for analysis. The European XFEL will serve as a pilot project for further collaboration between DESY, Forschungszentrum Jülich, and NRC KI on large-scale data management in high-performance computing.

June 2012

14 June

Tunnel construction completed

European XFEL reaches an important milestone by finishing the construction of the network of tunnels, which has a total length of nearly 5.8 km and extends 3.4 km from Hamburg-Bahrenfeld to Schenefeld in Schleswig-Holstein. The 11 tunnel sections are completed according to plan.

More than 400 participants—including guests from politics and science as well as staff from collaborating companies—celebrate the completion of tunnel construction. Films document the construction progress and the arrival of the tunnel boring machine AMELI after it finishes the last tunnel section. Following tradition, the patron saint of miners and tunnel builders, St. Barbara, is thanked in a short ceremony.

15 June

Hamburg physicists successful in Excellence Initiative

Physicists in Hamburg secure funding for the Hamburg Centre for Ultrafast Imaging (CUI) through the Excellence Initiative of the German federal and state governments. The aim of the new physics and chemistry research cluster is to study atomic motion in real time.

CUI THE HAMBURG CENTRE FOR ULTRAFAST IMAGING

The University of Hamburg submitted the proposal together with DESY, the Center for Free-Electron Laser Science (CFEL), the European Molecular Biology Laboratory (EMBL), the Center for Applied Nanotechnology (CAN), and European XFEL.

July 2012

10 July

Ultrashort X-ray laser pulses measured precisely for the first time

For successful research at X-ray lasers, the quality of the generated X-ray pulses is of great importance. An international team of scientists—headed by Christian David and Simon Rutishauser of Paul Scherrer Institut (PSI) in Villigen, Switzerland, and including researchers from European XFEL—precisely measures these pulses for the first time at the Linac Coherent Light Source (LCLS) X-ray laser at SLAC National Accelerator Laboratory in Menlo Park, California.

One key result of the observations is that the X-ray mirrors used do not reflect the radiation without modifying it, but (unintentionally) slightly focus it in the horizontal plane. This distortion impairs the focusing of the beam on the sample under investigation. Thanks to the new results, it is now possible to adapt the X-ray mirrors in such a way that the focusing can be compensated for and the full potential of the X-ray laser can be exploited.

August 2012

15–18 July

International conference on X-ray FEL science

About 200 scientists from more than 20 countries attend the world's first major international conference dedicated exclusively to science with X-ray free-electron lasers (FELs) at DESY.

At "Science at FELs 2012", researchers discuss experiments and approaches offering new insights into the nanoworld, and speakers present highlights achieved in the first seven years of operation of short-wavelength free-electron lasers (FELs). The conference is jointly organized by European XFEL and DESY.

17 July

125 magnets delivered from Russia and Sweden

A total of 125 quadrupole magnets custom-built for the European XFEL arrive in Hamburg. The magnets will be used to focus the electron beam between the undulator segments—the magnetic structures in which the electron beam generates the X-rays.

Based on a design devised by DESY, the magnets were produced by Budker Institute of Nuclear Physics (BINP) in Novosibirsk as a Russian in-kind contribution (IKC) to the European XFEL. After production, they were shipped to Manne Siegbahn Laboratory at Stockholm University, where they were measured and fiducialized as part of a Swedish IKC to the facility. The next step will be the final assembly and alignment in the undulator intersections of the European XFEL.

9 August

Cryostat from Poland for cryogenic tests

The first of two helium cryostats—part of Poland's IKCs to the European XFEL—arrives at the Accelerator Module Test Facility (AMTF) on the DESY site.

The 5 t, 4.5 m high metal cylinder, which a Polish truck delivered to DESY after a 10 h drive, will be used to test the superconducting niobium cavities for the accelerator of the European XFEL. The cryostat will be working at -271°C, and must be cooled and reheated on a weekly basis—an elaborate procedure that is only possible thanks to the sophisticated high-tech internal components.

August 2012

12 August

Self-seeding: Better pictures of the nanoworld

Scientists at LCLS in the USA announce that they successfully implemented a self-seeding method devised by researchers from DESY and European XFEL. The novel scheme, which involves a special crystal placed into the path of the radiation, dramatically improves the features of X-ray free-electron lasers.

Gianluca Geloni (European XFEL), Vitali Kocharyan (DESY), and Evgeni Saldin (DESY) invented the self-seeding method in 2010. In January 2012, a team of researchers from SLAC and Lawrence Berkeley National Laboratory (LBNL) in California, Argonne National Laboratory (ANL) in Illinois, and Technical Institute for Superhard and Novel Carbon Materials in Russia implements the proposed setting at LCLS and confirms the predicted outcome. The achievement immediately attracts widespread interest in the scientific community.

September 2012

18–22 September

European XFEL participates in physics festival

In Göttingen, Germany, more than 34 000 visitors attend the “Highlights of Physics” festival, which has the theme “Mysteries of Matter”. European XFEL staff members inform visitors about the new research centre and the progress of its construction, and present a hands-on laser experiment for students as well as other exhibits and films.

The festival is held every year and organized jointly by the German Federal Ministry of Education and Research (BMBF), the German Physical Society (DPG), and, in 2012, Georg-August-Universität Göttingen.

November 2012

13 November

Schleswig-Holstein Minister President Albig visits European XFEL

At the invitation of European XFEL, the minister president of the German federal state of Schleswig-Holstein, Torsten Albig, visits the European XFEL construction site in Schenefeld. The head of the Schleswig-Holstein government tours the 4500 m^2 future experiment hall and one of the photon tunnels.

December 2012

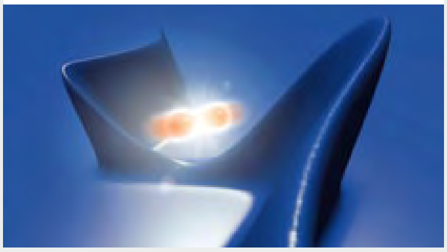
19 November

Profiling X-ray free-electron laser pulses

With their ultrashort X-ray flashes, free-electron lasers offer the opportunity to film chemical reactions and atoms in motion. However, for this super slow motion, the arrival time and the temporal profile of the pulses must be precisely known.

An international team led by Adrian Cavalieri from CFEL in Hamburg develops a measurement technique that provides complete temporal characterization of individual free-electron laser pulses at the Free-Electron Laser in Hamburg (FLASH) at DESY. The team, which includes researchers from the Small Quantum Systems (SQS) scientific instrument at European XFEL, is able to measure the temporal profile of each X-ray pulse with femtosecond precision.

Their technique can be implemented at any of the world's X-ray free-electron lasers, ultimately enabling the most effective utilization of these radiation sources.



11 December

Industrial production of undulators starts

The first undulators are delivered from industrial production to European XFEL. The facility will have three undulator systems. Each of the two larger ones will be 212 m long. They consist of 5 m long segments of 7.5 t each that have been developed at DESY and European XFEL since 2005. Companies in Germany and Spain produce them according to the European XFEL design.

Before the segments are installed in the underground tunnels in 2014 and 2015, the Undulator Systems group of European XFEL will follow a tough production schedule to complete the most important step: the magnetic measurements and tuning of all 91 segments.

13 December

DESY and European XFEL scientists win Innovation Award

Gianluca Geloni (European XFEL), Vitali Kocharyan (DESY), and Evgeni Saldin (DESY) receive the Innovation Award on Synchrotron Radiation 2012 from the Association of Friends of Helmholtz-Zentrum Berlin. Together with Paul Emma (LBNL), the physicists from DESY and European XFEL are honoured for their invention of a self-seeding method that significantly improves X-ray free-electron lasers (see 12 August).

The Innovation Award is conferred annually by the Association of Friends of Helmholtz-Zentrum Berlin to scientists at European research institutions.

02

CIVIL CONSTRUCTION

During its fourth year, civil construction made good progress on all three sites. With 5.77 km of tunnels, the 4500 m^2 experiment hall, and other underground, shaft, and surface buildings, the European XFEL site is one of the world's largest scientific construction endeavours.

Modulator hall in August 2012

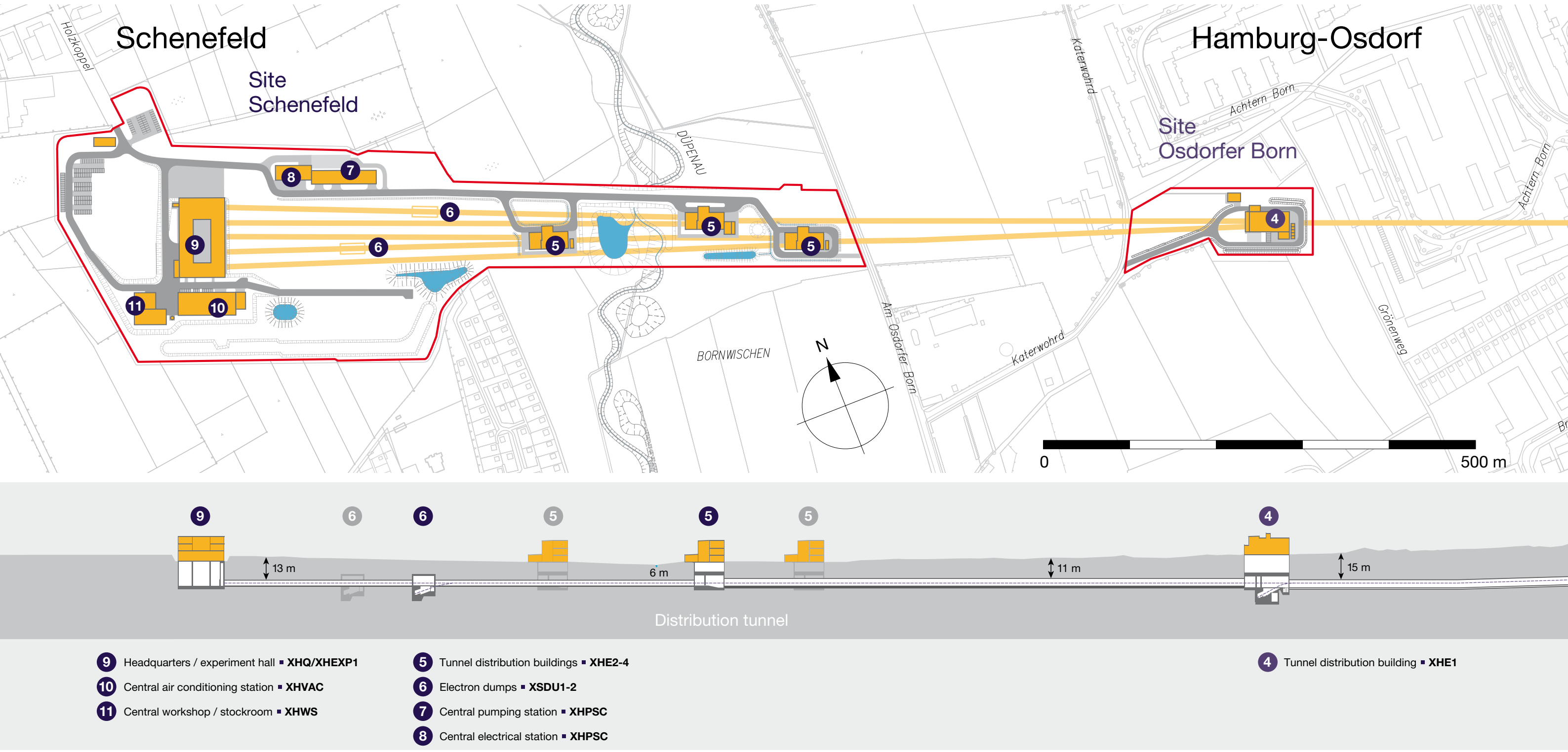


Figure 1 Layout of the European XFEL facility

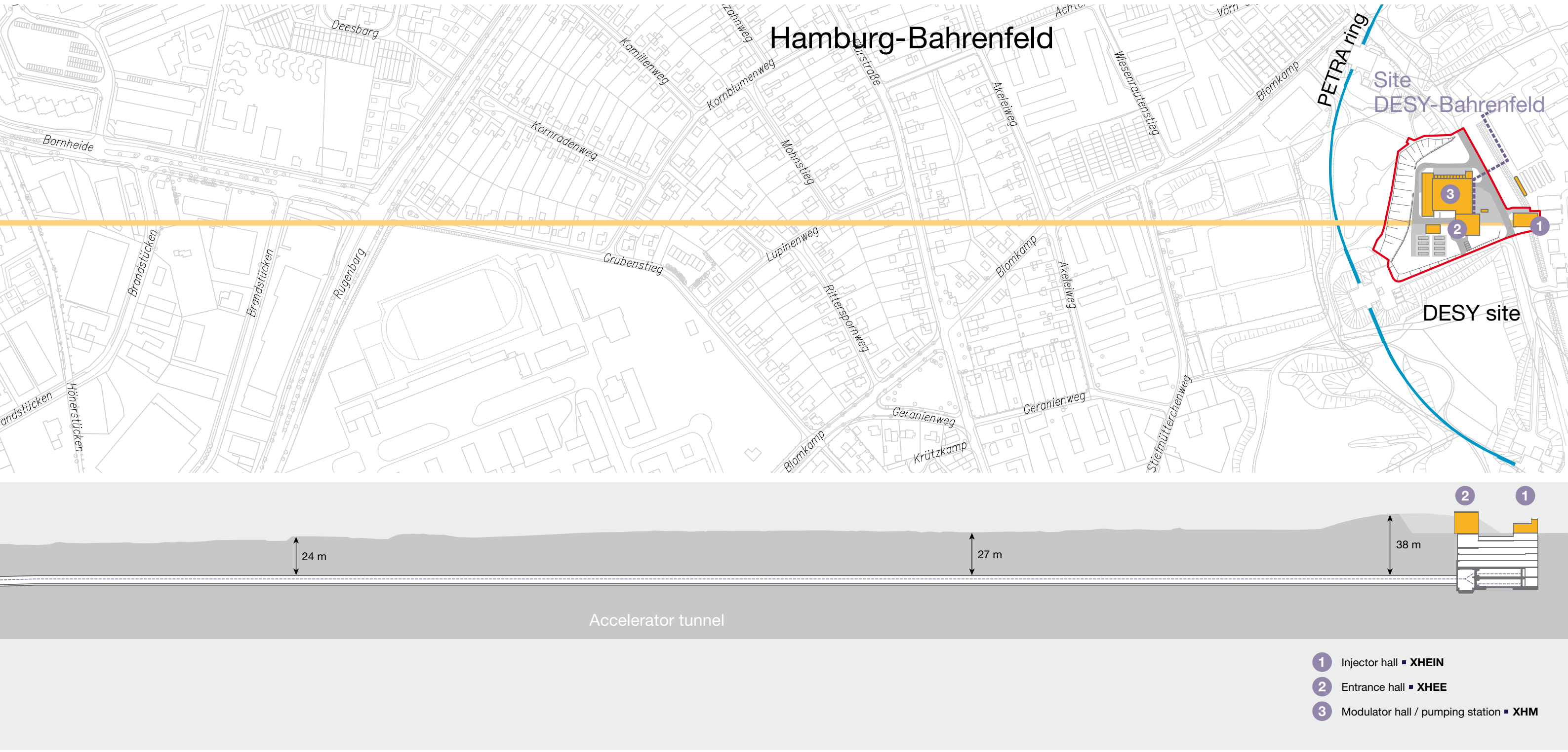
CIVIL CONSTRUCTION

In 2012, the civil construction project proceeded according to plan and all major milestones were met. The two-year tunnel boring effort was concluded in June, and installation of the technical infrastructure inside the tunnels has begun. The injector complex building and access halls are essentially finished and are now being prepared for the installation of the injector hardware and the linear accelerator. Approximately 80% of the experiment hall is completed, and the layout of the laboratory and office building has been planned.

Overview

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

The facility is approximately 3.4 km long and stretches from Deutsches Elektronen-Synchrotron (DESY) in Hamburg-Bahrenfeld all the way to the southern edge of the city of Schenefeld, in the German federal state of Schleswig-Holstein. It consists of a large network of tunnels for the accelerator and the photon beamlines

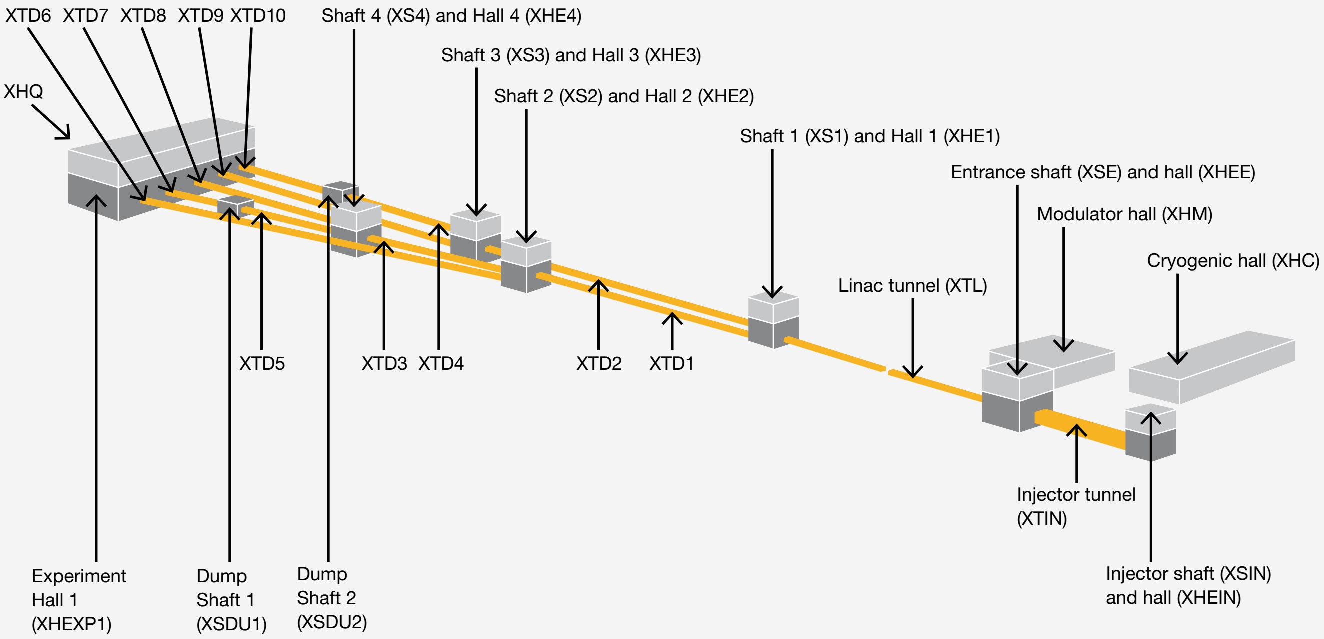


plus eight shaft building complexes, corresponding surface buildings, and assorted building structures for peripheral technical equipment (for example, pump housing, generators, and air conditioning). Most of the facility lies underground. The network of tunnels has a total length of about 5.77 km.

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

Status of tunnel construction—December 2012

At the end of 2011, only the undulator tunnels XTD3 and XTD6 remained to be excavated by the tunnel boring machine “AMELI” (“*Am Ende Licht*”, meaning “light at the end of the tunnel”). The two tunnels together comprised a total length of ca. 923 m. Tunnel boring began in February 2012 with XTD3, which was completed at the beginning of March. The approximately 70 m long machine was then dismantled and moved back to the experiment hall (XHEXP1), from where it started excavating the final tunnel, XTD6, at the beginning of April. Figure 3 shows the small celebration of the arrival of AMELI in the target shaft XS2 at the beginning of June 2012. The completion



Type

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

Building

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

Figure 2 Buildings of the European XFEL facility

of the two-year tunnel boring effort was celebrated with many invited guests on 14 June at the Schenefeld site. Figure 4 shows some of the guests in front of the large cutting wheel of AMELI.

After the completion of each tunnel shell, work started on the construction of the tunnel floors. By the end of 2012, the floors of the altogether 5.77 km long tunnels were completed. The civil construction crews then made way for the installation of the technical infrastructure. Figure 5 provides a view into the completed tunnel XTD3.

DESY-Bahrenfeld site

Figure 6 shows an aerial view of the injector complex region on the DESY campus in July 2012. The very deep shaft complex for the injector building had already been refilled, and the various walls for the many rooms of the seven-storey underground building, as well as the elevator shafts, were completed. Shown in the figure is the modulator

Figure 3 Celebration of AMELI arriving in the target shaft XS2 (June 2012)

Figure 4 Invited guests in front of the large cutting wheel of AMELI (June 2012)

Figure 5 View into the completed tunnel XTD3 (November 2012)

Figure 6 Aerial view of the injector complex region on the DESY campus (July 2012)

hall (XHM), which was completed at the end of 2011, as well as the entrance hall (XHEE) and injector hall (XHEIN) covering the access shafts to the injector building rooms and the linear accelerator tunnel (XTL).

Figure 7 offers a view into the entrance shaft of the injector complex (XSE). Figure 8 shows the corresponding ground floor of the entrance hall (XHEE). Both the two 20 t cranes and the elevator have been installed. Figure 9 (right) shows the finished injector hall (XHEIN) with the anthracite façade that will be used for all halls of the European XFEL facility placed above access shafts. A band around the façade will serve as a background for pictures illustrating the science related to the building. Figure 9 (left) shows a prototype piece produced and installed in 2012.

The underground injector complex building and the access halls are essentially finished, with only small cosmetic work left to be done.

Both the underground injector complex building and the access halls are essentially finished, with only small cosmetic work left to be done. The buildings have been handed over to the engineers and scientists in 2012 to prepare for the installation of the injector hardware and the linear accelerator.

Osdorfer Born site

At Shaft 1 (XS1) in Osdorfer Born, the linear accelerator tunnel (XTL) ends and the first two undulator tunnels (XTD1 and XTD2) begin. During 2012, work concentrated on the construction of the two underground

Figure 7 View into the entrance shaft of the injector complex XSE (August 2012)

Figure 8 View of the ground floor of the entrance hall XHEE (August 2012)

Figure 9 Finished injector hall XHEIN (October 2012)
Left Prototype piece of the band around the façade.
Right Anthracite façade for all halls placed above access shafts.

Figure 10 View into the accelerator tunnel XTL from inside the shaft building XS1 (November 2012)

storeys of the shaft building. The building is now complete and the call-for-tender documents for Hall 1 (XHE1) have been prepared. The order for the hall has been placed, and construction is scheduled to begin in early 2013. Figure 10 shows a view into the linear accelerator tunnel (XTL) from inside Shaft 1 (XS1). The entrance to the electron beam dump can be seen in the front.

Schenefeld campus

On the Schenefeld campus, work concentrated on the completion of the tunnelling and the construction of the floors and walls of the underground storeys of Shafts 2 to 4 (XS2 to XS4) and the two dump shafts (XSDU1 and XSDU2). Figure 11 shows the civil construction work inside Shaft 3 (XS3) as of August 2012. Figure 12 provides a view from the inside of the tunnel XTD3 through Shaft 4 (XS4) into the tunnels XTD5 (left) and XTD8 (right). Shaft 3 (XS3) is finished. Some work on Shafts 2 and 4 (XS2 and XS4) is still pending.

Since the site of the future experiment hall (XHEXP1) was still used to provide the infrastructure and material required by AMELI for boring the remaining tunnel sections (XTD3 and XTD6), work here concentrated on the construction of the floor and walls in the northern part of the hall until the tunnel boring machine reached its destination in June 2012. As of December, approximately 80% of the experiment hall was finished, including the ceiling, which also constitutes the floor of the laboratory and office building (XHQ) that will be placed on top. Figure 13 shows the activity in the experiment hall in April 2012. Figure 14 provides a view of the northern part of the hall in November. In this region, the hall including the ceiling is essentially finished.

Figure 11 Civil construction work inside the shaft XS3 (August 2012)

Figure 12 View from the tunnel XTD3 through the shaft XS4 into the tunnels XTD5 (left) and XTD8 (right) in November 2012

The call-for-tender documents for Halls 2 to 4 (XHE2 to XHE4) are currently being prepared, and the publication of the call is expected for early 2013. The same applies to the auxiliary technical buildings: the pump and electrical power building (XHPSC), the air conditioning building (XHVAC), and the workshop and storage building (XHWS).

In the course of 2012, the numerous and complex requirements for the laboratory and office building (XHQ) were reviewed and refined. A planning office prepared a first study of the laboratory tract, and a detailed layout of the two storeys of the office tract of the building was also drawn up. Figure 15 shows a cross-sectional view of the second floor of the office building, which sits on top of the underground experiment hall (XHEXP1).

Figure 13 Work in the experiment hall XHEXP1 (April 2012)

Figure 14 View of the northern part of the experiment hall XHEXP1 (November 2012)

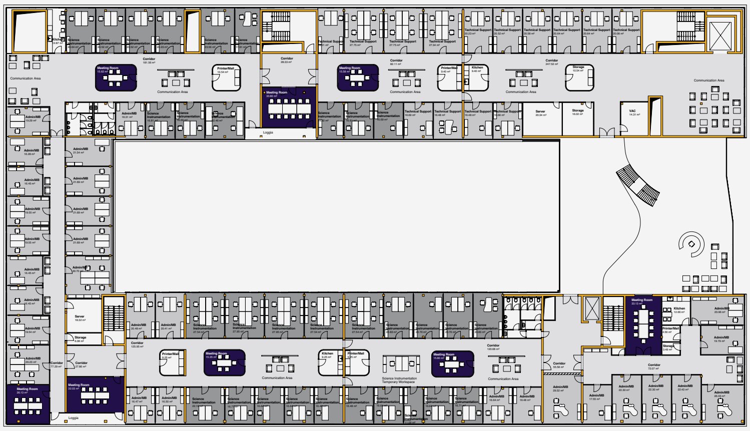


Figure 15 Cross-sectional view of the second floor of the office building (XHQ)

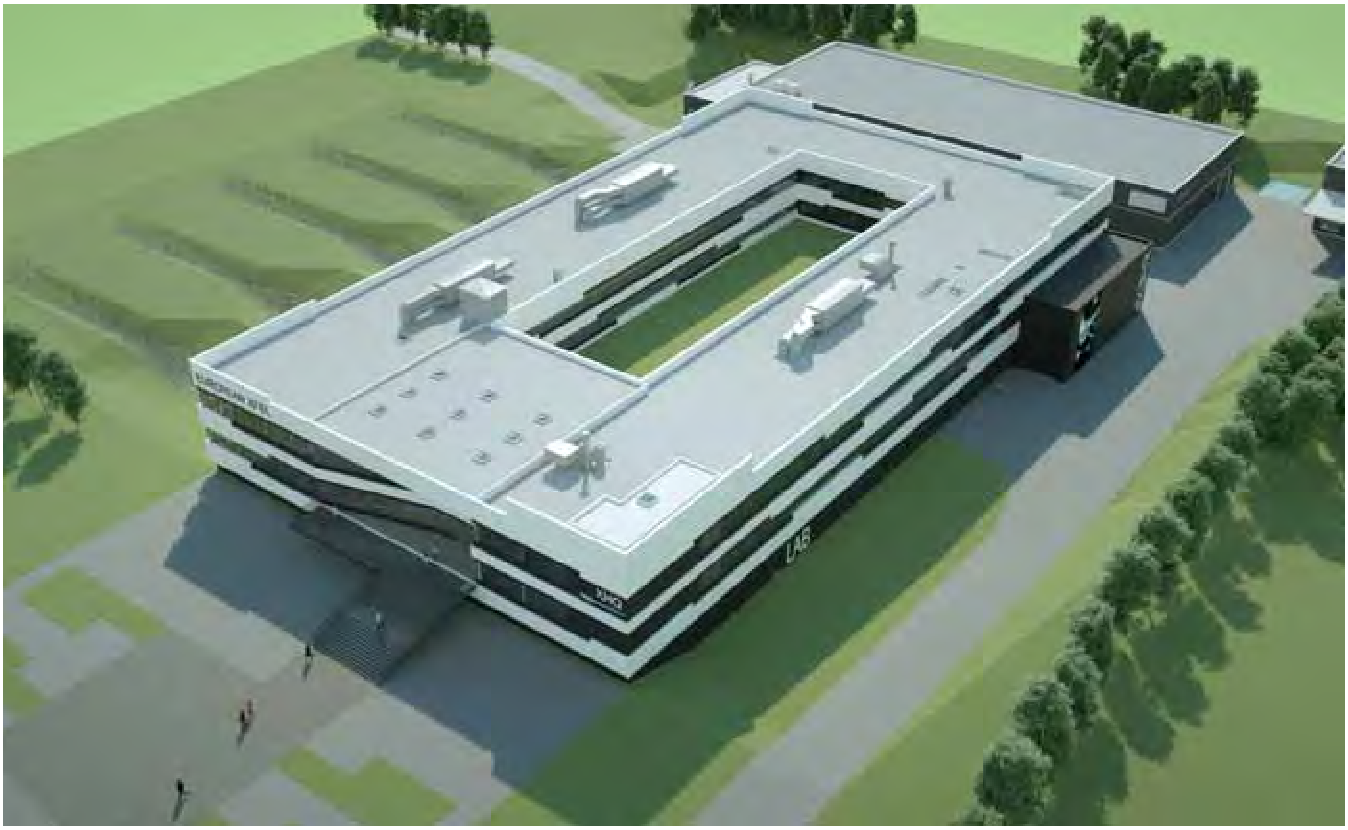


Figure 16 New layout of the laboratory and office building (XHQ)

Architecture

In parallel to the planning of the office building layout, the façade design was developed. As a first step, the layout of the accompanying technical buildings was investigated, and the campus was slightly reorganized. Figure 16 shows the new layout of the laboratory and office building (XHQ), with an example solution for the façade architecture. A decision on the choice of façade is expected for early 2013.

Summary and forecast

As in the previous years, in 2012, all major milestones in civil construction were met. Costs for civil construction remained within the budget foreseen for the year. We are optimistic that civil construction will continue to proceed according to plan in 2013. This includes the call for tenders and the start of construction for the auxiliary technical buildings (XHPSC, XHVAC and XHWS), the construction of the entrance halls XHE1–4 and the finalization of the planning work for the laboratory and office building (XHQ), the construction of which is to commence in early 2014.

03

IN-KIND CONTRIBUTIONS

To a great extent, our partners contribute to the construction costs in the form of components or human resources. To date, 75 such in-kind contributions are under way. An international consortium of 17 institutes is building the superconducting accelerator.

Preparing a superconducting cavity for cryogenic tests

OVERVIEW

European XFEL shareholders contribute to construction costs in cash or in kind. In-kind contributions (IKCs) can take the form of component delivery, secondment of staff, or both. To date, 73 IKCs by 21 institutes from 9 different countries are under way for a total of 564 million euro (M€), while a few other proposals are in preparation. IKC implementation started in 2010, and the first significant achievements were made in 2011. Important developments in 2012 were the completion of all infrastructure needed at the institutes, the overall procurement of raw material and parts, and the delivery of the first components. As a consequence, a significant number of milestones were achieved.

Changes in the IKC coordination office

Silvia Bertini joined the IKC office in 2012, and is deeply involved in the organization of the In-Kind Review Committee (IKRC) meetings and the process of milestone validation.

Overall contributions

In 2012, some adjustments in the respective amounts of IKCs were made. However, the total value of IKCs under way remains about 564 M€, including contracts to Russian institutes (Table 1).

Abbreviation	Country	Number of IKCs	IKC value (k€)
DK	Denmark	1	2 860
FR	France	4	36 000
DE	Germany	34	410 440
GR	Greece	0	0
HU	Hungary	0	0
IT	Italy	3	32 385
PL	Poland	4	15 977
RU	Russia	13	44 790
SK	Slovakia	0	0
ES	Spain	4	7 526
SE	Sweden	10	4 948
CH	Switzerland	2	9 077
Total		**75**	**564 003**

Table 1 Projected IKC amounts by country (in 2005 prices) in thousands of euro (k€) as of December 2012

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 who want to contribute to the project are awarded manufacturing contracts, which are then managed with the same procedures as IKCs. To date, European XFEL and five Russian institutes have concluded 13 manufacturing contracts.

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

Table 2 Institutes contributing in kind to the European XFEL facility

Contributing institutes

As of December 2012, a total of 21 institutes are contributing in kind to the European XFEL facility (Table 2).

IKRC recommendations

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

The IKRC performs the following tasks:

- Reviewing expressions of interest from institutes of participating countries to contribute in kind
- Checking the suitability of specific components to be treated as IKCs (that is, whether a component can be built separately and in a different location from the other components, and then be integrated into the rest of the facility)

Abbreviation	Institute	IKC No.	Work package	Title	Value (€)
DTU	Technical University of Denmark	DK01	81	Components for the scientific instrument FXE	2 860 000
DESY	Deutsches Elektronen-Synchrotron, Germany	DE12	12	Warm magnets	972 000
		DE18	18	Special electron beam diagnostics	10 234 000
		DE28	28	Accelerator control system	22 031 000
		DE34b	34	Utilities – IT network	3 569 191
		DE35	35	Radiation safety	3 266 100
		DE40	40	Information and process support	2 645 000
		DE46	46	3.9 GHz system: cavities and cryomodule	3 180 040
INFN	Istituto Nazionale di Fisica Nucleare, Italy	IT03	46	3.9 GHz system: RF system, BPM, HOM	3 050 600
BINP	Budker Institute of Nuclear Physics of SB RAS, Russia	RU21	34	Power supplies for the corrector magnets	1 915 500
SU	Stockholm University, Sweden	SE09	71	Radiation dose measurement system for undulators	421 190
UU	Uppsala University, Sweden	SE10	85	1D imaging spectrometer for the SQS instrument	270 000
		SE11	85	Magnetic-bottle electron spectrometer for the SQS instrument	65 000

Table 3 Contributions proposed in 2012 by Denmark, Germany, Italy, Russia, and Sweden (in 2005 prices)

- Verifying that the proposing team has the technical competence and experience to perform the corresponding task
- Verifying the adequacy of the available infrastructure
- Issuing a recommendation for or against the start of the next step (that is, the drafting of a detailed agreement between European XFEL and the contributing institute)

In 2012, the IKRC held its 5th and 6th meetings in April and October. During these two meetings, the IKRC analysed 13 contributions proposed by Denmark, Germany, Italy, Russia, and Sweden (Table 3).

The IKRC recommended all of these proposals for a total value of 54.5 M€.

As of December 2012, a total of 73 proposals received favourable recommendations from the IKRC.

In 2012, the IKRC analysed 13 contributions proposed by Denmark, Germany, Italy, Russia, and Sweden.

Allocations of IKCs

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

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

In 2012, three contributions were allocated by the management board (Table 4), and twelve contributions were allocated by the council (Table 5).

Abbreviation	Institute	IKC No.	Work package	Title	Value € 2005 (2012)
CEA	Commissariat à l’Énergie Atomique et aux Énergies Alternatives, France	FR04	17	Production, delivery and commissioning of re-entrant cavity BPMs	465 000
BINP	Budker Institute of Nuclear Physics, Russia	RU25	12	Production and delivery of 22 coil sets for the XQK warm magnets	306 008 (385 000)
UU	University of Uppsala, Sweden	SE01	79	Sample injector and diagnostic system	520 000

Table 4 IKCs allocated in 2012 by the European XFEL Management Board (in 2005 prices)

In 2012, 15 contributions with a total value of 140.8 M€ were allocated to the respective institutes.

As of the end of December 2012, a total of 43 IKCs have been allocated.

The progress of each contribution is monitored through specific milestones detailed explicitly in the IKC agreement. Seventy-eight milestones were completed and validated in 2012. The corresponding shareholders receive regular notification of the completion of each milestone.

Abbreviation	Institute	IKC No.	Work package	Title	Value € 2005 (2012)
DTU	Technical University of Denmark	DK01	81	Components for the scientific instrument FXE	2 860 000
DESY	Deutsches Elektronen-Synchrotron, Germany	DE17	17	Design, procurement, installation, and commissioning of a beam position monitor (BPM) system	3 094 410
		DE17b	17	Design, procurement, installation, and commissioning of standard electron beam diagnostics	11 195 960
		DE34	34	Design, procurement, installation, and commissioning of utilities systems	75 852 808
		DE36	36	Design, procurement, installation, and commissioning of general safety systems	6 265 380
		DE01b	01	Design, procurement, installation, and commissioning of the waveguide system	11 525 000
		DE07	07	Design, procurement, installation, and commissioning of the frequency tuner system	8 303 200
		DE10b	10	Design, procurement, installation, and commissioning of non-cryogenic test equipment for test stands in the AMTF hall	8 781 150
BINP	Budker Institute of Nuclear Physics, Russia	RU21	34	Power supplies for the corrector magnets	1 909 870 (2 416 360)
CIEMAT	Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas, Spain	ES02	11	Design, manufacturing, testing, and delivery of the superconducting magnets	2 129 100
UPM	Universidad Politécnica de Madrid, Spain	ES03	34	Design, manufacturing, testing, and delivery of the power supplies for the superconducting magnets	1 448 000
PSI	Paul Scherrer Institut, Switzerland	CH03	17	Design, procurement, installation, and commissioning of electronics software and hardware for the beam monitor system	6 138 000

Table 5 IKCs allocated in 2012 by the European XFEL Council (in 2005 prices)

Milestone validation

The progress of each contribution is monitored through specific milestones 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. A specific procedure for the validation of milestones was established in 2011 and has been implemented since then.

Seventy-eight milestones were completed and validated in 2012, each time involving the issuance of a certificate signed by the work package leader and the Accelerator Consortium coordinator (ACC) or scientific director, and submitted for approval by the management board.

The corresponding shareholders receive regular notification of the completion of each milestone.

As of the end of December 2012, a total of 102 milestones were completed and validated. All related documentation is stored in a specific database for future traceability.

Institute	Name of visited location	Contribution
NIIEFA	D.V. Efremov Scientific Research Institute of Electrophysical Apparatus in St. Petersburg, Russia	Production, tests, and delivery of 715 warm magnets of 23 different types (WP12). A total of 73 magnets were produced, and 15 delivered in December 2012.
CIEMAT	ANTEC S.A. in Bilbao, Spain	Production of 102 sets of quadrupole and dipole coils for the superconducting magnets (WP11). Special tooling and procedures were implemented in the series production.
	Trinos Vacuum Projects in Valencia, Spain	Production of 102 vacuum vessels and assembly of the superconducting magnets (WP11). The German association for technical inspection (TÜV) certified the manufacturing procedures and currently witnesses all individual pressure and vacuum tests. A total of 18 magnets were delivered.
MSL	Manne Siegbahn Laboratory at Stockholm University, Sweden	Fiducialization of quadrupole magnets type XQA (WP12). All measurements were done and reports delivered. The contribution was completed.
UU	Ångström Laboratory at Uppsala University, Sweden	Design, production, and installation of a laser heater system for the injector (WP14). Detailed design is completed, and procurement of parts is ongoing.
UU	Laboratory of Molecular Biophysics at Uppsala University, Sweden	Structural biology applications for the SPB instrument (WP84). Concept of a biomolecule imaging station is under development.

Table 6 IKC contributors visited by the IKC coordinator in 2012

Progress of IKC contracts

In 2012, the series production of components started for several IKCs in the accelerator complex, including pulse modulators and transformers, klystrons, waveguides, superconducting cavities, vacuum components, warm and cold magnets, and cryostats.

Two IKCs were successfully completed:

- RU17 by Budker Institute of Nuclear Physics, Russia, for WP12: "127 quadrupole magnets type XQA". All magnets were produced, tested, and delivered.
- SE04 by Manne Siegbahn Laboratory, Sweden, for WP12: "Fiducialization of quadrupole magnets type XQA". Measurements were done and test reports delivered, showing performance characteristics according to specifications.

To follow up on IKC activities and strengthen relationships with contributors, the IKC coordinator visited the facilities of several contributors (Table 6). Great progress was made in 2012: several components are already produced and have passed the acceptance tests, while most of other contributions successfully passed the production readiness review.

Some significant achievements in 2012 are shown in Figures 1 through 10.

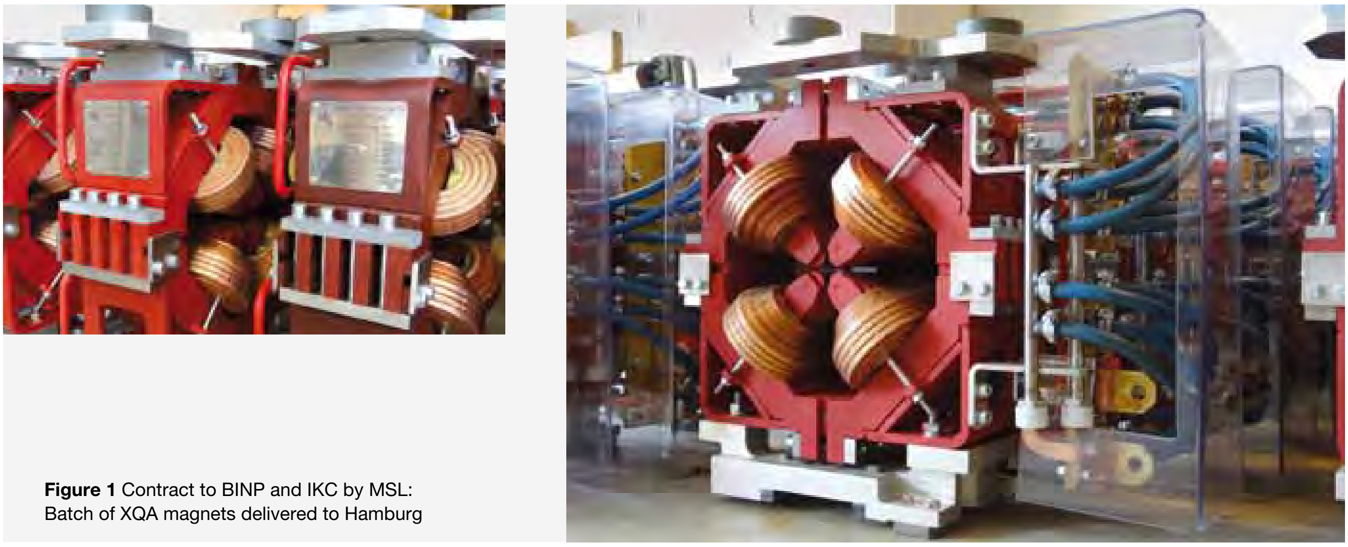


Figure 1 Contract to BINP and IKC by MSL: Batch of XQA magnets delivered to Hamburg

Figure 2 IKC by CIEMAT: Winding dipole and quadrupole coils for the superconducting magnets at ANTEC S.A. in Bilbao, Spain

Figure 3 IKC by CIEMAT: Manufacturing the vacuum vessel for the superconducting magnets (left) and integrating a magnet into the vacuum vessel (right) at Trinos Vacuum Projects in Valencia, Spain

Figure 4 Contract to NIIEFA: Quadrupole and sextupole magnets ready to be shipped

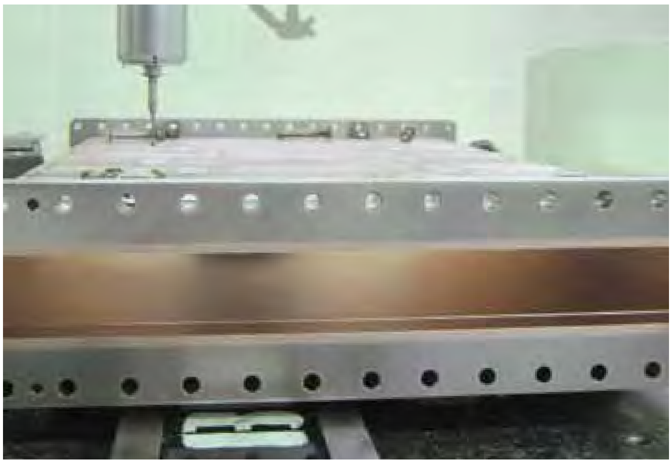


Figure 5 Contract to BINP: Vacuum chamber for dipole magnet of bunch compressor

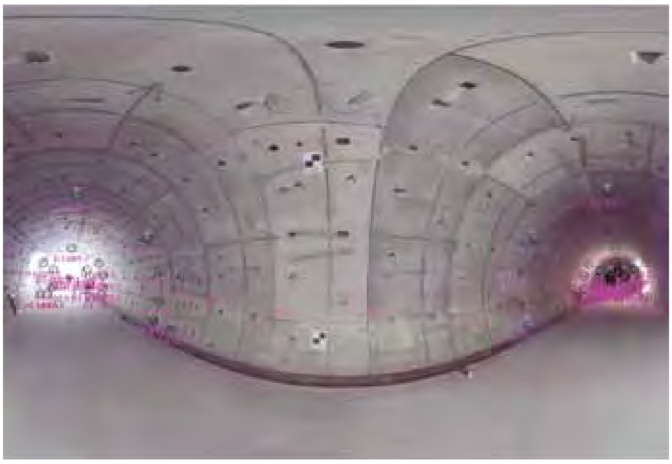


Figure 6 IKC by DESY: Survey of tunnel wall (WP32)

Figure 7 IKC by WUT: Production and installation of a 150 m long helium transfer line

Figure 8 IKC by WUT: Installation in AMTF of a vertical cryostat for testing superconducting cavities

Figure 9 Contract to BINP: Assembly of cryogenic equipment for accelerator module test bench

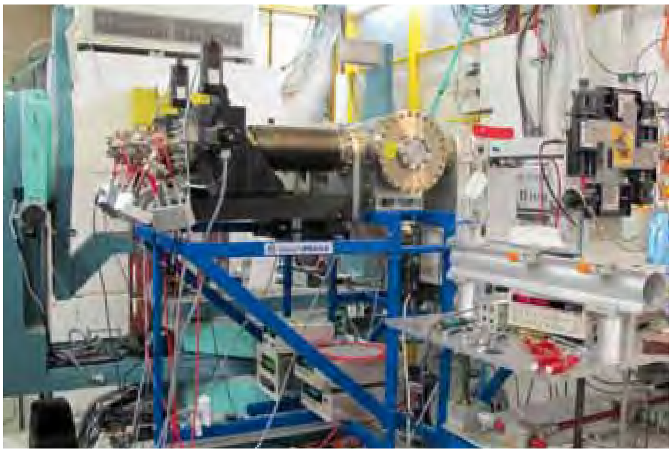


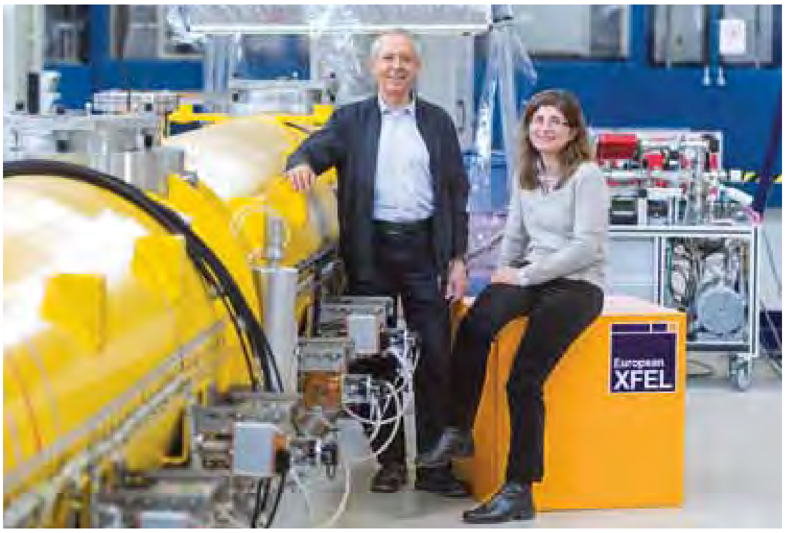
Figure 10 Contract to JINR: Prototype of microchannel plate (MCP)–based detector under test at the DORIS accelerator at DESY

Outlook

In 2013, allocation of the remaining IKCs is expected to be completed. In addition, a significant number of milestones should be achieved in the ongoing IKCs. The delivery of the first batch of superconducting cavities and cryomodules is expected in the first half of 2013, and the startup of the testing activities in the Accelerator Module Test Facility (AMTF) will be a major event. In parallel, other serial components of the accelerator complex should be delivered in 2013, and installation will start in the surface buildings at the DESY-Bahrenfeld site. ■

Publications

[1] Management and control of in-kind contributions
S. Prat
RAMIRI 2012 Learning Programme
Trieste, Italy, 17–20 June 2012



Group members
Serge Prat (group leader) and Silvia Bertini

ACCELERATOR CONSORTIUM

The accelerator complex of the European XFEL is being constructed by an international consortium under the leadership of Deutsches Elektronen-Synchrotron (DESY). Seventeen European research institutes are contributing to the complex and its comprehensive infrastructure, with DESY also providing technical building equipment and general infrastructure. The consortium already delivered first components. The production of series components is due to start in early 2013. Following the completion of the linear accelerator tunnel boring in summer 2011, the installation phase is now well under way.

Close collaboration

Work in an international consortium requires close collaboration. With the support of the work package leaders, a project team led by DESY is coordinating all activities related to the accelerator complex. At the same time, the team acts as a link to the European XFEL project management. Additional coordinators take care of selected general issues, like accelerator cavities or modules. The preparation of the accelerator installation phase also requires special attention.

To foster the team spirit required for such a complex international undertaking, the DESY project team organized a general meeting of all consortium members in spring 2012 (Figure 1). In addition, well-established regular meetings of the various work package groups and the Accelerator Consortium Board ensure information exchange and coordination between work packages and management. The daily work in teams with members from different institutes in different countries guarantees that local expertise is spread and knowledge transferred to the benefit of the European XFEL project.

Regular project status presentations help to update the project plan with its sophisticated interconnections. Corrections are made whenever and wherever required in order to ensure the overall project goal of starting the accelerator commissioning in 2015.

First components

Procurement of components, including tendering and contracting, is realized in close cooperations that sometimes last several months. Virtually all major contracts for manufacturing the accelerator components have been awarded. As long manufacturing times are not uncommon for large-series orders, contract supervision — which includes regular visits to manufacturers — may, in some cases, extend until the commissioning of the accelerator.

Many accomplishments of the work package groups and consortium institutes are directly visible through the delivery of first components. Prototypes and first series components are available for assembly checks. The production of the focusing magnets for the undulator beamlines by Budker Institute of Nuclear Physics (BINP) of the Siberian Branch of the Russian Academy of Sciences (SB RAS) in Novosibirsk, Russia, and the subsequent precision measurement of the magnets at Stockholm University in Sweden have already been completed. All other beam transport magnets are produced by D.V. Efremov Scientific Research Institute of Electrophysical Apparatus (NIIEFA) in St. Petersburg, Russia (Figure 2). Other components have passed critical prototyping steps, for instance the beam position monitor (BPM) system, a joint effort of Commissariat à l'Énergie Atomique et aux Énergies Alternatives (CEA) in Saclay, France, DESY, and Paul Scherrer Institut (PSI) in Villigen, Switzerland. Using the BPM system, a position resolution better than 1 μm has been measured at charges below 1 nC.

More than 70% of the niobium—including tubes—required to build the superconducting accelerator cavities was delivered to the cavity producers after inspection at DESY. First pre-series cavities have already been produced. The mechanical fabrication process has been qualified, and the surface treatment is currently being qualified in a multistep procedure with intermediate cavity tests at DESY carried out by a team from Henryk Niewodniczański Institute of Nuclear Physics (IFJ-PAN) of the Polish Academy of Sciences in Kraków, Poland. The actual work at the cavity producers is supervised by a team from DESY and Istituto Nazionale di Fisica Nucleare (INFN) in Milano, Italy.

Figure 1 Attendees of the spring meeting of the Accelerator Consortium

Figure 2 Dipoles for the bunch compressor chicanes at NIIEFA

Figure 3 First accelerator cavities for the European XFEL

Figure 4 Prototype accelerator module fully assembled with auxiliary equipment like waveguides, cable tray, and coupler vacuum pipes

At the end of 2012, the first cavities that were completely produced and surface-treated in industry were delivered to DESY (Figure 3). After full qualification of those first cavities, a final delivery rate of up to eight cavities per week is anticipated, yielding 50 tested cavities available by March 2013. This will allow for a timely start of the accelerator module assembly at Institut de Recherche sur les lois Fondamentales de l'Univers (IRFU) of CEA in Saclay.

In the production of high-power radio frequency (RF) couplers, brazing and copper plating remain challenging, but some progress has been achieved. Production of a first set of eight couplers, with relaxed specifications, was accepted by the coordinating institute, Laboratoire de l'Accélérateur Linéaire (LAL) in Orsay, France. Further couplers will be used to improve the process. The start of the industrial series production is still on a critical path. DESY continues to support the efforts of the consortium partner, LAL in Orsay.

The assembly of the accelerator modules requires not only cavities and high-power couplers, but also the cryostats themselves as well as superconducting quadrupole packages (Figure 4). Here, DESY is collaborating with INFN Milano and Centro de Investigaciones Energéticas, Medioambientales y Technológicas (CIEMAT), in Madrid, Spain. One third of the BPMs are provided by CEA in Saclay, higher-order mode absorbers by National Centre for Nuclear Research (NCBJ) in Świerk, Poland, and cold vacuum components by BINP.

At the end of 2012, the first cavities that were completely produced and surface-treated in industry were delivered to DESY. A final delivery rate of up to eight cavities per week will allow for a timely start of the accelerator module assembly.

Low-level RF control system

One of the most crucial accelerator subsystems needed for successful operation of the European XFEL is the low-level RF (LLRF) system. To deliver a high-quality electron beam with precisely defined energy, sufficiently small energy spread, stable peak current, and the required timing stability, a dedicated control system must regulate the accelerating field in all accelerating sections. The accelerating gradient has to be stabilized to a level of better than 0.01%, and the maximum accepted phase variation between the accelerator modules and the overall phase reference should stay below 0.01°. Each RF station, with its klystron on the high-power side, will get its own low-power-level control.

LLRF system description

The LLRF system measures probe signals from each cavity and calculates the klystron voltage and phase to ensure a constant accelerating field. In addition, it drives the piezo tuners that mechanically deform the cavity during an RF pulse to keep the resonance frequency constant.

The LLRF system measures probe signals from each cavity and calculates the klystron voltage and phase to ensure a constant accelerating field. In addition, it drives the piezo tuners that mechanically deform the cavity during an RF pulse to keep the resonance frequency constant.

The standard LLRF system is built as a semi-distributed system consisting of two groups of electronic racks located below the respective accelerator modules. Each group takes care of two accelerator modules, that is, 16 superconducting cavities. Patch panels are used to connect the LLRF system to the individual cavities (Figure 5), the overall phase reference, and the pre-amplifier of the klystron. The electronic hardware includes dedicated modules for amplitude and phase control as well as many more functional boards (Table 1).

The real complexity of the overall system becomes visible in Figure 6, which shows the components of the LLRF system. A major part of the

Figure 5 Patch panel connecting the RF signal cables to the LLRF system

Functional board	Abbreviation
Down converter	uDWC
Fast analogue-to-digital converter	uDS800
Digitizer board	uDAQ
Computing unit	CPU
Vector modulator	uVM
Power supply	uPS
Power supply module	PSM
Management and control hub	MCH
RF reference module	REFM
Local oscillator generation module	LOGM
Timing	TMG
Drift compensation module	DCM
Piezo driver module	PZ16M
Interlock	ITLK
Coupler processing interlock module	CPIM
Klystron lifetime management	KLM

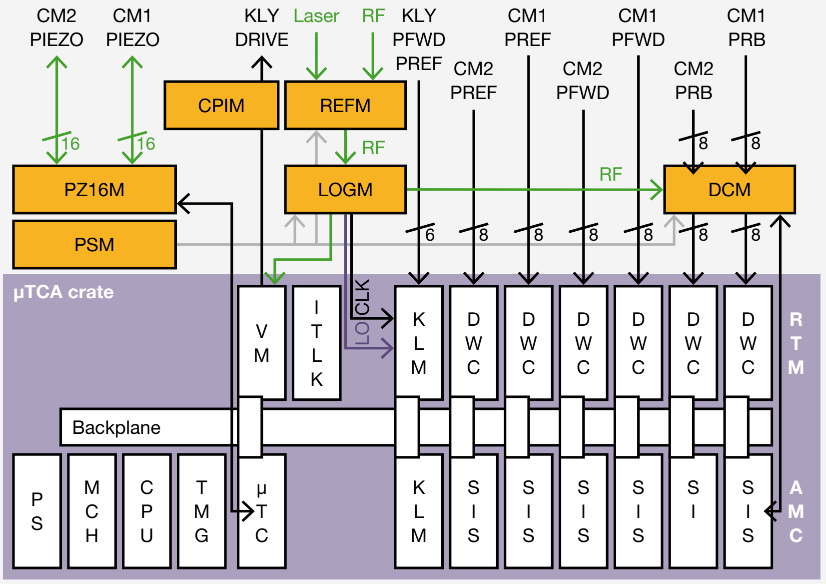
Table 1 Functional boards of the LLRF system as developed for the European XFEL

electronic boards is integrated in a newly developed micro-telecommunications computing architecture (µTCA) electronic crate (blue). Other blocks are installed next to it to keep the distance between all units as short as possible. Development of the boards is part of DESY's in-kind contribution to the European XFEL. The work strongly profits from collaboration with several Polish institutes and industry. The electronic boards are either in the prototyping phase, or pre-series production has started.

The most important result was the improvement of LLRF control performance, which clearly demonstrated amplitude and phase stability within European XFEL specifications.

LLRF system tests at FLASH

A complete LLRF system has been installed at DESY's Free-Electron Laser in Hamburg (FLASH) facility, where intensive studies are done to finalize the design and to develop and test the firmware and software required for optimum performance (Figure 7). New tools were implemented and tested at FLASH that support automation



AMC = Advanced mezzanine card
CLK = Clock
CM = Cryomodule
CPIM = Coupler processing interlock module
CPU = Computing unit
DCM = Drift compensation module
DWC = Down converter
ITLK = Interlock
KLM = Klystron lifetime management
KLY = Klystron
LO = Local oscillator
LOGM = Local oscillator generation module
MCH = Management and control hub

PFWD = Forward power
PIEZO = Piezo tuner
PRB = Cavity probe signal
PREF = Reflected power
PS = Power supply
PSM = Power supply module
PZ16M = Piezo driver module
REFM = RF reference module
RTM = Rear transition module
SIS = Digitizer board
TMG = Timing
µTC = Control board
VM = Vector modulator

Figure 6 The components of the LLRF system as developed for the European XFEL

(tuning with respect to the loaded quality factor Q_L and piezoelectric tuner setting) and machine protection (cavity gradient limiters $V_{cav} < V_{max}$, quench detection being crucial for cryogenic operation, and klystron lifetime management). New operation strategies were validated during high electron beam current studies. The most important result was the improvement of LLRF control performance, which clearly demonstrated amplitude and phase stability within European XFEL specifications (Figure 8).

Figure 7 LLRF electronics installed in a shielded rack underneath an accelerator module in the FLASH facility. The installation is similar to the situation in the European XFEL injector. In the linear accelerator tunnel, the LLRF racks will be higher.

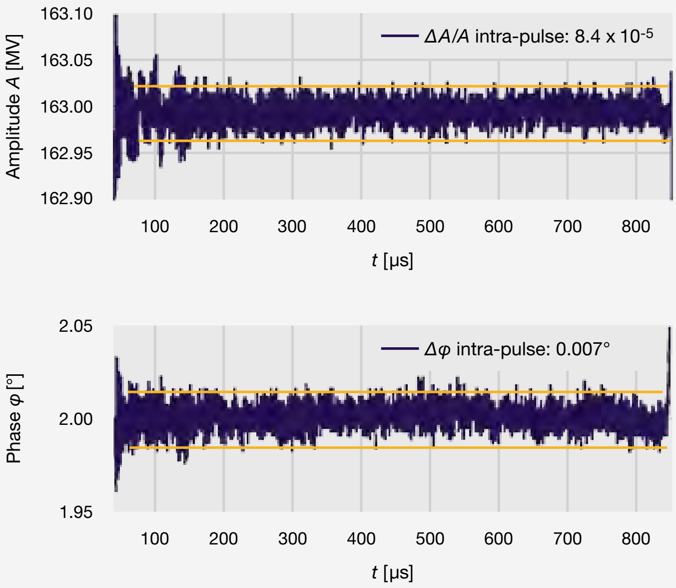


Figure 8 The improvement of LLRF control performance as demonstrated at FLASH showed the successful integration of a beam-based feedback system yielding an improvement in arrival time jitter by a factor of 3. Cavity fundamental modes were detected and filtered (8π/9 and 7π/9 modes). European XFEL specifications were achieved with respect to amplitude and phase stability ($\Delta A/A < 9 \times 10^{-5}$, $\Delta\varphi < 0.008°$).

Figure 9 Installation of a pulse cable in the open space beneath the tunnel floor

Infrastructure

An essential milestone for the European XFEL was reached when the boring of the linear accelerator tunnel was completed in the summer of 2011. Construction of the tunnel entry and floor followed. DESY took over the responsibility for further tunnel construction at the end of February 2012 and, together with subcontractors, immediately started to install the general infrastructure, such as tunnel lighting, safety equipment, and general energy supply. The pulse cables for the supply of the RF transmitter tubes followed a short time later (Figure 9). Installation of the accelerator itself will begin in 2013. First preparations started with some steel work for support structures and welding of accelerator module suspensions. The prerequisite was a precise survey of the overall tunnel geometry.

Figure 10 Vertical test cryostats in the AMTF are used to test all 800 superconducting cavities of the European XFEL.

The superconducting accelerator of the European XFEL requires a suitable cooling supply. During the acceptance tests in the Accelerator Module Test Facility (AMTF) at DESY, which are performed by IFJ-PAN and DESY, the individual cavities and the completed accelerator modules already need to be cooled to 2 K (Figure 10). For this purpose and later European XFEL operation, the existing refrigeration plant at DESY must be rebuilt and modernized. The corresponding work is well on track. Transfer lines to transport the cold helium must also be manufactured and installed together with sophisticated distribution boxes. ■

04

PHOTON BEAM SYSTEMS

From the generation of the X-rays to their use, four groups are involved. They design and construct the undulators generating the beam, develop schemes to improve its characteristics, build optical elements to transport it, and devise devices to monitor its properties.

Aligning undulator magnets with micrometre precision


Europ
XFEL

UNDULATOR SYSTEMS

Inside long arrays of magnets called undulators, the bunched electron beam follows a slalom trajectory, which induces it to emit intense pulses of radiation. These pulses are amplified through the self-amplified spontaneous emission (SASE) process, resulting in the generation of ultrabrilliant pulses of X-ray radiation. The design, construction, and operation of these systems are the responsibility of the Undulator Systems group.

Undulator technology at the European XFEL

The development of European XFEL undulator technology is the result of a synergetic collaboration between European XFEL and the PETRA III project at Deutsches Elektronen-Synchrotron (DESY). At the European XFEL, an undulator segment consists of a mechanical support system, which comprises the girders, support mechanics, spindles, motors, stands, and floor mounts as well as the local control system, as well as a magnetic structure made of NdFeB magnets and FeCo poles mounted in non-magnetic support modules. The magnetic structures are clamped onto the girders using a simple common interface, which enables the use of a suitably designed standard mechanical support system for all undulator segments.

Five main steps were established for undulator segment production:
1. Production of the support structure by specialized suppliers
2. Production of the magnetic structure by specialized suppliers
3. Combination of both structures at European XFEL
4. Magnetic measurements and precision tuning at European XFEL
5. Final commissioning and preparation for installation at European XFEL

The time available for the production of the undulator segments is about 24 months, starting in October 2012. On average, one undulator segment needs to be completed per week. Magnetic measurements and tuning are expected to take about three weeks per segment. Therefore, three magnetic-measurement benches need to be operated in parallel.

Activities in 2012

In 2012, activities included:
1. Implementation of final changes resulting from experience with the pre-series prototypes
2. Start of serial production of 85 undulator segments
3. Completion, characterization, and qualification of the three magnetic benches
4. Qualification and education of sufficient staff

5. Establishment of in-house procedures for hardware commissioning, pole tuning, alignment, and surveying
6. Start and ramp-up of in-house production, especially the throughput of the three magnetic labs
7. Implementation of a suitable control system

Magnetic labs

An important step was the validation of the three magnetic labs. A comparison was done using the pre-serial undulator segment U40-X001. Figure 1 shows a characteristic example, the phase jitter as a function of gap as measured on all three magnetic-measurement benches. The phase jitter is a reliable quality criterion of the radiation properties of an undulator. At the European XFEL, the phase jitter will need to be ≤ 8° over the whole operational gap range, which, for the wavelength range of the U40, extends from 10 to 20 mm. Pole tuning is done for a gap of 14 mm, where errors are minimized. The minimum phase jitter amounts to ≤ 2° only. However, as Figure 1 shows, the specifications are fulfilled even for a much larger gap range. The differences between the three magnetic labs amount to less than ≈ 0.5° (rms).

Serial production

Industrial production of the undulator segments started in February 2012. The first serial items were delivered in October 2012. Four mechanical support structures and four magnetic structures are scheduled to be delivered every month for the following 24 months. The mounting

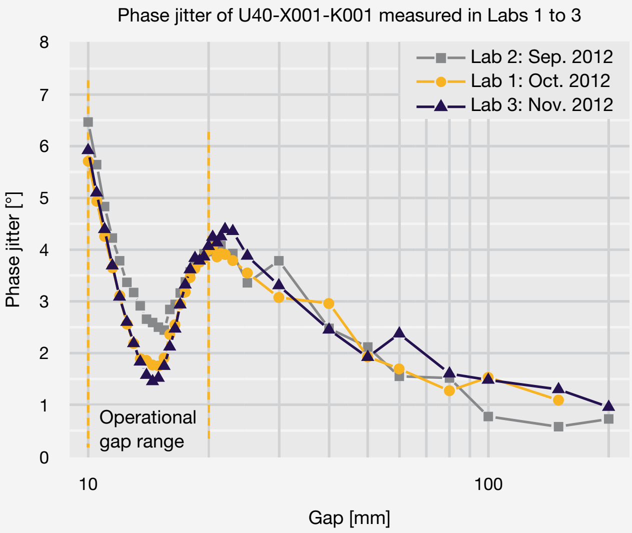


Figure 1 Comparison of the phase jitter as a function of gap measured on the pre-series undulator segment prototype U40-X001 in all three European XFEL magnetic labs

of the magnetic structures to the mechanical supports was started in parallel. By the end of 2012, six serial undulator segments were measured and tuned in the three magnetic labs. Twenty-two undulator segments and the corresponding magnetic structures had been delivered; four of them are waiting for the magnetic structures to be attached. Eleven, including the pre-series prototypes, have been measured and tuned.

Control system

Many parameters of the undulator systems need to be adjusted individually, such as motor positions or settings of various power supplies. In addition, information must be provided on actual gap sizes, currents, positions, limit switches, or status of components.

The undulator control system is based on industrial automation technology using the Ethernet for control automation technology (EtherCAT) fieldbus standard and hardware produced by Beckhoff GmbH. The TwinCAT software is used for implementation. An undulator system is composed of up to 35 individual cells, each consisting of one undulator segment and one intersection with a phase shifter and a quadrupole mover, all of which need to be integrated into the "local control system". All cells of the undulator system also need a "global control system", which runs, synchronizes, and coordinates the 245 axes, 175 power supplies, and 35 three-way valves of a 35-cell undulator system, in order to provide optimum parameters for the SASE lasing process.

Figure 2 European XFEL undulator lab in Building 36 in December 2012

A schematic view of the architecture of an undulator control system is shown in Figure 3. The front-end layer consists of the local control systems of up to 35 cells. The global control system—also known as the “central control node (CCN)”—in the middle layer is a separate 19-inch slide-in industrial PC running TwinCAT. The CCN connects

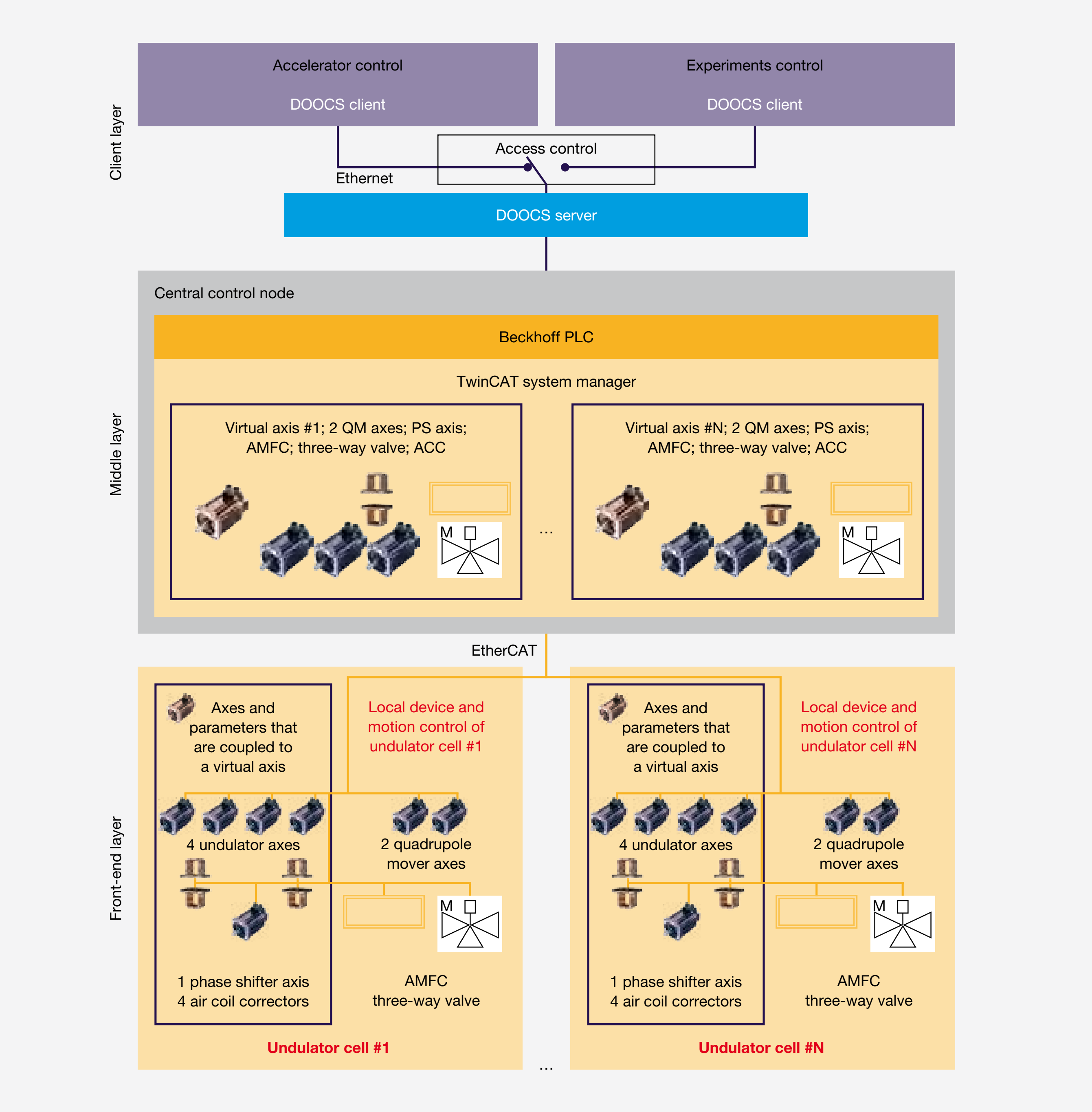


Figure 3 Schematic view of the global control system for one of the European XFEL undulator systems (PLC: programmable logic controller, QM: quadrupole mover, PS: phase shifter, AMFC: ambient magnetic-field correction coil, ACC: air coil corrector)

and controls all local cells. Moreover, it will provide an interface to connect to the distributed object-oriented control system (DOOCS) of the linear accelerator.

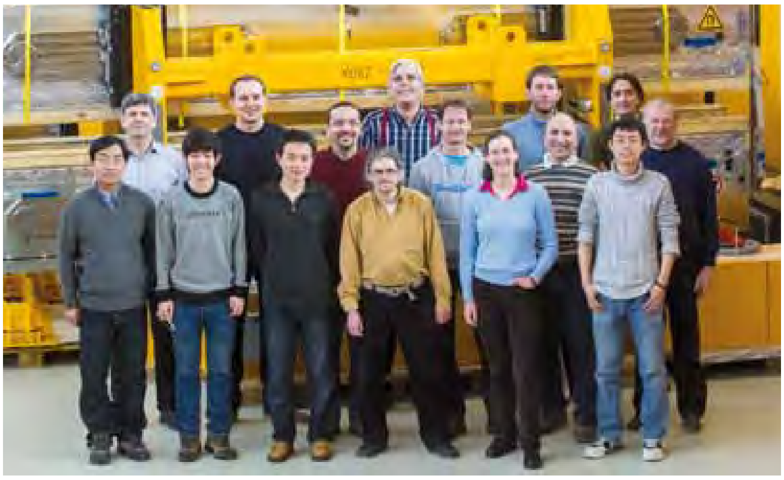
In addition to controlling the undulator gap plus related corrector coils, the following properties were added to the local control systems in 2012:

- Full control of the phase shifter gap and synchronization with the undulator gap
- Precise setting of the position of the quadrupole movers for beam steering
- Temperature monitoring of the undulator cells
- Precision control and stabilization of the temperature of the vacuum chamber

A first prototype system was set up and is still being tested. In parallel, the first important steps were made towards the global control system:

- Communication protocols for communication between the CCN and DOOCS established and tested
- Proof of principle for the synchronization of two undulator segments
- Database for operational parameters for undulator systems under development
- First test CCN under construction

In 2013, a test string—a prototype undulator system containing all components for two to three cells—will be built. ■



Group members
(left to right) Yufeng Yang (guest), Suren Karabekyan, Xiaoyu Li (guest), Georg Christian Deron, Yuhui Li, Bora Ketenoglu (since January 2013), Uwe Englisch, Joachim Pflüger (group leader), Andreas Beckmann, Sonia Utermann, Martin Knoll, Majid Bagha-Shanjani (since March 2012), Fredrik Wolff-Fabris, Hongxian Lin (guest), Karl-Heinz Berndgen (since March 2012), Manfred Gaida (not shown), Pablo Lopez (intern, not shown), Günther Nawrath (guest, not shown), Maike Röhling (until September 2012, not shown), Wolfgang Tscheu (not shown), Mohammad Vakili (intern, not shown), Mikhail Yakopov (not shown)

SIMULATION OF PHOTON FIELDS

The Simulation of Photon Fields (SPF) group develops novel schemes to improve the characteristics of X-ray free-electron lasers (FELs) to ensure that the European XFEL will be the best facility in a dynamically evolving global scientific environment. The SPF group also models the properties of the photon beams produced by the facility's undulators, simulating spontaneous radiation and X-ray FEL radiation to facilitate beamline optics design, photon beam–based diagnostics, and some scientific applications.

Cooperation with DESY

In 2012, SPF group leader Gianluca Geloni continued his long-term collaboration with Vitali Kocharyan and Evgeni Saldin of Deutsches Elektronen-Synchrotron (DESY). In early January, their scheme for self-seeding based on single-crystal monochromators was experimentally confirmed in a groundbreaking experiment at the Linac Coherent Light Source (LCLS) at SLAC National Accelerator Laboratory in Menlo Park, California. A direct method for carrying out X-ray pulse length autocorrelation measurements, as proposed by the collaboration in 2010, was also verified during that experiment. In December, the collaboration members—together with Paul Emma from Lawrence Berkeley National Laboratory in Berkeley, California, for the LCLS group—received the Innovation Award on Synchrotron Radiation from the Association of Friends of Helmholtz-Zentrum Berlin in recognition of their invention.

Investigating self-seeding configurations

Following the experimental demonstration of single-crystal self-seeding, the European XFEL Management Board established a working group under the coordination of Geloni to study possible implementations of self-seeding for the baseline configuration of the European XFEL. Possible applications of the scheme were discussed in a science workshop. Geloni, Kocharyan, and Saldin contributed studies of different self-seeding configurations, demonstrating the possibility of reaching TW-class pulses with the baseline European XFEL setup by combining self-seeding with post-saturation tapering (Figure 1). In particular, they showed how a double-chicane scheme could be used to ease the heat loading on the crystal monochromator, which is particularly relevant for operation at the high repetition rates typical of the European XFEL. A first self-seeding proposal was endorsed by the European XFEL Machine Advisory Committee (MAC), Scientific Advisory Committee (SAC), and Council.

Devising novel radiation sources

The experimental verification of self-seeding, together with the possibility of post-saturation tapering, disclosed novel and fascinating scenarios for bio-imaging applications. Following indications from the bio-imaging community, Geloni, Saldin, and Kocharyan studied a concept for a novel radiation source, capable of delivering TW-class pulses with variable duration between 2 fs and 10 fs over a very wide energy range, between the water window and the selenium K-edge. Such a source would use SASE3-type undulators and work at nominal electron energy points of the European XFEL. The concept is based on a combination of state-of-the-art FEL methods, including self-seeding, post-saturation tapering, and fresh-bunch techniques. The source would be dedicated to both nanocrystallography and single-molecular bio-imaging, and could be built by exploiting the empty tunnels in the present European XFEL layout. The status of this activity is at the level of an idea [1], and requires extensive funding to be realized. It is a concept worthy of further study, given its unique potential applications.

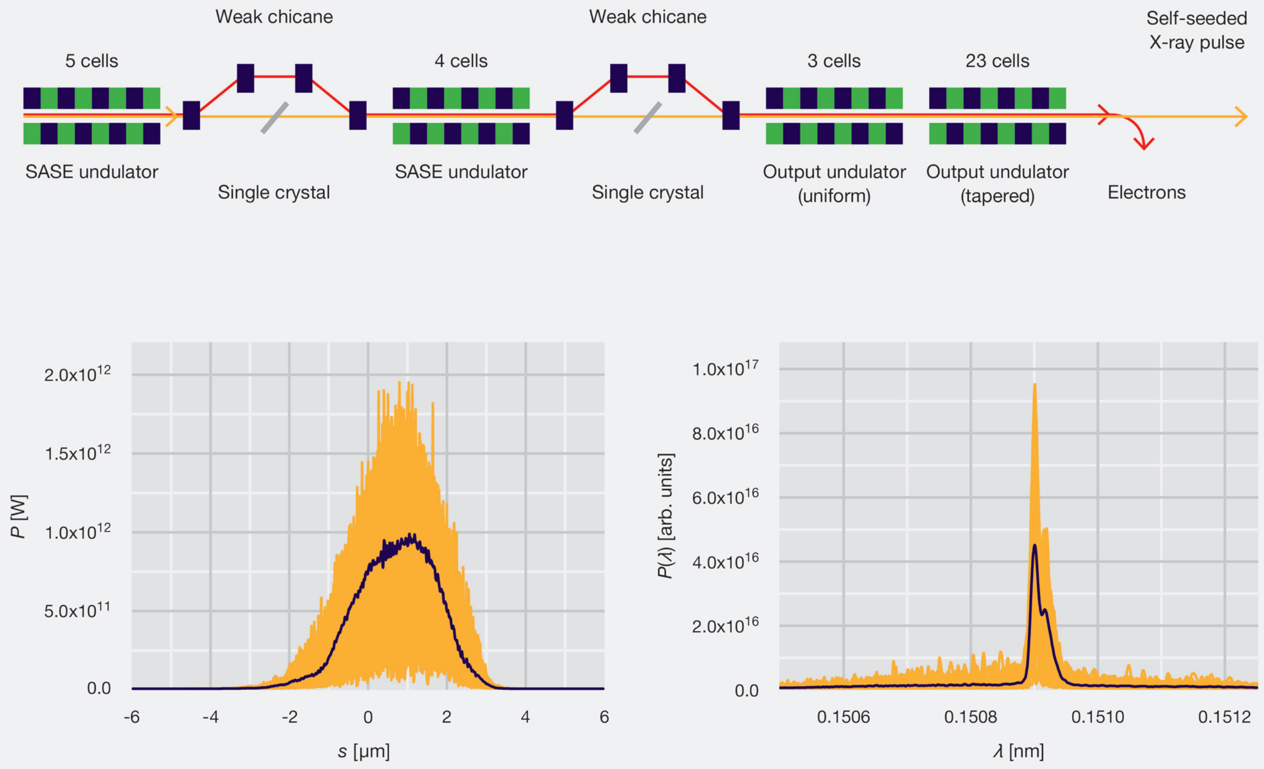


Figure 1
Top Schematic layout of a double-chicane self-seeding setup, working at SASE1 and SASE2 at an electron energy of 17.5 GeV and a nominal bunch charge of 100 pC.
Bottom Simulations (orange lines: 100 realizations; violet lines: average) demonstrate the possibility of reaching a power level of 1 TW.

Studying quantum effects in spontaneous radiation

The collaboration members also considered theoretical questions, such as the nature of quantum effects in spontaneous radiation (SR) emission. The importance of correctly understanding the characteristics of SR in relation to FEL developments is put into perspective by observing that the self-amplified spontaneous emission (SASE) process actually starts from SR. The collaboration members settled a theoretical question of fundamental importance: they demonstrated that, in the limit of a long undulator, a drift diffusion model can be used to model quantum diffusion in all cases of practical interest when the energy of the emitted photons is small compared to the electron energy [2].

Flexible software framework and PBBA studies

Group member Ilya Agapov continued to develop a computer simulation package capable of dealing with both SR and FEL radiation. SR is treated based on the Synchrotron Radiation Workshop (SRW) code developed by Oleg Chubar of Brookhaven National Laboratory in Upton, New York. FEL radiation is treated based on the Genesis code, developed by Sven Reiche of Paul Scherrer Institut (PSI) in Villigen, Switzerland. Agapov performed cross-checks with the WAVE code developed at Helmholtz-Zentrum Berlin (HZB) by Michael Scheer. He also continued to cooperate with Oleg Chubar on the inclusion of quantum effects and energy losses, which are being added to the code capabilities.

Guest scientists Nikolay Smolyakov and Sergey Tomin of National Research Centre Kurchatov Institute (NRC KI) in Moscow, Russia, mainly focused on the development of alternative routines for SR calculation to estimate the resolution and performance of photon beam–based alignment (PBBA) methods. In particular, they studied a method for fine-tuning the undulator magnetic strength, originally developed at LCLS, based on the use of a monochromator and an energy detector. They concluded that this method could be successfully applied at the European XFEL. They also independently analysed experimental results obtained by the Photon Diagnostics group, and confirmed the correctness of the original data analysis.

Outlook for 2013

In 2013, the SPF group plans to continue activities in the research areas initiated in 2010–2012. Agapov expects to complete activities on SR in 2013. It will then be possible to simulate long undulator setups with focusing elements in between, accounting for emittance, energy spread, energy losses, and quantum diffusion. The code will enable us to calculate intensity profiles at different frequencies. Post-processing will allow further manipulation of the calculated data. Further on, Agapov will start focusing his research activities on FEL simulations, which will be user-oriented, providing the possibility of optimizing FEL output parameters for particular applications or experiments. Guest scientists Smolyakov and Tomin will carry on their studies on SR and PBBA. Geloni will continue to cooperate with Kocharyan and Saldin to study novel upgrade possibilities for the European XFEL. Following the endorsement by the European XFEL Council, the SPF group expects that the cooperation with DESY will play a leading role in the development of a self-seeding setup for the European XFEL. ■

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DESY 12-022 (2012)

Group members
(left to right) Gianluca Geloni (group leader), Nikolay Smolyakov (guest scientist), and Ilya Agapov

X-RAY OPTICS AND BEAM TRANSPORT

The intense X-ray free-electron laser (FEL) beams generated in the undulators are preconditioned and transported in underground tunnels to the experiment hall. To reduce the amount of shielding required inside the hall, the intense high-energetic background radiation will be removed by the X-ray optics in the tunnels. Depending on the demands of each experiment, energy filtering by monochromators and prefocusing can be achieved as well. The X-Ray Optics and Beam Transport group is responsible for designing, building, and installing the X-ray optical and beam transport elements that meet these requirements and enable a safe and stable operation of the scientific instruments.

Progress made in 2012

In September 2012, an external expert committee reviewed the technical design concepts for the X-ray optics and beam transport systems. A detailed technical design report (TDR) was published on the European XFEL website [1].

One major activity in 2012 was to establish a new vacuum laboratory in a former experiment hall of the HERA accelerator of Deutsches Elektronen-Synchrotron (DESY), where cleaning of vacuum parts, assembly of larger beam transport elements, and residual-gas analysis will now be possible. In the already existing European XFEL laboratories in the PETRA III experiment hall at DESY, our group tested mechanical and vacuum properties of prototype slits, carried out interferometric measurements of vibrations and of long-term mechanical stability, and assessed cooling performance. We also developed the conceptual and technical design of adaptive mirrors, mirror chambers, and several other X-ray optical elements, such as the soft and hard X-ray monochromators discussed below.

In 2012, six new staff members joined the X-Ray Optics and Beam Transport group: Bianca Dickert (technician), Massimiliano Di Felice (technical draftsman), Xiaohao Dong (mechanical engineer), Daniele La Civita (mechanical engineer), Timo Korsch (electrical engineer), and Maurizio Vannoni (physicist).

Soft X-ray grating monochromator

The soft X-ray monochromator is designed to produce a narrow band pass of photon energies from $E/\Delta E$ = 10 000 to 30 000 for experiments at the SASE3 beamline (for photon energies E = 270 eV – 3 keV). During the monochromatization process, an X-ray pulse stretching significantly higher than the Heisenberg limit (here around 100 fs and less) should be avoided. This is achieved with an optical design working close to the diffraction limit of the X-rays. As a consequence, the reflective optics of the monochromator have to satisfy outstanding quality requirements of less than 2 nm peak-to-valley (PV) shape error—that is, the distance from the highest to the lowest point of the mirror surface—over a substrate length of 500 mm.

The chosen design concept is a plane grating monochromator with two cylindrically shaped pre-mirrors. (It is described in detail in the TDR [1].) A particular difficulty of this design is the manufacturing of the 500 mm long gratings with the required precision. Moreover, these gratings need to be mounted on four support points with their optical surfaces facing down. Deformations resulting from this mounting scheme were calculated by finite element analysis (FEA) methods (Figure 1). Deviations reach 12 nm PV along the substrate in the area where the beam will hit the grating. Since these distortions are larger than the allowed tolerance of 2 nm PV, the optical surface of the gratings will be shaped by a deterministic polishing technique to the inverted calculated FEA profile, such that the surface will become flat within the requirements when

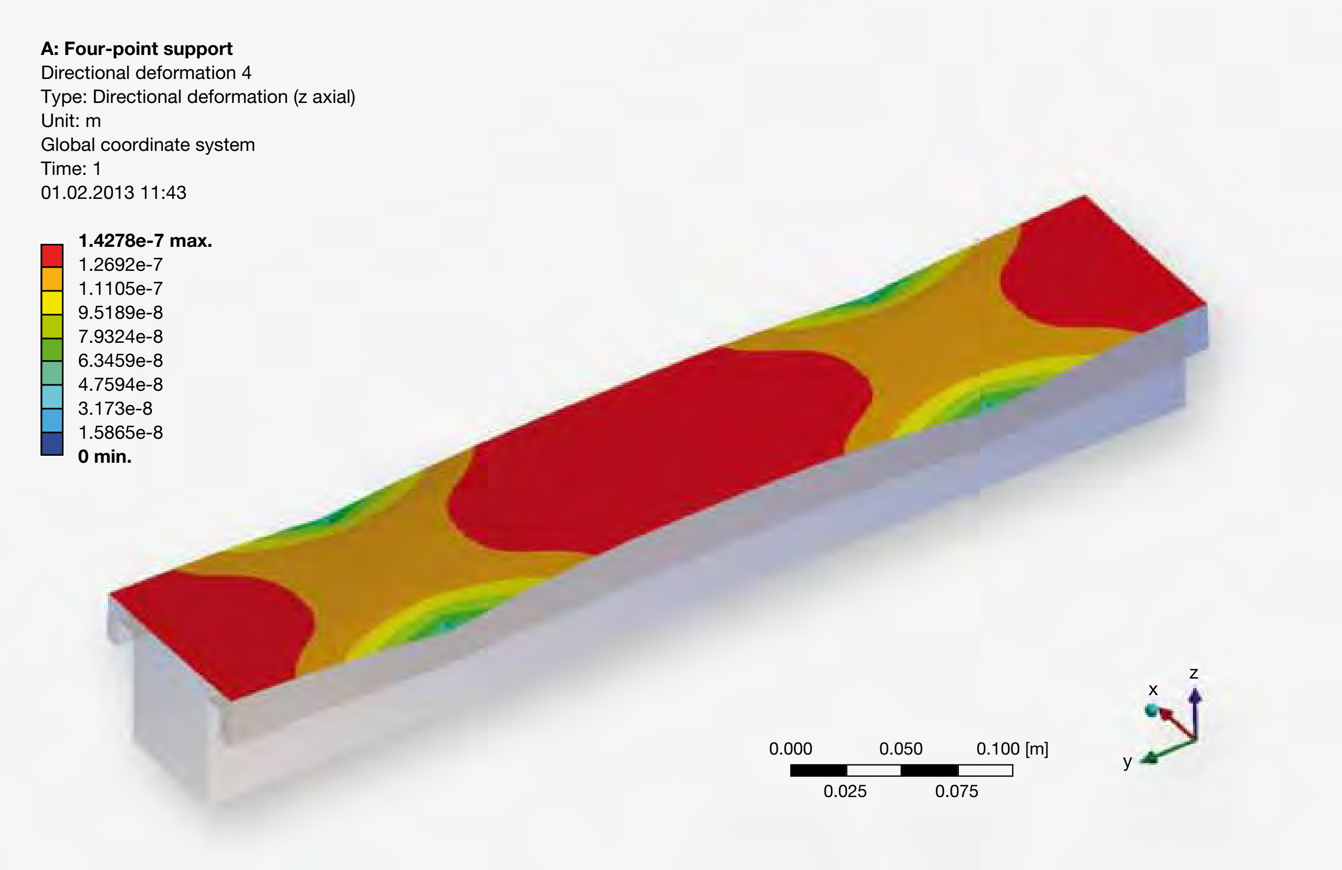

Figure 1 Surface profile of a flat grating mounted upside down inside the soft X-ray monochromator. The reflecting surface is shown here on the top.

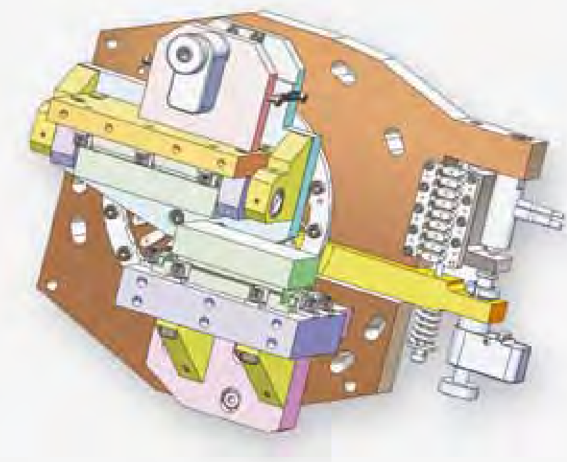

Figure 2 Artificial channel-cut mechanism for the hard X-ray monochromator

mounted face down. Similar to all other reflective optics used in the X-ray FEL beam transport system, the gratings will be water-cooled with a liquid-metal indium–gallium layer for thermal contact.

Hard X-ray monochromator

For the hard X-ray beamlines SASE1 and SASE2, monochromatization in a photon energy range of 5–24 keV will be achieved by reflecting the X-rays on perfect silicon crystals. To maintain the original beam direction, two crystals with identical crystal orientation are needed. In order to keep the beam stable on the sample, the angular stability of these crystals has to be significantly better than the divergence of the X-ray FEL beam of about 1 µrad. In collaboration with Argonne National Laboratory in Lemont, Illinois, a cryogenically cooled artificial channel-cut mechanism was developed that is expected to achieve a stability of better than 25 nrad/h (Figure 2).

The silicon crystals on the artificial channel-cut mechanism will be mounted inside a vacuum chamber (Figure 3). To change the average photon energy of the transmitted band path, the crystals can be rotated by a sine-bar mechanism and an ultraprecise in-vacuum linear stage. A pulse tube cooler will cool the silicon crystals to about 100 K. Since the second crystal is exposed to significantly less heat load than the first, heaters are installed on each crystal to keep both at the same optimized temperature.

Perspectives for 2013

The procurement of all mechanical parts for the first installation phases and of all long-lead items will begin in 2013, such that the installation in

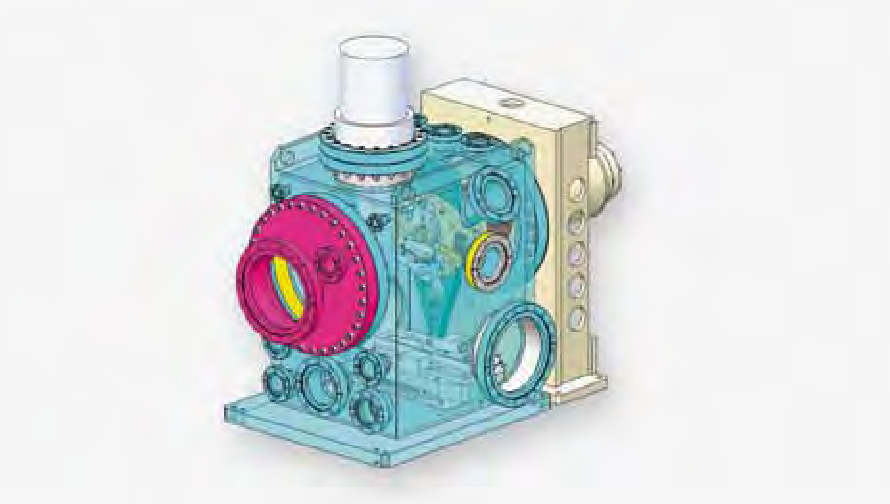

Figure 3 Vacuum chamber of the hard X-ray monochromator with the artificial channel cut and the driving mechanism shown inside

the tunnels can start in early 2014, as scheduled. Prototypes of adaptive mirrors, mirror chambers, the SASE3 gas attenuator system, differential pumping stages, and components of the control system that were ordered in 2012 will be tested in 2013.

A detailed layout of all beamline sections and its final integration into the facility-wide CAD model is required to set up the installation sequence of all the components inside the tunnels. The design of the beamlines in the first tunnels, XTD2 and XTD10, will be finished by mid-2013. ■

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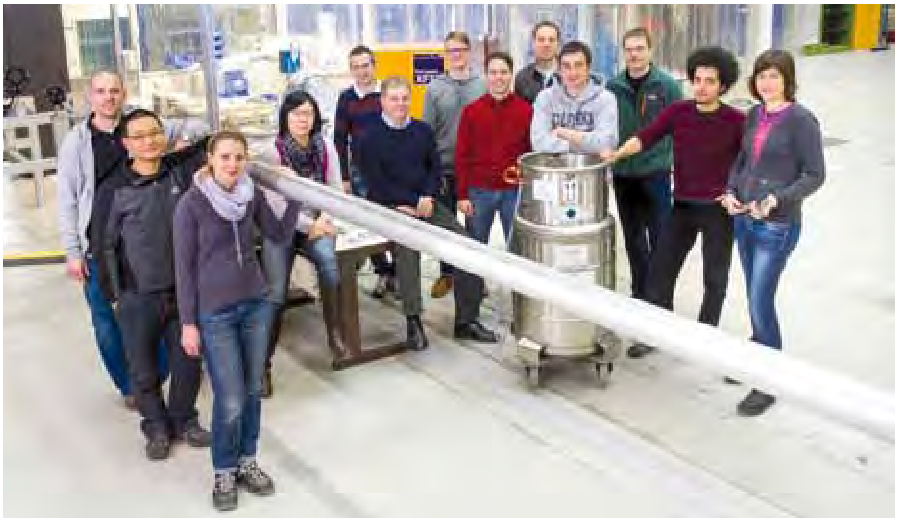

Group members
(left to right) Alexander Bartmann, Xiaohao Dong, Bianca Dickert, Fan Yang, Massimiliano Di Felice, Harald Sinn (group leader), Paul Frankenberger (since January 2013), Maurizio Vannoni, Timo Korsch, Daniele La Civita, Martin Dommach, Raul Villanueva, Idoia Freijo Martín, Shafagh Dastani Farahani (not shown), Jérôme Gaudin (through July 2012, not shown), Nicole Kohlstrunk (not shown), Liubov Samoylova (not shown), and Antje Trapp (not shown)

X-RAY PHOTON DIAGNOSTICS

The X-Ray Photon Diagnostics group is responsible for designing, constructing, and eventually operating the diagnostics devices to measure and monitor the properties of photon pulses generated by the European XFEL. In 2012, the group finalized the concept of the online photoemission spectrometer, carried out important tests for the development of the imaging stations and the undulator commissioning spectrometer, produced a conceptual design and tested a prototype of the microchannel plate (MCP)–based detector, and made decisive progress in the development of further diagnostics instruments.

Purpose of diagnostics devices

At the European XFEL, diagnostics devices are necessary for two major tasks. First, they measure the pulse properties of the X-ray beam during commissioning and maintenance to enable and optimize lasing. Second, they monitor each pulse of the photon beam during user operation to provide users with reference data essential for calibration, normalization, and comprehension of the experimental data. The delivered diagnostics data will encompass beam properties such as pulse intensity, position, and spectral as well as temporal information. The shot-to-shot capability is challenging because of the 4.5 MHz repetition rate, but it is particularly important when the radiation is created through self-amplified stimulated emission (SASE), where each pulse is different because the radiation originates from shot noise.

Online photoemission spectrometer

The year 2012 started with the conceptual design review meeting. The positive feedback lead to a strengthened concept, and the reviewed version was approved in September.

Through a joint proposal with the P04 group at PETRA III at Deutsches Elektronen-Synchrotron (DESY), the spectrometer in its current version was operated for six weeks at Beamline BW3 at DORIS III at DESY (Figure 1). In addition to scientific studies, the reliability and stability of the current design were proven, and computational approaches that optimize the electron-optical performance of the spectrometer over the very broad required range of kinetic energies were confirmed.

Substantial enhancements to the existing design are necessary to routinely operate the spectrometer as a single-shot diagnostics device. The data acquisition electronics were redesigned from scratch. Together with the DAQ and Control Systems group we defined the specifications of custom digitizer hardware. In December, the company SP Devices delivered the newly designed boards for one complete spectrometer with 16 independent channels.

Offline tests of one complete system with several upgrades will start in early 2013 in our HERA South labs, which are operational since summer 2012. The tests will incorporate a pulsed electron source, designed and implemented in house. Test operation at the Linac Coherent Light Source (LCLS) at SLAC National Accelerator Laboratory in Menlo Park, California, is expected for later in 2013, based on a joint project between LCLS, the P04 group (PETRA III), and our group.

Gas-based intensity and position monitors

The gas-based intensity and position monitors, a contribution from DESY, are the backbone of online diagnostics at the European XFEL. The main chamber of the first X-ray gas monitor detector (XGMD) was calibrated at Physikalisch-Technische Bundesanstalt in Berlin, Germany. The huge-aperture open multiplier (HAMP) chamber, which is essential for the resolution of individual pulses at MHz rates, was designed and put into prototype production. It will be tested with beam in early 2013.

In a related study, the partial photoionization cross sections of krypton and xenon were measured between 2 and 25 keV, providing information necessary for the operation of the monitor at the European XFEL.

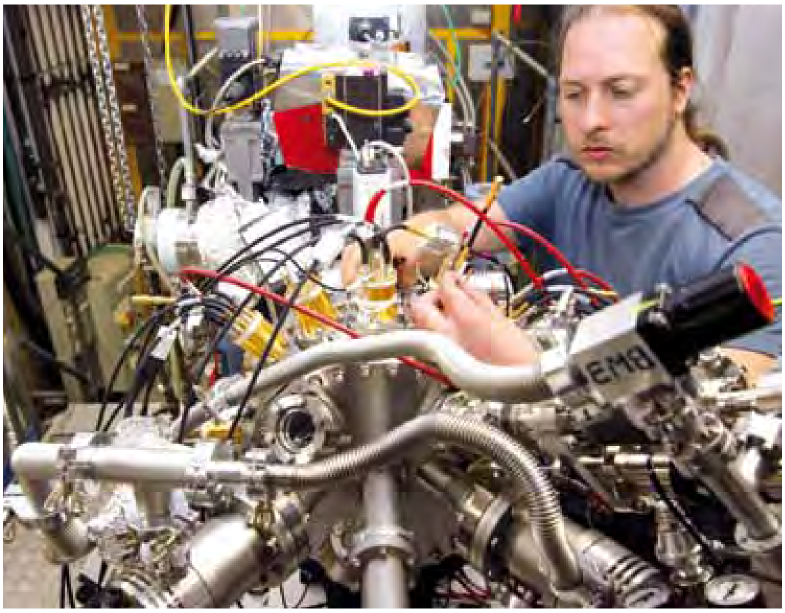

Figure 1 Jens Buck with a P04 photoelectron spectrometer during beamtime at DORIS III Beamline BW3

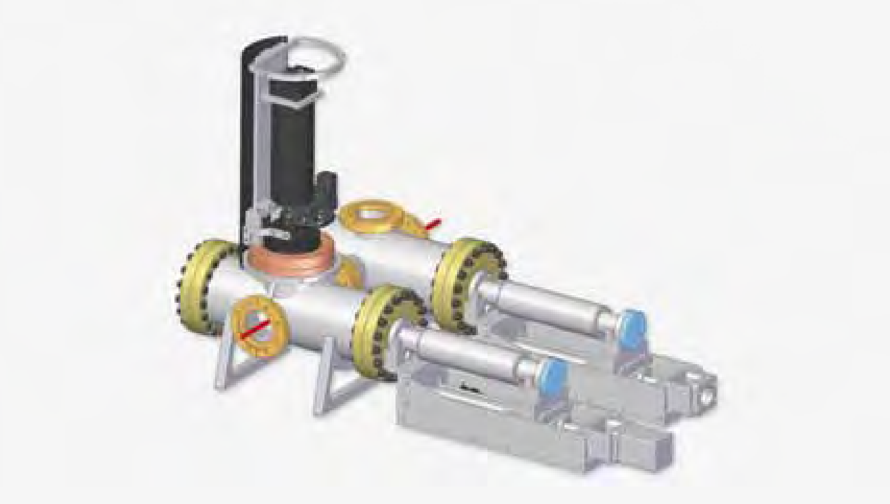

Figure 2 3D sketch of an imaging station. Two long manipulators insert different screens into the X-ray free-electron laser (FEL) beam, which is shown in red. The optical detection setup is pointing upwards (optics cover not shown).

Imaging stations and undulator commissioning spectrometer

The conceptual design for the imaging stations was presented at the European XFEL Users' Meeting and published in summer 2012. The technical design is now well under way (Figure 2).

At DESY's PETRA III X-ray source, we successfully tested the imaging and undulator commissioning spectrometer in-air prototypes. We also verified two of the proposed photon beam–based alignment procedures.

As a main step in the development of both the imagers and the undulator commissioning spectrometer (also known as "K-mono"), we received approval for experiments at DESY synchrotron beamlines: in a beamtime at DORIS III Beamline BW1, the motor controls and camera image acquisition using the European XFEL control software framework, Karabo, was tested, and basic functionality could be validated. We were the first group to use this control system during actual measurements.

In another beamtime at PETRA III Beamline P01, we successfully tested the imaging and K-mono in-air prototypes, and verified two of the proposed photon beam–based alignment (PBBA) procedures. A unique property of P01 is that there are two separately gap-controllable undulator segments, which allowed us to simulate what we will later face at the European XFEL undulators, where single- as well as pairwise-segment commissioning is planned. Results were presented at several conferences (Figure 3), see [1] and Chapter 8, "Scientific Record".

Experimental campaigns at FERMI@Elettra in Italy and the Free-Electron Laser in Hamburg (FLASH) at DESY were performed to test scintillators for our imagers and to study FEL-related damage processes.

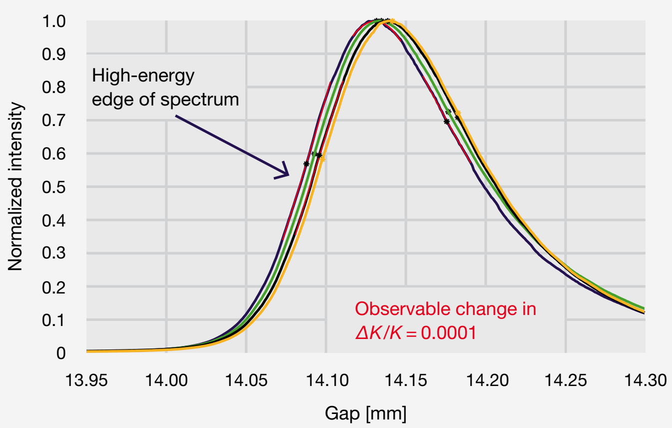

Figure 3 Single-segment tuning result from PETRA III Beamline P01. Scanning one undulator segment gap and observing the beam intensity transmitted through two monochromators, we detected a relative change in undulator parameter *K* even as small as 0.01%, which is required for photon beam–based commissioning.

MCP-based detector

We produced a conceptual design for the microchannel plate (MCP)–based detector, an invasive commissioning device, together with the Joint Institute for Nuclear Research (JINR) in Dubna, Russia. JINR produced and delivered the first prototype, which conforms to our strict ultrahigh-vacuum specifications, and which was put to the crucial hard X-ray test at DORIS III, where we were one of the last teams to receive beamtime before the facility was switched off. The detectors in the setup allowed us to monitor in real time each single photon pulse at 10 MHz repetition rates, and the detection efficiency of hard X-rays was shown to be sufficient, so that in December the technical design was successfully reviewed.

More diagnostics

Our involvement in the development of X-ray FEL radiation–capable wavefront imagers was documented in a publication [2] with colleagues from the Paul Scherrer Institut (PSI) in Villigen, Switzerland, on experiments performed at LCLS in 2011, using a grating interferometer.

Diffractive optics in the form of thin diamond gratings form the basis of another crucial instrument, a transmissive single-shot spectrometer, which was proposed recently by our PSI collaborators as a possible solution to a difficult task: minimally invasive monitoring of each single-shot spectrum in bunch trains with high resolution, while avoiding damage to the monitor itself.

Our collaborators at Helmholtz-Zentrum Berlin helped us with simulations to interpret our data from the synchrotron experiments on undulator commissioning.

Summary and outlook

In 2012, we were able to define several key devices of our photon diagnostics and to start working on the technical designs using several prototype systems. In 2013, we will continue development using prototypes, finalize technical designs, and start to order parts for the final devices in the second half of the year. All this, while keeping an eye on the scientific developments at the existing X-ray FEL facilities, where new experimental techniques can be exploited for diagnostics to the benefit of our future users. ■

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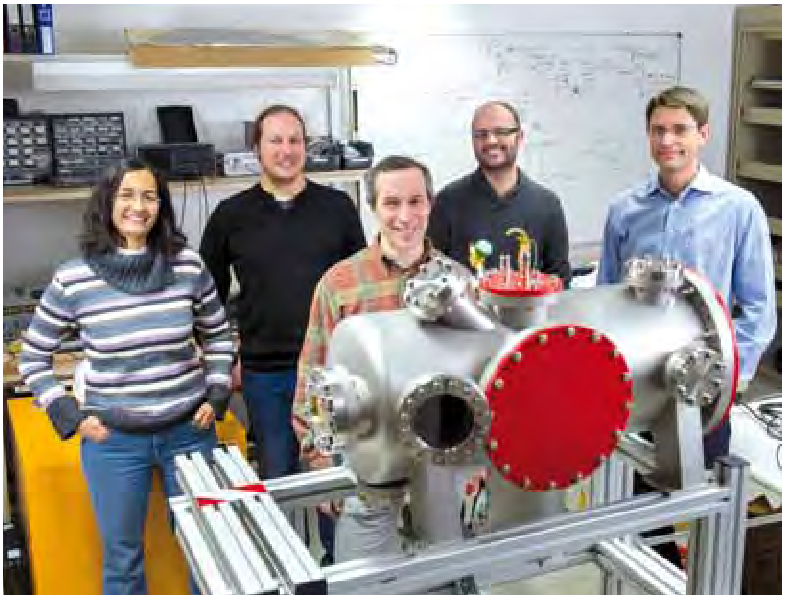


Group members
(left to right) Cigdem Ozkan, Jens Buck, Wolfgang Freund, Marc Planas, and Jan Grünert (group leader)

05

SCIENTIFIC INSTRUMENTS AND EQUIPMENT

The different instruments of the European XFEL will allow researchers to carry out a large variety of experiments. Currently, six instruments are being developed, as well as optical laser equipment, delivery methods, and target systems for the samples.

Preparing a time-resolved X-ray experiment at PETRA III


LINOS

SCIENTIFIC INSTRUMENT FXE

The Femtosecond X-Ray Experiments (FXE) instrument will be used to perform time-resolved pump–probe experiments on ultrafast time scales. In 2012, the FXE group wrote and presented the technical design report (TDR) for the instrument. In addition, the group is using laboratory laser sources, synchrotron sources, and free-electron laser (FEL) sources to advance new strategies foreseen for the FXE instrument and to acquire hands-on experience with X-ray FEL pump–probe measurements.

Technical design report and review process

In 2012, the FXE group delivered the TDR for the future instrument. After an internal review, the design was presented to the advisory and review team (ART) and the European XFEL Scientific Advisory Committee (SAC). Both approved the overall strategy and provided a list of essential issues to be addressed during the first quarter of 2013 (see “Outlook for 2013” below). The planned provision of complementary structural tools—such as X-ray absorption and emission spectroscopy as well as X-ray diffuse scattering—for simultaneous usage at the FXE instrument was very well received.

In-kind contribution of DTU Lyngby

In 2012, the FXE team joined forces with the Technical University of Denmark (DTU) in Lyngby and their subcontractor JJ X-Ray to work on a design of the FXE instrument that includes most of its components. This collaboration led to the creation of a Danish in-kind contribution (IKC) to the European XFEL, with a clear roadmap and milestones to have the instrument ready for beam in mid-2015, well before the SASE1 undulator will actually generate any radiation. The IKC contract was signed in November 2012, and the design and construction of the FXE instrument is well under way.

Testing FXE strategies at PETRA III and APS

The MHz burst mode of the European XFEL poses challenges for data acquisition regarding both data transfer speed and overall data rate. Together with the DAQ and Control Systems group, the FXE group tested the basic MHz data acquisition strategy at Beamline P01 of the PETRA III synchrotron radiation source at Deutsches Elektronen-Synchrotron (DESY) in Hamburg, Germany, in July and December 2012 (Figure 1). The basic concept utilizes a fast analogue-to-digital converter that can handle the high repetition rates of the European XFEL. This particular strategy proves to be very useful for point (0D) detectors, like avalanche photodiodes (APD) or positive intrinsic negative (PIN) diodes, which the FXE group seeks to employ as well.

In November 2012, the FXE group participated in an experiment at the Advanced Photon Source (APS) at Argonne National Laboratory in Lemont, Illinois, utilizing a MHz repetition rate pump laser for studies on ferrocyanide ions in aqueous solution. In this experimental campaign, we gained further hands-on experience in handling MHz-rate experiments, which will greatly benefit the FXE instrument. The initial data analysis is under way and scheduled to be published in 2013.

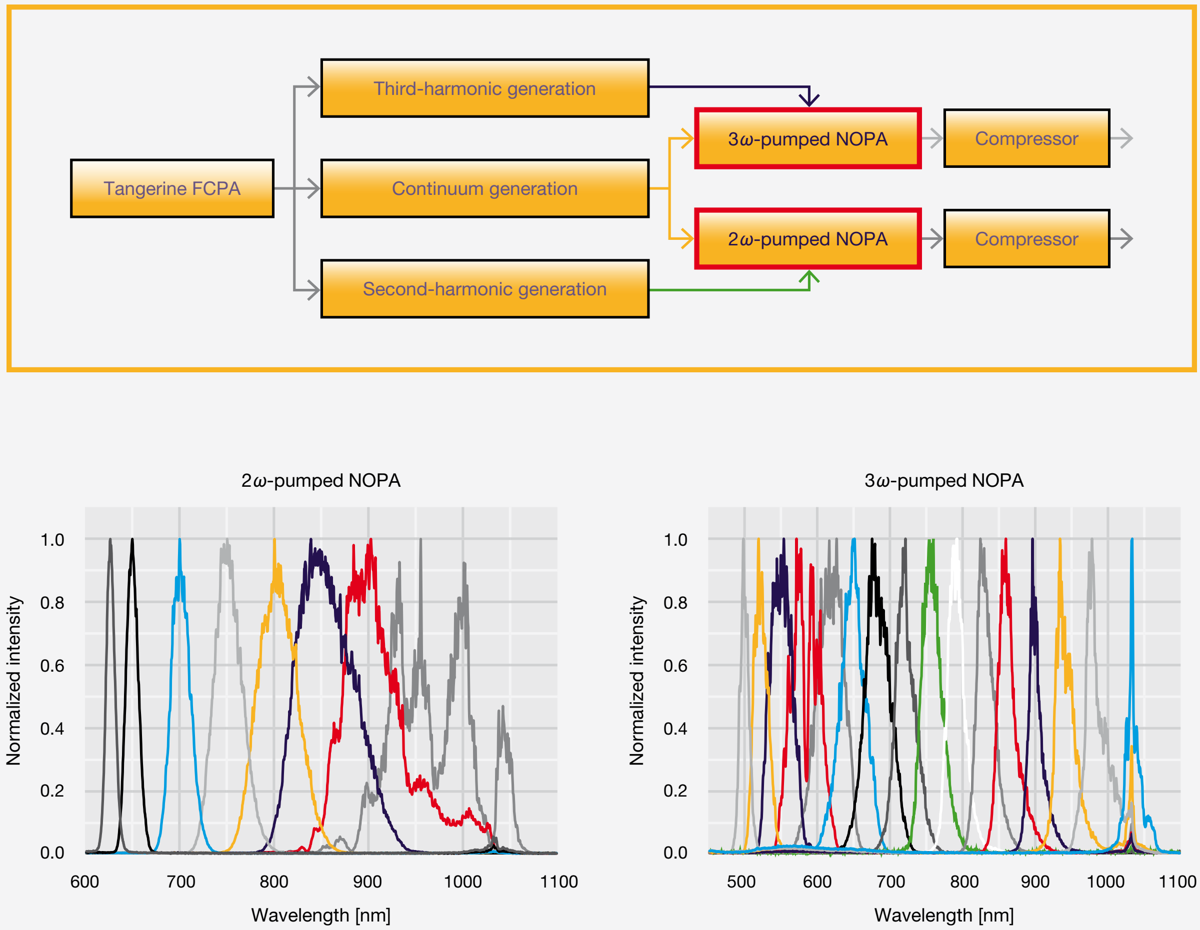
Figure 1 Scientist Andreas Galler aligns the FXE femtosecond laser system at Beamline P01 of PETRA III

MHz NOPA efforts

The EU-funded Cluster of Research Infrastructures for Synergies in Physics (CRISP) was launched in late 2011. Within this framework, the FXE group hired a postdoc, Julien Nillon, to work on the realization of a non-collinear optical parametric amplifier (NOPA) capable of MHz repetition rates to be used with the FXE MHz laser. Such a NOPA will greatly enhance the optical capabilities of the FXE instrument, like generating optical veto probe signals at a multitude of wavelengths tailored to the requirements of individual experiments. Nillon is based in Strasbourg with the group of Stefan Haacke, who closely collaborates with the FXE group on this topic. The recent progress in realizing high repetition rates with the NOPA is shown in Figure 2.

A non-collinear optical parametric amplifier (NOPA) capable of MHz repetition rates to be used with the MHz laser will greatly enhance the optical capabilities of the instrument, like generating optical veto probe signals at a multitude of wavelengths.

The experimental setup is composed of two independent NOPA stages, pumped and seeded by the same ytterbium-doped fibre laser, which delivers 350 fs pulses with an average power of 22 W at a repetition rate adjustable between 200 kHz and 2 MHz (Tangerine fibre laser by Amplitude Systèmes, Pessac, France). The first NOPA is pumped by the second harmonic of the fibre laser at 515 nm (40% efficiency of second-harmonic generation (SHG, 2ω)) and performs best in the 650 to 950 nm spectral range. The second NOPA is pumped by the third harmonic at 345 nm (25% efficiency of third-harmonic (THG, 3ω)) and works best between 500 and 700 nm. Both stages are seeded by the same white-light continuum with a cutoff wavelength at 480 nm generated through filamentation in a 4 mm thick ytterbium aluminium garnet (YAG) plate.



Tunable: 625–1000 nm

Tunable: 480–1000 nm

Figure 2 Achievements for 500 kHz NOPA operation: scheme (top) and results for 2ω- and 3ω-pumped operation (bottom).

International collaborations

Two years ago, the FXE group launched a collaboration with scientists from all over Europe to study structural dynamics of chemical and biologically relevant systems. In this context, Wojciech Gawelda was invited to take part in an experiment at the Linac Coherent Light Source (LCLS) at SLAC National Accelerator Laboratory in Menlo Park, California, in March 2012. The principal investigator, Kelly Gaffney, studied an Ir_2 complex. During these studies, the collaboration noticed a promising optical effect to check the overlap between the X-rays and the optical laser beam, namely a transmission change of the liquid sample, which can easily be detected.

New group member

A new Ph.D. student, Tadesse Assefa, was hired for R&D work on optical transient absorption spectroscopy as part of his thesis within the project A4 in the Collaborative Research Centre 925 (SFB 925) of the University of Hamburg, Germany.

Outlook for 2013

The TDR for the FXE instrument was published in December 2012. We will continue to work on the technical design of the FXE instrument in order to produce a final design report towards the end of 2013. Issues to be investigated include the optimal strategy to prevent both monochromatic and pink (non-monochromatized) beams from deviating significantly from the instrument axis and focusing them to the desired focal spot. This requires a four-bounce upstream monochromator, which will be designed by the X-Ray Optics and Beam Transport group. In addition, we will explore further strategies in an experimental campaign at LCLS in January 2013. ■

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Group members
(left to right) Christian Bressler (group leader), Andreas Galler, Tadesse Assefa, Wojciech Gawelda, and Julien Nillon (Institut de Physique et Chimie des Matériaux de Strasbourg, IPCMS, not shown)

SCIENTIFIC INSTRUMENT MID

The goal of the Materials Imaging and Dynamics (MID) instrument is to enable scientists to investigate nanostructured materials and dynamics on the nanoscale. Areas of application are materials science, nanomaterials, and the dynamics of condensed matter. In 2012, the MID group gained two new members, began developing the technical design for the instrument, and conducted related R&D through in-house workshops and experiments at other light sources.

Progress in 2012

In 2012, based on our conceptual design report for the MID instrument, we began to develop the technical design, which will be presented to the European XFEL Scientific Advisory Committee (SAC) in March 2013. We also conducted related experiments at the European Synchrotron Radiation Facility (ESRF) in Grenoble, France, PETRA III at Deutsches Elektronen-Synchrotron (DESY) in Hamburg, Germany, and the Linac Coherent Light Source (LCLS) at SLAC National Accelerator Laboratory in Menlo Park, California. In particular, we had our first user experiment as principal investigators at the X-ray Correlation Spectroscopy (XCS) instrument at LCLS.

The MID group was also involved in planning and organizing the “Science at FELs” meeting at DESY in July 2012, which was organized jointly by European XFEL and DESY. The session on science with seeded self-amplified spontaneous emission (SASE) beams was of particular interest for us because seeded operation will be required for the future science programme at the MID instrument.

In the second half of 2012, two new members joined the group: Gabriele Ansaldi, mechanical engineer, and Thomas Roth, research scientist.

Towards a technical design

The purpose of the technical design is to provide an instrument optimized for the study of disorder and fluctuations in condensed-matter science and materials science. The MID instrument will use speckle analysis and photon correlation spectroscopy in the hard X-ray range, taking advantage of the spatial coherence and the time structure of the X-ray free-electron laser (FEL) beam.

The basic ingredients of the MID optics, instrumentation, and detector systems have been identified, and specifications and proposed technical designs will be presented in the technical design report (TDR) in 2013

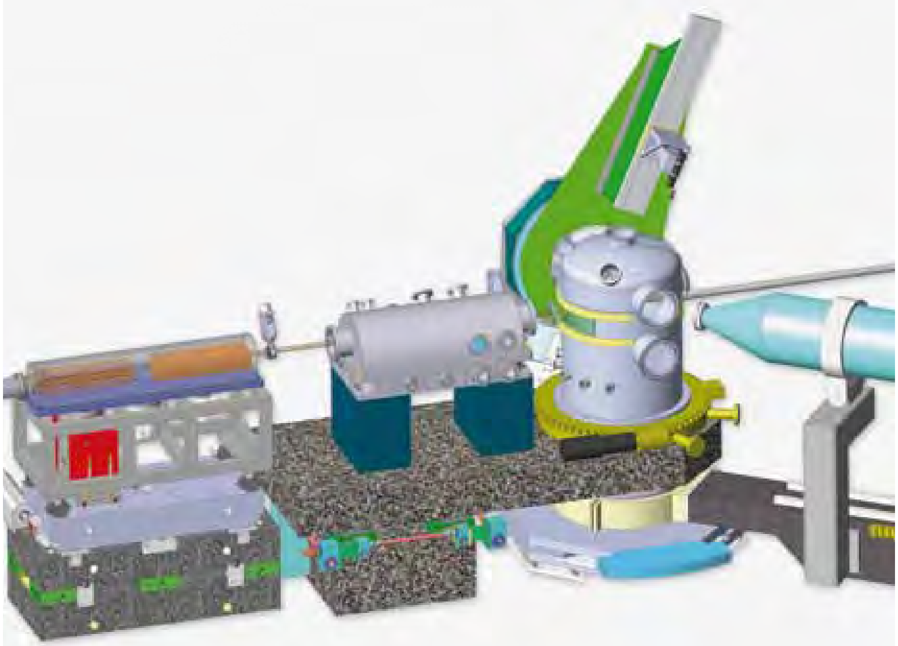


Figure 1 Drawing of the differential pumping section and experiment chambers of the MID instrument (image from the MID TDR)

(Figure 1). Part of the work is being realized in collaboration with ESRF in the framework of a Memorandum of Understanding that was signed between ESRF and European XFEL in 2012. To this end, Gabriele Ansaldi was hosted by ESRF's engineering group for three weeks in December 2012, when the collaboration was initiated, to be trained in scientific instrumentation design. This fruitful collaboration will continue in 2013.

The typical MID experiment will be very demanding in terms of beam quality and detection scheme. The specifications of all components will be extremely challenging, but the optimistic tone during the workshop was very encouraging.

In December 2012, we organized a workshop on “Materials Imaging and Dynamics at the European XFEL”, inviting all interested researchers to provide input to the scientific case and the technical ramifications that need to be considered for the TDR. The meeting was very timely. The last MID workshop took place in 2009. Since then, the scientific landscape has changed considerably. In particular, the first two hard X-ray FELs, LCLS in California and the Super Photon ring-8 GeV (SPring-8) Angstrom Compact Free-Electron Laser (SACLA) at the

RIKEN Harima institute in Hyogo, Japan, have started operation, generating interesting new results in biology, chemistry, and physics.

One of the main conclusions of the 2012 MID workshop was that sub-micrometre beams and optical laser pumps are also required in materials science experiments. Single-shot and multiple-exposure experiments are equally interesting. Both have been successfully performed at LCLS and the Free-Electron Laser in Hamburg (FLASH) at DESY, but the requirements regarding stability and sample environments are quite different in the two cases. The workshop concluded that the typical MID experiment will be very demanding both in terms of beam quality, that is, spectral purity and coherence properties, and in terms of the detection scheme, with as many small pixels as possible in a detector with little noise. The specifications of all components will be extremely challenging, but the optimistic tone during the workshop, underlining the huge progress made at LCLS and SACLA, was very encouraging.

The MID group strives to develop strong liaisons with leading groups in the field. Collaborations on specific instrumentation parts and science have already been initiated. This will be one of the key points for a successful startup and commissioning of the MID instrument in 2015–2016.

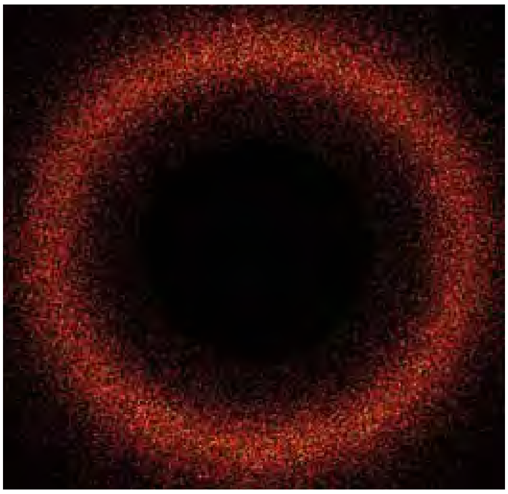


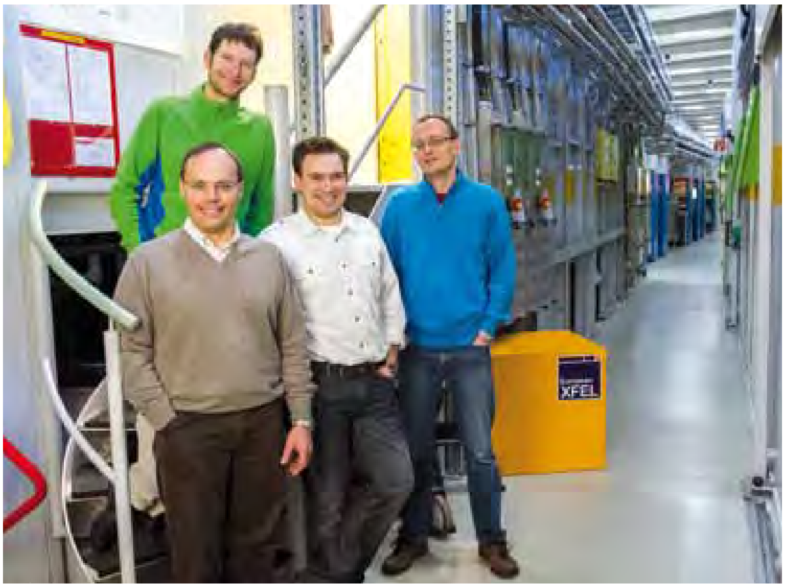
Figure 2 Single-shot diffraction pattern from an amorphous germanium oxide glass. The ring of scattering corresponds to a momentum transfer of 15 nm^{-1}. Source: LCLS experiment L467. Collaboration between B. Ruta[1], Y. Chushkin[1], G. Monaco[1], V. M. Giordano[2], P. Bruna[3], E. Pineda[3], M. Sikorski[4], A. Robert[4], J. Hallmann[5], and A. Madsen[5] (PI). [1]ESRF, [2]Université Claude Bernard Lyon 1, [3]Universitat Politècnica de Catalunya, Barcelona, [4]LCLS, and [5]European XFEL. Germanium glass courtesy of G. Baldi (IMEM - CNR, University of Parma, Italy).

Research activities

The MID group continued its activities in X-ray science with experiments at LCLS, ESRF, and PETRA III. At LCLS, we investigated, for the first time, the possibilities of performing single-shot-based correlation spectroscopy to access temporal and spatial information of disordered glassy materials (Figure 2). The experiment was the result of a collaboration between several groups and underlined the importance of the detector in such studies. Analysis of single-shot scattering measurements at high momentum transfers will also greatly benefit from a better-defined longitudinal coherence and reduced intensity fluctuations downstream of the monochromator. These aspects will be improved in the follow-up experiment scheduled for May 2013, when LCLS will run in self-seeded mode.

At ESRF, the MID group was involved in both X-ray photon correlation spectroscopy (XPCS) and coherent X-ray diffraction imaging (CXDI) experiments. The experiments were science-driven, but, in both cases, we were also interested in the technical details that will need to be revised for a successful transfer of XPCS and CXDI to the MID instrument. Our scientific interest in XPCS is based on the uniqueness of the technique to access dynamics in the time domain with X-rays; in the ESRF experiments, we were mostly addressing slow dynamics of highly concentrated colloidal suspensions. Interesting questions remain unanswered concerning the non-ergodic behaviour and freezing-out of the dynamics as the glass transition is approached. Our results suggest that reduction in free volume is decisive for the observed behaviour, and that internal stress provides the ergodicity-restoring relaxations near the glass transition.

At ESRF, we also performed Bragg CXDI experiments in ptychography mode. The aim was to demonstrate the feasibility of the technique to investigate ordered domains and antiphase domain boundaries in Fe–Al alloys close to the B2–$D0_3$ first-order phase transition. In both phases, the atoms organize on a simple cubic lattice, but the ordering of Fe and Al atoms on their respective sub-lattices is different. The B2 phase is equivalent to an imperfect simple CsCl structure, while the atoms organize in a 16-atom unit cell in the $D0_3$ phase. Due to degeneracy in the choice of basis for the unit cell, many ordered domains will exist in a given sample. The domain walls result in a phase shift of the diffracted X-rays, but they possess only little or no amplitude contrast. By scanning the partially coherent beam over a large crystal grain and recording 2D images of the scattered intensity (speckle pattern) over the rocking curve of the crystal, a full 3D data set was collected in reciprocal space. Analysis of this data set is in progress with the aim of reconstructing the real-space structure of domains and antiphase domain boundaries. ■



Group members
(left to right) Gabriele Ansaldi, Thomas Roth, Jörg Hallmann, and Anders Madsen (group leader)

SCIENTIFIC INSTRUMENT HED

The High Energy Density Physics (HED) instrument will be a new, unique platform for experiments not possible elsewhere, enabling a wide community of condensed-matter, plasma, and high-power laser physicists to investigate matter in states of very high excitation. Applications will include studies of matter occurring inside exoplanets, investigations of new extreme-pressure phases and solid-density plasmas, and analyses of structural phase transitions of complex solids in high magnetic fields.

Condensed matter and plasmas

The highly excited states of matter to be studied using the HED instrument can in some cases be described by condensed-matter theory; in others, plasma theories need to be applied. In addition, scientists are particularly interested in studying the intermediate regime, where both condensed-matter and plasma theories fail.

Plasmas are often described as a fourth state of matter—in addition to solids, liquids, and gases. Plasmas are characterized by ionization, that is, the presence of free electrons and ions. They are by nature unstable and short-lived. The HED instrument provides an important opportunity to investigate short-lived excitations and states as well as the related irreversible processes.

Plasmas are by nature unstable and short-lived. The HED instrument provides an important opportunity to investigate short-lived excitations and states as well as the related irreversible processes.

Experiments at the HED instrument

Experiments at the HED instrument will generally be performed in “pump–probe” mode, where a first pulse—a free-electron laser (FEL) or optical laser pulse—excites a sample, and a second pulse—typically an FEL pulse—probes the excited sample some delay time later. A particularity of the HED instrument is the increased use of optical lasers. Several systems will be required for creating samples through energy deposition and for probing the samples in their various excitation states. For these tasks, ultrashort- and long-pulse laser systems will be employed, with typical pulse durations of sub-10 to 100 fs and 0.5 to tens of ns, respectively.

The HED instrument will also enable the use of a large variety of X-ray techniques. In addition to exciting matter using medium or highly focused X-ray beams, it is planned to apply various diffraction, spectroscopy, and imaging techniques to probe the excited states. Many experiments will aim at maximizing information about the irreversible excitation and transformation of the samples using several such observation channels.

The HED instrument will be located at the SASE2 undulator of the European XFEL, which is designed to deliver FEL radiation with photon energies from 3 to above 20 keV.

Helmholtz International Beamline for Extreme Fields (HIBEF) consortium

An important activity in 2012 was the evaluation of a proposal for contributions to the HED instrument by an external user consortium, provisionally called the Helmholtz International Beamline for Extreme Fields (HIBEF) consortium, coordinated by Thomas Cowan from Helmholtz-Zentrum Dresden-Rossendorf (HZDR), Germany. Contributions of the consortium will include two high-energy laser systems for ultrashort and nanosecond pulses, a laser building, and additional instrumentation and diagnostic components. Proposing institutes were HZDR, Deutsches Elektronen-Synchrotron (DESY), and Helmholtz-Institute Jena. By the end of the year, the collaboration included more than 70 institutes from around the world. Following approval of the proposal by the European XFEL Council in October 2012, integration of this huge and challenging contribution began.

Launching the HED group

The effort to design the HED instrument—and the HED group by the same token—was launched in 2012, in accordance with the overall timeline aiming at the construction of six scientific instruments for the European XFEL by 2015. With the completion of the technical design of the X-ray beam transport systems and the preparation of the technical design of the experiment hall, the time had come to develop the conceptual design of the HED instrument and define its interfaces with other, more advanced parts of the construction project.

As no suitable leading scientist for the HED instrument could be found, Thomas Tschentscher, scientific director at European XFEL, agreed in early 2012 to coordinate this activity on an interim basis. Motoaki Nakatsutsumi, a very experienced laser scientist, joined European XFEL in September 2012, marking the real start of design activities for the HED instrument. Nakatsutsumi had previously worked on high-energy laser–plasma interaction experiments, first in Japan, where he obtained his Ph.D. in the group of Ryosuke Kodama at Osaka University, and later with Patrick Audebert at Laboratoire pour l'Utilisation des Lasers Intenses (LULI) in Palaiseau, France. The position of a second scientist with a background in X-ray instrumentation was advertised, and

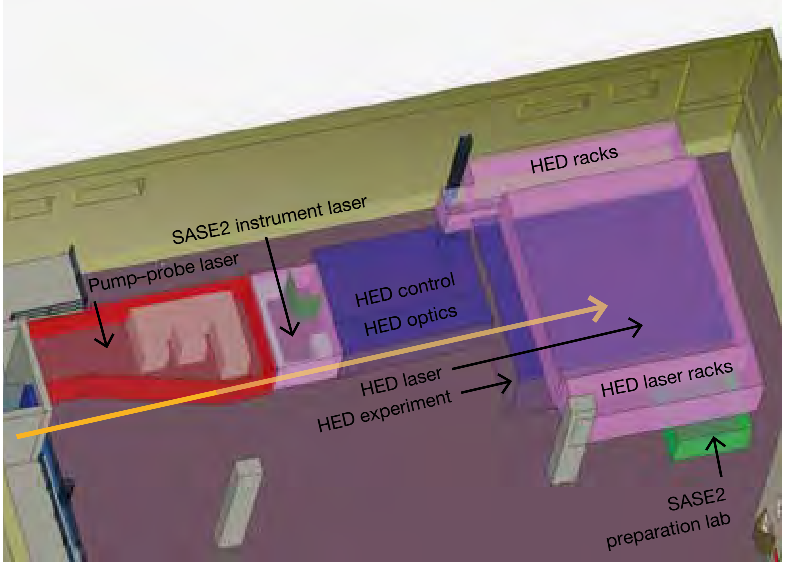


Figure 1 Layout of the HED instrument area: 3D rendering of the experiment floor showing the beam transport system from the tunnel XTD6 to the HED optics hutch, the HED control hutch, and the two laser hutches for preparation and tuning of the laser pulses delivered by the SASE2 pump–probe laser. The mezzanine level (shown in pink on the right) comprises the HED laser room for the two high-energy laser systems and the adjacent electronic racks rooms.

towards the end of the year, a very good candidate was found, who will start in April 2013. The search for a leading scientist has continued.

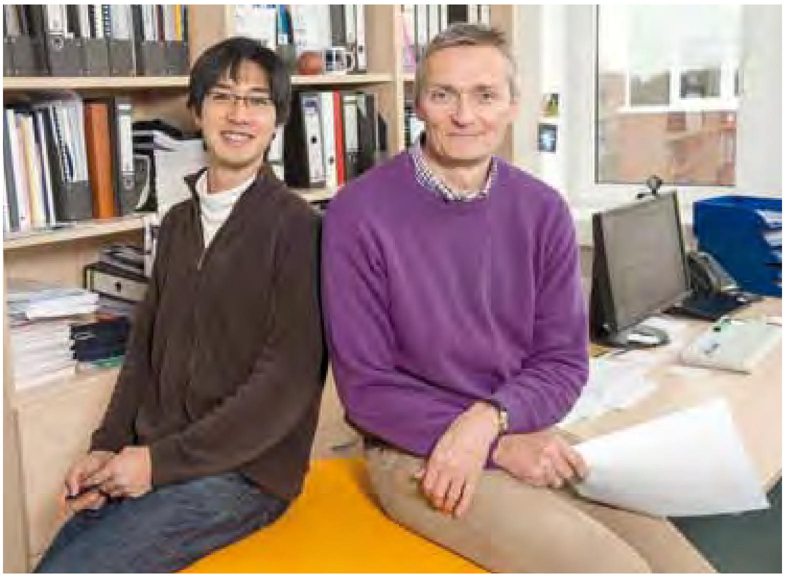
Defining the instrument layout

The major activity during the remaining part of 2012 was the definition of the instrument layout at the SASE2 beamline (Figure 1). Allocating space to the Materials Imaging and Dynamics (MID) and HED instruments, while maximizing the opportunities for both, proved a particular challenge. Finding space for the HED laser systems was equally demanding. The HED group soon realized that the required space of more than 100 m^2 could hardly be allocated on the experiment floor. The solution was finally to build a mezzanine level on top of the HED instrument.

In addition to the space allocation, the infrastructure requirements of the HED area were defined along with those of the other instruments in order to proceed with the design and layout of the experiment hall infrastructure. These first activities are described in the conceptual design report for the HED instrument, which is scheduled to be published in spring 2013.

Research activities

To prepare for the science programme at the HED instrument, the HED group participated in experiments at the Matter in Extreme Conditions (MEC) instrument at the Linac Coherent Light Source (LCLS) in Menlo Park, California, and at the Free-Electron Laser in Hamburg (FLASH), Germany. The LCLS experiment—whose principal investigator was Fabien Dorchies of Centre National de la Recherche Scientifique (CNRS) in Bordeaux, France—was particularly instructive, as the design and instrumentation of the MEC instrument are closely related to those of the HED instrument at the European XFEL. The experiment aimed at observing the increase in electron temperature following the impact of an ultrashort laser pulse using X-ray absorption techniques. The data analysis is ongoing. ■



Group members
Motoaki Nakatsutsumi and Thomas Tschentscher (interim group leader)

SCIENTIFIC INSTRUMENT SCS

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

Experiments at the SCS instrument

Experiments at the SCS instrument will utilize coherent, ultrashort X-ray pulses to capture ground-state properties or excited-state dynamics of nanostructures and nanomaterials in coherent diffraction patterns. These patterns can be transformed into real-space images with a resolution of 10 nm or better by coherent diffraction imaging (CDI) techniques. The instrument operates in the soft X-ray energy range (0.25–3 keV) where X-ray absorption resonances of various elements reside (3d transition metal L edges, 4f rare earth M edges, and oxygen as well as carbon K edges) that are relevant to the understanding of the properties and functions of complex materials, chemical reactions, or biological processes. Resonant X-ray spectroscopy at the SCS instrument will offer researchers an element-, chemical-, and spin-selective tool to study emergent phenomena in materials on both femtosecond time and nanometre length scales.

SCS conceptual design

To provide a wide platform for spectroscopy and coherent scattering techniques, the SCS concept entails modular instrumentation from the layout of the X-ray optics to the instruments and detectors. The conceptual design of SCS includes monochromatic-beam operation at high and medium resolving powers as well as pink-beam operation.

It further includes a variable beam size at the sample and an X-ray split-and-delay line to enable X-ray pump–probe experiments for X-ray photon correlation spectroscopy and nonlinear X-ray science in materials. The experiment setups will allow for forward- and back-scattering geometries (Figure 1). The envisioned modular sample environment will enable users to combine temperature control over a wide temperature range and strong magnetic fields with ultrashort optical laser excitations.

Launching the SCS team

The SCS group was founded in mid-2012, when leading scientist and group leader Andreas Scherz joined European XFEL. Prior to that, Scherz was a scientific staff member at the Stanford Institute for Materials and Energy Science (SIMES) at SLAC National Accelerator Laboratory in Menlo Park, California.

In 2012, the main objectives of the SCS group were to build up the team as well as to assess and consolidate the experimental requirements for the preparation of the conceptual design report for the SCS instrument, which is due to be reviewed in March 2013.

At the beginning of 2013, Oleg Krupin will join the group as scientific staff. He is currently a postdoctoral researcher and collaborator at the Soft X-ray Materials Science (SXR) beamline of Linac Coherent Light Source (LCLS) at SLAC, where European XFEL seconded him in 2010. His knowledge and experience will substantially contribute to the research, design, and realization of the SCS instrument.

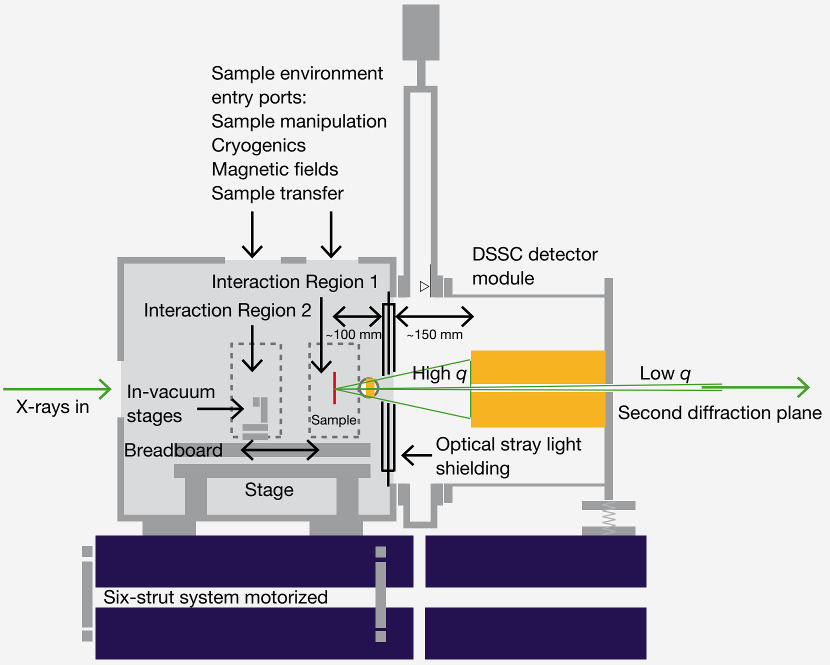
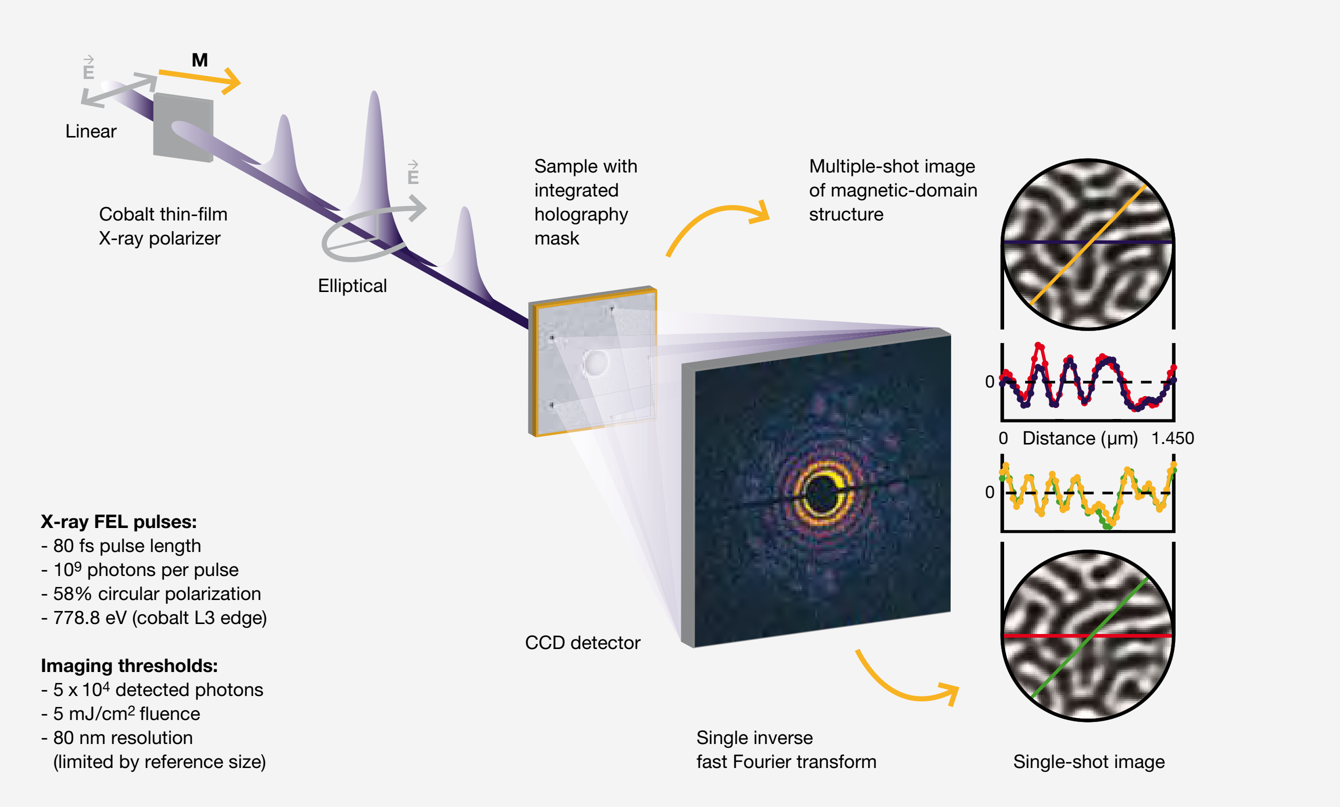


Figure 1 Conceptual design of the forward-scattering fixed-target (FFT) chamber as one of the experiment setups to be provided at the SCS instrument (schematic, not to scale)

q = scattering vector

Following ultrafast electronic and spin dynamics in real space and time is one of the key drivers of X-ray free-electron laser (FEL) science in the soft X-ray energy range. In 2010, an international collaboration of scientists led by Scherz—then at SIMES—successfully recorded images of magnetic nanostructures using a single X-ray pulse [1].

The team used a technique called X-ray Fourier transform holography (X-FTH), which allows a real-space image to be obtained from a coherent diffraction pattern through a single 2D Fourier transformation (Figure 2). The main objective of this single-shot imaging study was to explore attainable spatial resolutions and potential limitations using intense and ultrashort X-ray pulses with their photon energy tuned to absorption resonances. In the vicinity of X-ray absorption resonances, measurements are extremely sensitive to local atomic orbitals and spins, and the electronic structure of a material is inherently most sensitive to perturbations from the X-ray laser probe. The study showed that short enough pulses mitigate sample perturbations that may become prominent during the time after the pulse has passed the sample. It was further demonstrated that, with pulse energies



X-ray FEL pulses:
- 80 fs pulse length
- 10^9 photons per pulse
- 58% circular polarization
- 778.8 eV (cobalt L3 edge)

Imaging thresholds:
- 5 x 10^4 detected photons
- 5 mJ/cm^2 fluence
- 80 nm resolution (limited by reference size)

Figure 2 Experimental geometry for femtosecond single-shot X-ray holographic imaging of nanoscale ferromagnetic ordering. The incident peak intensity on the sample was low enough to prevent sample destruction but still high enough to recover an image from an X-ray hologram containing 10^4–10^5 photons only. A series of single-shot images was taken on the same sample. By comparing consecutive snapshots and analysing the image contrast and the lateral structure, sample perturbations caused by the X-rays during and after the pulse were characterized as a function of the X-ray fluence up to 30 mJ/cm^2. The results are summarized in [1].

between the imaging and the sample damage thresholds, single-shot imaging in a “diffraction without destruction” mode becomes possible at moderate resolutions of 50–80 nm. These results serve as first benchmarks for the further development of this technique and of the instrumentation at SCS.

Milestones for 2013

In 2013, the SCS group will quadruple in size. The main objectives of the group are the completion of the conceptual design of the SCS instrument for review in March 2013 and the transition to the technical design phase. User consortia expressed interest in complementing the capabilities of the SCS instrument and facilitating time-resolved resonant inelastic X-ray scattering (RIXS) and photoelectron spectroscopy (PES) experiments. Together with the user consortia, the SCS group will plan the integration of the add-on instrumentation with the goal to serve an even broader user community when the SCS instrument becomes operational in 2016. ■

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Phys. Rev. Lett. **108**, 267403 (2012)

Group members
(left to right) Andreas Scherz (group leader), Oleg Krupin (since January 2013), and Manuel Izquierdo (guest scientist)

SCIENTIFIC INSTRUMENT SPB

The Single Particles, Clusters, and Biomolecules (SPB) group aims to deliver a state-of-the-art single-particle imaging instrument for the European XFEL. Imaging capabilities will cover the whole range of single particles—from larger biological particles, such as cells and organelles, to certain material particles and nanocrystalline biomolecules [1], with aspirations to also image individual, biologically relevant molecules. In the past year, significant progress has been made in defining the technical requirements for this instrument.

New group members

In 2012, the SPB group welcomed three new members, in three different facets of the group's activities. Mechanical engineer Nadja Reimers started in early April as part of the Central Instrumentation Engineering (CIE) team, initially assigned to the SPB instrument. Chun Hong ("Chuck") Yoon joined the SPB group in February in an appointment that shared equal time with the Center for Free-Electron Laser Science (CFEL) at Deutsches Elektronen-Synchrotron (DESY). Yoon has worked with colleagues at CFEL to implement the CrystFEL software package developed by Thomas White of CFEL and others for analysis of FEL nanocrystallographic diffraction data [2]. Gannon Borchers joined the group in October as the SPB instrument engineer.

Achievements

In January 2012, we presented the SPB conceptual design report at the European XFEL Users' Meeting. In the course of the year, we made significant progress in defining the technical specifications of the SPB instrument, including the focusing system as well as the 2D detector and diagnostic needs. These technical considerations will be detailed in our technical design report (TDR), which we will submit to the SPB advisory review team (ART) and the European XFEL Scientific Advisory Committee (SAC) for review and feedback in 2013.

In the course of 2012, the SPB group made significant progress in defining the technical specifications of the SPB instrument, including the focusing system as well as the 2D detector and diagnostic needs.

In 2012, we outlined the requirements of the SPB instrument's detector geometry, in close collaboration with the Detector Development group. By considering the likely sample sizes and useful photon energy ranges,

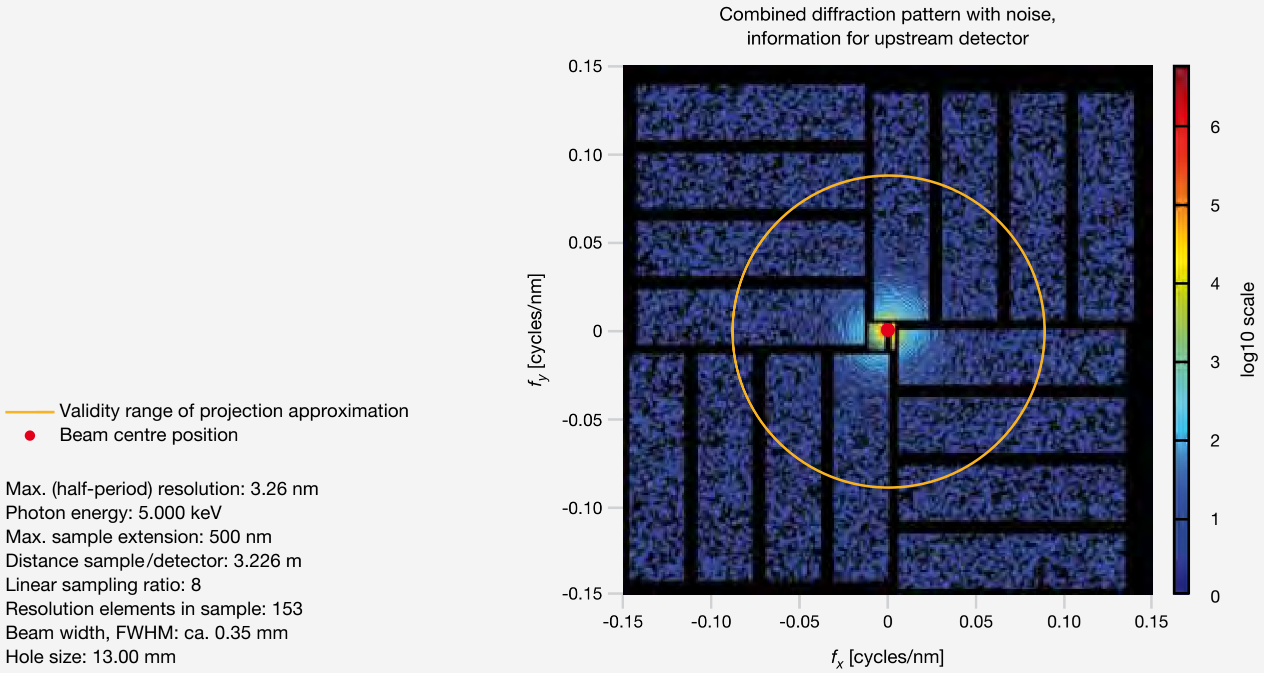

Figure 1 Representation of the signal scattered from a simulated 500 nm diameter biological particle, as measured on two AGIPD planes. These simulations allow us to predict the best geometrical arrangement of the detectors for different sample sizes.

Klaus Giewekemeyer and others simulated the signal provided by a model biological specimen on Adaptive Gain Integration Pixel Detector (AGIPD) modules to optimize their location in the SPB instrument (Figure 1). A technical note, which explores a range of sample sizes and photon energies to best exploit the AGIPD detector for single-particle imaging at the SPB instrument, is currently being finalized.

Spectrometer requirements at the SPB instrument have also been outlined, in collaboration with the X-Ray Photon Diagnostics group, and a document describing these needs will be included in the upcoming TDR.

A critical component of the optical design of the SPB instrument is the focusing optics required to produce two different focal spot sizes. Focusing mirrors have been chosen as the focusing optics, mainly because of their high transmission. However, the required optical coatings had never been tested with a free-electron laser (FEL) beam—until October 2012, when Andrew Aquila, Cigdem Ozkan, a team of researchers from the SPring-8 Angstrom Compact Free-Electron Laser (SACLA) at the RIKEN Harima institute in Hyogo, Japan, and other institutions performed measurements at SACLA to determine the damage thresholds of materials suitable to coat these optics (Figure 2).

The goal was to find out under what conditions the coatings will fail in the FEL beam. Based on this knowledge, the team performed simulations to determine the parameters of the optics. As X-ray mirrors are a long-lead-time component, their specific definition must be finalized in 2013, and will be outlined in the TDR.

Figure 2
Top Andrew Aquila (SPB) and Cigdem Ozkan (X-Ray Photon Diagnostics) at SACLA, Japan, preparing grazing- and normal-incidence damage studies.
Bottom A section of test mirror with coating for a grazing-incidence damage measurement.

Research activities

Imaging work has continued with two different experiments to image materials and biological specimens with ptychography at the Advanced Photon Source (APS) in Argonne, Illinois, and at the PETRA III facility of DESY. Diffraction data has been successfully collected at both facilities, and data analysis is ongoing.

In a collaborative effort undertaken with Garth Williams, Marc Messerschmidt, and Sébastien Boutet of the Linac Coherent Light Source (LCLS) at SLAC National Accelerator Laboratory in Menlo Park, California, measurements at the Coherent X-Ray Imaging (CXI) instrument at LCLS were carried out to determine the wavefront of the FEL beam (Figure 3). This data, which is presently being evaluated, will provide insight into the structure of the beam and its impact on imaging with FELs. A further study investigating the suitability of various substrates for sample mounting and diagnostic use has also been performed at Elettra in Trieste, Italy, by Klaus Giewekemeyer with Cigdem Ozkan of the X-Ray Photon Diagnostics group.

In these activities, we gained critical information about coherent imaging and its instrumentation requirements, which is important input for our TDR. The report will include optics design, detector requirements, diagnostic requirements, slit characteristics, optical layout, and sample chamber design.

Figure 3 Close-up of two planes of the wavefront measuring device developed in cooperation with the X-Ray Photon Diagnostics group and used at the CXI instrument at LCLS

Perspectives for 2013

The first and highest priority for 2013 is the delivery of the TDR in March, first to the SPB ART, and then to the SAC. The report will outline the requirements of the components for the instrument and, in some cases, the technical solutions. It will be made available to all potential users to present the expected capabilities of the SPB instrument. Following the delivery of the TDR, we will further detail the technical realization of the instrument and initiate the first steps of production and procurement, especially of the X-ray mirrors.

A proposal to construct a dedicated second interaction region in the SPB instrument for serial femtosecond crystallography (SFX) has been put forward by Henry Chapman of CFEL and others. With this instrumentation, the spent beam from certain experiments at SPB could be used to screen nanocrystals or perform nanocrystallographic structure determination. This project will be further specified in 2013. Research activities in optics, imaging, and methods will continue, including experiments at PETRA III at DESY and ideally at FEL facilities, as will the analysis of the data collected in 2012, allowing us to determine the best conditions for diffractive imaging and the best design for an instrument purpose-built for this kind of science. ■

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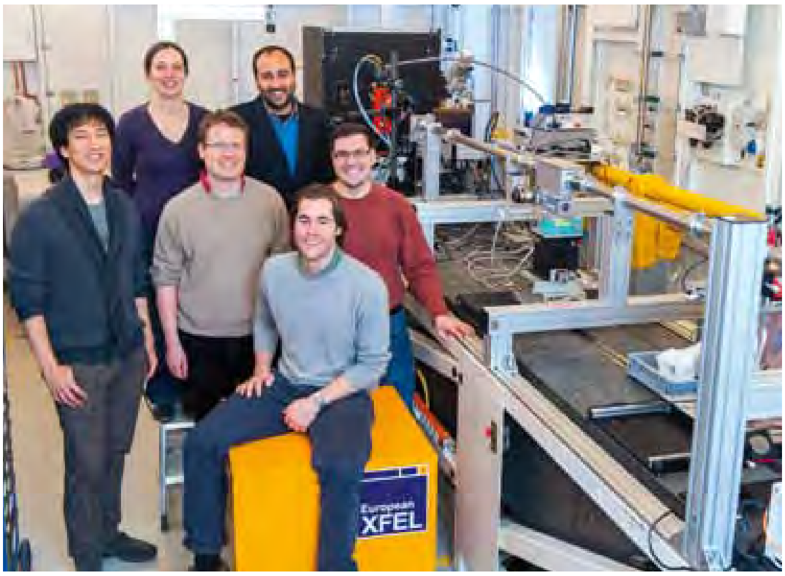

Group members
(left to right) Chun Hong (“Chuck”) Yoon (through the Biostruct-X project in partnership with CFEL), Nadja Reimers (Central Instrumentation Engineering), Klaus Giewekemeyer, Adrian Mancuso (group leader), Gannon Borchers, and Andrew Aquila

SCIENTIFIC INSTRUMENT SQS

The Small Quantum Systems (SQS) instrument was brought one major step closer to realization with the publication of its technical design report (TDR) in 2012. At the same time, the SQS group continued its science programme—dedicated to the application of two-colour experiments for the study of atomic and molecular photoionization dynamics and to investigations of non-linear processes in prototype atomic samples—with experiments at two free-electron laser (FEL) sources.

Technical design report

A decisive step in the planning and construction of the SQS instrument was accomplished in 2012 with the completion of the TDR. This report describes the detailed technical layout of the instrument, which is installed on the central branch behind the SASE3 soft X-ray undulator. In particular, the TDR defines the technical characterization of two experiment chambers, including various electron, ion, and photon spectrometers, as well as of all additional instrumentation. The report is available on the European XFEL website [1].

The general concept of the SQS instrument is based on a two-chamber system separating applications on atomic-like quantum systems (AQS), such as free atoms, atomic ions, and small molecules, and those on larger targets, that is, nano-size quantum systems (NQS), such as clusters and large biomolecules (Figure 1). Great emphasis is placed on a flexible arrangement of the spectrometers, which will enable users of the SQS instrument to employ various coincidence techniques and thus make maximal use of the uniquely high repetition rate of the European XFEL. In addition, investigations of non-linear phenomena, which are one of the main research topics of the SQS instrument, will take advantage of the very small focus size (1 μm or less) realized in both experiment chambers. The required optical system enabling such performances is a major challenge of the experiment setup, as it entails mirrors of an optical quality at the limits—or even beyond—presently available specifications.

A two-chamber system separates applications on atomic-like quantum systems, such as free atoms, atomic ions, and small molecules, and those on larger, nano-size quantum systems, such as clusters and large biomolecules.

Experiments at FLASH and LCLS

In parallel to working on the design of the SQS instrument, the group has continued its science programme dedicated to the application of two-colour experiments for the study of atomic and molecular photoionization dynamics, and to investigations of non-linear processes in prototype atomic samples. These experiments were performed at two FEL sources: the Free-Electron Laser in Hamburg (FLASH) at Deutsches Elektronen-Synchrotron (DESY) in Germany and the Linac Coherent Light Source (LCLS) at SLAC National Accelerator Laboratory in Menlo Park, California.

The main challenge for all two-colour experiments combining an FEL and an external optical laser consists in precisely characterizing the temporal delay between the two ultrashort light pulses. A very promising method to provide this information to users, called “terahertz (THz) streaking”, was developed and successfully tested at FLASH in 2012 [2]. A large collaboration, including research groups from the Center for Free-Electron Laser Science (CFEL) in Hamburg, European XFEL, DESY, and SLAC, demonstrated that the photoionization spectrum of an atom (or molecule) is affected in a well-defined way when the extreme-ultraviolet (XUV) radiation overlaps with a long-wavelength (THz) single-cycle pulse. The kinetic-energy distribution of the emitted photoelectrons depends directly on the position of the FEL pulse with respect to the THz pulse, more precisely with respect to the electric

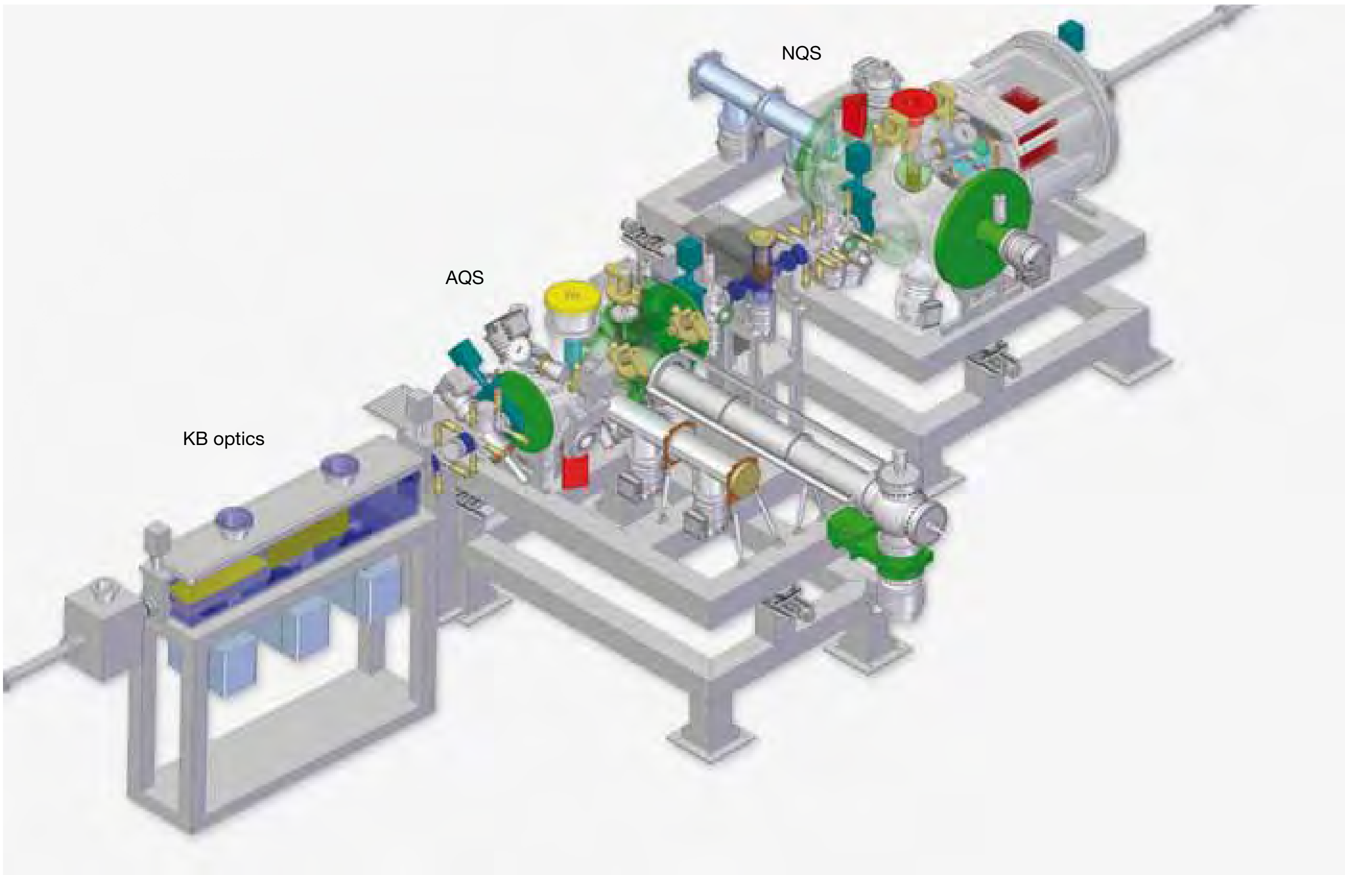

Figure 1 Global view of the SQS instrument with the AQS and NQS vacuum chambers and the Kirkpatrick-Baez (KB) focusing optics

field of the THz pulse (Figure 2). The electron emission is shifted and broadened on the kinetic-energy axis. The precise determination of these two quantities—shifting and broadening—enables the extraction of the essential parameters of the FEL pulse with high accuracy, that is, 5 fs (FWHM) for the temporal profile and 6 fs (rms) for the arrival time. Further studies are under way to explore how this technique can be adapted to the particular structure of the European XFEL, especially to its high repetition rate.

In another experimental campaign at FLASH, atomic photoionization in an intense XUV field was investigated using electron spectroscopy. In these experiments, the FEL beam was focused to a diameter of less than 5 µm. Under these conditions, the simultaneous and the sequential absorption of two (or more) photons from the same FEL pulse becomes important and gives rise to multiple ionization of the atom. The phenomenon has been observed in many experiments using charge-resolved ion spectroscopy, but only the analysis of the emitted electrons allows a clear determination of the actual photoionization process and the underlying dynamics.

Next year, the first major modules of the SQS instrument—such as the Kirkpatrick-Baez focusing optics equipment, which requires long delivery time because of its non-standard specification—are scheduled to be ordered.

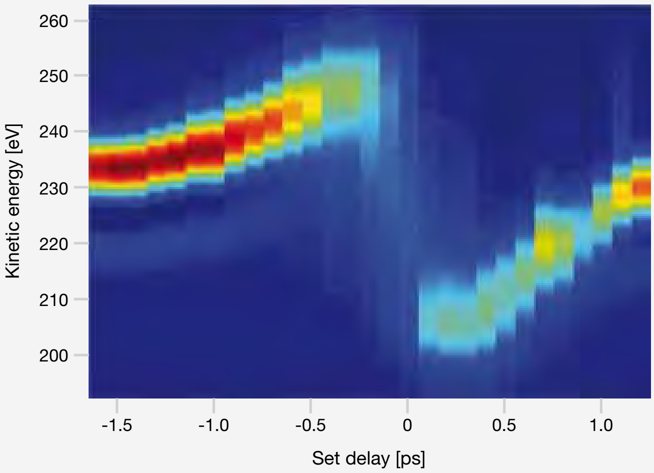

Figure 2 Streaked photoelectron spectra of atomic helium as a function of the temporal delay between the THz streaking pulse and the ionizing FEL pulse from FLASH [2]

A typical example of the measurements is shown in Figure 3. When argon atoms are ionized with intense FEL pulses of 123 eV photon energy, sequential ionization is observed in the kinetic-energy range below 110 eV. Various transitions caused by the ionization of the neutral atom, the singly charged ion, and the doubly charged ion can be identified. In the high kinetic energy range, processes related to the direct absorption of two photons—so-called “above-threshold ionization” (ATI)—are detected. The efficient production of ions during the first part of the FEL pulses leads to the observation of two-photon processes also on the ionic species, opening access to measurements on ions using electron spectroscopy without initial preparation. Precise identification of all transitions and their relative intensities enables us to unravel the dynamics of multiple ionization in strong FEL beams, and is a crucial test for theoretical descriptions of these processes.

Perspectives for 2013

Next year, the first major modules of the SQS instrument—such as the Kirkpatrick-Baez (KB) focusing optics equipment, which requires long delivery time because of its non-standard specification—are scheduled to be ordered. As a continuation of the research programme at FLASH and LCLS, additional experiments are planned at the Free Electron Laser for Multidisciplinary Investigations (FERMI) next to the

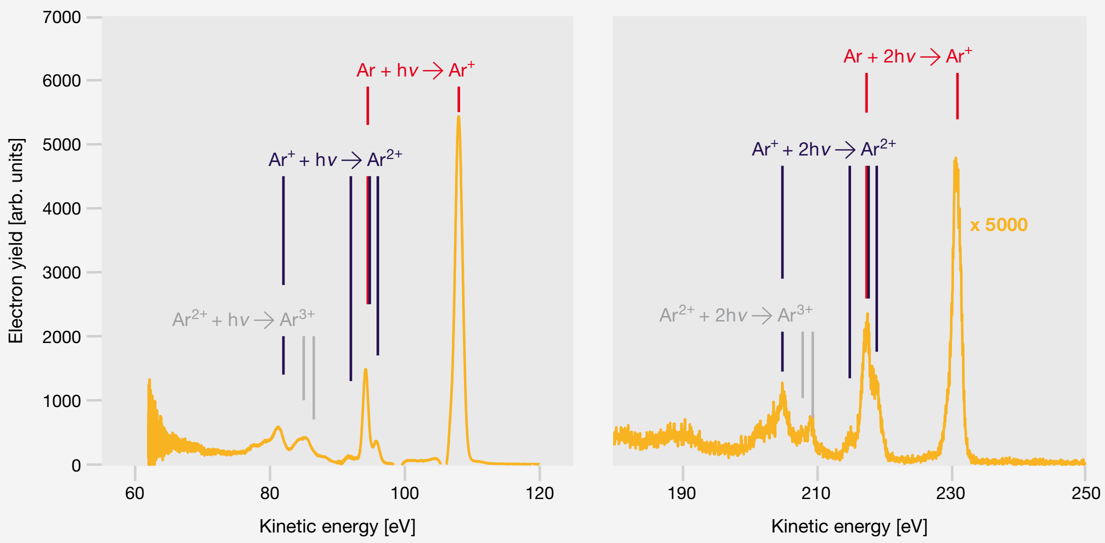

Figure 3 Typical electron spectra recorded at FLASH operating at 123 eV photon energy.
Left Sequential processes induced by the subsequent absorption of one photon.
Right Processes induced by the simultaneous absorption of two photons.

Elettra synchrotron in Trieste, Italy. For the first time, circularly polarized FEL radiation will be used to study circular dichroism in atomic two-colour photoionization. ■

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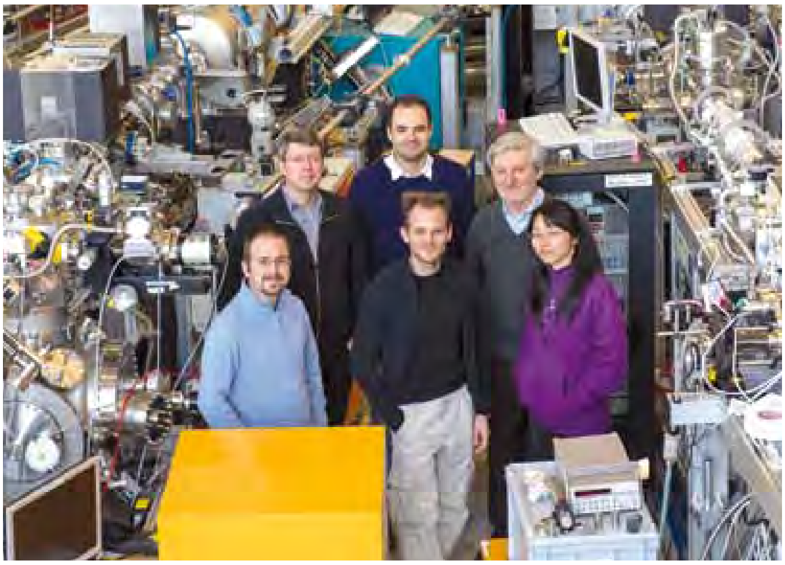

Group members
(left to right) Tommaso Mazza, Michael Meyer (group leader), Sadegh Bakhtiarzadeh, Markus Ilchen, Nikolay Kabachnik (visiting scientist), Haiou Zhang, and Amir Jones Rafipoor (not shown)

OPTICAL LASERS

The Optical Lasers group will provide laser equipment for pump–probe and other experiments at the European XFEL. This equipment will be developed in house and in close collaboration with industrial and academic partners. In 2012, the group started experimental R&D work on the pump–probe laser and designed, constructed, and characterized various components of the laser system.

Laser development lab completed

The Optical Lasers group currently consists of five laser scientists and engineers. In 2012, two new members joined the group.

European XFEL and Deutsches Elektronen-Synchrotron (DESY) decided to put laser-related activities under the scrutiny of a common Laser Advisory Committee (LAC). The LAC, consisting of six leading international laser experts, convened for the first time in March 2012.

With the completion of the laser development lab at DESY in August 2012, experimental R&D work on the pump–probe laser has started. The lab now offers state-of-the-art features for laser R&D, such as two 21 m^2 laser table assemblies with Class 100 cleanroom conditions. The 230 m^2 lab is shared with the group of Franz X. Kärtner of the Center for Free-Electron Laser Science (CFEL) at DESY, thereby fostering collaboration and exchange.

Pump–probe laser development: front-end design

In 2012, the group focused on developing the pump–probe laser system that will be combined with the scientific instruments of the European XFEL. The front end of the pump–probe laser consists of two all-in-fibre amplifier chains seeded at 1030 nm. One output is used to generate a synchronized super-continuum to seed the first stage of the non-collinear optical parametric amplifier (NOPA), while the other output seeds the burst mode power amplifier, which finally pumps the NOPA. Various switching elements in the all-in-fibre amplifier allow operation at repetition rates between 200 kHz and 4.5 MHz, with pulse energies scaling accordingly.

The front end was designed in collaboration with industry. The group took part in the assembly and debugging of this complex system, which was installed in October 2012. All parameters and operation modes are fully in accordance with design specifications. All intra-burst repetition rates of the pump–probe laser are generated by the front end, derived from an X-ray free-electron laser (FEL) timing signal, and various information is communicated via Ethernet to the front-end controller. The design of the front-end interface was coordinated with the DAQ and Control Systems group.

Burst mode power amplifier

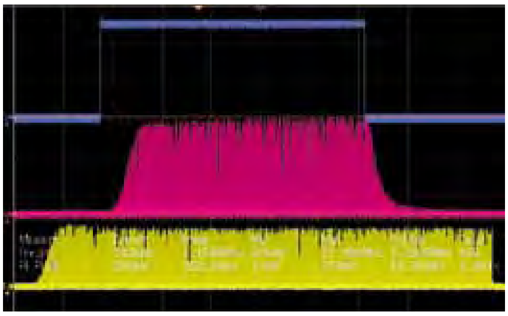

Figure 1 Temporal evolution of burst power: 5 ms long seeding burst from front-end amplifier (yellow), 400 W amplified burst output from first booster amplifier (magenta), and energizing of booster amplifier (blue)

To generate the pump pulses for the NOPA, very high-power, -energy, and -frequency picosecond pulses are required in short bursts of 10 Hz repetition rate. In 2012, we finalized contractual work for the development of a 20 kW ytterbium-doped yttrium aluminium garnet (Yb:YAG) InnoSlab burst mode amplifier according to a staged development plan devised together with industry. The collaboration resulted in a 400 W first-stage booster amplifier delivered in August 2012, with the final 20 kW stages scheduled to follow in mid-2013. Characterization of the 400 W system showed that the essential performance criteria were fulfilled, namely > 400 W burst power at 10 Hz, low duty cycle burst mode operation with the required beam quality. Since the amplifier is also energized in burst mode, it was essential to measure the temporal evolution of beam parameters during the burst. Such variations are typically due to thermal dynamics resulting from a partially caloric pump regime, as well as to

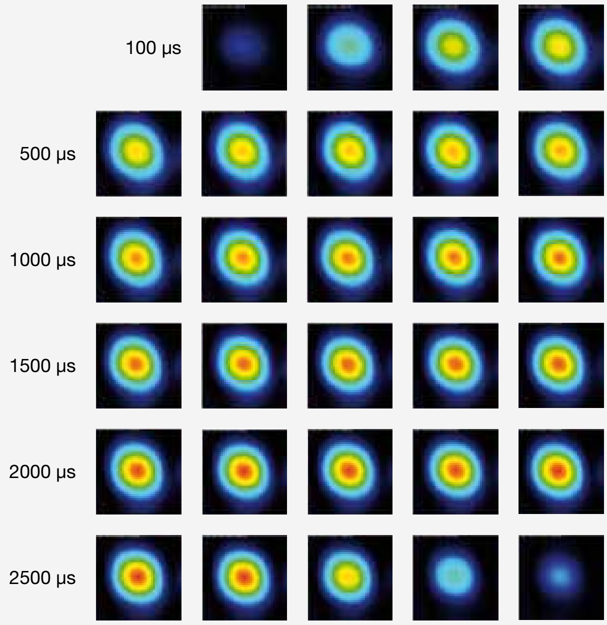

Figure 2 Temporal evolution of the burst beam shape at the output of the 400 W booster amplifier

gain dynamics. The measurements revealed these effects and allowed us to choose seeding conditions and burst timing so as to bring them down to a negligible level (Figures 1 and 2).

NOPA

At the beginning of 2012, we presented the conceptual design of a multistage NOPA fulfilling the pulse width, energy, and repetition rate goals of the European XFEL pump–probe laser. To aid in the design, we developed a simulation code for NOPAs, including all relevant linear and nonlinear effects in one spatial dimension plus time (1D+T). Using 3D+T software contributed through collaboration with Gunnar Arisholm from the Forsvarets Forskningsinstitutt (Norwegian Defence Research Establishment) in Kjeller, Norway, helped us to understand the intricate nonlinear dynamics during parametric amplification. We are currently building the first two stages of the NOPA, and first results are expected in January 2013. To characterize the seeding of the NOPA and verify the feasibility of the planned dispersion management, we performed first experiments with supercontinuum generation, from which we could derive conditions for optimal power spectral density in the spectral region of interest.

Pulse-on-demand, pulse timing, and pointing drift

The conceptual design of the European XFEL pump–probe laser foresees the possibility of choosing arbitrary pulse sequences from the burst on user demand. Our pulse-on-demand unit is based on a fast Pockels cell switch in the pump beam of the NOPA. With our industry partners, we started developing a suitably scaled large-aperture Pockels cell and a driver to achieve the fast switching required at repetition rates of up to 4.5 MHz and with switching voltages of up to 13 kV.

Utilization of the ultrashort laser pulses from the pump–probe laser together with the X-ray pulses from the European XFEL in experiments requires highly stable pulse arrival timing. Similarly stringent requirements concern the pointing stability of the pump–probe laser beam and the seed and pump beams of the NOPA. We identified both passive and active measures to be implemented to achieve both goals, and began design and characterization.

Further activities

Apart from the pump–probe laser, planning for the High Energy Density Physics (HED) instrument at SASE2 foresees a 100 TW-class commercial titanium–sapphire laser. Procurement and integration is synchronized with the planning for the HED instrument. Additionally, an external user consortium has signalled interest in contributing petawatt and high-energy nanosecond lasers to the European XFEL.

In 2012, we also advanced the planning, specification, and integration of laser hutches in collaboration with the Technical Coordination group and instrument scientists. In addition, we planned and specified the details of the future laser R&D lab at the European XFEL campus in Schenefeld.

Outlook for 2013

Major milestones and tasks for the Optical Lasers group in 2013 include:

- Commissioning the 20 kW burst mode booster
- Operating the high-power and high-energy multistage NOPA
- Realizing various subsystems of the pump–probe laser, such as beam pointing stabilization, timing stabilization, and pulse-on-demand
- Planning the final layout of the pump–probe laser
- Planning the 100 TW laser for the HED instrument
- Increasing the group by up to five full-time employees ■

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Paper 8504-20, SPIE Conference on Optics and Photonics 2012, 12–16 August 2012, San Diego, invited talk

Group members
(from left to right) Martin Kellert, Mikhail Pergament, Kai Kruse, Max Lederer (group leader), Jinxiong Wang, Guido Palmer (since January 2013), and Cruz Mendez (until February 2012, not shown)

SAMPLE ENVIRONMENT

The high repetition rate and the outstanding peak brilliance of the European XFEL facility are challenges for sample preparation and delivery to the scientific instruments. The Sample Environment group was established in the fall of 2011 to develop state-of-the-art sample delivery techniques and to help external and internal user groups bring their samples into the European XFEL beam.

Objectives

The group aims to standardize sample environment methods and technologies to be used at all six baseline instruments as well as those instruments that may be provided by user consortia. In 2012, we intensified the discussions with leading scientists at European XFEL and with external users to define the goals for developing sample technologies. In addition to the aerosol source, which was contracted as an in-kind contribution with Uppsala University in 2011, we started to build up our own project for developing liquid jets for sample injection.

Preparing and handling biological samples

Biological samples—such as proteins, protein complexes, and whole cells and viruses—will be important specimens to be examined using the short pulses and intense radiation of the European XFEL. Guest scientist Charlotte Uetrecht investigated new possibilities for preparing biological samples for the facility. She also helped to define the requirements for handling biological samples in the lab space of the European XFEL headquarters in Schenefeld.

Together with the UseXBI user consortium and the Single Particles, Clusters, and Biomolecules (SPB) group, the Sample Environment group considered the required lab space and the necessary equipment for preparing biological samples. Under the leadership of the European Molecular Biology Laboratory (EMBL), the UseXBI user consortium will contribute a biology facility to the project. The facility will be open to all user groups with beamtime at the instruments of the European XFEL. In 2012, we evaluated the user needs for this kind of facility and specified the requirements.

In collaboration with the X-Ray Photon Diagnostics group, we took part in a beamtime at the Elettra facility in Trieste, Italy, to evaluate different kinds of substrates for biological imaging.

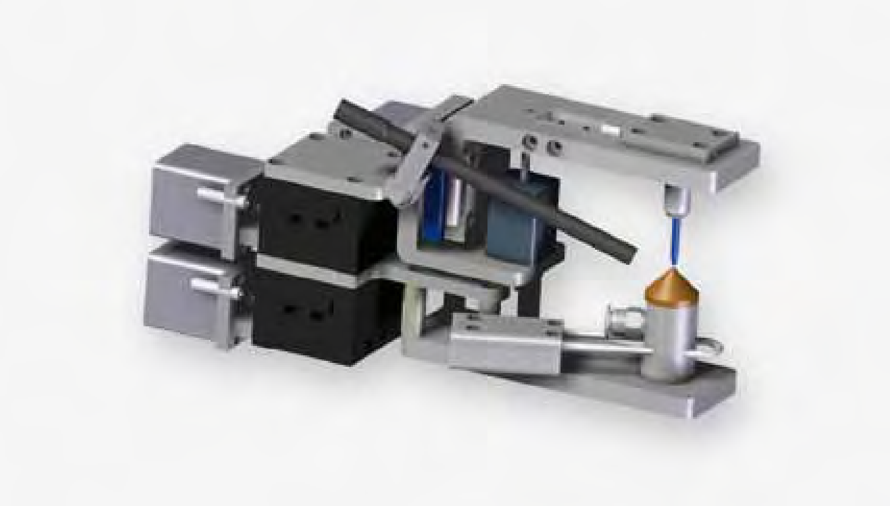


Figure 1 Modular and compact setup for liquid-jet delivery designed by Microliquids GmbH in Göttingen, Germany, in collaboration with the Sample Environment group. Nozzle (blue) and catcher for recovery (copper colour) can be replaced separately. This ensures a versatile setup with state-of-the-art technology for the operation phase of the European XFEL starting in 2016.

Defining research fields

Liquid targets will be an important focus of the Sample Environment group because they can provide samples that refresh fast enough for the bunch mode of the European XFEL and can be used to study matter in the liquid phase (Figure 1). In June 2012, Sadia Bari joined the group. She has experience with both aerosol and liquid-jet sources at the Linac Coherent Light Source (LCLS) at SLAC National Accelerator Laboratory in Menlo Park, California, and the Free-Electron Laser in Hamburg (FLASH) at Deutsches Elektronen-Synchrotron (DESY), and will set up the project for liquid jets.

Beside liquid beams and aerosols, we defined two further fields of research for the Sample Environment group: fast and precise manipulation of fixed targets, and cryogenic environments and magnetic fields.

Beside liquid beams and aerosols, we defined two further fields of research for the Sample Environment group: fast and precise manipulation of fixed targets, and cryogenic environments and magnetic fields. To make effective use of the high repetition rate of the European XFEL for fixed targets, we created a scientist position to develop fixed-target preparation and positioning systems to address the special requirements of the facility. A suitable candidate has been found and will join the group in summer 2013. Cryogenic environments and magnetic fields have been specified to be the focus of the third scientist position in the Sample Environment group. To combine low temperatures and magnetic fields with the requirements of the free-electron laser will entail the development of new sample handling devices. In 2012, we found an experienced candidate who will join the group in February 2013.

Preparing a preliminary laboratory

In 2012, we also started to prepare the preliminary sample environment laboratory. The laboratory is located in the HERA South hall, one of the former experiment halls of DESY’s HERA accelerator. Here, we will develop sample delivery methods and prepare samples for experiments until the laboratories in the European XFEL headquarters building in Schenefeld are ready for use. Tools and basic equipment for the lab, as well as a first vacuum chamber for sample delivery development, have been ordered and will be available in January 2013.

Designing user lab space

Another area of activity in 2012 has been the design of the user lab space for the facility. The group has collected the needs of the scientific instruments and their user communities. From this information, we derived a plan to equip the lab with the necessary instrumentation to prepare samples on site and characterize them before introduction into the beam.

It is planned to construct an X-ray lab for sample characterization as well as for reflectometry. We will be able to characterize samples with photoelectron spectroscopy, scanning electron microscopy, and atomic-force microscopy. We also foresee possibilities to grow multilayers and clean surfaces, and to transfer the prepared surface samples to the instruments. Planning and designing a clean sample transfer system between the scientific instruments and the preparation facilities will be one of the tasks of the fixed-target expert. ■

Group members
(left to right) Sadia Bari, Joachim Schulz (group leader), and Charlotte Uetrecht (guest scientist)

06

DETECTORS AND DATA ACQUISITION

High-speed imaging X-ray detectors are essential to exploit the European XFEL's potential. Further challenges are the development of electronics and software systems to control and read out the scientific instruments, as well as solutions to handle large volumes of data.

Testing the first LPD detector prototype

DETECTOR DEVELOPMENT

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

Improving technical and scientific skills

In 2012, our group started developing data analysis software for detector calibration, characterization, and scientific data processing. Fast raw-data processing capabilities are particularly important for real-time performance monitoring of detectors and efficient high-throughput data analysis. Taking into account the enormous data rates expected from large-area two-dimensional imaging detectors, development of new concepts for raw-data treatment close to or at the detector front end is mandatory.

Additional manpower for electronics engineering and technical tasks has strengthened the joint electronics group that we established together with the DAQ and Control Systems group in 2012. This widens the expertise of our group in developing analogue front-end electronics (for example, for avalanche photodiode (APD) detectors).

Detector laboratory

The detector development activities require laboratory infrastructure for performance tests, calibration, and commissioning of prototype detectors and data acquisition (DAQ) components. In 2012, the first temporary detector laboratory became operational in a hall formerly used for one of the experiments at the HERA accelerator of Deutsches Elektronen-Synchrotron (DESY). The laboratory provides a clean and dust-free environment to operate, characterize, and integrate small two-dimensional imaging detectors, such as charge-coupled devices (CCD, Figure 1).

Infrastructure to test and operate large-area two-dimensional imaging detectors and strip detectors will become available in the second expansion stage of the laboratory at the end of 2013. It is particularly important that detector systems can be tested under similar conditions as expected during experiments at the European XFEL. This requires X-ray generators that provide a similar pulse structure as the European XFEL and specific test setups optimized for vacuum and ambient-pressure operation. Our group has explored the option for single-shot,

Figure 1 Detector Development group member installing a CCD test setup in the detector laboratory. The detector vacuum vessel (copper cylinder) with cooling (on top of the vacuum vessel) and vacuum system (to the right of the vacuum vessel) is shown.

high-intensity X-ray sources and defined the requirements for the detector test and calibration infrastructure. We expect to converge to the final technical design and start implementing the calibration infrastructure in 2013.

Progress of the AGIPD, DSSC, and LPD projects

At the 11th and 13th meetings of the European XFEL Detector Advisory Committee (DAC) in May and November 2012, the Adaptive Gain Integration Pixel Detector (AGIPD), the Depleted P-Channel Field Effect Transistor (DEPFET) Sensor with Signal Compression (DSSC), and the Large Pixel Detector (LPD) projects faced an in-depth review of their progress. The collaborations presented mechanics concepts of their detector systems, which have been further refined. Particular attention was devoted, on the one hand, to improving the modularity of the sensor plane and maximizing the flexibility of the sensor geometry using moveable detector segments and, on the other hand, to first concepts for integrating the detectors into the experiment stations (Figure 2).

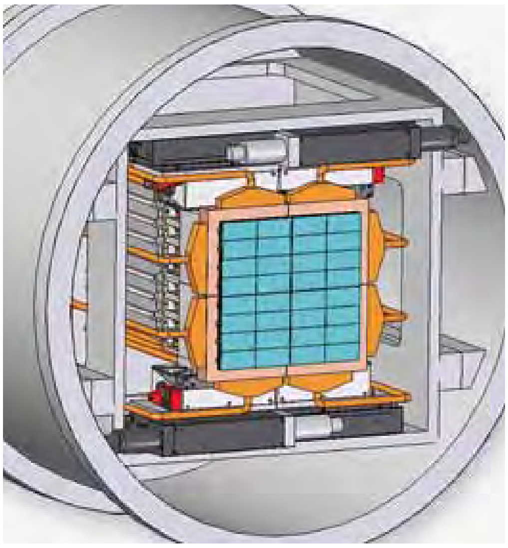


Figure 2 Baseline mechanics concept of the 1 Mpx DSSC detector. Shown are sensor tiles (blue), cooling system (orange), mechanics, and vacuum components (grey).

The LPD collaboration has made major progress, optimizing its application-specific integrated circuit (ASIC) design for low-noise operation and improved radiation tolerance of the chip. The capabilities of a small LPD detector system in terms of readout speed have been demonstrated by taking a movie of a metal wheel spinning at a frequency of 45 kHz while being illuminated with X-rays (Figure 3).

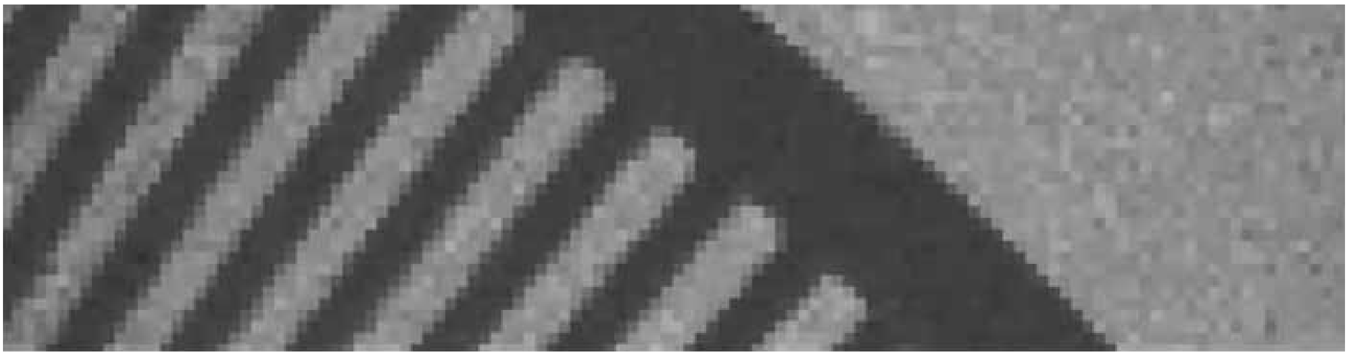


Figure 3 LPD “first light” image taken with a small prototype system. The image is a single frame taken from a movie of a spinning wheel illuminated with X-rays and rotating at a frequency of 45 kHz (light grey: illuminated area; dark grey: shadow cast by the wheel onto the sensor).

The DSSC collaboration has successfully produced and tested a small DEPFET sensor in the final technology providing non-linear amplification characteristics. The collaboration is now facing the transition to the implementation phase and the extension of the contract with European XFEL.

The final AGIPD sensor will be delivered at the beginning of 2013. This big step forward will allow the collaboration to demonstrate the performance of the sensor.

The final AGIPD sensor will be delivered to the AGIPD collaboration at the beginning of 2013. This big step forward will allow the collaboration to demonstrate the performance of the final AGIPD sensor and ASIC in 2013.

Towards imaging detectors with small pixels

Experimental imaging techniques, like X-ray photon correlation spectroscopy (XPCS) or X-ray photon cross-correlation spectroscopy (XCCS), require two-dimensional imaging detectors with an angular resolution that is much higher than the resolution of the two-dimensional imaging detectors presently under development for the European XFEL. These systems provide pixel sizes of 200 µm x 200 µm or larger. In the long term, we endeavour to improve the angular resolution by at least a factor of four, which means that, in the medium term, new detectors are needed with pixel sizes at a maximum of 50 µm x 50 µm. This goal cannot be achieved with current sensor and ASIC technology while maintaining performance parameters like European XFEL burst mode support, large dynamic range, and memory size. Our group has started a review to identify technologies that might have the potential to close this gap in the near future, such as three-dimensional high-density integration technologies.

Slow CCD-based imaging detector systems operated at 10 Hz can bridge the gap until high-speed detectors with small pixels become available in the future. We have established a collaboration with new partners with the aim to deliver a first prototype CCD detector to European XFEL by the end of 2013.

Looking forward to 2013

In 2013, European XFEL will receive the first ¼ Mpx LPD prototype detector system, allowing performance and characterization measurements with a device that is fully comparable to the final 1 Mpx LPD detector. The group will also finalize the planning for the detector and cleanroom laboratories in the European XFEL headquarter building (XHQ). New test setups for characterization and calibration of CCD and LPD detector technology will become operational. The technical design for X-ray sources and detector test environments will be finalized. High-intensity X-ray sources, providing photons with different energies, will enhance the capabilities of our group to calibrate and characterize detectors. ■

Group members
(left to right) Balakumaar Baskaran, Kai-Erik Ballak, Melanie Eich, Marko Ekmedzic (since January 2013), Patrick Gessler (WP75 and WP76), Markus Kuster (group leader), Steffen Hauf, Monica Turcato, Markus Bohlen (student assistant), Andreas Koch, and Jolanta Sztuk-Dambietz

DAQ AND CONTROL SYSTEMS

Through in-house development and contracts with external research institutes and commercial companies, the DAQ and Control Systems group develops electronics and software systems to control and read out instruments at the European XFEL. Handling and processing the large volumes of data generated by facility users is the principal offline challenge addressed by the group.

In pursuit of simple solutions

Data acquisition (DAQ) and control systems activities are wide, and the following development areas have been defined:

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

Figure 1 Group members participating in handover tests of the first train builder demonstrator prototype electronics board with one of the development team's firmware specialists. Train builder electronics are developed for the European XFEL at RAL in the UK, and are principally used to acquire and process data from AGIPD, LPD, and DSSC cameras.

To simultaneously and efficiently satisfy the development issues posed, the group is applying state-of-the-art technological solutions that are simple, elegant, and extensible. To meet the challenges, three full-time positions and three intern positions were filled in 2012.

To simultaneously and efficiently satisfy the development issues posed, the group is applying state-of-the-art technological solutions that are simple, elegant, and extensible.

Ideal control software

In 2012, significant progress was made in the production of the in-house Karabo software framework to control hardware and software devices at the European XFEL. A key feature of the design is the principle of equality of devices, whereby hardware (valves, pumps, motors, power supplies, commercial cameras, custom front-end electronics, and so on) and software (analysis algorithms, monitoring processes, and so on) are represented within the framework as devices with identical command and property handling functions. The equality principle allows the Karabo software to be used wherever control is required—starting with beamline and experiment configuration and control, through the DAQ systems, and on to user scientific data analysis. Three ingredients—communication, flow control, and configuration—have been added to the device view to enable the additional functionality needed to provide a user-friendly control system.

Figure 2 SP Devices digitizer board selected by the electronics group

There have been a number of highlights in the Karabo project during 2012: the first beta release, fine-tuning of the Python binding to the underlying Boost C++ framework implementation, integration of e-machine and Beckhoff programmable logic controller (PLC) control systems, and the Python graphical user interface (GUI).

Progress towards final systems

In 2012, work continued on the outsourced development of electronics to synchronize and read out large-area cameras for the Adaptive Gain Integrating Pixel Detector (AGIPD), Large Pixel Detector (LPD), and Depleted P-Channel Field Effect Transistor (DEPFET) Sensor with Signal Compression (DSSC), which are specifically designed for the 4.5 MHz pulse frequency at the European XFEL. Synchronization electronics are being developed at University College London, readout electronics at Rutherford Appleton Laboratory (RAL) in the UK. First series prototypes have been manufactured and are undergoing bench testing and firmware development (Figure 1). Tests with prototype LPD area camera modules will begin in 2013.

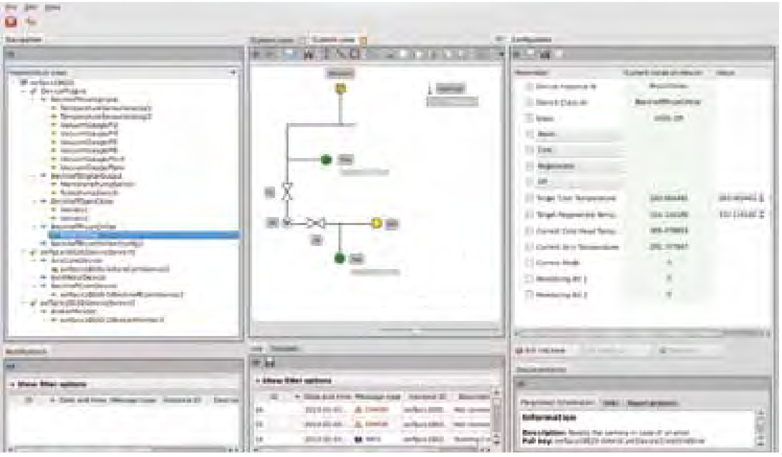


Figure 3 The “default generic GUI” uses all underlying functionalities of Karabo to allow users to configure and control individual and groups of devices.

The joint electronics subgroup created in 2011 with the Detector Development group has successfully established itself. The principal tasks of the group are the in-house development of digital and analogue electronics, requirements gathering, coordination of external electronics acquisition and usage, development of a framework for field programmable gate array (FPGA) firmware design and implementation, and so on.

Low-level control of positioning equipment and vacuum systems is performed using industrial automotive control equipment from Beckhoff GmbH. The Ethernet for control automation technology (EtherCAT) fieldbus used allows large numbers of widely distributed motors, pumps, gauges, valves, actuators, and sensors to be coupled and controlled by PLCs. In the fall of 2012, the Detector Development group’s pnCCD test stand was equipped and has since been used to prove PLC firmware and Karabo software interfaces (Figure 3). Experience acquired at this test stand should simplify system installation at others.

In 2012, a “test slice” was built up in the DESY computer centre. This implements a complete slice of the DAQ and DM multilayer data handling architecture for a ½ Mpx camera. The system is used to prove the developed data handling concepts by testing the software implementation in an environment that is almost identical to the eventual solution. Large numbers of computation and data storage server machines connected via a 10 Gb Ethernet switch are used to implement the slice.

Initial measurements made using the test slice are encouraging. Concurrent data transfers in and out of the various layers of the slice at full speed are attained, as are sustained data storage rates of

~ 1 GB/s per storage server. These results confirm the feasibility of the proposed data handling architecture for the European XFEL. The test slice will continue to be an important testing environment, as many issues remain to be addressed.

Outlook for 2013

In 2013, the first non-beta release of the Karabo software framework will be made. This will allow the many control test stands (monochromator, diagnostic camera, laser, and so on) planned for 2013 to be implemented. Test stands are important challenges in understanding whether the chosen conceptual design solutions satisfy the precision, reproducibility, and reliability requirements.

The year 2013 will see the first tests of small-scale prototypes of area cameras specifically designed to operate at the European XFEL. Early in the year, control and DAQ integration of the two-tile LPD table-top camera will be completed. Later in the year, a ¼ Mpx LPD prototype will require control and DAQ integration.

In 2013, the group's test of a complete slice for the data handling—from front-end electronics to archive data analysis—will continue, emphasizing on-the-fly data rejection, the performance of clustered file systems, and so on. Feedback concerning data handling is also expected from a work group being set up with the DataXpress user consortium. ■

Group members
(in alphabetical order) Olivier Batindek (intern), Djelloul Boukhelef, Nicola Coppola, Anastasia Disterhof (intern), Jorge Elizondo (IT), Sergey Esenov, Bruno Fernandes, Patrick Gessler (WP75 and WP76), Burkhard Heisen, Hermann Höhne (intern), Martin Knaack (IT), Iryna Kozlova, Luis Maia, Andrea Parenti, Bartosz Poljancewicz (IT), Nikhil Shastri (intern), Janusz Szuba, Jan Tolkiehn, Kerstin Weger, Krzyzstof Wrona (IT group leader/ WP76), and Christopher Youngman (group leader)

07

FACTS, FIGURES, AND SERVICES

European XFEL is a truly international company with an extensive research network. Our workforce includes employees from 28 countries. Non-scientific staff provides administrative services, technical coordination, safety and radiation protection, and public relations.

International team: Staff members from different countries

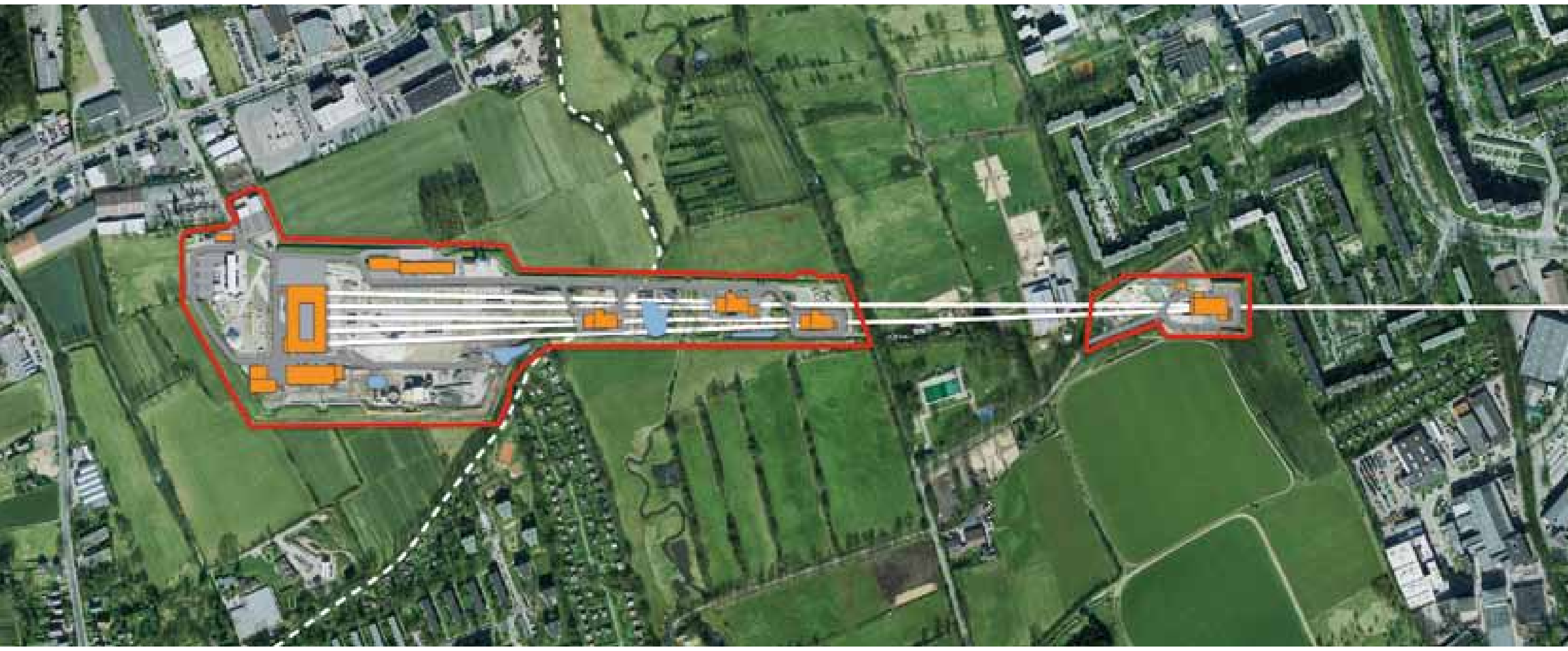


Figure 1 Aerial view of the European XFEL facility. **Right to left** DESY-Bahrenfeld, Osdorfer Born, and Schenefeld sites.

AT A GLANCE

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

Brilliant light for new research opportunities

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

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

European XFEL GmbH

As of December 2012, 12 countries are participating in the European XFEL project: Denmark, France, Germany, Greece, Hungary, Italy, Poland, Russia, Slovakia, Spain, Sweden, and Switzerland. The international partners have entrusted the construction and operation of the European XFEL facility to the non-profit European X-Ray Free-Electron Laser Facility GmbH, which was established in October 2009 as a limited liability company under German law. When user operation starts in 2016, the company will employ about 250 people.

Construction costs

The European XFEL is a joint effort of many partners, among them the DESY research centre and other organizations worldwide. Construction started in early 2009. The beginning of commissioning is planned for 2015. User operation with one beamline and two instruments will start in 2016.

The construction costs, including commissioning, amount to 1.15 billion euro (at 2005 price levels). Higher costs for underground civil construction, as well as a reduction of anticipated contributions from some countries, had caused a funding gap in 2011. Following a joint initiative from Germany, Russia, and other countries, the gap was closed and the percentage of shares recalculated accordingly. 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. ■

SHORT HISTORY OF EUROPEAN XFEL

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

1980–1984

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

1992

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

1997

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

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

2000

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

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

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

2001

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

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

2002

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

TESLA

TESLA XFEL

Technical Design Report

Supplement

Figure 4 Supplement to the TESLA TDR

2003

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

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

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

2004

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

Figure 5 On 29 September 2004, Schleswig-Holstein's Minister President Heide Simonis (right) and Hamburg's Mayor Ole von Beust sign a state treaty that provides the legal basis for the construction and operation of the X-ray laser.

2005

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

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

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

2006

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

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

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

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

2007

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

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

In July, the four-year Pre-XFEL project is launched. This project is funded by the EU and designed to support the foundation of the European XFEL as a major new research institution in Europe. The main purpose of the project is to provide all technical, legal, and financial documents necessary for the foundation of a company to build and operate the European XFEL facility. Other Pre-XFEL activities include recruiting international staff, informing potential users about the European XFEL, and facilitating the specification, research and development, prototyping, and industrialization required to build the technical infrastructure and components for the facility

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

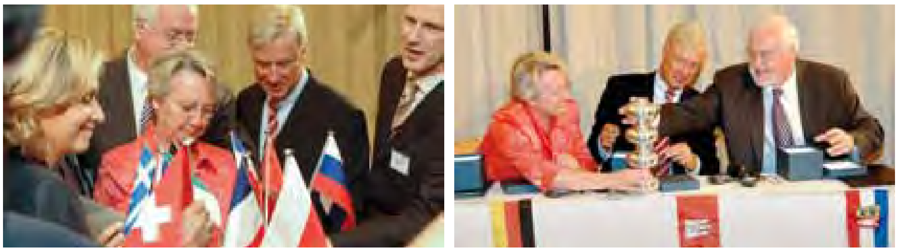


Figure 8 The European XFEL is officially launched on 5 June 2007.
Left Valérie Pécresse, French Minister of Higher Education and Research; Peter Harry Carstensen, Minister President of Schleswig-Holstein; Annette Schavan, German Federal Minister of Education and Research; Ole von Beust, Mayor of the City of Hamburg; and Andrej A. Fursenko, Minister of Education and Science of the Russian Federation
Right Annette Schavan, Ole von Beust, and Peter Harry Carstensen

2008

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

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

Figure 9 Signing of the building contracts for the three underground construction lots for the European XFEL facility on 12 December 2008

Figure 10 In 2008, European XFEL moves into its current headquarters at Albert-Einstein-Ring 19, near the DESY site.

2009

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

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

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

Figure 11 On 30 November 2009, representatives from 10 partner countries sign the European XFEL Convention and Final Act.
Left to right Mauro Dell’Ambrogio, State Secretary, State Secretariat for Education and Research, Switzerland; Peter Honeth, State Secretary, Ministry of Education and Research, Sweden; Andrej A. Fursenko, Minister of Education and Science of the Russian Federation; Prof. Jerzy Szwed, Undersecretary of State, Ministry of Science and Higher Education, Poland; Ole von Beust, Mayor of Hamburg; Giuseppe Pizza, State Secretary, Ministry for Education, Universities and Research, Italy; Prof. Frieder Meyer-Krahmer, State Secretary, Federal Ministry for Education and Research, Germany; Dr. Peter Ammon, State Secretary, Federal Foreign Office, Germany; Prof. Mikulás Supín, Director General, Division of Science and Technology, Ministry of Education of the Slovak Republic; Dr. Christos Vasilakos, Representative of the General Secretariat for Research and Technology in the Permanent Delegation of Greece at the European Union; István Varga, Minister for National Development and Economy, Hungary; Hans Müller Pedersen, Deputy Director General of the Danish Agency for Science, Technology and Innovation; and Peter Harry Carstensen, Minister President of Schleswig-Holstein

2010

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

In May, European XFEL and DESY sign a long-term agreement on future collaboration. DESY has played an important role in fostering the X-ray laser project. It advanced the funding for the preparatory work and hosted the European XFEL project team. DESY will continue to provide administrative services and lead the international Accelerator Consortium that is constructing the 1.7 km long superconducting accelerator, including the electron source. After completion, DESY will take over the operation of the accelerator on behalf of European XFEL.

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

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

Figure 12 First tunnel and borer christening ceremony on the European XFEL construction site Schenefeld on 30 June 2010

2011

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

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

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

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

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

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

Figure 13 First tunnel boring machine after its arrival in the final shaft

2012

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

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

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

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

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

Figure 14 Arrival of the tunnel boring machine AMELI in the final reception shaft on 4 June 2012

COOPERATION

European XFEL has established an extensive international research network with partners around the world. Cooperations with research organizations as well as partnership agreements serve to further advance X-ray laser science and help scientists to prepare for the unique research opportunities at the new research facility. In 2012, European XFEL signed a Memorandum of Understanding (MoU) with the Turkish Accelerator Center, an MoU with the Collaboration of European FEL and SPS Facilities, a collaboration agreement with the Technological Institute for Superhard and Novel Carbon Materials in Troitsk, Russia, and consortium agreements with its partners in the existing EU programmes BioStruct-X and CRISP.

Cooperations with research institutions

CLPU

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

Figure 1 Representatives from CLPU and European XFEL sign an MoU on 10 October 2011. **Left to right** Thomas Tschentscher, Scientific Director, European XFEL; Luis Roso, Director, CLPU; Massimo Altarelli, Managing Director, European XFEL; Maximilian Lederer, Group Leader, Optical Lasers group, European XFEL; and Karl Witte, Administrative Director, European XFEL

Collaboration of European FEL and SPS Facilities

European research facilities that operate or develop X-ray free-electron lasers (FELs) and advanced short-pulse and coherent light sources (SPS) cooperate to promote FEL science and technology in Europe and to provide the experimental conditions needed by a large, multidisciplinary user community. An MoU was signed in May 2012. Other members are Deutsches Elektronen-Synchrotron (DESY) in Germany, Sincrotrone Trieste (Elettra) in Italy, Helmholtz-Zentrum Berlin (HZB) in Germany, Istituto Nazionale di Fisica Nucleare (INFN) in Italy, MAX IV Laboratory in Sweden, Paul Scherrer Institut (PSI) in Switzerland, SOLEIL in France, Science and Technology Facilities Council (STFC) in the UK, and National Centre for Nuclear Research (NCBJ) in Poland.

DESY

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

EMBL

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

Figure 2 Signing of the MoU between EMBL and European XFEL on 12 September 2011 **Left to right** Karl Witte, Administrative Director, European XFEL; Massimo Altarelli, Managing Director, European XFEL; Iain Mattaj, Director General, EMBL; and Matthias Wilmanns, Head of EMBL Hamburg

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.

Kurchatov Institute

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

LNLS

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

Figure 3 Signing of a cooperation agreement in Brasília on 5 May 2011
Left to right José Roque da Silva, Director, LNLS; Christian Wulff, President of the Federal Republic of Germany; Dilma Rousseff, President of the Federal Republic of Brazil; Helmut Dosch, Chairman of the Board of Directors, DESY; and Massimo Altarelli, Managing Director, European XFEL

SLAC

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

Southern Federal University

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

Shubnikov Institute of Crystallography

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

STFC

The Science and Technology Facilities Council (STFC) in Swindon, UK, develops the Large Pixel Detector (LPD) for the European XFEL as well as hardware elements for the readout and data acquisition architecture.

Technological Institute for Superhard and Novel Carbon Materials

European XFEL and Technological Institute for Superhard and Novel Carbon Materials (FSBI TISNCM) in Troitsk, Russia, agreed to develop an in-line seeding monochromator for the high power and high repetition rate of the European XFEL based on synthetic diamonds. The collaboration agreement was signed in August 2012.

Turkish Accelerator Center

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

University College London

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

University of Hamburg

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

Figure 4 Representatives of European XFEL and the MIN School at the University of Hamburg with the signed cooperation agreement
Left to right Serguei Molodtsov, European XFEL; Heinrich Graener, MIN; Massimo Altarelli and Karl Witte, European XFEL; Daniela Pfannkuche, MIN; and Thomas Tschentscher, European XFEL

Uppsala University

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

Participation in EU programmes

BioStruct-X

BioStruct-X is a consortium of 19 institutions from 11 European Union (EU) member and associated states. Within a broader research programme, European XFEL scientists work with colleagues from leading international research centres to improve the structure determination of biomolecules. The EU project was started in 2011 and a consortium agreement specifying the relationship between the parties was signed in 2012.

CRISP

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

Memberships in research cooperations

Development and Use of Accelerator-Driven Photon Sources

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

EIROforum

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

Hard X-ray FEL collaboration (formerly "FEL three-site meeting")

The LCLS, the Japanese SPring-8 Compact SASE Source (SCSS), and the Hamburg FEL projects (FLASH at DESY and European XFEL) collaborate, share project information, and identify topics of common interest in a meeting series.

Physics on Accelerators and Reactors of Western Europe

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

PRESS AND PUBLIC RELATIONS

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

Objectives

The PR group works to improve the profile of European XFEL among the public and in the media, as follows:

- Sustaining and improving regional, national, and international press and other media coverage of the European XFEL project
- Maintaining and further improving communication through the European XFEL website (www.xfel.eu) and new media (Facebook and Twitter)
- Communicating information about the project to the general public and different stakeholder groups, such as future users
- Fostering neighbourhood relations
- Preparing and organizing exhibitions and presentations to the public
- Providing visitor services at the constructions sites
- Managing events directed at the general public or specific target groups

In addition, the PR group represents European XFEL at selected events, publishes PR posters, brochures, and other publications, and answers requests for information about the project. In 2012, the PR group leader represented European XFEL in the coordination and international affairs working groups of EIROforum, a partnership between eight of Europe’s largest intergovernmental research organizations.

Accomplishments

Among others, the PR group implemented the following communication measures in 2012:

- Published news releases, press releases, and newsletters
- Organized more than 60 guided tours of the European XFEL construction sites for scientists, journalists, politicians, students, and other stakeholders
- Produced and published the *European XFEL Annual Report 2011*
- Organized a celebration marking the end of tunnel civil construction, with more than 400 participants and guests from politics and science, and produced a film covering the highlights of the construction project for the event
- Published a flyer for the Human Resources group
- Contributed to the PR activities of EIROforum (*Science in School* and other brochures)
- Represented European XFEL with a booth at the International Conference on Research Infrastructures (ICRI) in Copenhagen, Denmark, and at the physics festival *Highlights der Physik* in Göttingen, Germany

Figure 1 TV and print journalists on the construction site in Schenefeld

- Cooperated with the PR departments of the Polish and Russian shareholders, resulting in increased media coverage in these countries and in Polish and Russian versions of the European XFEL film and flyers
- Supported scientific events, like the 2012 European XFEL Users' Meeting, the Femtochemistry, Photosynthesis, and Catalysis lecture series, the Science at FELs meeting, and the CORPES13 conference, with news and photo coverage, website presence, posters, merchandising items, and guided tours of the construction sites
- Produced a number of new merchandising items, such as folders, bags, ballpoint pens, bookmarks, and coffee mugs with the European XFEL design

Neighbourhood work

During civil construction of the European XFEL (2009–2015), major emphasis is also being placed on communication with local residents, as the facility is located in a predominantly residential area.

The neighbourhood office is open to local residents at any time. The PR group makes a special point of establishing contact with the residents living near the three sites of the European XFEL and along the tunnel route. The group informs these long-term neighbours about upcoming construction work through specially designed flyers and brochures, as well as through the Internet, phone calls, and even personal visits.

Civil construction work for the 2 km long accelerator tunnel, which runs under a largely residential area, was concluded at the end of 2011. However, local residents near the tunnel route continued to express strong irritation with noise regularly emanating from the tunnel on working days. One of the main tasks of the PR group's neighbourhood work was to instigate an investigation into the sources of the noise (which turned out to be caused primarily by concrete floor slabs wobbling beneath the tunnel transport vehicles) and initiate its elimination (by adding special sound-proofing material beneath the slabs). The PR group communicated every step of the process to the neighbours.

Overall, the PR team had around 180 individual contacts with local residents, mainly in the form of telephone calls, letters, and home visits. ■

TECHNICAL COORDINATION

The complexity of the European XFEL project arises not only from its size, but also from the profusion of interfaces between the different components that are planned and built by many scientific and technical groups worldwide. These groups collaborate within a work package structure that does not follow strict hierarchical principles. In this structure, the Technical Coordination (TC) group acts as the prime systems integrator for the construction of the European XFEL facility.

Mission of the group

The mission of the TC group is to guide the overall integration of deliverables and pre-integrated subsystems into a fully functional X-ray laser facility:

- Ensure technical coherence of deliverables from the individual work packages
- Identify and follow up on common issues between different work packages and help resolve "who does what"
- Provide direct support to the work packages in various fields, where needed
- Resolve conflicts by arbitrating between work packages on the technical level
- Maintain the overall integration and installation schedule

Structure of the group

The TC group recruits its members from European XFEL and Deutsches Elektronen-Synchrotron (DESY), which leads the Accelerator Consortium and is the largest in-kind contributor. The accelerator technical coordinator (ATC) from DESY leads the TC group. The photon systems coordinator (PSC) from European XFEL acts as his deputy. Both are members of the European XFEL project board.

Project integration schedule

The TC group maintains the overall project integration time (PIT) schedule. The work is carried out in close collaboration with the work package leaders and the European XFEL project management. At the end of 2012, the PIT contained over 1000 closely interlinked installation and integration tasks. It provides an up-to-date project schedule with a well-identified critical path. The information required to perform this work is gathered in a number of regular coordination meetings on the section level. Currently, there are four such sections led by a section coordinator from the TC group. For the section covering the photon tunnels and the experiment hall, this coordination meeting was changed from biweekly to weekly in 2012. This change reflects the increased need for communication and coordination as the project picks up pace.

As a direct and positive result of these measures, it became apparent that the originally foreseen timeline of the infrastructure installation activities in the photon tunnels and the experiment hall would lead to difficulties in commissioning the first beamlines. Hence, it

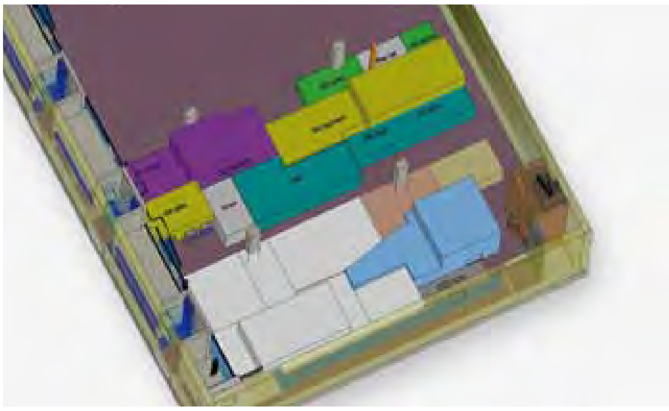


Figure 1 Perspective view of the SASE1 and SASE3 experiment areas in the experiment hall. The view was generated from the CAD integration model of the hall and gives an idea of the current level of planning detail.

was decided to advance the above-ground infrastructure installation on the Schenefeld campus at the expense of similar activities at the SASE2 beamline. This measure leads to a small delay in the readiness of the SASE2 instruments, but it ensures that the first beamlines of the facility will be ready in late 2015.

High-level milestones

In 2012, the TC group took on the task of consolidating the list of milestones for the project. It currently contains 26 entries that cover the period from the first installation activities to the final readiness of the facility for user operation. The milestones are integrated into the PIT schedule so they can be readily and quickly tracked at all times.

Planning the experiment hall

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

A CAD model incorporating the outer boundaries of all hutches in the experiment hall was provided and agreed on at the end of 2012. The model provides the basis for infrastructure planning for the experiment hall as a whole and for the infrastructure needed within the individual hutches on the floor. Figure 1 shows the current level of detail.

Headquarters in Schenefeld

At the end 2012, the planning activities for the laboratory and office building in Schenefeld picked up pace as it became clear that the original design dating back to 2005 fell far short of the updated needs of the facility, mostly in terms of laboratory space. An engineering company was contracted to perform a feasibility study for laboratories and the technical infrastructure in the building, and to provide a cost estimate. The TC group guided this effort and provided the necessary link to the future scientific users. One result of the study was that laboratory floor space has to increase by a factor of three. The outer dimensions of the building are fixed by the plan approval order and by the dimensions of the experiment hall, which provides the foundation. Hence, the increased laboratory requirements can be met only by using parts of the originally foreseen atrium for laboratories, by closing the U-shape of the building to an O-shape, and by a very dense layout of the office space now foreseen on the first and second levels above the laboratories.

Despite these complications, a conceptual design satisfying the new requirements, albeit with increased cost, could be presented to the European XFEL Council. The council authorized the next planning steps, which will eventually lead to a start of construction at the end of 2013, making it possible to move in during the summer of 2015.

Restructuring TC

During 2012, it became apparent that the workload of the TC group was growing and including very different activities, encompassing coordination and project management, supervision of engineering activities, organization of technicians and technical-support workshops, and so on. To focus the activities in a more rational way, it was decided at the end of the year that a new structure would be implemented in 2013. In the new structure, the TC group will concentrate its activities on scheduling and project management for Work Package Group 3, taking the name “Photon Systems Project Office”. Central Instrument Engineering will become a separate group, led by Wolfgang Tscheu and supervised by Serguei Molodtsov. Activities related to technical support and the management of buildings and related infrastructure will be the task of a new Technical Services group, to be created and led by a senior engineer to be recruited, under the supervision of Andreas Schwarz. ■

Group members
Hrvoje Kristic, Lewis Batchelor, Tobias Haas (group leader), Antonios Lalechos, Osama Salem, Carola Schulz, Gerd Wellenreuther, Marco Schrage, Bernd Meier, Sabine Cunis, Wolfgang Tscheu, Konrad Piórecki (since January 2013), Nadja Reimers (not shown), and Niko Saaristo (not shown)

SAFETY AND RADIATION PROTECTION

The Safety and Radiation Protection group strives to ensure a safe and healthy work environment for everyone at European XFEL. The group's mission is to support and advise the management board, the group leaders, staff, and guests in the application of health and safety law and practice. To fulfil its mission, the group works independently and reports directly to the administrative director, who is in charge of safety and security.

In November 2011, the group was founded and Sigrid Kozielski appointed safety engineer. One year later, Sabrina Scherz joined her as a content management assistant. In 2013, the group plans to recruit a radiation protection officer, as this area will play an increasingly important role within European XFEL. The group works closely together with the European XFEL company doctor, Katharina Bünz, who is also the company doctor for Deutsches Elektronen-Synchrotron (DESY).

Safety support

The Safety and Radiation Protection group provides the following support to the company:

- Planning, operating, and maintaining buildings and facilities
- Purchasing technical equipment and introducing working procedures and materials
- Selecting and testing personal protective equipment
- Establishing and documenting guidelines for a safe and ergonomic working environment
- Evaluating working conditions and assessing work safety risks
- Updating safety information on the company intranet and safety information boards
- Organizing safety training for newcomers and guests
- Organizing specialized safety training (for example, for first aid or use of fire extinguishers, lasers, and lifting equipment)
- Preparing safety forms and other documents in English and German

Safety enforcement

The Safety and Radiation Protection group also ensures the implementation of occupational health and safety as well as environmental measures within the company:

- Regularly monitoring workplaces, suggesting corrective measures, and working towards implementing these measures
- Regularly organizing building evacuation exercises
- Verifying that protective equipment is properly used
- Investigating work accidents, recording and evaluating investigations, and suggesting ways to overcome and prevent accidents to the management board
- Maintaining close contact with the accident insurer and occupational health and safety authorities

Safety regulations

Safety regulations are based on national laws and are therefore written in German. Nevertheless, the regulations have to be understood and respected by everyone in the company. Given that the official language at European XFEL is English, the Safety and Radiation Protection group translates national safety regulations from German into English whenever possible. Workplace safety risk assessments and resulting safety instructions are written in English and German.

The group and the company doctor help all staff members and guests to understand the occupational health and safety procedures. Theoretical and practical safety training for various safety hazards and emergency procedures (for example, first aid training, fire extinguisher training, laser safety training) is offered in English and German.

Medical support is provided by our company doctor. Depending on workplace conditions, medical examinations are offered and, in some cases, required by law. One example is working with cranes, for which a regular medical examination is mandatory.

The work safety committee, which is required by German work safety regulations, meets every three months. It is a communication platform where occupational health and safety issues are discussed and analysed, and decisions prepared. Members of the committee are the safety engineer, one delegate from the management board, the company doctor, delegates from the works council and the Human Resources group, the persons responsible for occupational safety in each work area, and the safety representatives. The purpose of the work safety committee is to ensure and facilitate a safe operation of the facility.

In 2012, the Safety and Radiation Protection group drafted a first safety regulation document about the safety organization of the company. The document established responsibilities for work safety in the workplaces of European XFEL on the DESY-Bahrenfeld site. After the move to the Schenefeld campus, the regulation document will be modified accordingly.

Safety training

In September 2012, Sigrid Kozielski became certified as a biological safety officer, according to the German genetic engineering ordinance. She will support and advise the planning of the biological laboratories and instruments on the future Schenefeld campus. For the new laser laboratory, Martin Kellert and Kai Kruse of the Optical Lasers group have been trained as laser safety officers. Both are working closely with the Safety and Radiation Protection group. Given the increasing staff numbers, the group also trained 12 volunteers as new first-aiders. The training sessions were provided in German and English. In 2012, two sessions of practical fire extinguisher training were offered to our staff and guests. This training was provided by the DESY safety group and will be offered regularly.

The Safety and Radiation Protection group also deals with radiation protection matters not related to the operation of the facility, such as the handling of radioactive sources for X-ray detector development. A radiation protection organization has been set up with two qualified radiation protection officers, Sigrid Kozielski and Joachim Schulz, who have been trained and certified by the authorities in 2012. In 2013, a new radiation protection officer will also coordinate safety issues related to our powerful laser installations on the Schenefeld campus.

Safety planning

The Safety and Radiation Protection group intensified the planning of the future safety organization on the Schenefeld campus. The respective roles, responsibilities, and services of DESY and European XFEL were defined in work safety risk assessments of all workplaces on the DESY-Bahrenfeld site. For the future European XFEL facility, the emergency response organization will be set up in collaboration with the DESY technical emergency service and the local fire brigades to ensure a smooth and safe start of operations in 2015–2016.

The DESY Access Control System, DACHS, is used for laboratories and instruments. This access control ensures that staff and guests are adequately trained in safety and emergency procedures before starting to work, especially in the future laboratory areas, workshops, the experiment hall, and at the instruments on the Schenefeld campus. The Safety and Radiation Protection group will implement this access control together with the IT groups at European XFEL and DESY as well as the DACHS team at DESY. So far, the system is working for our workplaces located in the HERA South hall on the DESY-Bahrenfeld site.

To fulfil its mission at the European XFEL, the Safety and Radiation Protection group works in close collaboration with the safety group at DESY. We are also in close contact with the safety groups of other X-ray free-electron laser facilities as well as with EIROforum, a partnership of the eight largest European intergovernmental research organizations. ■

Group members
Sabrina Scherz and Sigrid Kozielski

ADMINISTRATIVE SERVICES

The administration of European XFEL comprises 21 employees. One third of the team members joined the company in 2012. All vacancies were filled.

Providing internal services

The administrative team is an internal service provider. It provides financial, human, and material resources to help the scientific groups advance the European XFEL project.

This support starts with the recruitment of new colleagues, one of the core activities of the Human Resources (HR) group in 2012 (see "Human Resources"). Our employees are supported by further HR services, such as relocation, flextime, and training.

Procuring the goods and services needed for the project is another important task. As a publicly funded company, European XFEL applies public procurement procedures. Even though the Procurement group was understaffed until September, all public calls for tender due in 2012 were successfully finalized before the end of the year. A few milestones were the procurement of undulators and phase shifters, followed by EU-wide calls for tender to procure the long-distance heating for the Schenefeld campus and the planning services for the technical building systems of the new headquarters building.

Small purchases were simplified by making an e-procurement tool accessible to all European XFEL employees. In 2012, we issued 364 orders using the e-procurement tool, worked on 1100 purchase requests (compared to 550 purchase requests in 2011), and made purchases with a total net value of 42 500 000 € (compared to 4 043 000 € in 2011). To make purchases easier, an even more effective e-procurement solution is planned for 2013.

The management of the financial resources of the company includes liquidity management, based on the requirements of the project and the scheduled cash contributions by the different contracting parties funding the project. Liquid funds not immediately needed to pay invoices are invested as time deposits. All financial transactions, like the payment of invoices, salaries, and so on, are processed by the Finance group.

Cost controlling of a complex project like the European XFEL is a challenge in which almost all work packages are involved. This effort is coordinated by the Controlling group. The project has a budget of more than 1.1 billion € (in 2005 values). Given that the construction of the facility means working at the frontier of technology, a high level of uncertainty has to be met through high-level flexibility in project controlling. Adding another layer of complexity is the high number of international partners, many of which contribute a large fraction of their share to the project in kind. The Controlling group issues regular cost reports and forecasts that help management and other groups to proactively oversee the project. In 2012, the risk management system was fundamentally revised to provide an effective early warning system to the management board and the supervisory committees.

The Legal group handles a broad range of tasks, such as drafting contracts with external partners and giving advice on a wide variety of legal questions to all other groups in the company.

Ensuring compliance with legal requirements

European XFEL was set up as a non-profit limited liability company under German law. Consequently, specific German and European legislation has to be obeyed. To run a company entails a range of legal obligations, such as ensuring proper bookkeeping and accounting in accordance with the applicable German accounting standards, delivering an annual financial statement, correctly fulfilling all tax obligations, following the rules of public procurement law, complying with labour and corporate law, and so on. The general legal framework is supplemented by the rules and regulations of the company to ensure appropriate and economical use of funds and proper safeguards for the assets.

In 2012, external auditors issued an unconditional certification for the annual statement 2011. A first income tax audit was passed without any reservations. ■

HUMAN RESOURCES

An advanced scientific facility such as the European XFEL requires a highly professional administrative infrastructure. In 2012, our workforce grew by 37%. We filled key administrative and scientific positions and increased the percentage of women in management positions. We also offered a number of training courses to further improve the competence and skills of our staff. Employees elected a works council, and a telecommuting agreement was negotiated and settled.

Sustained growth

As in previous years, 2012 was characterized by a steady increase in the size of our workforce. This year, the number of employees, students, and guests grew from 119 to 163 (+37%). The net growth by 44 comprises 19 scientists, 16 engineers, 6 technicians, and 3 administrative employees (Figure 1). Including short-term employment of guests and students during the year, 68 newcomers started in 2012.

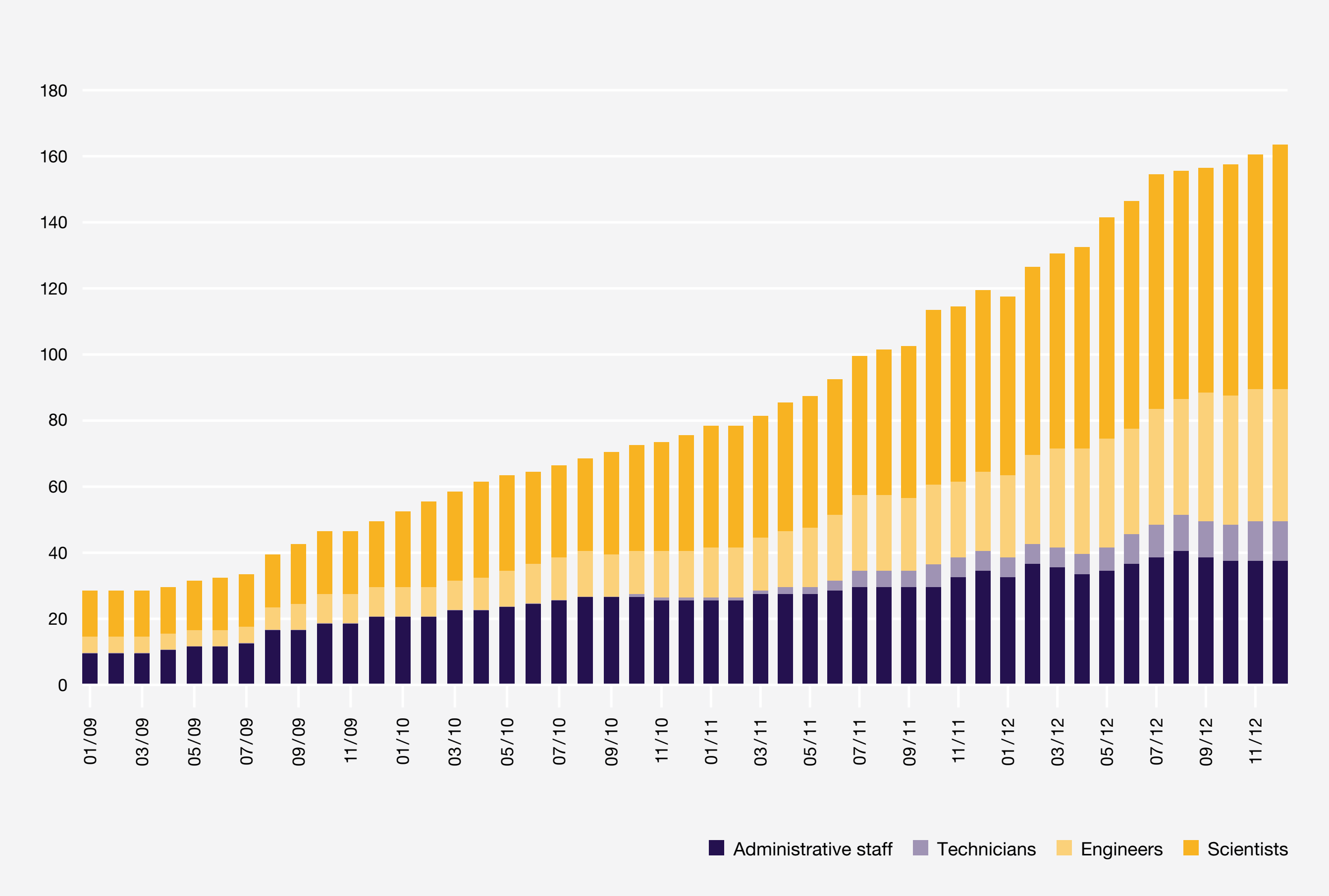
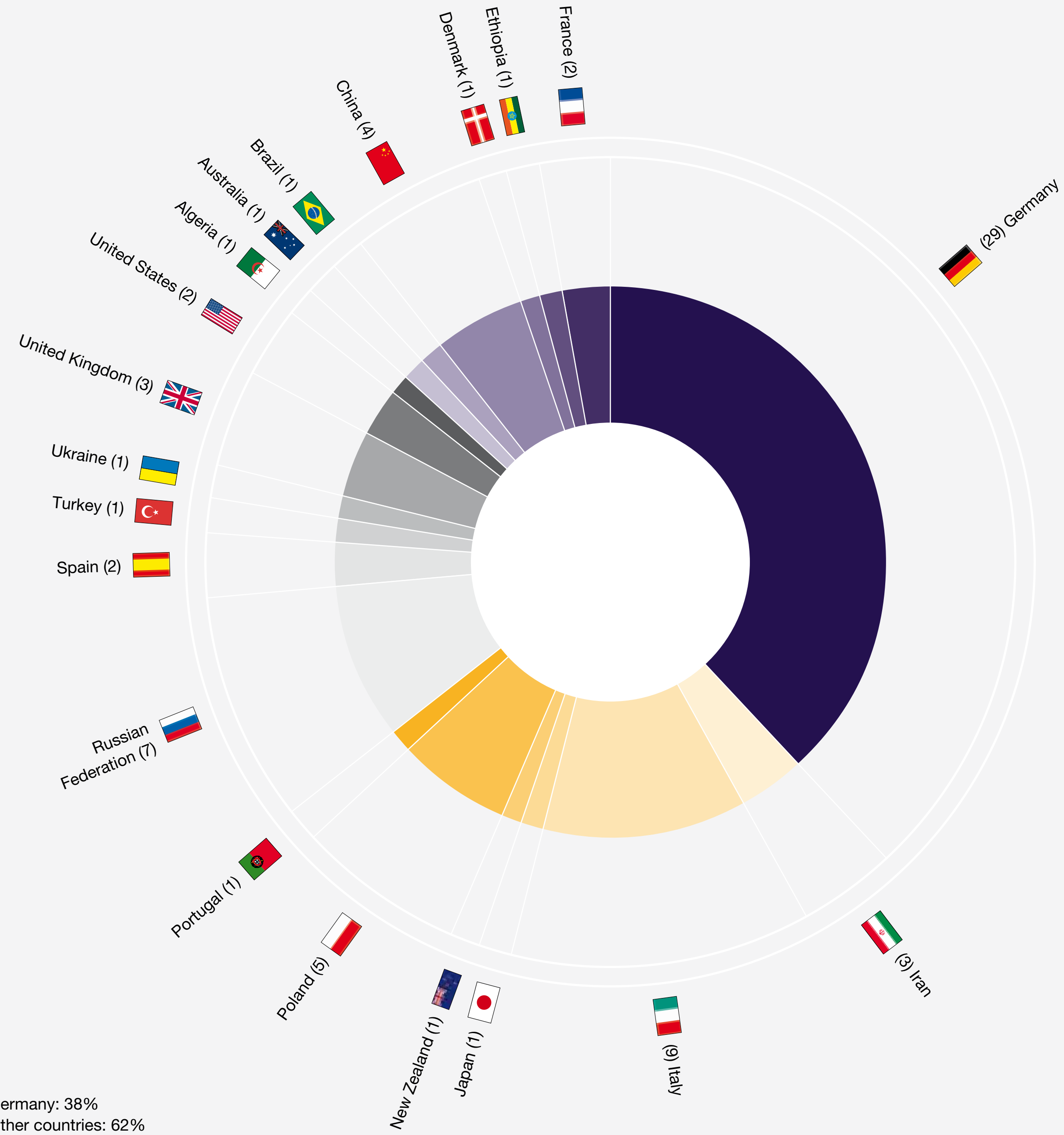


Figure 1 Overall growth in the number of employees, students, and guests (2009–2012)

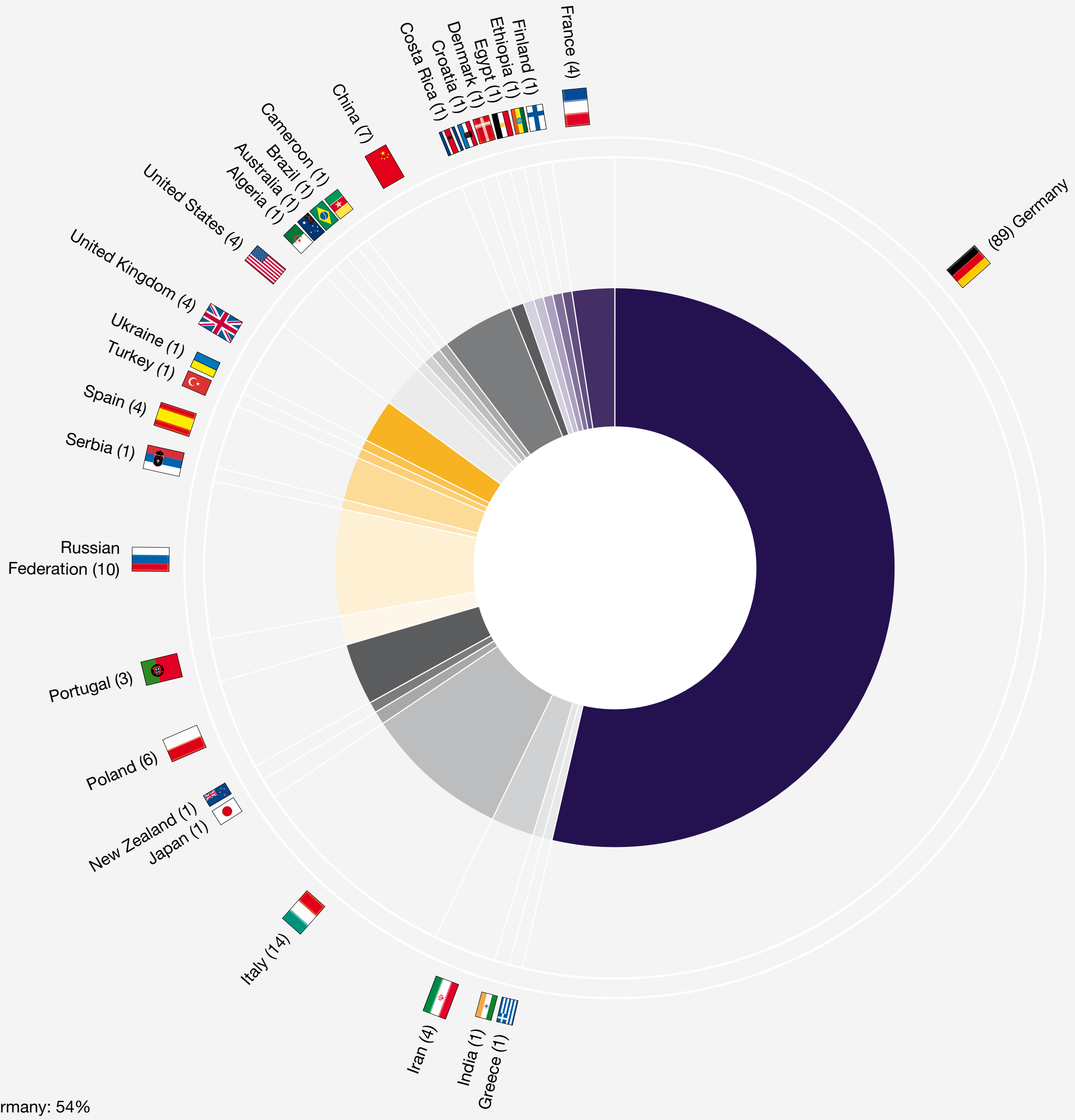
Particularly noteworthy is the increase in the share of employees from outside Germany, which rose from 42% to 46%. As of December 2012, staff members from 28 countries worked at European XFEL.



Germany: 38%
Other countries: 62%
20 nationalities

Figure 2 Nationalities of scientific staff

Recruitment activities remained at the high level of the previous year. The increasing demand for engineers was met by targeting this important group on national and international Internet platforms. In the course of the year, 1235 applications were processed, 355 (29%) from Germany, and 880 (71%) from other countries.



Germany: 54%
Other countries: 46%
28 nationalities

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

The administration was completely staffed in 2012. The recruitment of two key administrative positions—the head of procurement and the head of finance and controlling—proved to be particularly challenging. We also filled two other key positions: the leading scientist for the Spectroscopy and Coherent Scattering (SCS) scientific instrument and the new management board assistant.

Because of the small numbers of female applicants, the total share of female employees (currently 27%) could not be increased. However, with the arrival of our new managing and administrative director, our new head of procurement, and our new head of finance and controlling—all three of whom are women—the percentage of women in management positions is now significantly higher.

Integration

To help the rising number of non-German employees and their families (Figures 2 and 3) feel at home in Germany, appropriate activities have been stepped up. In cooperation with a local relocation partner, comprehensive support is now provided for housing, schooling, and regulatory issues. In addition, we introduced a special programme to help the partners of our new staff members secure employment locally. The majority of these partners have, in fact, found work.

Training and development

The development of leadership competence is decisive for a fast-growing, diversified organization. Building on their success in 2011, all supervisors completed a second series of training sessions in 2012.

We also offered in-house training in technical English for non-native speakers, which has proven to be popular with employees. This training is financed by the company. Next year, we plan to offer in-house German lessons on different levels for our non-German employees and their partners. This training will be funded publicly.

Works council

In spring 2012, employees initiated the election of a works council, based on German labour law. The company now has a body of seven members with comprehensive co-determination rights to information, consultation, and participation. Dialogue partners for the works council are the managing directors and, on the operational level, the Human Resources group leader. A first works agreement for telecommuting—primarily designed to help employees reconcile their professional and family duties—was negotiated and settled at the end of the year. ■

Staff and guests of the European XFEL GmbH (December 2012)

Agapov, Ilya
Altarelli, Massimo
Ament, Kurt
Ansaldi, Gabriele
Aquila, Andrew Lee
Arnold, Mathias
Assefa, Tadesse
Bagha-Shanjani, Majid
Bakhtiarzadeh, Sadegh
Ballak, Kai-Erik
Bari, Sadia
Bartmann, Alexander
Baskaran, Balakumaar
Batchelor, Lewis
Batindek Embok, Camille Olivier
Beckmann, Andreas
Berndgen, Karl-Heinz
Bertini, Silvia
Borchers, Gannon
Boukhelef, Djelloul
Bozhevolnov, Astislav
Bressler, Christian
Buck, Jens
Burger, Claudia
Coppola, Nicola
Cunis, Sabine
Da Costa Pereira, Maria Helena
Dastjani Farahani, Shafagh
De Fanis, Alberto
Deiter, Carsten
Delmas, Elisa
Deron, Georg Christian
Di Felice, Massimiliano
Dickert, Bianca
Disterhof, Anastasia
Dommach, Martin
Dong, Xiaohao
Ebeling, Bernd
Eich, Melanie
Ekmedzic, Marko
Elizondo, Jorge
Englisch, Uwe
Esenov, Sergey
Ferreira Maia, Luís Goncalo
Flammer, Meike
Folkerts, Petra
Freijo Martín, Idoia
Freund, Wolfgang
Fritz, Mareike
Fritz-Nielen, Kitty
Gaida, Manfred
Galler, Andreas
Gawelda, Wojciech
Geloni, Gianluca
Gembalies, Imke
Geßler, Patrick
Giewekemeyer, Klaus
Grünert, Jan
Guhlmann, Florian
Haas, Tobias
Hagitte, Martin C.
Hallmann, Jörg
Harms, Gesa
Hauf, Steffen
Heeßel, Gabriela
Heisen, Burkhard
Ilchen, Markus
Izquierdo, Manuel
Jiang, Guoyang
Kabachnik, Nikolay
Karabekyan, Suren
Kellert, Martin
Knaack, Manfred
Knoll, Martin
Koch, Andreas
Kohlstrunk, Nicole
Korsch, Timo
Kozielski, Sigrid Susanne
Kozlova, Iryna
Kristic, Hrvoje
Krupin, Oleg
Kruse, Kai
Kunz, Marc
Kuster, Markus
La Civita, Daniele
Lalechos, Antonios-Vassilios
Lange, Torsten
Laub, Malte
Le Pimpec, Frédéric
Lederer, Maximilian Josef
Li, Yuhui
Lin, Hongxiang
Madsen, Anders
Mancuso, Adrian
Mazza, Tommaso
Meger-Farshad, Danuta
Meier, Bernd
Mergen, Julia
Meyer, Michael
Molodtsov, Serguei
Mulá Mathews, Gabriella
Nakatsutsumi, Motoaki
Nawrath, Günther
Neumann, Maik
Neumann, Michael
Nillon, Julien
Osterland, Christiane
Özkan, Cigdem
Palmer, Guido
Parenti, Andrea
Pereira Bahia, Liliane
Pergament, Mikhail
Pflüger, Joachim
Planas Carbonell, Marc
Poljancewicz, Bartosz
Poolton, Nigel
Poppe, Frank
Prat, Serge
Raciniewski, Magdalena
Rafipoor, Amir Jones
Reimers, Nadja
Rodrigues Fernandes, Bruno Jesus
Roth, Thomas
Rüscher, Jan Christoph
Rychev, Mikhail
Saaristo, Niko
Salem, Osama Ahmed
Samoylova, Liubov
Sauermann, Wolf-Ulrich
Scherz, Andreas
Scherz, Sabrina
Schrage, Marco
Schulz, Carola
Schulz, Joachim
Schwarz, Andreas S.
Shie, Halimah
Sinn, Harald
Sprenger, Uta
Sztuk-Dambietz, Jolanta
Szuba, Janusz
Tolkiehn, Jan
Trapp, Antje
Tschentscher, Thomas
Tscheu, Wolfgang
Turcato, Monica
Uetrecht, Charlotte
Utermann, Sonia
van Hees, Brunhilde
Vannoni, Maurizio
Villanueva Guerrero, José Wamuyu
Eder, Catherine Ann
Wang, Jinxiong
Weger, Kerstin
Wellenreuther, Gerd
Wolff Fabris, Frederik
Wrona, Krzysztof
Yakopov, Mikhail
Yang, Fan
Yoon, Chunhong
Youngman, Christopher
Zhang, Haiou

Figure 4 117 European XFEL staff members and guests in the HERA-S hall (March 2013)

BUDGET

During 2012, most of our contracting parties increased their financial pledges to ensure a sound financial basis for the European XFEL project. The overall project budget amounts to around 1.15 billion euro (2005 value). Almost half of the project volume is contributed in kind by the various partners (see Chapter 3, “In-Kind Contributions”). The remaining budget, amounting to more than 0.6 billion euro (current value), is contributed in cash to the company by its shareholders and associated partners. The European XFEL Council, which is the shareholder assembly of the company, decides on the annual budget available to the company to cover all project expenses during a given year.

In 2012, the total European XFEL payment budget amounted to 137.0 million euro (M€). The largest activity was machine and technical infrastructure, with an annual payment budget of 93.2 M€ (Figure 1). This activity included civil construction, with 61.4 M€, of which 50.7 M€ was related to underground construction. With 36.6 M€, beamlines and experiments were the second largest activity, the largest fraction (29.5 M€) being spent on capital investment. In general, the overwhelming fraction of 89% of the 2012 payment budget was related to capital investment (Figure 2). This trend will continue in the future, as by far the biggest share of project expenses is related to capital investment, with personnel and recurrent cost being only of subordinate importance.

For 2013, an annual payment budget of 107 M€ was approved. The decrease from 2012 to 2013 is primarily due to the near completion of the costly underground civil construction work in 2012. ■

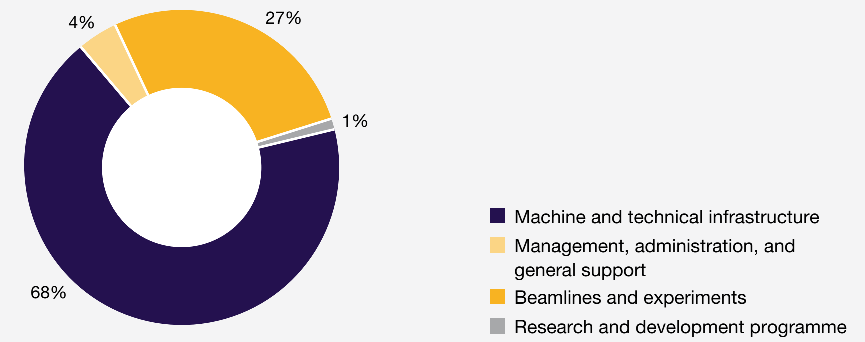


Figure 1 Payments by major activity in 2012

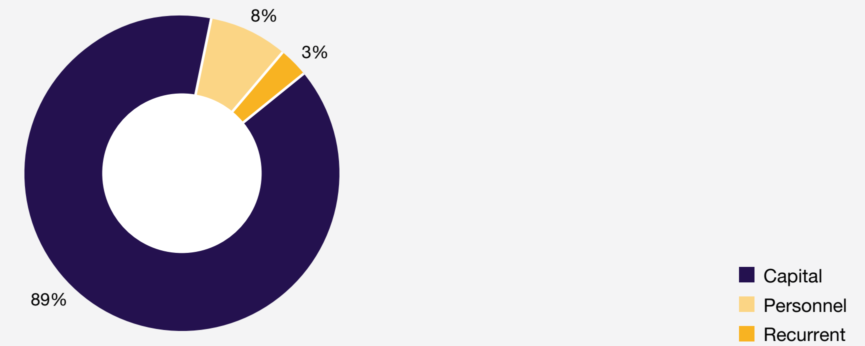


Figure 2 Payments by budget items in 2012

SHAREHOLDERS

The European XFEL is organized as a non-profit company with limited liability (GmbH) under German law that 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 2012)

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

Likely future shareholders of the European XFEL GmbH

France	CEA (Alternative Energies and Atomic Energy Commission), CNRS (National Centre for Scientific Research)
Italy	Republic of Italy, represented by the Ministry of Education, University and Research
Spain	Kingdom of Spain, represented by the Ministry of Economic Affairs and Competitiveness

ORGANS AND COMMITTEES

The Council of the European X-Ray Free-Electron Laser Facility GmbH (European XFEL GmbH) is the supreme organ of the company. It functions as the shareholder assembly and decides on important issues of company policy.

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.

Advisory committees support the European XFEL GmbH in various matters: Administrative and Finance Committee, Machine Advisory Committee, Scientific Advisory Committee, In-Kind Review Committee, Detector Advisory Committee, Laser Advisory Committee, and and Advisory Review Teams for scientific instruments as well as for X-ray optics and beam transport systems.

European XFEL Council	
Chairman	Robert K. Feidenhans'l (University of Copenhagen, Denmark)
Vice chairman	Pavol Sovák (P.J. Šafárik University, Košice, Slovak Republic)
Delegates	
Denmark	Anders Kjær (DASTI, Copenhagen) and Martin Meedom Nielsen (DTU, Roskilde)
Germany	Helmut Dosch (DESY, Hamburg) and Beatrix Vierkorn-Rudolph (BMBF, Bonn)
Hungary	Dénes Lajos Nagy (Wigner Research Centre for Physics, Budapest)
Poland	Grzegorz Wrochna (NCBJ, Otwock)
Russia	Mikhail Kovalchuk (NRC KI, Moscow) and Andrey Svinarenko (RUSNANO, Moscow)
Slovak Republic	Karel Saksl (Institute of Materials Research, SAS, Košice)
Sweden	Lars Börjesson (Swedish Research Council, Stockholm)
Switzerland	Bruno Moor (State Secretariat for Education and Research, Bern)
Secretary	
	Malte Laub (European XFEL, Hamburg)

European XFEL GmbH Management Board

Chairman	Massimo Altarelli
Administrative Director	Claudia Burger
Scientific Director	Serguei Molodtsov
Scientific Director	Andreas S. Schwarz
Scientific Director	Thomas Tschentscher

Administrative and Finance Committee (AFC)

Chairman	Leif Eriksson (Swedish Research Council, Stockholm, Sweden)
Delegates	
Denmark	Anders Kjær (DASTI, Copenhagen)
Germany	Rafael Paplocki (BMBF, Bonn) and Christian Scherf (DESY, Hamburg)
Hungary	Barbara Vizkelety (NIH, Budapest)
Poland	Zbigniew Golebiewski (NCBJ, Otwock)
Russia	Alexey Raykevich (RUSNANO, Moscow) and Valeriy Nosik (NRC KI, Moscow)
Slovak Republic	Pavol Sovák (P.J. Šafárik University, Košice)
Sweden	Johan Holmberg (Swedish Research Council, Stockholm) and Elin Swedenborg (Swedish Research Council, Stockholm)
Switzerland	Peter Allenspach (PSI, Villigen)
Secretary	
	Meike Flammer (European XFEL, Hamburg)

Machine Advisory Committee (MAC)	
Chairman	Mikael Eriksson (MAX-lab, Lund, Sweden)
Members	
	Hans-Heinrich Braun (PSI, Villigen, Switzerland)
	Paul Emma (Berkeley Lab, Berkeley, California)
	Massimo Ferrario (INFN, Frascati, Italy)
	Jacek Krzywinski (SLAC, Menlo Park, California)
	Gennady Kulipanov (BINP, Novosibirsk, Russia)
	John Mammosser (Jefferson Lab, Newport News, Virginia)
	Andreas Jankowiak (HZB, Berlin, Germany)
	Félix Rodriguez Mateos (CERN, Geneva, Switzerland; ITER, St. Paul-lez-Durance, France)
	Richard Walker (DIAMOND, Oxfordshire, United Kingdom)
Secretary	
	Gianluca Geloni (European XFEL, Hamburg, Germany)

Scientific Advisory Committee (SAC)

Chairman	Gyula Faigel (Wigner Research Centre for Physics – Hungarian Academy of Sciences, Budapest, Hungary)
Vice chairman	Salvador Ferrer (CELLS–ALBA, Cerdanyola del Vallès, Spain)
Members	
	Rafael Abela (PSI, Villigen, Switzerland)
	Patrick Audebert (École Polytechnique, Palaiseau, France)
	Dimitrios Charalambidis (Foundation for Research and Technology-Hellas, Institute of Electronic Structure and Laser, Greece)
	Jerome Hastings (SLAC, Menlo Park, California)
	Krystyna Jablonska (Institute of Physics, Polish Academy of Sciences, Warsaw, Poland)
	Sine Larsen (University of Copenhagen, Denmark)
	Joseph Nordgren (University of Uppsala, Sweden)
	Vladislav Ya. Panchenko (Institute on Laser and Information Technologies, Russian Academy of Sciences, Shatura, Russia)
	Franz Pfeiffer (TU Munich, Germany)
	Aymeric Robert (LCLS SLAC, Menlo Park, California)
	Karel Saksl (Institute of Materials Research, Slovak Academy of Sciences, Košice, Slovak Republic)
	Francesco Sette (ESRF, Grenoble, France)
	Edgar Weckert (DESY, Hamburg, Germany)
Secretary	
	Gianluca Geloni (European XFEL, Hamburg, Germany)

Laser Advisory Committee (LAC)	
Chairman	Uwe Morgner (Laserzentrum Hannover, Germany)
Members	
	Giulio Cerullo (Politecnico Milano, Italy)
	Patrick Georges (Institut d'Optique, Paris, France)
	Alfred Leitensdorfer (University Konstanz, Germany)
	Robert Schoenlein (LBNL, Berkeley, California)
	William E. White (SLAC, Menlo Park, California)

In-Kind Review Committee (IKRC)	
Chairman, Russia	Leonid Kravchuk (Institute for Nuclear Research of the Russian Academy of Sciences, Moscow)
Vice chairman, Switzerland	Volker Schlott (PSI, Villigen)
Members	
Denmark	Søren Schmidt (Technical University of Denmark, DTU)
France	Alex Mueller (CNRS, Paris)
Germany	Reinhard Brinkmann (DESY, Hamburg)
Hungary	Gyula Faigel (Research Institute for Solid State Physics and Optics, Budapest)
Italy	Carlo Pagani (INFN Sezione di Milano, Laboratorio LASA, Milano)
Poland	Krzysztof Meissner (NCBJ, Otwock)
Slovak Republic	Štefan Molokáč (CRYOSOFT LTD, Košice)
Spain	Teresa Martínez De Álvaro (CIEMAT, Madrid)
Sweden	Håkan Danared (ESS, Lund)
European XFEL GmbH	Andreas S. Schwarz (for the accelerator) and Thomas Tschentscher (for the beamlines)
Secretary and Lawyer	
	Serge Prat (European XFEL, Hamburg, Germany)
	Malte Laub (European XFEL, Hamburg, Germany)

Detector Advisory Committee (DAC)	
Chairman	Karl Tasso Knöpfle (MPI for Nuclear Physics, Heidelberg, Germany)
Members	
	Michael Campbell (CERN, Geneva, Switzerland)
	Pablo Fajardo (ESRF, Grenoble, France)
	Sol M. Gruner (Cornell University, Ithaca, New York)
	Christopher J. Kenney (SLAC, Menlo Park, California)
	Jörg Klora (CELLS–ALBA, Cerdanyola del Vallès, Spain)
	Tim Nicholls (RAL, Oxfordshire, UK)
	Paul O'Connor (BNL, Upton, New York)
	Amedeo Perazzo, (SLAC, Menlo Park, California)
	Peter Siddons (NSLS BNL, Upton, New York)

Advisory Review Team (ART)—Scientific Instrument FXE	
Chairman	Martin Meedom Nielsen (DTU, Roskilde, Denmark)
Members	
Reporter to SAC	Rafael Abela (PSI, Villigen, Switzerland)
	Pieter Glatzel (ESRF, Grenoble, France)
	Steven L. Johnson (ETH Zürich, Switzerland)
	Alke Meents (DESY, Hamburg, Germany)
	Simone Techert (MPI for Biophysical Chemistry, Göttingen, Germany)

Advisory Review Team (ART)—Scientific Instrument MID

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

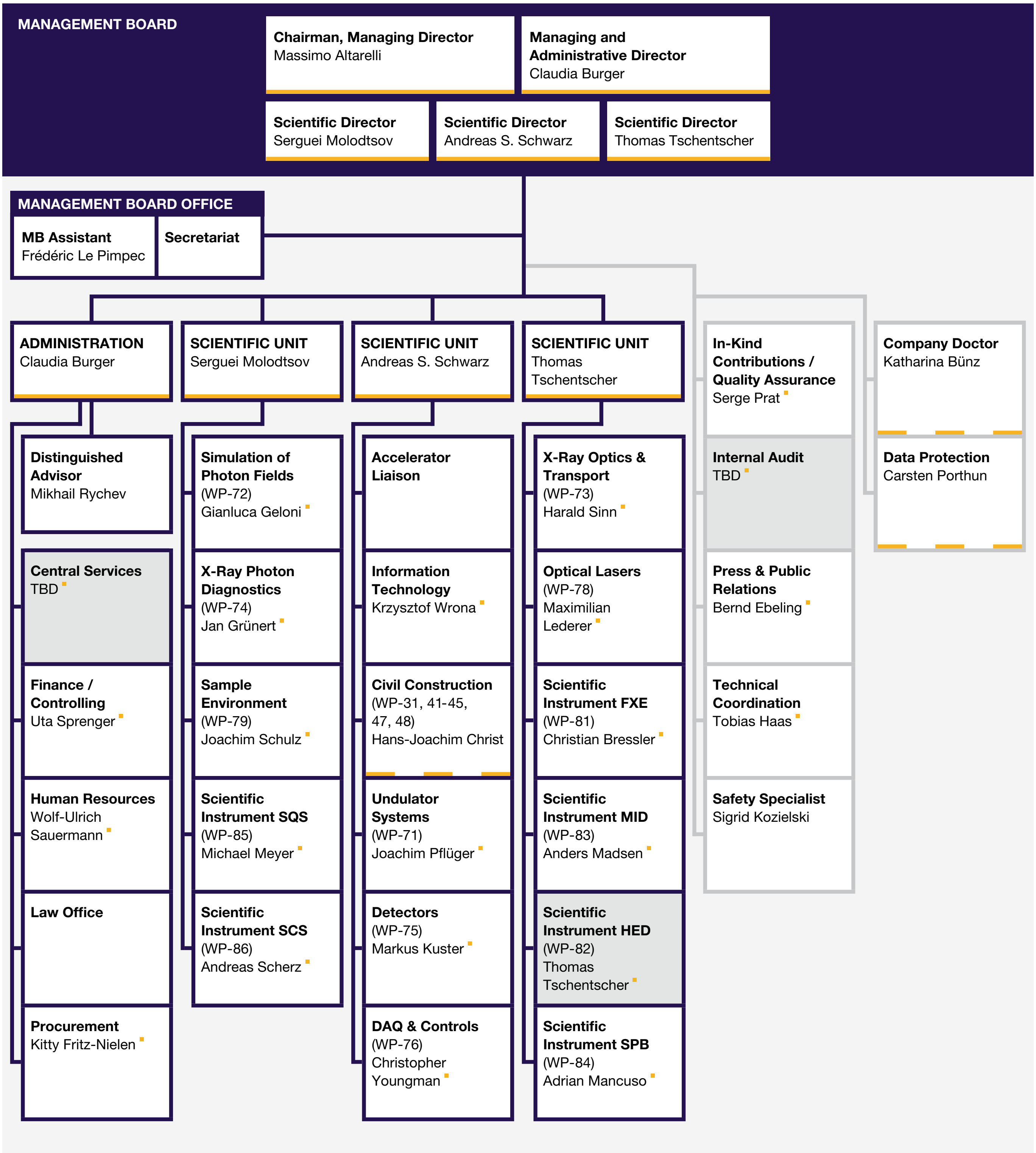
Advisory Review Team (ART)—Scientific Instrument SPB

Chairman	Franz Pfeiffer (TU Munich, Germany)
Members	
	Anton Barty (CFEL and DESY, Hamburg, Germany)
	Sebastien Boutet (LCLS SLAC, Menlo Park, California)
	Daniel DePonte (CFEL and DESY, Hamburg, Germany)
	Victor Lamzin (EMBL, Hamburg, Germany)
	Ilme Schlichting (MPI for Medical Research, Heidelberg, Germany)
	Garth Williams (LCLS SLAC, Menlo Park, California)

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

Advisory Review Team (ART)—X-Ray Optics and Beam Transport	
Chairman	Christian Schroer (TU Dresden, Germany)
Members	
	John Arthur (SLAC, Menlo Park, California)
	Ray Barrett (ESRF, Grenoble, France)
	Rolf Follath (HZB, Berlin, Germany)
	Aymeric Robert (LCLS SLAC, Menlo Park, California)
	Horst Schulte-Schrepping (DESY, Hamburg, Germany)
	Edgar Weckert (DESY, Hamburg, Germany)
	Timm Weitkamp (Synchrotron SOLEIL, Saint Aubin, France)

ORGANIZATION CHART



MANAGEMENT BOARD

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

MANAGEMENT BOARD OFFICE

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

ADMINISTRATION
Claudia Burger

- **Distinguished Advisor** Mikhail Rychev
- **Central Services** TBD ▪
- **Finance / Controlling** Uta Sprenger ▪
- **Human Resources** Wolf-Ulrich Sauermann ▪
- **Law Office**
- **Procurement** Kitty Fritz-Nielen ▪

SCIENTIFIC UNIT
Serguei Molodtsov

- **Simulation of Photon Fields** (WP-72) Gianluca Geloni ▪
- **X-Ray Photon Diagnostics** (WP-74) Jan Grünert ▪
- **Sample Environment** (WP-79) Joachim Schulz ▪
- **Scientific Instrument SQS** (WP-85) Michael Meyer ▪
- **Scientific Instrument SCS** (WP-86) Andreas Scherz ▪

SCIENTIFIC UNIT
Andreas S. Schwarz

- **Accelerator Liaison**
- **Information Technology** Krzysztof Wrona ▪
- **Civil Construction** (WP-31, 41-45, 47, 48) Hans-Joachim Christ
- **Undulator Systems** (WP-71) Joachim Pflüger ▪
- **Detectors** (WP-75) Markus Kuster ▪
- **DAQ & Controls** (WP-76) Christopher Youngman ▪

SCIENTIFIC UNIT
Thomas Tschentscher

- **X-Ray Optics & Transport** (WP-73) Harald Sinn ▪
- **Optical Lasers** (WP-78) Maximilian Lederer ▪
- **Scientific Instrument FXE** (WP-81) Christian Bressler ▪
- **Scientific Instrument MID** (WP-83) Anders Madsen ▪
- **Scientific Instrument HED** (WP-82) Thomas Tschentscher ▪
- **Scientific Instrument SPB** (WP-84) Adrian Mancuso ▪

- **In-Kind Contributions / Quality Assurance** Serge Prat ▪
- **Internal Audit** TBD ▪
- **Press & Public Relations** Bernd Ebeling ▪
- **Technical Coordination** Tobias Haas ▪
- **Safety Specialist** Sigrid Kozielski

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

Director

External staff

▪ Group leader/Supervisor

Vacant position

European X-Ray Free-Electron Laser Facility GmbH (December 2012)

08

SCIENTIFIC RECORD

In 2012, scientific activities at European XFEL gained further momentum. Participation in the Users' Meeting reached a new record, various workshops and seminars were held, a new lecture series was introduced, and a number of articles and reports were published.

Poster session at the 6th European XFEL Users' Meeting

EUROPEAN XFEL USERS' MEETING

25–27 January 2012
Deutsches Elektronen-Synchrotron (DESY), Hamburg, Germany

The joint European XFEL and DESY HASYLAB (now DESY Photon Science) Users' Meeting is an annual opportunity to strengthen the interaction between European XFEL and the scientific user community. At the sixth meeting, the number of participants more than doubled from 320 in 2011 to about 680 in 2012, beating the previous year's record by an impressive margin. The programme included talks, a number of workshops, satellite meetings and group meetings on the second day, and a poster session with almost 300 posters on the third. Participants welcomed the opportunity to exchange and update their knowledge about the European XFEL project and the related photon science.

The Users' Meeting focused on the following topics:

- Progress and current status of the European XFEL
- Results of the 2011 conceptual design reviews
- Selected science applications
- Current developments in the field of X-ray free-electron laser facilities
- Job opportunities at European XFEL

Figure 1 Participants of the 6th European XFEL Users' Meeting (January 2012)

SCIENCE AT FELS 2012 (SRI SATELLITE MEETING)

15–18 July 2012
Deutsches Elektronen-Synchrotron (DESY), Hamburg, Germany

The Science at FELs meeting presented scientific highlights achieved in the first seven years of operation of short-wavelength free-electron lasers (FELs), featuring applications from quantum optics to life sciences and systems from atoms to complex solids. Important topics were new directions in science at FELs and challenges to scientific instrumentation. More than 200 scientists participated in this first major international conference dedicated exclusively to science with X-ray FELs. The conference was jointly organized by European XFEL and DESY as a satellite meeting to the 11th International Conference on Synchrotron Radiation Instrumentation in Lyon, France.

WORKSHOPS

19–20 July 2012
Science with seeded FEL beams
Deutsches Elektronen-Synchrotron (DESY), Hamburg, Germany

European XFEL is investigating the possibilities of implementing a seeding scheme at the forthcoming facility. First tests of self-seeding carried out at the Linac Coherent Light Source (LCLS) at SLAC National Accelerator Laboratory in Menlo Park, California, were very encouraging. The aim of the workshop was to discuss new and emerging scientific applications of seeded soft and hard X-ray FEL radiation.

10–11 December 2012
Materials Imaging and Dynamics with Hard X-Ray Laser Light
European XFEL, Hamburg, Germany

In December 2012, the Materials Imaging and Dynamics (MID) instrument was in the design phase, and the aim of the workshop was to inform the future user community about the status, the latest updates and new scientific possibilities that had emerged. The programme also included news about the performance of the European XFEL linear accelerator, undulators, and self-seeding, as well as reports on experiments from other hard X-ray laser sources and information about the latest detector developments. ■

Figure 2 Discussion during the coffee break at the 6th European XFEL Users' Meeting

SEMINARS

2 February 2012
New optical parametric amplifiers for isolated attosecond pulse generation at ultrahigh repetition rate
Julien Nillon, Centre Lasers Intenses et Applications (CELIA), Université Bordeaux, France

3 February 2012
Partial coherence in diffractive X-ray imaging: past experience as prologue for biomolecular structure determination using XFEL sources
Harry M. Quiney, ARC Centre of Excellence for Coherent X-ray Science and Theoretical Condensed Matter Physics Group, School of Physics, University of Melbourne, Australia

1 March 2012
Science at the LCLS—A first summary
Uwe Bergmann, SLAC National Accelerator Laboratory, Menlo Park, California

22 March 2012
3D Bragg X-ray ptychography: a new microscopy for strain imaging
Virginie Chamard, Institut Fresnel, Centre National de la Recherche Scientifique (CNRS), Aix-Marseille Université, Faculté des Sciences et Techniques Saint Jérôme, Marseille, France

20 April 2012
Simulation of chirped pulse optical parametric amplifiers
Gunnar Arisholm, Forsvarets Forskningsinstitutt, Norwegian Defence Research Establishment, Kjeller, Norway

25 April 2012
Structural study of metallic glasses using X-rays
Stefan Michalik, Institute of Physics, P.J. Šafárik University in Košice, Slovakia

26 April 2012
Combined hydrodynamics and atomic configuration-average description of XFEL interaction with matter
Olivier Peyrusse, CELIA, Université Bordeaux, France

26 April 2012
From superconductors to solar energy conversion—Characterizing and controlling electronic properties and dynamics
Wolfgang Eberhardt, Center for Free-Electron Laser Science (CFEL) at DESY and TU Berlin, Germany

1 June 2012
Creation and probing of high energy density matter using high-power laser-based sources
Motoaki Nakatsutsumi, LULI, Ecole Polytechnique, Palaiseau, France

8 June 2012
Data challenges in XFEL coherent imaging
Filipe Maia, Lawrence Berkeley National Laboratory, USA

15 August 2012
How to study low Z elements' absorption edges at extreme conditions
Christian Sternemann, TU Dortmund, Germany

7 December 2012
HERMES—High Energy density Revolution of Matter in Extreme States
Ryosuke Kodama, Institute for Laser Engineering, Osaka University, Japan

LECTURE SERIES

Figure 1 Announcement for the lecture series "Femtochemistry, Photsynthesis, and Catalysts"

Femtochemistry, Photosynthesis, and Catalysis

This series covered contemporary problems in chemical physics, with a particular emphasis on catalytic and light-conversion schemes. Both theoretical and experimental aspects were treated, making use of the entire range of contemporary techniques.
The series, which addressed graduate students, including the participants of the different graduate schools for excellence, as well as faculty and staff members of the various Hamburg institutes, was organized by the Femtosecond X-Ray Experiments (FXE) instrument group in the winter semester from October 2012 to February 2013.

18 October 2012
Iron(II) spin-crossover systems: Intersystem-crossing and cooperative effects
Andreas Hauser, Département de Chimie Physique, Université de Genève, Switzerland

1 November 2012
Ultrafast exciton dynamics in organic materials and aggregates
Stefan Lochbrunner, Institut für Physik, Universität Rostock, Germany

8 November 2012
Structure–performance relation in heterogeneous catalysts:
Time scales in catalytic processes
Jeroen van Bokhoven, Institute for Chemical and Bioengineering,
Eidgenössische Technische Hochschule (ETH) Zürich, Switzerland

15 November 2012
Dynamics of photoinduced electron transfer at the surface of dye-sensitized nanocrystalline titanium dioxide
Jacques Moser, Institute of Chemical Sciences and Engineering, Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland

29 November 2012
Nonadiabatic dynamics of complex molecular systems in external laser fields
Ivano Tavernelli, Institute for Chemical and Bioengineering, EPFL, Switzerland

6 December 2012
Controlling coupled electron transfers in artificial photosynthesis
Leif Hammarström, Department of Photochemistry and Molecular Science,
Uppsala Universitet, Sweden

20 December 2012
The photocycle of light-induced spin crossover: A quantum chemical perspective
Coen de Graaf, Department of Physical and Inorganic Chemistry, Universitat Rovira i Virgili, Spain ■

PUBLICATIONS

JOURNALS

Ad-hoc design of temporally shaped fs laser pulses based on plasma dynamics for deep ablation in fused silica
J. Hernandez-Rueda, J. Siegel, D. Puerto, M. Galvan-Sosa, W. Gawelda, J. Solis
Appl. Phys. A (2012)
doi:10.1007/s00339-012-7238-2

Amorphous to crystalline phase transition in carbon induced by intense femtosecond x-ray free-electron laser pulses
J. Gaudin, O. Peyrusse, J. Chalupský, M. Toufarová, L. Vysín, V. Hájková, R. Sobierajski, T. Burian, Sh. Dastjani-Farahani, A. Graf, M. Amati, L. Gregoratti, S.P. Hau-Riege, G. Hoffmann, L. Juha, J. Krzywinski, R.A. London, S. Moeller, H. Sinn, S. Schorb, M. Störmer, Th. Tschentscher, V. Vorlícek, H. Vu, J. Bozek, C. Bostedt
Phys. Rev. B **86** (2012) 2, 024103
doi:10.1103/PhysRevB.86.024103

Angle-Resolved Electron Spectroscopy of Laser-Assisted Auger Decay Induced by a Few-Femtosecond X-Ray Pulse
M. Meyer, P. Radcliffe, T. Tschentscher, J.T. Costello, A.L. Cavalieri, I. Grguras, A.R. Maier, R. Kienberger, J. Bozek, C. Bostedt, S. Schorb, R. Coffee, M. Messerschmidt, C. Roedig, E. Sistrunk, L.F. Di Mauro, G. Doumy, K. Ueda, S. Wada, S. Düsterer, A.K. Kazansky, N.M. Kabachnik
Phys. Rev. Lett. **108** (2012) 6, 063007
doi:10.1103/PhysRevLett.108.063007

CrystFEL: a software suite for snapshot serial crystallography
T.A. White, R.A. Kirian, A.V. Martin, A. Aquila, K. Nass, A. Barty, H.N. Chapman
J. Appl. Cryst. **45** (2012), 335–341
doi:10.1107/S0021889812002312

Dichroism in the above-threshold two-colour photoionization of singly charged neon
V. Richardson, W.B. Li, T.J. Kelly, J.T. Costello, L.A.A. Nikolopoulos, S. Düsterer, D. Cubaynes, M. Meyer
J. Phys. B **45** (2012) 8, 085601
doi:10.1088/0953-4075/45/8/085601

Dynamics of colloidal crystals studied by pump-probe experiments at FLASH
R. Dronyak, J. Gulden, O.M. Yefanov, A. Singer, T. Gorniak, T. Senkbeil, J.-M. Meijer, A. Al-Shemmary, J. Hallmann, D.D. Mai, T. Reusch, D. Dzhigaev, R.P. Kurta, U. Lorenz, A.V. Petukhov, S. Düsterer, R. Treusch, M.N. Strikhanov, E. Weckert, A.P. Mancuso, T. Salditt, A. Rosenhahn, I.A. Vartanyants
Phys. Rev. B **86** (2012), 064303
doi:10.1103/PhysRevB.86.064303

Effects of autoionising states on the single and double ionisation yields of neon with soft X-ray fields
D.P.W. Middleton, L.A.A. Nikolopoulos
J. Mod. Opt. **59** (2012), 1650–1663
doi:10.1080/09500340.2012.737481

Exploring the wavefront of hard X-ray free-electron laser radiation
S. Rutishauser, L. Samoylova, J. Krzywinski, O. Bunk, J. Grünert, H. Sinn, M. Cammarata, D.M. Fritz, Ch. David
Nat. Comm. **3** (2012), 947
doi:10.1038/ncomms1950

Femtosecond Single-Shot Imaging of Nanoscale Ferromagnetic Order in Co/Pd Multilayers Using Resonant X-ray Holography
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