European XFEL

ANNUAL REPORT

European X-Ray Free-Electron Laser Facility GmbH

2010

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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2010

ANNUAL REPORT

European X-Ray Free-Electron Laser Facility GmbH

The European X-Ray Free-Electron Laser Facility GmbH is a limited liability company under German law that was officially founded in Hamburg, Germany, on 28 September 2009. The company is in charge of the construction and operation of what will be the world's brightest source of ultrashort X-ray pulses: the European XFEL, a 3.4 km long X-ray free-electron laser facility extending from Hamburg to the neighbouring town of Schenefeld in the German federal state of Schleswig-Holstein. The new research facility is due to begin user operation in 2015.

The European XFEL is a truly international endeavour. Representatives of the governments of Denmark, Germany, Greece, Hungary, Italy, Poland, Russia, Slovakia, Sweden, and Switzerland signed the intergovernmental convention governing the construction and operation of the new facility in Hamburg on 30 November 2009. France signed in February 2010. Spain is expected to sign in 2011. Construction activities on the three building sites of the facility—DESY-Bahrenfeld, Osdorfer Born, and Schenefeld—started in January 2009, even before the founding of the company, thanks to the support of the German government and Deutsches Elektronen-Synchrotron (DESY).

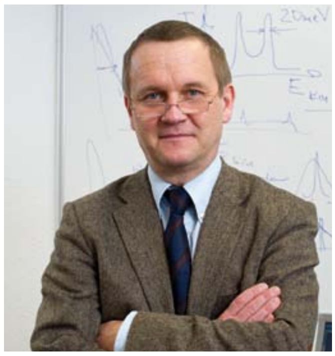
With the foundation of the company and the signing of the intergovernmental convention in late 2009, the legal basis for the construction and operation of the new research facility was completed, and the European XFEL GmbH started to function as an independent institution. This was accomplished through a rather long political process, dating back to at least 2003, when the German government stated its intention to build an X-ray laser facility in Hamburg and Schleswig-Holstein, and invited the other European countries to participate by providing about 50% of the necessary resources for construction.

This annual report covers the first year of activity at the European XFEL, from the creation of the company in September 2009 to the end of its first full year of activity in December 2010.

This early startup period witnessed many milestone events:

- Start of tunneling activities and the completion of the first kilometre of tunnels
- Initial growth to 75 employees, including some of the key scientific appointments
- Installation of the European XFEL Council and its advisory committees
- Launch of some very important long-lead orders for accelerator components, undulators, and detector development
- Start of tendering for the above-ground buildings
- Signature of the first in-kind contribution agreements

The support of the scientific community for our endeavour is evident in the large number of scientists from all over the world who attended our annual Users' Meetings—the fourth meeting in January 2010 attracted more than 280 scientists from 20 countries—as well as our topical workshops on instruments and technical

issues. The scientific enthusiasm for the European XFEL remains high, despite the consequences of the worldwide economic recession and the resulting financial situation felt by all participating countries. At the end of 2010, a special working group, appointed by the European XFEL Council to formulate proposals to resolve the funding shortage of the project, stated once more the commitment of the partner countries to support the construction of a cutting-edge, world-class facility.

This most recent expression of strong support for the project is not the exception but the rule. We thank all those who have supported the project for many years and have helped to overcome the sometimes formidable obstacles with hard work, a constructive attitude, and an unwavering belief that worthy scientific causes prevail in the end.

We hope that the reading of this first annual report, which describes how we laid the cornerstones of success for this ambitious project, will be pleasant and informative.

Massimo Altarelli
Managing Director

Serguei Molodtsov
Scientific Director

Karl Witte
Managing Director

Andreas S. Schwarz
Scientific Director

Thomas Tschentscher
Scientific Director

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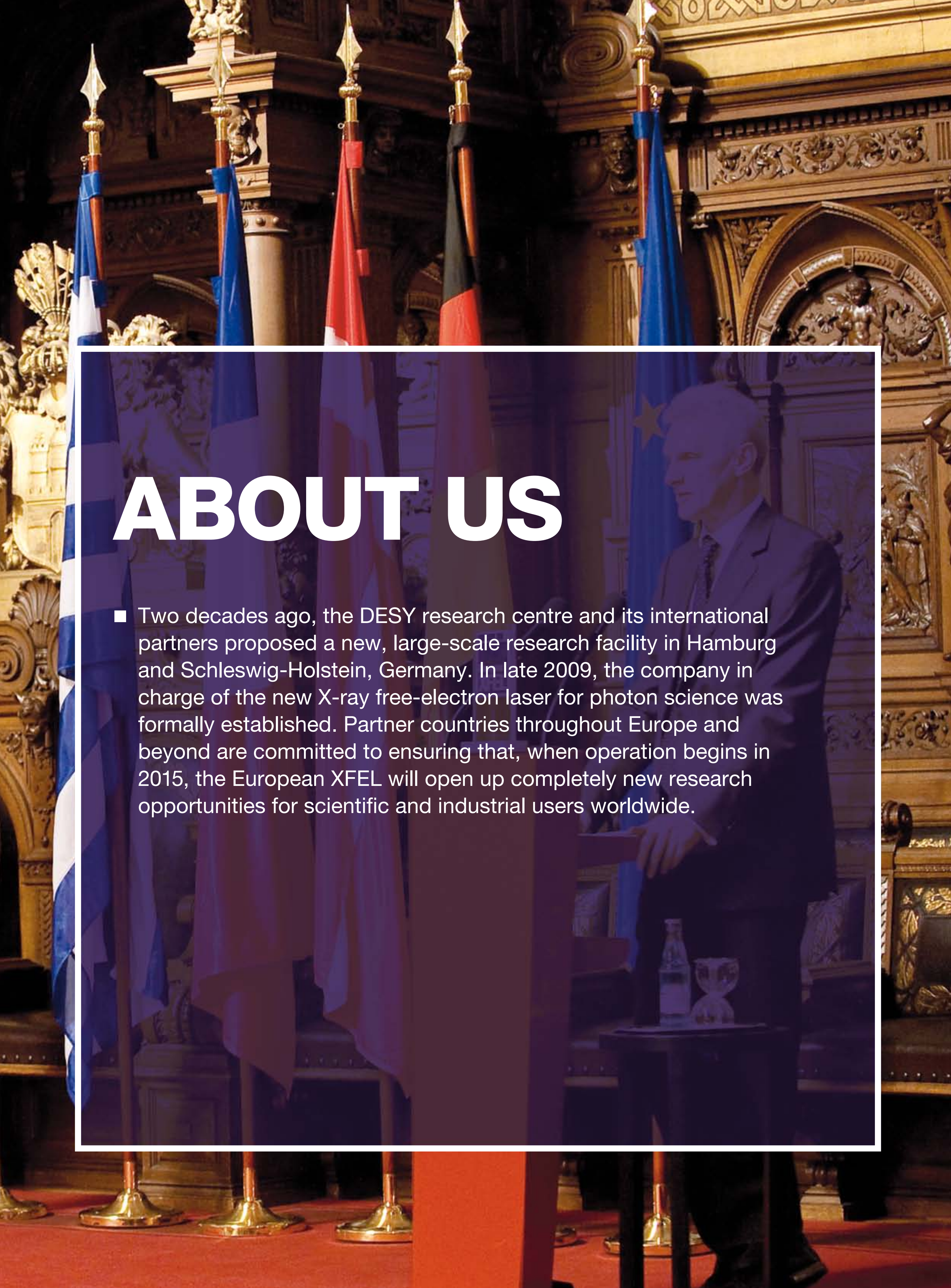


ABOUT US

■ Two decades ago, the DESY research centre and its international partners proposed a new, large-scale research facility in Hamburg and Schleswig-Holstein, Germany. In late 2009, the company in charge of the new X-ray free-electron laser for photon science was formally established. Partner countries throughout Europe and beyond are committed to ensuring that, when operation begins in 2015, the European XFEL will open up completely new research opportunities for scientific and industrial users worldwide.

HOW IT ALL BEGAN

In the 1990s, the Deutsches Elektronen-Synchrotron (DESY) and its international partners developed a proposal for a new research institution in Hamburg and Schleswig-Holstein: 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 got the go-ahead from the German Ministry of Education and Research (BMBF) in early 2003, on the condition that it be realized as a European project. The new research institution was formally established in late 2009 with 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 facility.

Figure 1 On 29 September 2004, Schleswig-Holstein's Minister President Heide Simonis (right) and Hamburg's Mayor Ole von Beust signed a state treaty that provided the legal basis for the construction and operation of the X-ray laser.

Finding a new location

Establishing a new, large-scale research institution requires long-term planning and development, not only in scientific and technological fields, but in the political and administrative realm as well. When the German research ministry approved the X-ray FEL, but deferred a decision on the linear collider—a de facto separation of the two projects—it became clear that both facilities could not be realized on the same time scale. According to the original plan, which aimed to maximize synergy between the two projects, the X-ray laser was to be located around 20 km from the DESY site, in the neighbouring German federal state of Schleswig-Holstein. With the two projects now effectively separated, a new site near DESY was found in late 2003. This nearby location enabled the new institution to make use of existing DESY infrastructure, thereby increasing the already intense synergy between brilliant minds in Hamburg and Schleswig-Holstein (Figure 1). It also required no new plots of land to be bought for the supply buildings.

Preparing the research institution

The decision by the German research ministry to cover around half of the investment costs for the X-ray FEL, provided that the rest be borne by European partner countries, gave the starting signal for intense negotiations on funding and participation in the project at the national and international level. Most of these negotiations, which depended strongly on the internal political climate of the various countries, were concluded by the time the new research institution was founded. Others continue to the present day. As a result of this complex long-term process, the number of participating countries continues to change.

Figure 2 On 27 April 2005, DESY directors Jochen Schneider (centre) and Albrecht Wagner (right) handed 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 authority for mining, energy, and geology in Clausthal-Zellerfeld.

A first important milestone in the preparations was reached in January 2005, when 9 out of the then 14 interested countries—France, Germany, Greece, Italy, Poland, Spain, Sweden, Switzerland, and the UK—signed a Memorandum of Understanding (MoU) in which they agreed to jointly prepare the ground for a governmental agreement on the construction and operation of the facility by mid-2006. These preparations included working out proposals for time schedules and financing schemes, the future organizational structure, the detailed technical design, and the operation of the X-ray laser. Together with Denmark, Hungary, the Netherlands, Russia, Slovakia, and the European Union, whose representatives were present as observers, the signatory countries formed an International Steering Committee (ISC) that coordinated the preparations for the construction of the European XFEL. By December 2005, the MoU had been signed by China, Denmark, Hungary, and Russia. In October 2007, it was signed by Slovakia as well.

These preparations reached two major milestones in 2006. In July, the DESY XFEL project group and the European XFEL project team published the technical design report (TDR) for the facility (Figure 3). In 580 pages, 270 authors from 69 institutes in 17 countries described all of the scientific and technical details of the research facility. In August 2006, the authority for mining, energy, and geology in Clausthal-Zellerfeld, which was in charge of the European XFEL public planning approval procedure (Figure 2), published the official approval statement comprising the necessary statutory permissions for the construction and operation of the facility—thereby giving the formal go-ahead for the realization of the X-ray laser.

Figure 3 On 25 July 2006, representatives of European XFEL and DESY handed over the European XFEL TDR to the chairman of the ISC.
Left to right Jochen Schneider, Albrecht Wagner, Hermann Schunck (BMBF), Massimo Altarelli, Karl Witte, Andreas Schwarz, Reinhard Brinkmann, and Thomas Delissen.

Scientific and technological development

The idea of a single-pass FEL for short wavelengths goes back to the independent work of A.M. Kondratenko and E.L. Saldin in 1979 and of R. Bonifacio, C. Pellegrini, and L.M. Narducci in 1984, respectively. The latter authors introduced the term “self-amplified spontaneous emission” (SASE) to describe the corresponding amplification process. Science to be enabled by X-ray FELs was first discussed in several workshops in the early 1990s. DESY produced a conceptual design report (CDR) for a linear collider with an integrated X-ray laser facility in 1997 and a TDR for the same project in 2001. These important documents, prepared with the help of a large number of scientists worldwide, were followed in 2006 by the European XFEL TDR, prepared at DESY by the European XFEL project team.

In 2001, shortly after the first demonstrations in the USA of the SASE process in the infrared and visible regions of the spectrum, a test facility, built at DESY as part of the TESLA collaboration, demonstrated lasing at 98 nm (see figure below). A user programme with first experiments started soon afterwards at the new facility, now known as the Free-Electron Laser in Hamburg (FLASH). The development of the electron source continued in parallel. Today, FLASH—which is based on a 1.2 GeV superconducting linear accelerator—routinely reaches wavelengths down to 4.2 nm. In a parallel development, as a result of an original proposal by C. Pellegrini in 1992, the SLAC National Accelerator Laboratory in the USA started a programme to use part of its 3 km long normal-conducting linear accelerator as an X-ray FEL, resulting in the Linac Coherent Light Source (LCLS). This effort was a spectacular success: in April 2009, lasing at 0.15 nm was first observed. Since then, experiments have shown the first instances of the extraordinary scientific potential of X-ray FELs.

TESLA test facility at DESY in 1997

High-level project on the ESFRI roadmap

In October 2006, after an intensive two-year consultation and peer review process that involved over 1 000 high-level international experts, the European Strategy Forum on Research Infrastructures (ESFRI) committee of the European Union (EU) published the first European roadmap for new, large-scale research infrastructures. This roadmap has the objective of identifying high-level projects that are of critical importance to the worldwide rank of European research organizations for the next 10 to 20 years and whose impact will extend well beyond European borders. The European XFEL facility is among the first 35 projects on the list to proceed to the construction phase.

Figure 4 The European XFEL was officially launched on 5 June 2007.
Top 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.
Bottom Annette Schavan, Ole von Beust, and Peter Harry Carstensen.

Launching the European XFEL

In January 2007, 260 scientists from 22 countries met at DESY in Hamburg for the first European XFEL Users' Meeting. This event marked the beginning of a series of regular workshops and meetings between the scientists interested in the research opportunities at the European XFEL and the planners of the facility.

By June 2007, funding negotiations between Germany and the 12 interested partner countries at the time—China, Denmark, France, Greece, Hungary, Italy, Poland, Russia, Spain, Sweden, Switzerland, and the UK—were so far advanced that the German research ministry decided to officially launch the European XFEL (Figure 4). The partners agreed 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.

In a communiqué signed during the launching ceremony in Hamburg, the representatives of the partner countries declared: "We are convinced that it is appropriate to begin the construction of the [European] XFEL as quickly as possible in view of the international competition situation." They also stated their intention to sign a convention on the foundation of a European XFEL company responsible for the construction and operation of the facility as soon as possible. The launch marked the starting signal for the calls for tender for the construction of the underground tunnel system and the buildings.

Pre-XFEL project

The year 2007 also saw the launch of the Pre-XFEL project, an EU-funded project designed to support the foundation of the European XFEL as a major new research institution in Europe. The main purpose of the project was to provide all technical, legal, and financial documents necessary for the foundation of the European XFEL GmbH. One of the main Pre-XFEL activities was the immediate recruitment of international staff, mostly in the relevant scientific and technical fields, supported by the EU funding. The second objective of the Pre-XFEL project was to mobilize potential users and inform them about the possibilities and requirements at the European XFEL (for example, by organizing a series of workshops and user meetings). The third Pre-XFEL objective was to facilitate the specification—and, where appropriate, research and development, prototyping, and industrialization—of technical infrastructure and technical components. The project, which is coordinated by DESY, will be concluded in June 2011.

On 30 November 2009, ministers, state secretaries, and other high-ranking government representatives from 10 partner countries met in the Hamburg city hall to sign the European XFEL Convention and Final Act, thus establishing the European XFEL GmbH under international law.

Designating the future management

In October 2007, the ISC designated an Italian physicist, Massimo Altarelli, who at the time was the leader of the European XFEL project team, and Karl Witte, a German physicist in charge of administrative and financial issues within the European XFEL project team, as the two managing directors of the future European XFEL GmbH. Both designated directors had managed large research centres in the past. Altarelli was the research director of the European Synchrotron Radiation Source (ESRF) in Grenoble during its period of foundation, and later managing director of the ELETTRA Synchrotron Light Source in Trieste. Witte worked as executive secretary of the department of physics at the University of Hamburg and, from 1987 to 2005, as a member of the ESRF management team. The ISC also nominated the members of a selection committee to designate three more directors of the future European XFEL GmbH.

Adopting the convention

In September 2008, the ISC adopted the contents of the “Convention concerning the Construction and Operation of a European X-ray Free-Electron Laser Facility”, as the official title of the English version reads. Formulating the text of the intergovernmental convention was painstaking work because all of the particulars had to be elaborated at length and agreed to at the time by 13 eastern and western European countries with very different cultures. The convention formed the basis for the foundation of the European XFEL GmbH. This company could be established immediately after the signing of the convention.

Start of civil construction

In December 2008, acting on behalf of the not-yet-founded European XFEL GmbH, DESY commissioned two consortia of renowned building contractors to construct the underground buildings (tunnels, shafts, and halls) for the 3.4 km long X-ray laser facility. The two contracts for the sites Schenefeld in the Pinneberg district (Schleswig-Holstein) and Osdorfer Born (Hamburg), which totalled nearly 206 million euro (M€), were awarded to the consortium of Hochtief and Bilfinger Berger. The commission for the civil engineering works at the Hamburg site DESY-Bahrenfeld, which amounted to 36 M€, went to the consortium of Züblin and Aug. Prien. Construction then officially started in Schenefeld and Hamburg on 8 January 2009. (For a detailed report about construction activities, see Chapter 2, “Civil construction”.)

Initialling the convention

Before the intergovernmental convention on the construction and operation of the European XFEL facility could be signed, it had to be translated from English into French, German, Italian, Russian, and Spanish. To ensure that the six different language versions of the founding documents (European XFEL Convention, Articles of Association, and Final Act) were correct, a cross-checking conference was organized by the German Ministry of Education and Research and the German Foreign Office (*Auswärtiges Amt*) in Berlin in September 2009. The translators were supported in their task by government representatives from 13 participating countries: Denmark, France, Germany, Greece, Hungary, Italy, Poland, Russia, Slovakia, Spain, Sweden, Switzerland, and the UK. At the end of the conference, they initialled the founding documents in all six available versions, thereby clearing the last hurdle for the signing of the convention and the foundation of the European XFEL GmbH.

Figure 5 On 28 September 2009, Massimo Altarelli (right) and Karl Witte signed the request for registration of the European XFEL GmbH in the commercial register of the Hamburg district court.

Establishing the European XFEL GmbH

The construction and operation of the European XFEL was to be entrusted to a non-profit limited liability company under German law with international shareholders: the European XFEL GmbH. To avoid losing time after the convention had been initialled, it was decided, with the consent of all the partners, to establish the company with DESY as the first and initially only shareholder. Other shareholders from the partner countries would then join after the signing of the convention.

On 28 September 2009, the DESY directors Helmut Dosch and Christian Scherf met the two designated members of the European XFEL Management Board, Massimo Altarelli and Karl Witte (Figure 5), at a Hamburg notary’s office. As representatives of DESY, Dosch and

Scherf signed the Articles of Association that established the new international research institution. Subsequently, they appointed Altarelli and Witte as managing directors of the European XFEL GmbH. Altarelli and Witte then immediately signed the request for registration in the commercial register of the Hamburg district court (*Amtsgericht Hamburg*).

On 8 October 2009, the new research institution was finally legally authorized to operate: the European X-Ray Free-Electron Laser Facility GmbH was officially registered as number HRB 111165 in the Hamburg commercial register. Speaking for the project team, Altarelli expressed eagerness to finally start operations: “The decisive thing is that we can now conclude employment contracts, place orders, subcontract machine components, plan the future research operation—that is, start full speed ahead at the business level too.”

Figure 6 On 30 November 2009, representatives from 10 partner countries signed 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.

Signing the convention

On 30 November 2009, ministers, state secretaries, and other high-ranking government representatives from 10 partner countries—Denmark, Germany, Greece, Hungary, Italy, Poland, Russia, Slovakia, Sweden, and Switzerland—met in the Hamburg city hall to sign the European XFEL Convention and Final Act, thus establishing the European XFEL GmbH under international law (Figure 6). For internal reasons, France and Spain decided to sign the documents at a later date. China and the UK planned to join within the next six months. Representatives of the German federal government and the federal states of Hamburg and Schleswig-Holstein also signed an additional agreement regulating the financing of the German share in the European XFEL.

The European XFEL Convention and Final Act laid the foundations for the European XFEL project, defined the financial contributions of the partner countries, and conferred the responsibility for the construction and operation of the facility on the European XFEL GmbH. As the host country, Germany (the federal government and the states of Hamburg and Schleswig-Holstein) covers 54% of the construction and commissioning costs, which amount to 1 082 M€ (in 2005 price levels). Russia bears 23% and the other international partners between 1% and 3.5% each. To a great extent, these shares will be provided as in-kind contributions. (For details about in-kind contributions, see Chapter 3, "In-kind contributions".) As agreed in 2007, construction has begun with a startup version comprising 6 of 10 planned scientific instruments, with the aim to upgrade it as soon as possible to the complete facility with 10 instruments.

First shareholders

The governments of the international partners designate the shareholders of the European XFEL GmbH. As a rule, these shareholders are research institutions or organizations of the corresponding country, or the governments themselves. Given that the GmbH was founded only a few weeks earlier, initially with DESY as the only shareholder, other shareholders were able to join the company right after the convention signing ceremony.

Whereas the Science and Technology Facilities Council (STFC) in the UK announced its withdrawal from the European XFEL project in December 2009 for financial reasons, France officially sealed its participation in February 2010. By the end of 2010, Denmark, Germany, Poland, Russia, Slovakia, and Sweden had appointed shareholders to join the European XFEL GmbH. (For a list of shareholders, see Chapter 7, "Facts and figures".) Other shareholders are expected to join in 2011.

Collaboration with DESY

From the inception of the plan to build an X-ray FEL facility in Hamburg and Schleswig-Holstein, DESY has played an important role in fostering the project. Over many years, DESY advanced the funding for the preparatory work and hosted the European XFEL project team. DESY continues to provide its administrative services. DESY is the leader of the international Accelerator Consortium that is constructing the heart of the facility: the 1.7 km long superconducting accelerator including the electron source. After the completion of the accelerator, DESY will take over its operation on behalf of the European XFEL GmbH.

As set out in the European XFEL Convention and in the Articles of Association, DESY and the European XFEL GmbH collaborate on the basis of a long-term agreement. A first draft of this agreement was approved by the ISC in March 2008. As foreseen in this draft, the continuing provision of services by DESY to the company is regulated in a host agreement. Both documents were signed on 21 May 2010, shortly after their approval at the fourth meeting of the European XFEL Council.

Work on the annexes to the host agreement is progressing. The annexes on general IT services and "campus services" were signed in late 2010.

The host agreement will be expanded with the following annexes:

- Purchasing services (electronic procurement, stores, and specific procurement)
- General safety, emergency intervention, data protection
- Workshop services
- Information services (library, electronic journal subscriptions, and so on)
- Use of certain premises (Hall 36, PETRA III hall)

Work on an annex for scientific data handling and computing has begun. It remains to be clarified whether these areas should be governed by a separate agreement (that is, not as part of the host agreement).

Figure 7 Signing of the building contracts for the three underground construction lots for the European XFEL facility on 12 December 2008

Regarding the civil construction of the facility, the contracts for the three underground construction lots (tunnels and shaft buildings) were awarded by DESY (Figure 7). These underground buildings will be complemented by eight above-ground buildings. It is planned that Lots 1 to 3 will be completed with DESY as the contract-awarding authority and handed over after completion, whereas the European XFEL GmbH will act as the contract-awarding authority for the above-ground buildings that will close the shafts. Agreements on the kind of joint supervision of Lots 1 to 3 and on the transfer are in preparation. The administrations of DESY and the European XFEL are also

Figure 8 Headquarters of the European XFEL GmbH in Hamburg at Albert-Einstein-Ring 19, in front of the DESY site

investigating how the extensive experience of the DESY procurement group might be employed for the forthcoming calls for tender and follow-up procedures.

Challenges as opportunities

Looking ahead, the European XFEL GmbH faces a number of challenges:

- To adjust the facility design and implementation, based on new scientific knowledge gained at FLASH (DESY) and LCLS (SLAC), within the general budgetary situation
- To ensure that, when user operation begins in 2015, the European XFEL is a cutting-edge, state-of-the-art facility

The European XFEL GmbH is tackling these challenges using all available resources:

- Advice from scientific and technical committees
- Close collaborations with many partners and laboratories worldwide
- Feedback from and active interaction with the scientific community

Together with the European XFEL Council and through the support of the various advisory committees—the Administrative and Finance Committee (AFC), Machine Advisory Committee (MAC), Scientific Advisory Committee (SAC), In-Kind Review Committee (IKRC), and Detector Advisory Committee (DAC)—the European XFEL GmbH is confident that it can meet these challenges. ■

October 2009

8 October
Foundation of the European XFEL GmbH

The European X-Ray Free-Electron Laser Facility GmbH—the new non-profit limited liability company under German law in charge of the construction and operation of the European XFEL—is registered in the commercial register of the Hamburg district court *(Amtsgericht Hamburg).*

On 28 September, the DESY directors Helmut Dosch and Christian Scherf sign the Articles of Association establishing the new research institution. They then appoint Massimo Altarelli and Karl Witte as managing directors of the European XFEL GmbH. Altarelli and Witte immediately sign the request for registration in the commercial register.

November 2009

30 November
European XFEL established under international law

Representatives from Denmark, Germany, Greece, Hungary, Italy, Poland, Russia, Slovakia, Sweden, and Switzerland meet in the Hamburg city hall to sign the European XFEL Convention and Final Act, thus establishing the European XFEL GmbH under international law. For internal reasons, France and Spain plan to sign the convention at a later date.

The European XFEL Convention and Final Act lay the foundations of the European XFEL project, define the financial contributions of the partner countries, and confer the responsibility for the construction and operation of the X-ray free-electron laser facility on the European XFEL GmbH.

As the host country, Germany covers 54% of the construction and commissioning costs, which amount to 1 082 million euro (at 2005 price levels). Russia bears 23% and the other international partners between 1% and 3.5% each.

December 2009

16 December
UK withdraws participation in the European XFEL

The UK Science and Technology Facilities Council (STFC) announces its withdrawal from the European XFEL project. Due to financial restrictions, the STFC has to reprioritize its budget over the next five years. The European XFEL is one of 33 research projects from which the UK is now withdrawing completely. The planned UK contribution to the construction cost of the facility had been 2.8%.

22 December
Season's greetings

The year 2009 was momentous in the history of the European XFEL. With the construction of the facility well under way, and the political and organizational framework in place, the European XFEL is definitely on the map of advanced research in Europe.

February 2010

1 February

Record attendance at the 4th European XFEL Users' Meeting

More than 280 future users of the European XFEL from 20 countries gather in Hamburg for the 4th European XFEL Users' Meeting. The spotlight of the event is on the planning, development, and realization of the first six experiment stations for the facility.

3 February

First tunnel boring machine checked and accepted

Two tunnel boring machines are required to construct the 5777 m European XFEL tunnel system. The larger of the two machines, which has an external diameter of 6.17 m, passes the factory acceptance test in the first week of February.

4 February

France joins European XFEL

As the 11th partner country, France officially seals its participation in the European XFEL project on the occasion of the French–German government consultations in Paris.

April 2010

29 April

First tunnel boring machine arrives at the Port of Hamburg

The first of the two tunnel boring machines for the European XFEL arrives by waterway at the Port of Hamburg, disassembled into five parts. The 9 m long front part of the machine has a diameter of 6.17 m and weighs 320 tonnes. Its two-week journey, which began in Kehl near Strasburg close to the manufacturing plant, covered around 1 200 km on six different waterways.

The parts of the tunnel boring machine will be stored at the Port of Hamburg until mid-May and then transported in two nights to the launch shaft on the Schenefeld construction site, where the machine will be reassembled.

July 2010

7 July

Tunnel construction begins

The first tunnel boring machine—called TULA ("tunnel for laser")—starts drilling into the wall of its launch shaft on the Schenefeld construction site. It will take TULA around one year to excavate the first two sections of the "tunnel fan" and the main tunnel for the accelerator.

Following an old German mining tradition, the tunnel and boring machine were christened by their respective patronesses on 30 June during a major tunnel celebration attended by 560 guests. The ceremony included the blessing of a wooden statue of Saint Barbara, the patron saint of miners and tunnel builders, who is said to protect them from the dangers of their labour.

July 2010

21 July
Federal Cross of Merit for John Wood

The German ambassador in London, Georg Boomgaarden, confers the Officer's Cross of the Order of Merit of the Federal Republic of Germany on Prof. John Wood. In particular, he is decorated in recognition of his outstanding contribution to the complex international negotiations surrounding the European XFEL project, which he led with great skill and dedication as chairman of the XFEL International Steering Committee (ISC).

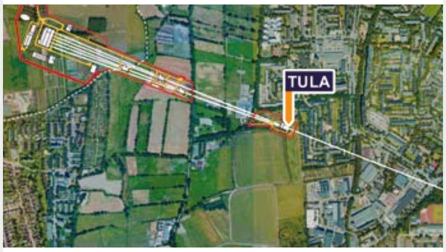
According to the embassy, John Wood played an important role in coordinating the documents required for the creation of the European XFEL GmbH. Thanks to his significant international experience, mediation skills, and constructive approach, the founding documents were agreed on and signed at the end of 2009.

August 2010

27 August
Construction progress online

Shortly before the successful completion of the first tunnel section, a new webpage that tracks the progress of European XFEL tunnel construction goes online:

www.xfel.eu/project
/construction_progress



This webpage provides information on the status of the construction for facility neighbours and other interested people. Updated every Monday morning, it shows the positions of the two tunnel boring machines.

In addition, the percentage of the tunnels already completed is shown on every page of the European XFEL website:

www.xfel.eu

September 2010

3 September
TULA reaches first milestone

After less than two months, the tunnel boring machine TULA breaks through the wall of its reception shaft on the Osdorfer Born construction site, completing the first 480 m of the tunnel system between Schenefeld and Osdorfer Born.

When TULA embarked on its "maiden voyage" at the beginning of July, it was not at all clear that the machine would reach its goal on schedule eight weeks later. How long the machine will actually take depends on the composition of the soil, on the presence of unknown obstacles underground, and, of course, on the skill of the tunnel builders in guiding the colossus through the earth.

8 September
Poland joins the company

Poland joins the European XFEL GmbH, with the Andrzej Soltan Institute for Nuclear Studies (IPJ) as its designated shareholder. The company now has eight member countries.

October 2010

15 October
Close cooperation between European XFEL and Uppsala University

Uppsala University in Sweden and the European XFEL GmbH agree to cooperate in the field of X-ray science with a focus on structural biology. In particular, the agreement stipulates the secondment of Prof. Janos Hajdu, an internationally renowned expert in structural biology, to the European XFEL GmbH.

21 October
TULA drills its second tunnel

TULA sets off on the second leg of its journey: the second, 594 m long tunnel section between the construction sites Schenefeld and Osdorfer Born.

If construction proceeds as smoothly as before, the machine will arrive in Osdorfer Born at the end of December. This time, it will not be dismantled, but moved on rails to the other side of the shaft to resume its way straight ahead toward DESY-Bahrenfeld at the beginning of January 2011.

November 2010

8 November
European XFEL joins EIROforum

The European XFEL GmbH becomes the eighth member of EIROforum, a partnership of seven European intergovernmental research organizations with large scientific infrastructures. EIROforum combines the resources, facilities, and expertise of these organizations to support European science in reaching its full potential.

EIROforum simplifies and facilitates interactions with the European Commission and other organs of the European Union, national governments, industry, science teachers, students, and journalists. By combining international facilities and human resources, EIROforum synergizes the research potential of the individual organizations, achieving world-class scientific and technological excellence in interdisciplinary fields.

December 2010

21 December
AMELI joins TULA

The second tunnel boring machine is christened, together with the tunnel sections it is to build, in the presence of around 250 guests. Until the summer of 2012, the smaller of the two machines, called AMELI (the German acronym for “at the end there will be light”), will construct eight tunnel sections under the future research campus in Schenefeld.

Constructing so many short tunnel sections is a major challenge. The machine must be disassembled four times, transported back to its new launch point inside the future experiment hall, and reassembled again. A further three times, it must be moved through an existing open shaft to start boring again on the opposite side of the shaft. The machine was designed especially for this purpose.


02

CIVIL CONSTRUCTION

■ The European XFEL comprises three sites: the DESY-Bahrenfeld site, hosting the injector complex; the Osdorfer Born site, hosting one distribution shaft; and the Schenefeld campus site, hosting distribution shafts, electron dump shafts, and the underground experiment hall, with a large laboratory and office building on top. The latter will serve as the company headquarters.

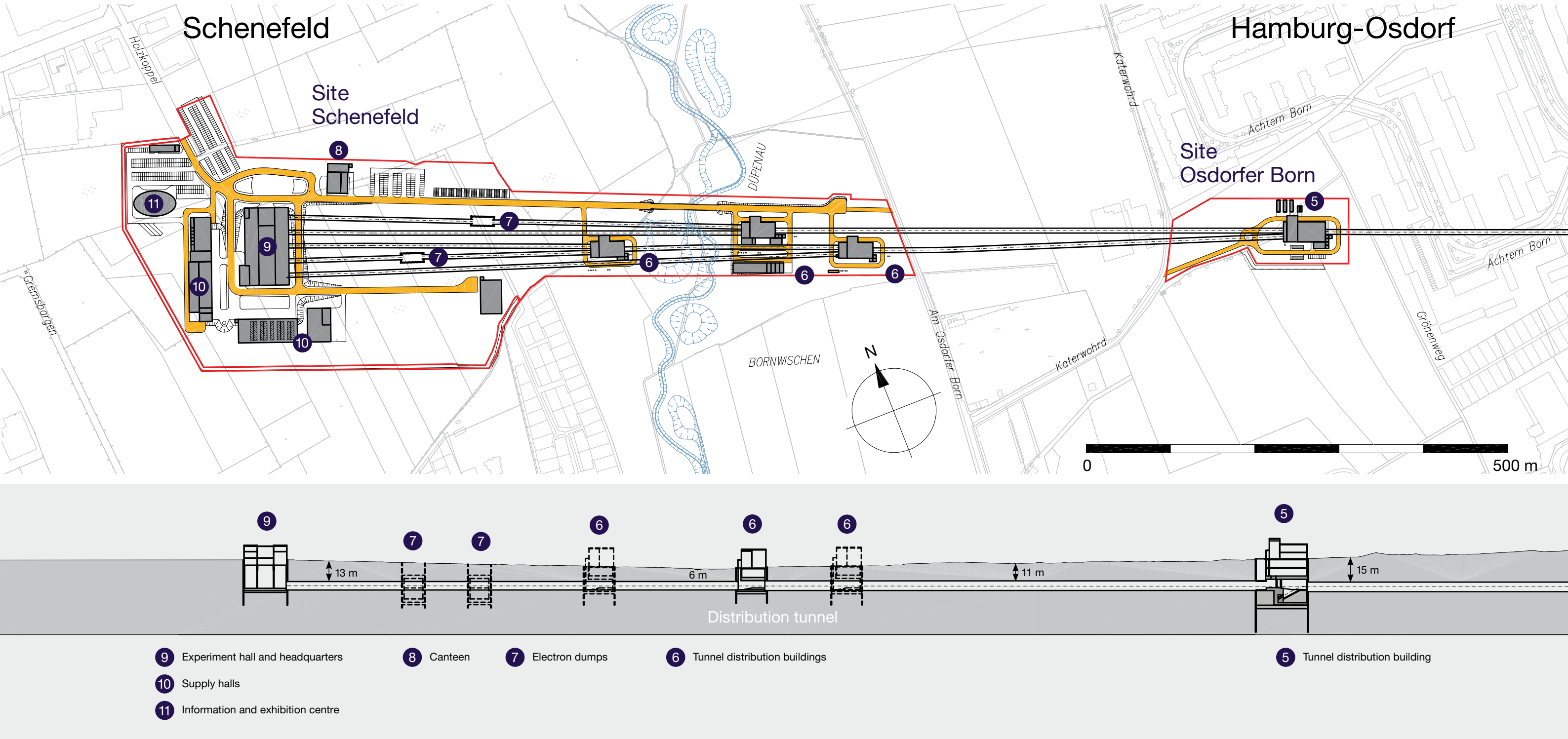


Figure 1 Layout of the European XFEL facility

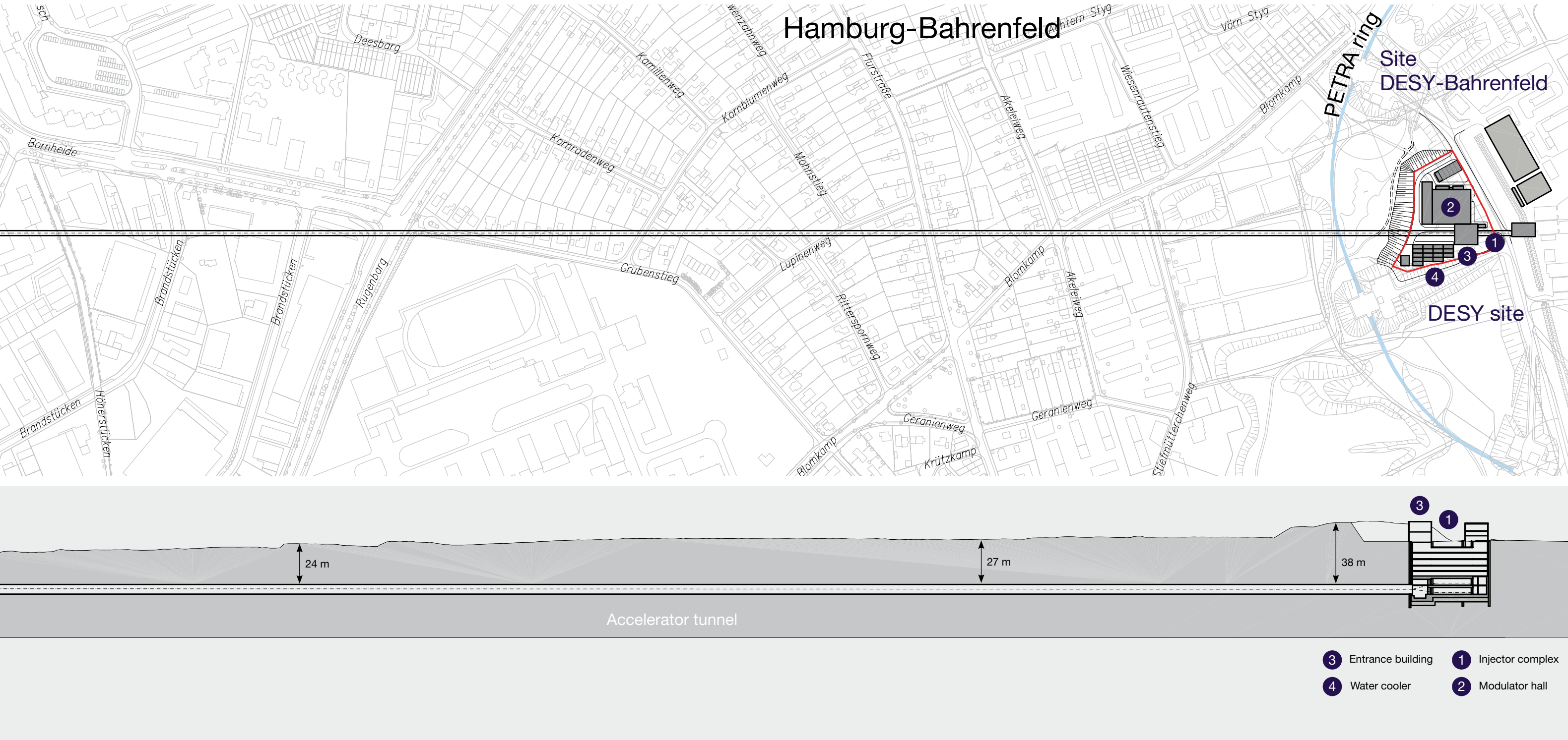
CIVIL CONSTRUCTION

The vast building sites and the enormous shafts are the most impressive evidence of the start and progress of the European XFEL project. This article summarizes the most important milestones from the start of construction work to the present.

Layout of the new facility

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

The facility stretches from the campus of 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. The facility is approximately 3.4 km long and consists of eight shaft building complexes of various sizes, corresponding surface buildings, and assorted smaller building structures for peripheral technical equipment (for example, pump housing, generators, and air conditioning).



The European XFEL comprises three different sites: the DESY-Bahrenfeld site with the injector complex, the Osdorfer Born site with the distribution shaft XS1, and the Schenefeld campus site hosting the remaining distribution shafts, the electron dump shafts, and the underground experiment hall. On top of the experiment hall, a large laboratory and office building will be erected. The latter will serve as the company headquarters.

The shaft buildings will be connected underground by 5.77 km of tunnels with two different inner diameters (4.5 m and 5.3 m, respectively). These tunnels will contain the linear accelerator, the undulator equipment, and the electron and photon beam transport lines. The shafts will serve as launch and reception areas for the two large tunnel boring machines (TBMs) that will excavate the tunnels. The shafts also provide access to the tunnels for installation and commissioning purposes, and allow for the routing of services to and from the tunnels (for example, air, water, electricity, and liquid helium).

Start of construction

The calls for tender for the underground buildings (shafts and tunnels) were finalized with the award of contracts in three different lots to two bidder consortia at the end of 2008. The civil construction for all underground buildings started officially on 8 January 2009.

The designs for the above-ground buildings are not yet final, with two exceptions: the Accelerator Module Test Facility (AMTF) hall and the modulator hall, both at the DESY-Bahrenfeld site. The AMTF is a large hall to be used starting in 2011 for the tests of the accelerator modules and various related auxiliary equipment before they are installed in the accelerator tunnel. The call for tender for the AMTF was sent out in April 2009. The building was completed and handed over to the infrastructure installation teams in September 2010. The call for tender for the modulator hall was completed in December 2010. Start of civil construction of this hall is expected in May 2011.

The 3.4 km long European XFEL facility extends from the DESY campus in Hamburg-Bahrenfeld to the southern edge of the city of Schenefeld, in the German federal state of Schleswig-Holstein. The facility consists of eight underground shaft building complexes of various sizes, connected by 5.77 km of tunnels, and corresponding surface buildings on three different sites.

Civil construction of the underground buildings proceeded as follows.

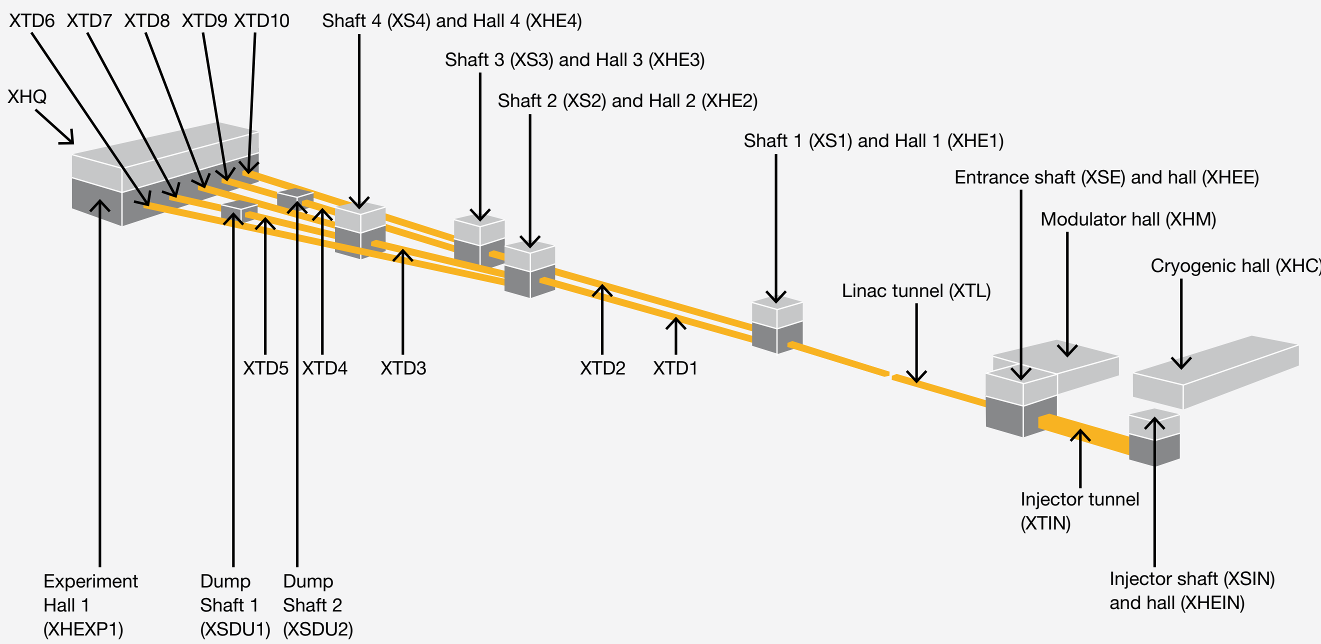
The startup work included preparing access roads and setting up the logistics for the construction site crews. Trees and surface vegetation on the three building sites (DESY-Bahrenfeld, Osdorfer Born, and Schenefeld) were removed, buildings for the construction personnel were set up, and fences for personnel safety were erected. Before major soil-moving activities could begin, the entire underground area had to be checked for munition remnants from World War II.

Tunnel boring began after the hulls of the shafts were finished and suitably fortified. Two TBMs are being used for the European XFEL, corresponding to the two different tunnel diameters needed. The TBMs are transported into their first launch shafts for final assembly and subsequent construction of the tunnel sections starting from these shafts. After a TBM has reached its reception shaft, it is dismantled and moved to its next launch shaft.

As a final step, the actual civil construction building—with all the subdivisions needed to house the technical equipment and route the services in and out of the shafts and tunnels—will be built inside the shaft hull. The buildings of the facility are shown in Figure 2.

DESY-Bahrenfeld site

Early in 2009, considerable amounts of earth were removed in Lise Meitner Park, adjacent to the western part of the DESY campus, to bring the entire area needed for the excavation of the injector complex



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

Figure 2 Buildings of the European XFEL facility

to the same level. This earth removal was followed by the construction of the diaphragm walls that form the hull of the injector building complex. The earth inside these walls, which are up to 1.5 m thick, was then excavated to a depth of up to 40 m. As the ground water table is much higher than this level, most of the excavation had to be performed under water. Finally, an underwater concrete floor was poured to seal the inner volume from ground water. Large anchors were drilled into the surrounding earth to provide stability.

Figure 3 shows an aerial view of the injector complex region on the DESY campus in September 2010. The first two underground floors of the injector building were finalized at the end of December 2010. In addition, the planning is well under way to erect the structures needed to receive the TBM that will excavate the linear accelerator tunnel (XTL).

Figure 4 shows a snapshot of the interior building structure in October 2010 and a 3D simulation of how the final injector building complex will look when it is completed.

Figure 3 Aerial view of the injector complex region on the DESY campus (September 2010)

On 21 July 2009, Germany's research minister, Annette Schavan, Hamburg's science senator, Herlind Gundelach, and Schleswig-Holstein's research minister, Jörn Biel, met at DESY in Hamburg to lay the cornerstone for the AMTF hall and sign an agreement for the participation of the German federal states of Hamburg and Schleswig-Holstein in the European XFEL facility.

The work on the about 4 500 m^2 AMTF hall proceeded according to schedule. The building was completed in September 2010. On 19 May 2010, the hall could already be used to celebrate the 50th anniversary of DESY.

Figure 4 Left Final injector building complex when completed
Right Interior building structure (October 2010)

Osdorfer Born site

The Osdorfer Born site accommodates the shaft XS1, where the linear accelerator tunnel ends and the two first undulator tunnels, XTD1 and XTD2, start. Figure 5 shows an aerial view of the site in September 2010, together with a 3D simulation of the completed building complex.

In 2010, the hull of the shaft building XS1 served as the reception shaft for the TBM that excavated the two undulator tunnels, XTD1 and XTD2, starting on the Schenefeld campus. In January 2011, XS1 will be used as the launch shaft for the TBM to dig the linear accelerator tunnel XTL that will connect the Osdorfer Born site with the DESY-Bahrenfeld site. Because of the very close proximity of the Osdorfer Born site to private housing areas, extra care has to be taken to minimize noise from the building site.

Schenefeld campus

As a first step in building the Schenefeld campus, the streets to the site had to be reinforced to accommodate the heavy truck traffic expected during the construction period. As a second step, the entire building site (roughly 15 ha) was levelled to prepare for the shaft construction.

The Schenefeld campus includes six shaft buildings of different sizes. The smallest shafts will accommodate the two underground halls, XSDU1 and XSDU2. These halls will house the dumps in which the electron bunches will be stopped after having generated the laser light used for scientific experiments. Shafts XS2, XS3, and XS4 are used for installation purposes, as well as to provide power, water, and air conditioning. During civil construction, they serve as launch and

Figure 5 Left Simulation of the completed building complex
Right Aerial view of the Osdorfer Born site (September 2010)

reception shafts for the TBM that excavates the tunnels connected to them. For logistical reasons, all tunnels are excavated in a south-eastern direction from Schenefeld towards Osdorfer Born.

The tunnelling is performed using two tunnel boring machines with slightly different diameters to accommodate the different tunnel sizes of the accelerator and photon tunnels, respectively. The cutting wheel of the larger machine, called TULA, has a diameter of 6.17 m. The smaller one, named AMELI, has a cutting wheel of 5.48 m.

All shafts lie in ground water. As a result, the final steps of the excavation and the construction of the concrete bottom plate had to be performed under water.

Figure 6 Overview of the experiment hall (October 2010)

The underground building with the largest area is the experiment hall, XHEXP1. It is approximately 4 500 m^2 in area. Parts of the building are up to 18 m underground. The stability of the construction is assured by anchors that are drilled into the ground for the vertical walls and the ground plate. In addition, a grid of concrete girders has been erected at surface level. Figure 6 provides an overview of the experiment hall in October 2010.

Figure 7 shows an aerial view of the entire Schenefeld site, together with a 3D simulation of the completed experiment hall and the laboratory and office building (XHQ). All shaft hulls are completed. Work is now focused on the tunnelling procedure.

Tunnel construction

The tunnelling is performed using two TBMs with slightly different diameters to accommodate the different tunnel sizes of the accelerator and photon tunnels, respectively. The larger of the two machines, named TULA ("tunnel for laser"), is a total of 71 m long and weighs 550 tonnes. The cutting wheel has a diameter of 6.17 m. The machine was installed in the launch shaft XS2 in June 2010 to excavate the first tunnel, XTD1, that connects this shaft with the reception shaft XS1 on the Osdorfer Born site. The christening ceremony for the TBM and the tunnel took place on 30 June 2010.

The first two tunnels, XTD1 and XTD2, are now finished. They make up approximately 18% of the total length of tunnel to be excavated. The machine has been put into position in the XS1 shaft to start digging the 2 km tunnel for the accelerator (XTL), which connects the Osdorfer Born site with the DESY-Bahrenfeld site. The machine is due to start excavating the XTL tunnel in January 2011.

The second TBM, called AMELI (the German acronym for "at the end there will be light"), was installed in the XHEXP1 experiment hall in late 2010. Figure 8 shows the machine after test assembly at the manufacturing company Herrenknecht in Schwanau, Germany. The christening ceremony took place on 21 December 2010. The machine is scheduled to begin excavating the XTD9 photon tunnel in early January 2011.

The progress made by both TBMs can be followed through a website specifically set up for that purpose:

www.xfel.eu/project/construction_progress

Figure 7 Left Simulation of the completed underground experiment hall and the above-ground laboratory and office building on the Schenefeld site
Right Aerial view of the Schenefeld site (September 2010)

Figure 8 Smaller tunnel boring machine, AMELI, after its test assembly at the manufacturer

Figure 9 View of the first metres of the tunnel XTD1 with the end of the TBM in the back (July 2010)

Figure 10 First breakthrough of the larger tunnel boring machine, TULA, at Osdorfer Born (September 2010)

Challenges

By their very nature, large-scale civil construction endeavours face unforeseen challenges and unplanned events. In addition to two unusually hard back-to-back winters, the primary obstacles for the European XFEL civil construction involved the search for explosive residue from World War II and the routine analysis of contamination levels of the excavated soil on all three construction sites.

On the DESY-Bahrenfeld site, several anti-aircraft grenades and bazookas had to be removed by specialists or detonated on site. On the Schenefeld site, part of the excavated soil was contaminated with sulphates and arsenic—a finding that contradicted previous results of spot-check drilling that had been performed before the excavation work. The contaminated material had to be disposed of differently than normal soil, resulting in additional costs for the project.

In November 2010, during the excavation of the second tunnel, XTD2, a hole with an area of approximately 15 m^2 was discovered on a meadow near a horse farm located above the path of the TBM TULA. The hole was approximately 1.5 m deep and obviously related to the tunnelling process. The area was immediately secured and monitored for changes. After that, it was filled with soil. As studies revealed, the subsidence was caused by a localized, very rare geological formation on the path of the TBM. Even though the probability of such a subsidence occurring again is extremely low, additional monitoring and safety measures were taken for the remaining tunnel construction. Further changes have not been observed.

03

IN-KIND CONTRIBUTIONS

■ To a great extent, the shares that the partner countries contribute to the European XFEL are provided as in-kind contributions. The majority are related to the linear accelerator and the associated infrastructure. The institutions delivering contributions to the accelerator are grouped in the Accelerator Consortium, which is coordinated by DESY.

OVERVIEW

Shareholders of the European XFEL GmbH can contribute to construction costs in cash or in kind. In-kind contributions (IKCs) can take the form of components, human resources, or both. The company has so far received proposals for roughly 70 IKCs from seven different countries for a total of more than 500 million euro.

What are IKCs?

The intergovernmental convention that constitutes the basis for the European XFEL GmbH stipulates that the shareholders of the company can contribute to its construction costs either in cash or in kind. Cash contributions are the direct transfer of funds from a shareholder to the company. In-kind contributions can take the form of facility components, human resources, or both. One of the documents included as an annex to the convention states that an “in-kind contribution may cover a technical component as well as personnel needed for its installation and integration on site, or personnel made available for specific tasks during the construction phase”.

In fact, many participating countries choose to deliver part or even all of their contribution in kind rather than in cash. There are good reasons for this choice. For example, it is sometimes easier to convince governments to provide money to be at least partly spent in their own country. Such IKCs enable local industries to acquire advanced technologies for which a market may be developing. For example, the superconducting linear accelerator technology promises to be relevant for future colliders, spallation neutron sources, and so on. By providing IKCs, domestic research laboratories may acquire competences of interest for the possible later development of other facilities.

In the present European XFEL project organization, the value of in-kind contributions accounts for around 50% of the total project budget.

When a government signs the convention, it pledges to contribute a certain amount of money to the construction costs. This amount is expected to be provided by the shareholders representing that country at the European XFEL GmbH. When a country delivers one of the agreed milestones as an IKC, its account is credited. That is, a corresponding fraction of the pledged total amount is subtracted from the country’s total contribution (in 2005 prices). For each IKC, there must therefore be an agreed set of well-specified (intermediate or final) deliverables and milestones, and an agreed value to be credited to the shareholder for each achieved milestone. For every IKC, these deliverables and milestones must be formalized in a contract with precise specifications, timelines, and the corresponding values to be credited. During the execution of the contract, the deliverables must be verified and validated at each agreed milestone.

Abbrevation	Country	IKC value (k€)	Total contribution (k€)
DK	Denmark	0	11 000
FR	France	36 000	36 000
DE	Germany	396 517	580 000
GR	Greece	0	4 000
HU	Hungary	0	11 000
IT	Italy	33 000	33 000
PL	Poland	15 977	21 600
RU	Russia	0	250 000
SK	Slovakia	0	11 000
ES	Spain	8 276	11 000
SE	Sweden	3 672	16 000
CH	Switzerland	8 967	15 000
Total		**502 409**	**999 600**

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

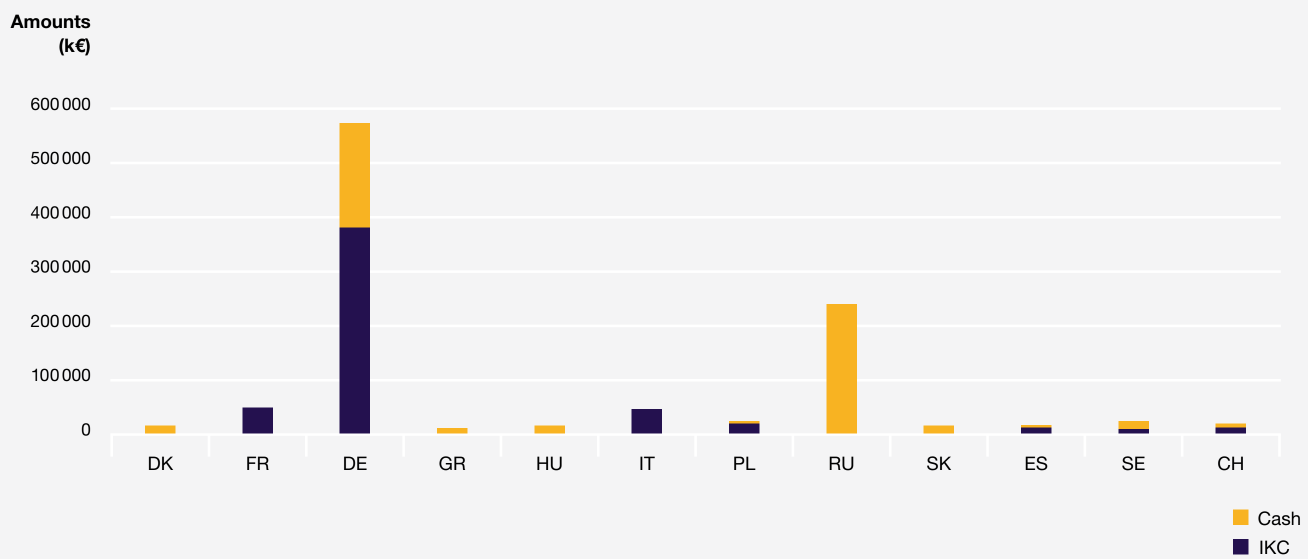


Figure 1 Contributions by country (in 2005 prices) in thousands of euro (k€)

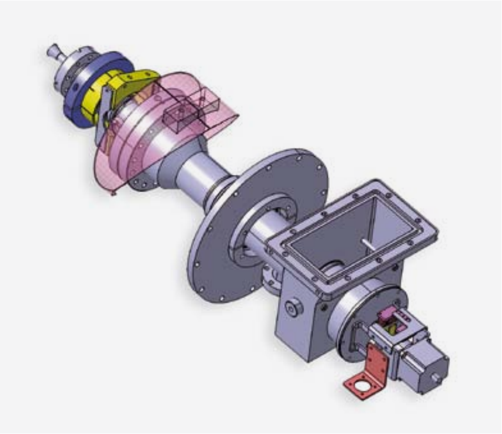


Figure 2 Power coupler for the Power Coupler WP of the Linac WPG

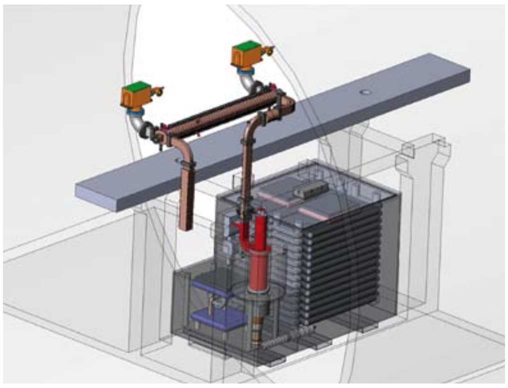


Figure 3 Transverse deflecting structure for the Special e-Beam Diagnostics WP of the Accelerator Subsystems WPG

Scope of IKCs

In the present project organization, the value of IKCs accounts for around 50% of the total project budget. Table 1 and Figure 1 show the projected amounts of IKCs for the participating countries as of December 2010.

IKCs are an essential part of the construction process. To ensure the successful completion of the project, these contributions must be selected, organized, monitored, and integrated carefully.

The overwhelming majority of the approved IKCs are related to the production of the linear accelerator and the associated infrastructure. A smaller number are linked to the undulators, photon beam systems, and instruments. The institutions delivering contributions to the accelerator are grouped in the Accelerator Consortium, which is coordinated by Deutsches Elektronen-Synchrotron (DESY).

To date, the European XFEL GmbH has received proposals for roughly 70 different IKCs that have been agreed or at least proposed and preliminarily scrutinized. In other words, each country with an IKC entry in Table 1 provides several in-kind contributions.

Figures 2 through 8 illustrate the variety of IKCs. They are examples of equipment to be delivered by the contributing institutes to different work packages (WPs) in different work package groups (WPGs).

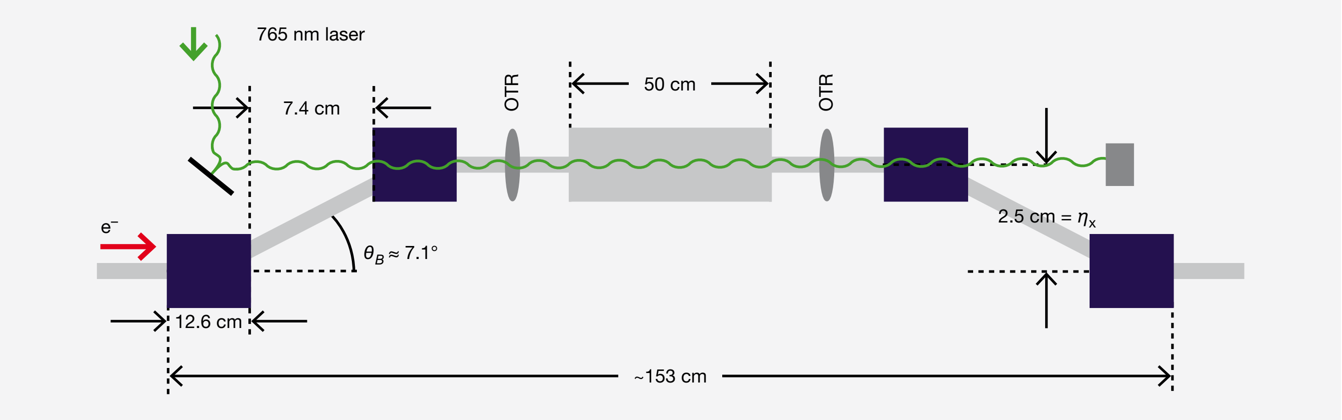


Figure 4 Schematic of the laser heater system for the Injector WP of the Accelerator Subsystems WPG

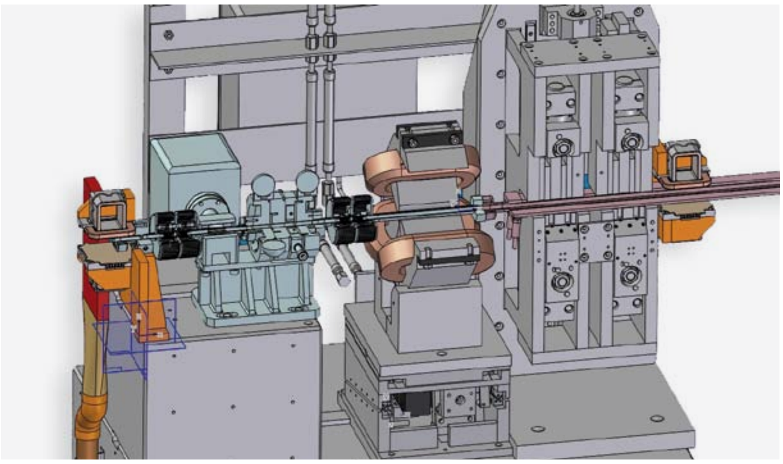


Figure 5 Undulator intersection for the Undulator Systems WP of the Photon Beam Systems WPG

Figure 6 Electron beam dump for the Beam Dumps WP of the Accelerator Subsystems WPG

Figure 7 Cold magnet prototype for the Cold Magnets WP of the Linac WPG

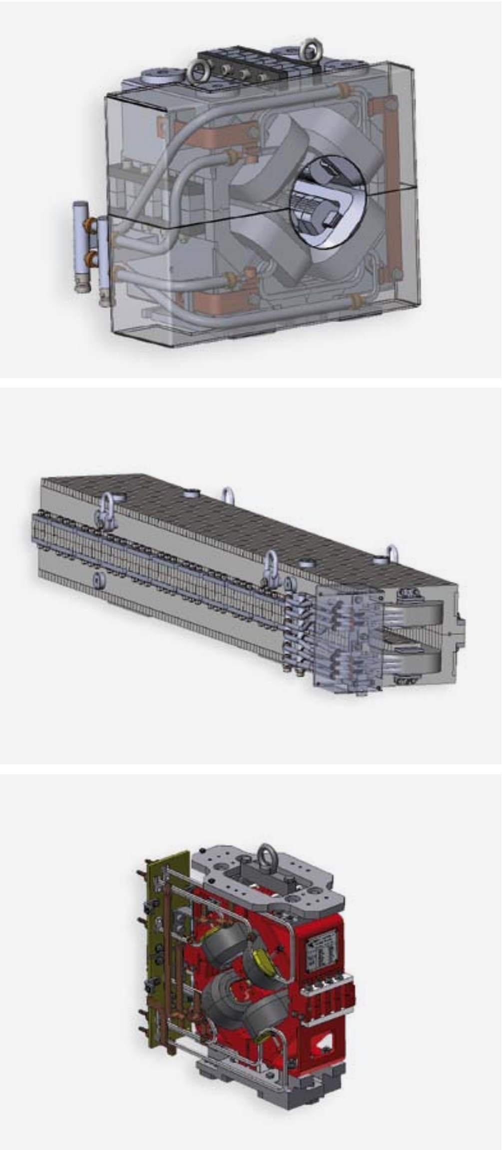


Figure 8 Different types of magnets for the accelerator complex

Allocating and implementing IKCs

Implementing IKC procedures, preparing contractual agreements, and tracking IKC achievements are extensive tasks governed by precise guidelines and internal rules. Guidelines for the allocation and implementation of IKCs are addressed in one of the technical documents attached as an annex to the convention.

Article 3 of the annex prescribes the following:

> the in-kind contribution agreement for each task should contain *inter alia*:
> - a technical description and specifications,
> - time schedules and milestones,
> - deliverables,
> - quality control issues,
> - performance testing, acceptance and commissioning,
> - technical and financial control systems,
> - appointment of responsible technical personnel,
> - intellectual property right issues.

Article 4 stipulates that “an In-Kind Review Committee (IKRC) is set up…to propose to the [European] XFEL Management the allocation of in-kind tasks to specific partner institutes for decision by Council.”

IKRC recommendations

The IKRC was in place, in an informal way, before the European XFEL GmbH was created. Since then, it has been formally established and now meets regularly three times per year.

The committee fulfils very technical tasks:

- Reviews expressions of interest from institutes of the participating countries to contribute in kind
- Checks 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 of the facility, and then be integrated into the rest of the facility)
- Verifies that the proposing team has the technical competence and experience to perform the corresponding task
- Verifies the adequacy of the available infrastructure
- Issues a recommendation for or against the start of the next step (that is, the drafting of a detailed agreement between the company and the contributing institute)

The contract governing each IKC has a different format for contributions taking place in the framework of the Accelerator Consortium and for those not related to the accelerator. In the former case, the coordinator of the consortium, DESY, has a very important role to play in defining the scope of the contribution, and in specifying and verifying the deliverables. In the latter case, the agreement involves only the contributing institute and the European XFEL GmbH.

Russian contributions are treated somewhat differently because the Russian shareholder decided, for internal administrative reasons, to send its full contribution to the European XFEL GmbH in cash. After a Russian institute is selected to produce a specific piece of equipment, the company issues an order to the institute in the form of a manufacturing contract, which is then managed with the same procedures as IKCs.

As of December 2010, out of 47 proposals that had received favourable recommendations from the In-Kind Review Committee, 15 contracts for in-kind contributions were signed or ready for signature with German, Polish, Russian, and Swedish institutes.

Council allocations

After the essential contract elements are fixed and agreed to by the parties, the next step is the formal allocation of the IKC by the European XFEL Council. For contract values below 1 million euro (M€), the council takes note of the corresponding decision by the European XFEL Management Board. For values between 1 and 5 M€, the council takes note of the corresponding decision by the Administrative and Finance Committee (AFC). For values above 5 M€, the council discusses the AFC recommendations and then decides whether to follow them.

The most sensitive aspect of the IKC contracts is the value to be credited for the specific IKC. The reference for this information is the project cost book. The cost book is the list of all components and activities necessary for the construction of the facility with the corresponding cost estimates. These estimates were established between 2005 and 2007. Even when inflation is taken into account, a certain margin of error is unavoidable. In general, however, the council tends to consider deviations from the cost book as exceptions rather than rules. To handle irreconcilable differences of value between the cost book and estimates of in-kind contributors, the council set up a special procedure involving an ad hoc panel that recommends ways to resolve these conflicts.

The essential steps for setting up an IKC are combined in a workflow, as illustrated in Figures 9 and 10. Figure 9 shows the workflow from Expression of Interest (EoI) to the allocation of an IKC. Figure 10 shows the workflow for preparing contractual documents for an IKC.

Each agreement includes a technical annex that describes in detail the extent of the contribution and provides the required specifications. This annex must be prepared carefully so the delivered equipment has the correct interfaces and its expected performance is reached. An additional difficulty encountered in the preparation of the documents is that the contribution's extent established in 2005 often needs adaptation, due to a change of specifications or a change in the distribution of tasks between the different contributors within each WP.

After the formal signatures of the IKC agreement, each contribution has to be followed-up in terms of scheduled achievements. At each agreed milestone, the contributing institute delivers either documents or parts of equipment. To credit the involved shareholder with the corresponding value, a specific procedure has been set up to verify the conformity of the deliverables (performed by the WP leader) and to validate the milestone achievement (performed by the IKC coordinator).

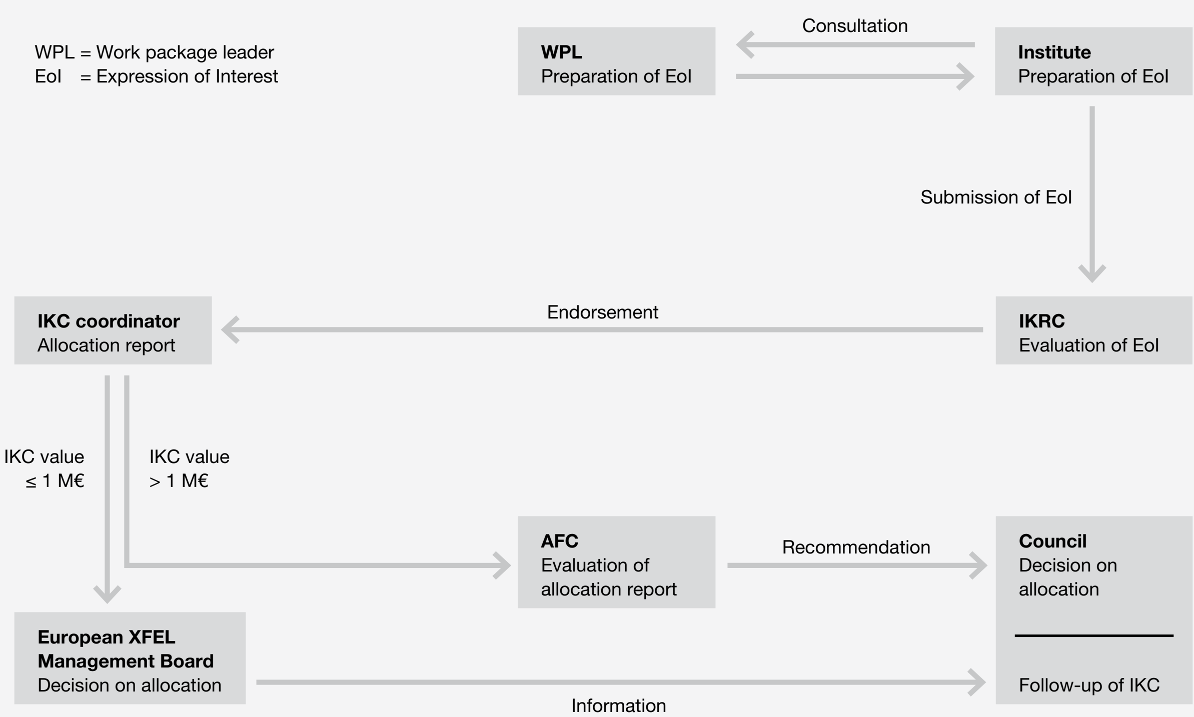


Figure 9 Workflow from EoI to IKC allocation

Status of IKC contracts

Preparing and monitoring this complex set of procedures, as well as coordinating its formal and substantive aspects, is the task of the IKC coordinator. In addition, several other groups within the European XFEL GmbH are involved in the preparation and follow-up of IKC contracts. Legal issues are resolved with the assistance of the Legal group. Crediting operations are monitored and integrated in the yearly budget by the Controlling group. Payment of invoices generated by Russian in-kind contracts is processed by the Finance group.

As of December 2010, 15 contracts for IKCs were signed (or were ready for signature) with German, Polish, Russian and Swedish institutes, out of a total of 47 proposals that, so far, have received favourable recommendations from the IKRC.

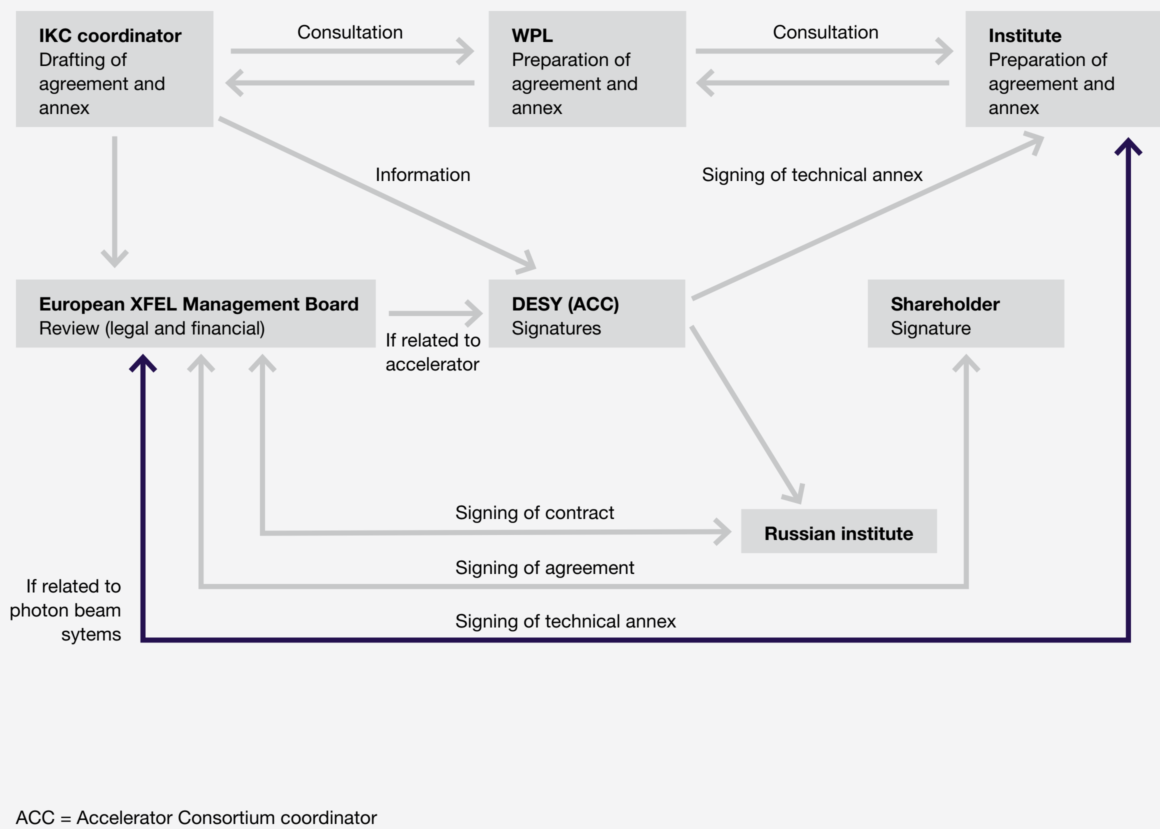


Figure 10 Workflow for preparing contractual documents for an IKC

On the surface, the IKC process sounds extremely complicated and bureaucratic. However, what actually drives the process is the extraordinary motivation of the participating institutes, all of which want to see the facility built successfully. In a number of countries, work has begun and the corresponding investments—sometimes very substantial investments—have been made long before the IKC procedures were completed or the contracts were signed. This spirit of collaboration is a formidable asset to the project. ■

IKC coordinator
Serge Prat

ACCELERATOR CONSORTIUM

The European XFEL is based on the superconducting accelerator technology that was developed by the TESLA collaboration in the 1990s. The facility uses the self-amplified stimulated emission (SASE) free-electron laser (FEL) principle for the production of extremely brilliant photon beams in the 0.1 nm wavelength region. Both the superconducting technology and the SASE principle were successfully demonstrated at lower electron beam energy and longer wavelengths at the Free-Electron Laser in Hamburg (FLASH) facility of Deutsches Elektronen-Synchrotron (DESY).

New accelerator parameters

The European XFEL will comprise a 1.7 km long linear accelerator (linac) made of up to 100 superconducting modules, each of which contains eight accelerator cavities. Inside these cavities, oscillating radio frequency (RF) electromagnetic fields will accelerate bunches of electrons to high energies. The particles will then be directed through long magnet arrangements, called undulators. These undulators cause the electrons to follow a slalom course, which induces them to emit extremely brilliant flashes of X-ray laser radiation.

While the overall coordination of the European XFEL facility, as well as the design and construction of photon beamlines and scientific instruments, is the purview of the European XFEL GmbH, the accelerator complex will be built by an Accelerator Consortium of 16 institutes from 8 countries, coordinated by DESY.

The scenario originally described in the European XFEL technical design report (TDR) is based on an electron beam energy of 17.5 GeV and relatively conservative beam quality parameters: an electron beam emittance of 1.4 mm mrad was assumed at a bunch charge of 1 nC. Extensive computer simulations have demonstrated that lasing at 0.1 nm is achievable with a sufficient safety margin at these electron beam parameters. Both the achievement of much smaller emittances well below 1 mm mrad at the PITZ photo injector test facility at DESY in Zeuthen and the very successful commissioning of the Linac Coherent Light Source (LCLS) at SLAC National Accelerator Laboratory (demonstrating the reliability of simulation codes) allow for a more aggressive strategy. Improved beam quality makes it possible to reach the TDR parameters at reduced electron energies (and thus to save money by shortening the linac) or to extend the performance beyond the shortest wavelength originally foreseen.

Extensive simulations support a new parameter set that features a reduced electron energy of 14 GeV. However, shortening the linac reduces the safety margin and makes a later conversion to continuous wave (CW) operation more expensive: because of reduced acceleration gradients (limited by cryogenics), the conversion would require lengthening the linac at a later date. Although the new parameter set at 14 GeV enables lasing down to a wavelength of 0.05 nm, higher electron beam energies would allow for even shorter photon wavelengths. At this time, the impact of a change in linac length is still being discussed within the project and with the funding authorities.

Building the accelerator

While the overall coordination of the European XFEL facility, as well as the design and construction of photon beamlines and scientific

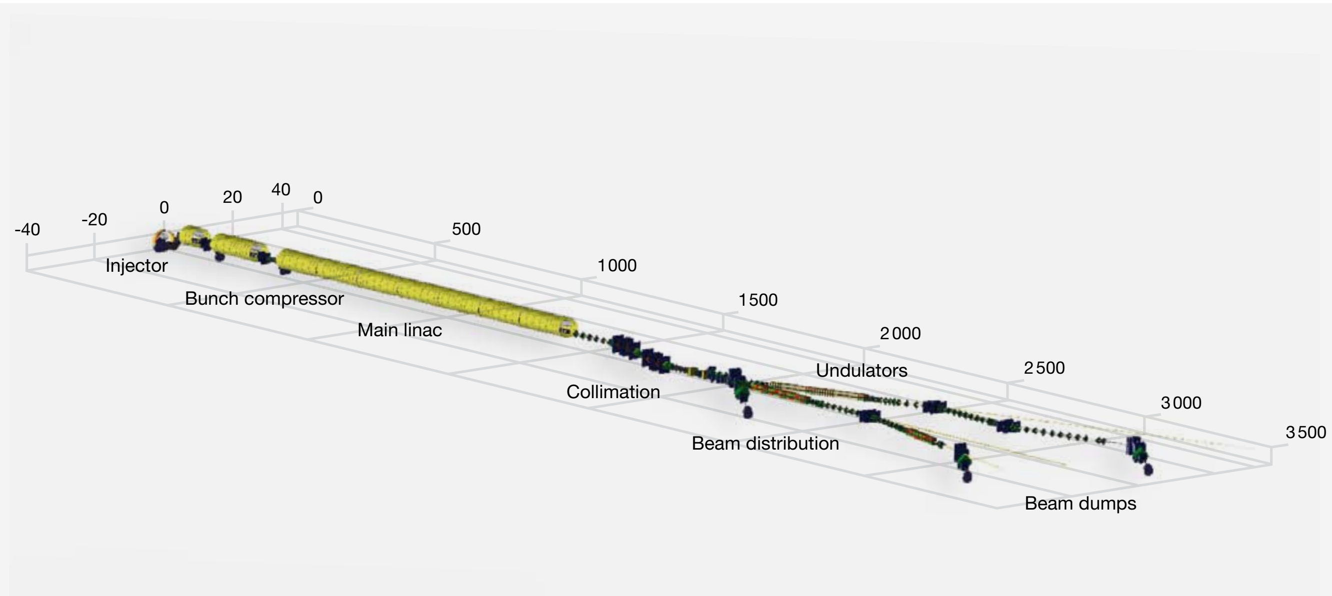


Figure 1 Sixteen institutes contribute to the accelerator complex at the European XFEL facility.

instruments, is the purview of the European XFEL GmbH, the accelerator complex will be built by an Accelerator Consortium. Many partners (Figure 1) have begun setting up infrastructure, and first components are available at each contributing institute. A small DESY team, interacting with all work package leaders and institutes, coordinates the work. All essential responsibilities within the consortium have now been defined.

The accelerator of the European XFEL will be assembled from a large number of superconducting accelerator modules. These modules are contributed by DESY in Hamburg, Commissariat à l’Énergie Atomique et aux Énergies Alternatives (CEA) in Saclay, Centre National de la Recherche Scientifique (CNRS–LAL) in Orsay, Istituto Nazionale di Fisica Nucleare (INFN) in Milano, Andrzej Soltan Institute for Nuclear Studies (IPJ) in Świerk, Henryk Niewodniczański Institute for Nuclear Physics (IFJ-PAN) in Kraków, Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT) in Madrid, and Budker Institute of Nuclear Physics of SB RAS (BINP) in Novosibirsk.

Other institutes are contributing to the roughly 3 000 m of electron beamlines remaining. Warm magnets are being supplied by the D.V. Efremov Scientific Research Institute of Electrophysical Apparatus (NIIEFA) in St. Petersburg and by BINP, and are being measured in part at Stockholm University. The vacuum system is being constructed by DESY and BINP. Magnet power supplies are being delivered by DESY, BINP, and Universidad Politécnica de Madrid. Diagnostic components are being contributed by DESY, the Paul Scherrer Institut (PSI) in Villigen, CEA, the Institute for High Energy Physics (IHEP) in Protvino, and the Institute for Nuclear Research RAS (INR) in Troitsk (Moscow region). The laser heater system is being developed at and delivered by Uppsala University. Beam dumps will be produced by IHEP Protvino. As the host laboratory, DESY will supply large parts of the infrastructure, with Wrocław University of Technology (WUT) and BINP contributing to the cryogenic installation. Some examples of the ongoing activities are provided below.

Clean-room infrastructure

At CEA in Saclay, a new clean-room infrastructure is available for accelerator string and module assembly. The infrastructure includes a large clean room (ISO 7 and ISO 4), and a number of assembly and alignment areas. Colleagues from DESY, CEA in Saclay, and INFN in Milano started the commissioning during the module assembly training: a prototype accelerator module that was built and tested at DESY was shipped to CEA in Saclay, disassembled, and then reassembled to train the future supervisors who will be responsible for the overall module assembly. The assembly of the series of modules will be subcontracted to industry.

Coupler infrastructure

CNRS–LAL in Orsay is responsible for the procurement and conditioning of the RF power coupler attached to each accelerator cavity. The new coupler infrastructure needed for the acceptance tests and conditioning is depicted in Figure 2. It consists of a clean-room area and an RF power station (modulator, pulse transformer, and klystron) shown in the lower right of the figure. The contract for the production of 640 power couplers was placed in late summer 2010.

Figure 2 New CNRS–LAL Orsay infrastructure to be used for the RF power coupler conditioning

Accelerator module test facility

At DESY, a new test area for accelerator cavities and completed accelerator modules is under construction. This accelerator module test facility (AMTF) includes two vertical cryostats for cavity testing and three test stands for module testing, as well as a waveguide assembly and test area (Figure 3). The relatively large hall was finished in May 2010. The first infrastructure is now in place. Commissioning of the facility is scheduled for the end of 2011.

Cavity production

Although some individual accelerator components are still in the prototyping phase, the ordering of important items with long lead times was started in 2010. Two contracts for the production and surface treatment of 300 superconducting niobium cavities each were placed by

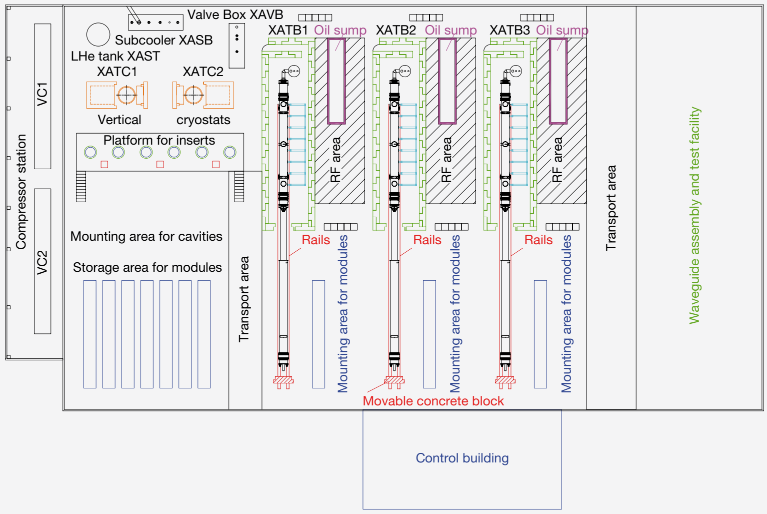


Figure 3 Layout of the new accelerator module test facility at DESY

DESY. The first series cavities will arrive in early 2012. The total production time is two years. Material procurement was taken over by DESY. Contracts will be placed in January 2011.

A receiving inspection process, various quality checks, and a procedure for unmistakable numbering in accordance with the pressure vessel regulations—which have to be applied to the final cavity—were established for approximately 22 000 semi-finished niobium parts. The new infrastructure to perform this very important task was set up at DESY, and is already used for the semi-finished products of the first reference cavities.

Cryostats and power stations

The procurement of cryostats (that is, the cryogenic part and outer shell of the accelerator module) was started in the autumn of 2010. Based on experience with prototypes built during the last two years, four suppliers were qualified for the production. Contracts for the cryostats will be placed after negotiations with the suppliers before the end of February 2011.

The European XFEL accelerator modules will be equipped with waveguide and coupler vacuum systems right after module testing. One of the three prototype accelerator modules at DESY is shown in Figure 4.

Figure 4 Prototype accelerator module at DESY

A total of 22 RF power stations—consisting of a modulator, pulse transformer, and klystron—are needed. The procurement of klystrons has begun. Contracts will be placed in March 2011. For modulators and pulse transformers, the production readiness reviews were prepared in the second half of 2010.

Many partners in the Accelerator Consortium have begun setting up infrastructure, and first components are available at each contributing institute. All essential responsibilities within the consortium have been defined.

Beamline infrastructure

In-kind contributions (see previous article) for warm beamline systems were worked out in a number of contracts. Nearly all warm beamline magnets will be delivered by NIIEFA and BINP. Both institutes are producing first prototypes. Major parts of the vacuum system will be built by BINP. DESY will cover the second half of this system (including pump stations). Beam dumps will be produced by IHEP in Protvino with the support of DESY. In the field of electron beam diagnostics, a number of smaller but important contracts were prepared and partly signed around the end of 2010 (for example, INR in Troitsk and CEA in Saclay). First prototypes of the focusing magnets that will be used in the undulator sections have been produced by BINP and are being measured at Stockholm University. A special setup has been developed that enables the accurate determination of the magnetic axis of the magnets, an important prerequisite to achieving the required electron trajectory straightness in the undulators. All 127 quadrupole magnets will be produced and measured by mid-2012.

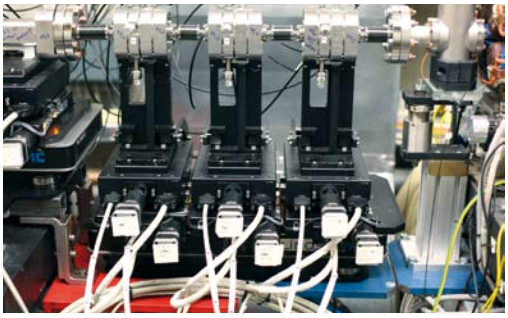


Figure 5 Three cavity BPM prototypes installed on translation stages in FLASH

In addition to the magnetic axis of the quadrupole, the electron beam trajectory must be measured with an accuracy of 1 μm. Such measurements are done using cavity beam position monitors (BPMs), which are being developed as a collaborative effort by DESY and PSI in Villigen. Three BPM prototypes have been installed in the FLASH facility at DESY, as shown in Figure 5. Recent measurements with a first version of the readout electronics demonstrate that the ambitious resolution goal can be reached.

Cryogenic infrastructure

The work on the cryogenic system is proceeding. DESY will soon contract the refurbishing and adaptation of the existing refrigerator to the needs of the European XFEL project. Cryogenic transfer lines and boxes will be delivered by IHEP Protvino and Wrocław University. Test benches for the AMTF are being built at BINP in Novosibirsk.

Figure 6 Transport vehicle for the pulse transformer

Technical infrastructure

During 2010, emphasis was placed on defining the technical infrastructure for all accelerator sections (that is, tunnels, shafts, and above-ground buildings). The European XFEL technical coordinator interacted with all work packages involved in the different accelerator systems. Responsibilities for infrastructure setup and component installation, as well as installation procedures, were defined and some of the first equipment arrived at DESY.

Installation in the accelerator tunnel requires special tooling. The vehicle shown in Figure 6 will be used to transport the pulse transformer to its final position in the main linac tunnel. ■

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04

PHOTON BEAM SYSTEMS

■ At the European XFEL, X-ray pulses are generated in long arrays of magnets, designed by the Undulator Systems group. Predicting the properties of the X-ray beams is the task of the Simulation of Photon Fields group. The X-Ray Optics and Beam Transport group is constructing the systems to transport the pulses to the experiment hall. The task of the X-Ray Photon Diagnostics group is to build the devices to measure the properties of the photon pulses.

UNDULATOR SYSTEMS

To produce coherent, ultrabright X-ray beams, accelerated electrons are directed through long arrays of magnets, known as undulators. The magnetic fields they generate force the particles to follow a slalom trajectory, thereby inducing them to emit intense pulses of X-ray radiation. These large and demanding devices, which will be mass-produced by industry for the European XFEL, are being designed by the Undulator Systems group.

Long systems for short wavelengths

Undulator systems play an important role for the European XFEL: they provide the periodically oscillating transverse magnetic field that enables the self-amplified spontaneous emission (SASE) process to take place. For the European XFEL, these systems have to be very long. To obtain wavelengths shorter than one Ångström (Å), a system length in excess of 200 m is required.

For reasons of technical feasibility, the systems need to be subdivided. A length of 5 m was found to be the best for each individual undulator segment, or section, which is followed by a 1.1 m long intersection. Such a unit of section and intersection is called an undulator cell. Every intersection comprises a quadrupole magnet on a moving support, a beam position monitor, a phase shifter, air coil correctors, a radiation absorber, and a vacuum pump. A small cutout of an undulator system is shown schematically in Figure 1.

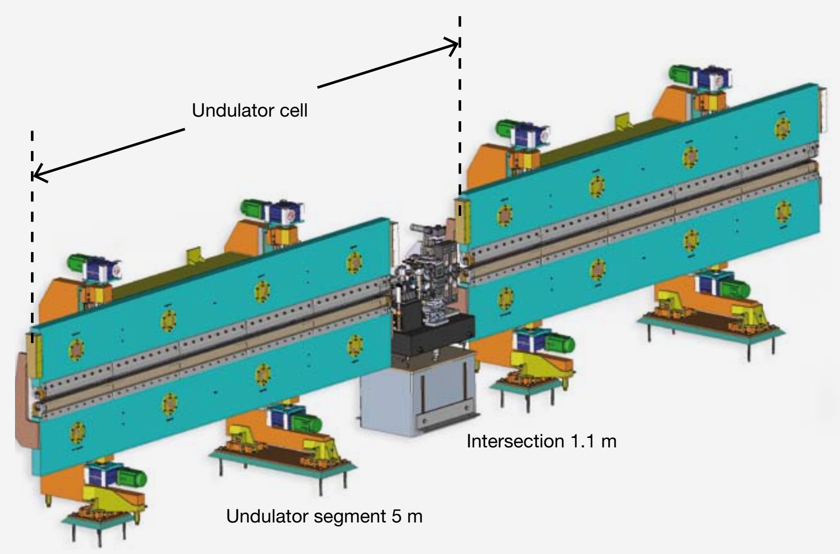


Figure 1 Cutout of an undulator system for the European XFEL. The undulator systems will be composed of up to 35 cells with a total length of 213.5 m.

Establishing design criteria

Technologically, the undulator segments are the most demanding. The first preliminary design specifications were developed in 2004, when some of the fundamental criteria for these systems became clear.

These criteria include the following:
- Design parameters that enable us to safely attain wavelengths of 1 Å and below. This criterion relates to the use of well-proven permanent magnet technology, as well as the choice of a sufficiently large magnet gap and vacuum chamber aperture to minimize the effects of wake fields and the exposure of the magnets to radiation damage.
- High reliability of each system, to allow for the simultaneous operation of a large number of undulator segments. This criterion is a must for any user operation.
- Standardization of all mechanical and magnetic components and their specifications.
- Optimization of the undulator systems for large-scale production in collaboration with industrial suppliers.

The last two points minimize the design effort, allow for cost-effective production, and, after commissioning, will facilitate operation and maintenance.

The undulator systems are a unique combination of high-precision mechanical engineering, motion-control technology, with typical accuracies of ±1 μm, and permanent magnet technology based on NdFeB and using the most advanced materials available.

Designing undulator segments with DESY

From the beginning, in 2004, undulator segments were developed in a joint and synergetic effort by the European XFEL and the PETRA III project at Deutsches Elektronen-Synchrotron (DESY). PETRA III was a great opportunity for the European XFEL: the undulators required for PETRA III enabled design optimization and provided initial experience with the production of a small series. Today, the same undulator technology is used in both projects.

The undulator systems are a unique combination of high-precision mechanical engineering, motion-control technology, with typical accuracies of ±1 μm, and permanent magnet technology based on NdFeB and using the most advanced materials available. The standard design is quite flexible. It is straightforward to accommodate magnet structures with different period lengths.

Revising parameters based on LCLS experience

In the startup phase of the European XFEL, there will be three undulator systems, named SASE1, SASE2, and SASE3. SASE1 and SASE2 will cover the hard X-ray range around 1 Å. In contrast, the focus of SASE3 will be the soft X-ray range up to 52 Å.

The very successful commissioning of the Linac Coherent Light Source (LCLS) at SLAC National Accelerator Laboratory in 2009 had a great impact on the European XFEL undulator systems and resulted in a new and extended definition of the European XFEL wavelength ranges. For SASE1 and SASE2, the longest wavelength at the minimum gap of 10 mm is now 3 Å. The shortest attainable wavelength is determined by the length of the undulator systems and by the electron beam properties. Although the European XFEL can be operated at electron beam energies ranging from about 10 GeV to a maximum of 17.5 GeV, the nominal energy of 14 GeV was chosen to optimize the SASE1 and SASE2 parameters. This process resulted in an undulator period length (λ_0) of 40 mm. For SASE3, with λ_0 = 68 mm, the longest radiation wavelength requested by users is 52 Å, which can be obtained only at 10 GeV.

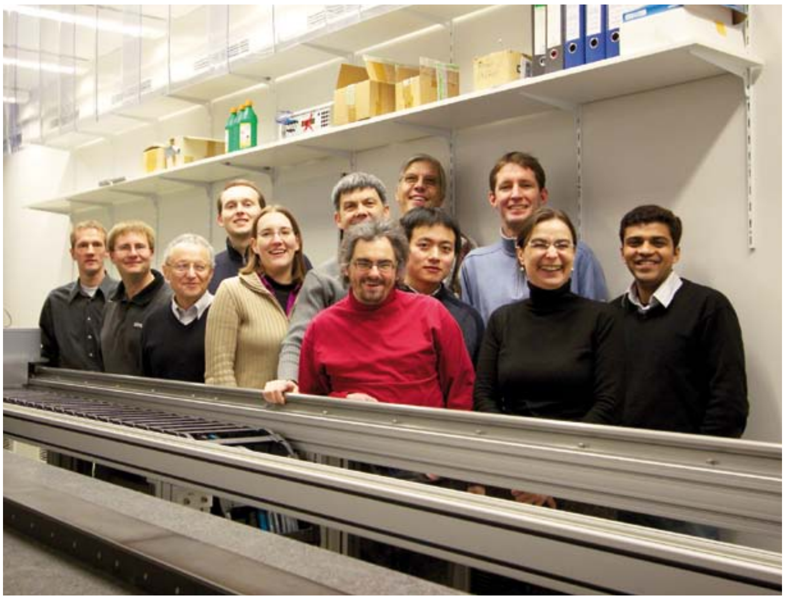
	E [GeV]	λ_R [Å]	λ_0 [mm]	Gap [mm]	B_{Max} [T]	K_{Max}	β_0 [m]	N_{Tot}	L_{Mag} [m]	L_{Tot}
	10	1.1–5.7		22–10						
SASE1	14	0.75–3	40	19–10	1.2	4.43	32–15	35	175	213.5
	17.5	0.72–1.9		15.5–10						
	10	1–5.7		23–10						
SASE2	14	0.65–3	40	20–10	1.2	4.43	46–15	35	175	213.5
	17.5	0.55–1.9		17.5–10						
	10	2.5–52		40–10						
SASE3	14	2–26	68	33–10	1.7	10.75	15	21	105	128.1
	17.5	2–17		29–10						
Total								**91**	**455**	**555.1**

Table 1 Undulator system parameters and wavelength ranges for the European XFEL.
Electron beam parameters: ε_n = 0.6 µm, ΔE = 2.6 MeV, I_p = 3.0 kA, Q = 0.25 nC

Table 1 provides an overview of the three undulator systems and their properties. The range of the radiation wavelength (λ_R), the undulator period (λ_0), the gap range, the peak field (B_{Max}), the maximum K parameter at a 10 mm gap, the range of the beta function (β_0), the number of undulator cells (N_{Tot}), the net magnetic length (L_{Mag}), and the total length of the undulator system (L_{Tot}) are listed at beam energies of 10, 14, and 17.5 GeV, and at the values for the normalized emittance (ε_n), energy spread (ΔE), peak current (I_p), and bunch charge (Q) specified in the caption of Table 1. In addition, some total numbers for the three undulators are listed at the bottom of the table. The electron beam parameters shown in the caption are conservative numbers. They have a strong impact on the short wavelength limits for SASE1 and SASE2.

Preparing for the future

During 2010, the construction of the so-called pre-series prototypes was started. These are the first undulator segments to not only make use of the undulator development described above, but to use the parameters specific to the European XFEL, as shown in Table 1. Four prototypes with λ_0 = 40 mm (U40s) and two prototypes with λ_0 = 68 mm (U68s) are under construction and will be finished by mid-2011. There will be a test and evaluation phase of about six months, which gives a last chance to implement design changes and improvements. Serial production of the large numbers of devices specified in Table 1 will begin in 2012.



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SIMULATION OF PHOTON FIELDS

The task of the Simulation of Photon Fields (SPF) group is to understand and predict the properties of the photon beams produced by the undulators of the European XFEL. This work is indispensable to the design of the optical components for the beamlines, of the diagnostics systems, and of the instruments themselves. The deep understanding of the free-electron laser (FEL) process that the SPF group aims to provide is also a condition for future improvements and developments.

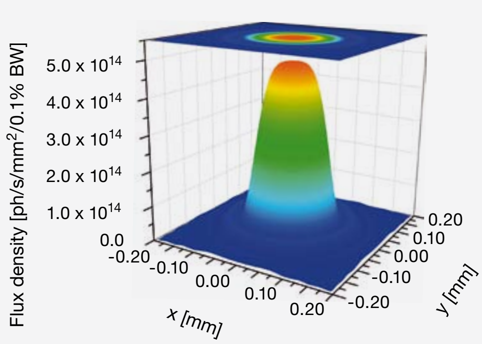

Figure 1 Together with numerical techniques, analytical techniques helped in the benchmark process. This example shows analytical calculations of the near-zone spatial flux density for the fundamental harmonic for a filament beam, referring to a particular benchmark case.

Simulating spontaneous radiation

In 2010, the SPF group began activities related to simulations of spontaneous radiation (SR) from the baseline European XFEL undulators. Aside from the main FEL signal, it is also important to quantitatively describe SR emission at X-ray FEL facilities. SR emission defines the background signal for FEL measurements and contributes to heat-loading that must be accounted for in the design of optical components for beamlines. It is also used in photon-beam-based alignment (PBBA) procedures.

To begin to address these issues, the SPF group did the following:

- Began R&D activities to develop a novel, well-documented software tool for SR studies that will take into account the unique characteristics of the baseline European XFEL setup (see "Developing SR simulation software")
- Collaborated with the X-Ray Optics and Transport group to estimate heat-loading contributions (see "Estimating heat-loading contributions")
- Collaborated with the X-Ray Photon Diagnostics group to study PBBA procedures (see "Studying PBBA procedures")

Progress on each on each of these efforts is described below.

Developing SR simulation software

To simulate SR properly, a software tool must make allowances for emittance effects because the ratio of the geometrical emittance to the reduced X-ray wavelength is of the order of unity. However, the presence of a focusing lattice at the European XFEL baseline means that the typical folding procedures to calculate radiation properties cannot be used. Quantum diffusion of the energy spread should be taken into account as well because its contribution to the relative energy spread is comparable to the relative bandwidth of the central cone. For similar reasons, energy losses of electrons due to radiation should be included in the simulation as well.

To resolve these issues, the SPF group first performed a benchmark of existing simulation codes to assess best practices with the help of numerical and analytical techniques (Figure 1). Because no simulation tool could account for all of the above-mentioned effects, the group decided to begin R&D collaboration with the creator of the Synchrotron Radiation Workshop (SRW) code, O. Chubar, at the Brookhaven National Laboratory (BNL) in the USA. This cooperation aims at providing a C++ library to be used, together with algorithms to be developed at the European XFEL, to create a simulation tool capable of modelling the specific properties of the facility’s spontaneous radiation output. The project is under way. An independent cooperation with N. Smolyakov and S. Tomin at the Kurchatov Institute in Russia on alternative routines for SR calculations was also started in the framework of a bilateral cooperation between Germany and Russia.

When the simulation tool is ready, the issue of how to check the validity of obtained results will arise. To this end, a future cooperation with M. Scheer at the Helmholtz-Zentrum Berlin (HZB) in Germany has been defined to cross-check with the WAVE code, which is also being upgraded, and to exchange useful information.

Estimating heat-loading contributions

The SPF group cooperated with the X-Ray Optics and Beam Transport group to create a tool that would estimate the total heat load induced by spontaneous radiation on an aperture at a given distance from the source. To estimate heat-loading effects, the two groups modelled the undulator output as the sum of contributions from a number of dipoles. The SPF group supervised the writing of a Mathematica script, and cross-checked it with the SPECTRA and SRW codes, using both wiggler and undulator integration methods.

In close cooperation with DESY, the SPF group also devised novel schemes to enable enhanced output characteristics of the free-electron laser with minimal modifications to the baseline European XFEL undulator setup.

Studying PBBA procedures

A collaboration with the X-Ray Photon Diagnostics group started and is currently under way. The aim is to perform numerical and analytical studies on the characteristics of spontaneous radiation that are of particular relevance in PBBA techniques. The two groups began a feasibility analysis of methods based on spatial profiles. They also investigated a two-segment and kicker scheme for determining the difference in the undulator *K* parameter between different segments.

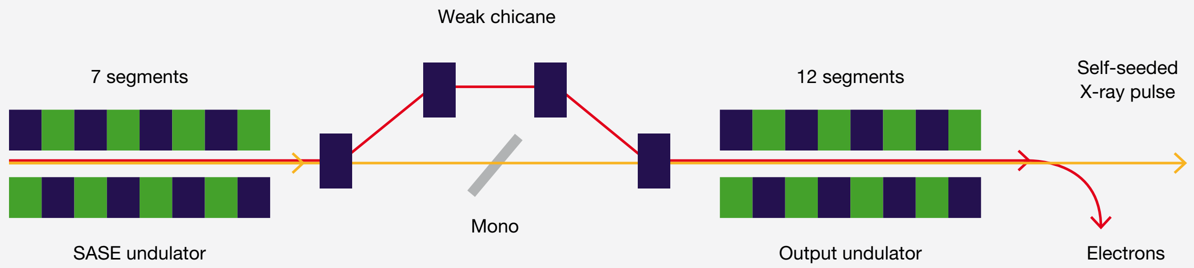

Figure 2 Self-seeding setup with a single-crystal monochromator, a two-undulator configuration, and a SASE2 beamline

Enhancing output characteristics

In 2010, the SPF group was also involved in developing novel schemes to enable enhanced output characteristics with minimal modifications to the baseline undulator setup. These schemes were devised in close cooperation with Deutsches Elektronen-Synchrotron (DESY), together with V. Kocharyan and E. Saldin. Among other things, we investigated the possibility of generating self-amplified spontaneous emission (SASE) pulses of several colours, controlling the spectral width of the output radiation up to the Fourier limit, and controlling the polarization properties of the SASE radiation.

One of these ideas is a self-seeding technique [1] that enables nearly Fourier-limited pulses of radiation, and that, in contrast to previously proposed self-seeding setups, requires minimal modifications of the baseline setup of the European XFEL. Our proposed setup (Figure 2) consists of an input undulator and an output undulator separated by a short (5 m long) magnetic chicane. The chicane creates a small (several mm) transverse offset, removes the electron beam microbunching produced in the first undulator, and acts as a tunable delay line for the electrons. The input undulator operates in the linear high-gain regime starting from the shot noise in the electron beam. After the first undulator, electrons and radiation are separated by the chicane, and the radiation goes through a crystal set for Bragg diffraction, which is introduced in the transverse offset created by the chicane. The crystal operates as a bandstop filter for the transmitted X-ray SASE radiation pulse (Figure 3 [2]). As a consequence, the temporal waveform of the transmitted radiation

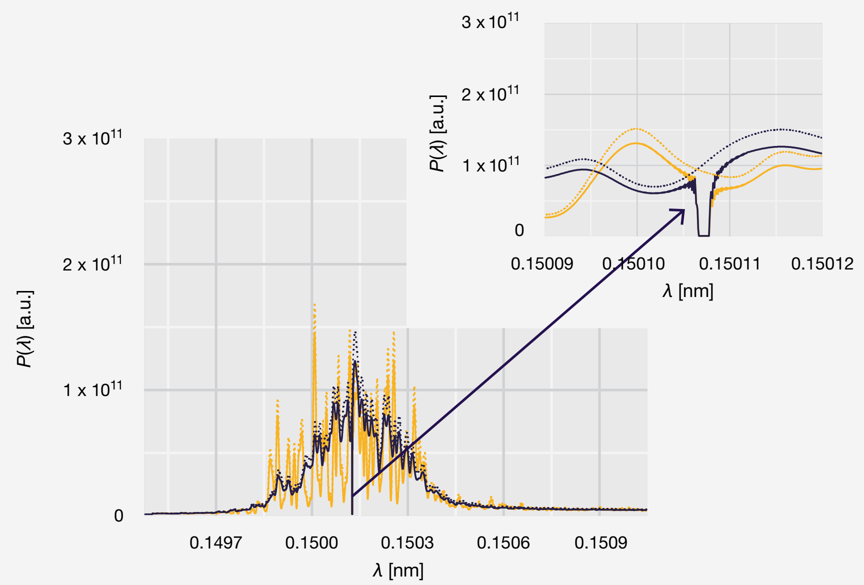

Figure 3 Average output spectrum after the diamond crystal (violet solid line) and a typical shot (orange solid line) for the setup described in Figure 2. The bandstop effect is clearly visible and highlighted in the inset. For comparison purposes, the average spectrum before the diamond crystal (violet dotted line) and a typical shot (orange dotted line) are also shown.

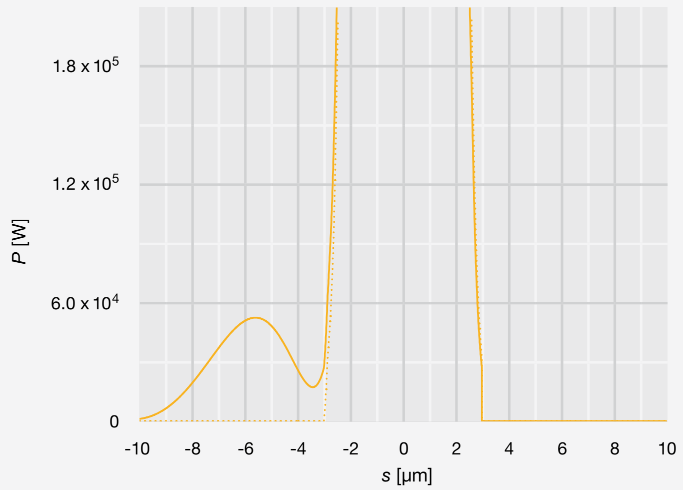

Figure 4 Power distribution before (dotted line) and after (solid line) transmission through the crystal for the setup described in Figure 2. The monochromatic tail due to the transmission through the bandstop filter is evident at the left of the figure.

pulse shows a long monochromatic tail (Figure 4 [2]) whose duration is inversely proportional to the bandwidth of the absorption line in the transmittance spectrum. The magnetic chicane shifts the electron bunch on top of the monochromatic tail created by the bandstop filter, thus selecting (through temporal windowing) a part of it. By this, the electron bunch is seeded with a radiation pulse characterized by a bandwidth much narrower than the natural FEL bandwidth, and the output of the second undulator is a temporally coherent X-ray pulse. This scheme is currently under consideration by the European XFEL and other facilities around the world.

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X-RAY OPTICS AND BEAM TRANSPORT

To enable scientists to perform X-ray free-electron laser (FEL) experiments, the pulses generated in the undulators must be transported to the experiment hall in a way that preserves their qualities and, at least in some cases, focuses and converts them into a beam containing only a narrow band of wavelengths. The task of the X-Ray Optics and Beam Transport group is to design and build the corresponding systems.

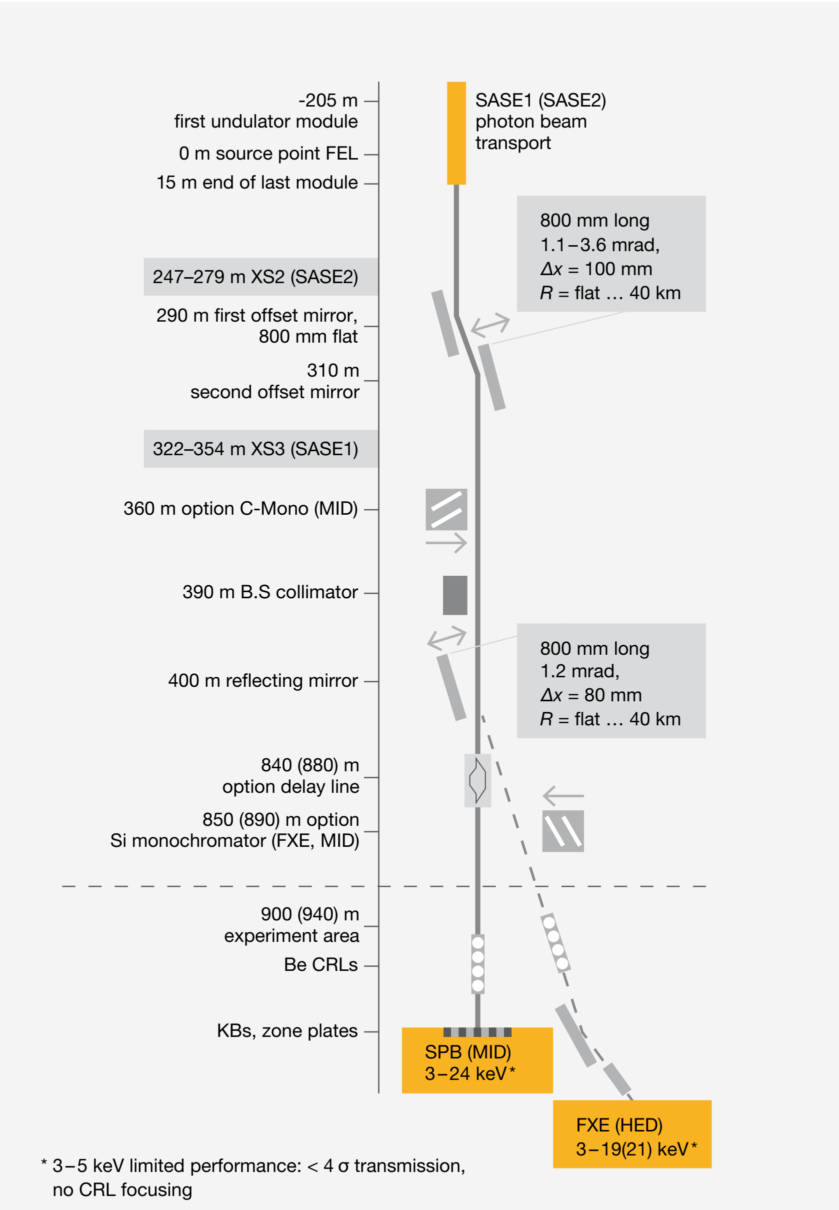


Figure 1 Conceptual layout of X-ray beam transport systems for SASE1 and SASE2. The shaft buildings XS2 and XS3 separate electron tunnels from photon tunnels.

Optimizing FEL beams

The European XFEL will deliver up to 2700 X-ray pulses within trains of 0.6 ms. The energy per pulse can reach 1 to 10 mJ, corresponding to a power of 4.5 to 45 kW averaged over one pulse train. The primary challenges for the beam transport systems are to withstand the peak power of individual X-ray pulses, to sustain the average heat load during pulse trains while maintaining wavefront properties of the FEL beam, and to transmit a maximum possible number of photons. In the startup phase of the facility, there will be three X-ray beam transport systems, named SASE1, SASE2, and SASE3. The current conceptual design of the SASE1 and SASE2 systems, which enable transmission from 3 to 24 keV, is shown in Figure 1.

Withstanding high-energy X-ray pulses

A few hundred metres after the undulator, the survival of optics exposed to single pulses (for example, during commissioning activities) can be assured by choosing light materials with low atomic numbers. For example, 280 m from the SASE1 source point, a single X-ray pulse (9 keV, 1.5 μrad FWHM divergence, 3 mJ pulse energy) will heat up a piece of graphite or boron carbide by 3°C. However, copper and platinum would be heated by a single pulse close to melting conditions with 1100 °C and 1600 °C, respectively.

Therefore, all parts of the photon beam transport systems that can be exposed to the direct FEL beam have to be made out of light materials ($Z \leq 14$) for the hard X-ray beamlines, and out of graphite or boron carbide ($Z \leq 6$) for the soft X-ray beamlines. Total reflection geometry can be used on X-ray mirrors to reduce the single-pulse damage, in part also because of heat removal by photoelectrons.

For the optics to withstand entire pulse trains, the heat accumulated from many pulses has to be either conducted away on the microsecond time scale, or buffered in the material and removed in between pulse trains. The first mechanism can be improved by grazing incidence geometry, the second by a sufficiently large buffer volume. For example, a water-cooled block of boron carbide changes its thermal function from a heat conductor at low photon energies to a heat buffer for hard X-rays. This concept is used in the design of apertures (for example, in front of mirrors).

The primary challenges for the beam transport systems are to withstand the peak power of individual X-ray pulses, to sustain the average heat load during pulse trains while maintaining wavefront properties of the FEL beam, and to transmit a maximum possible number of photons.

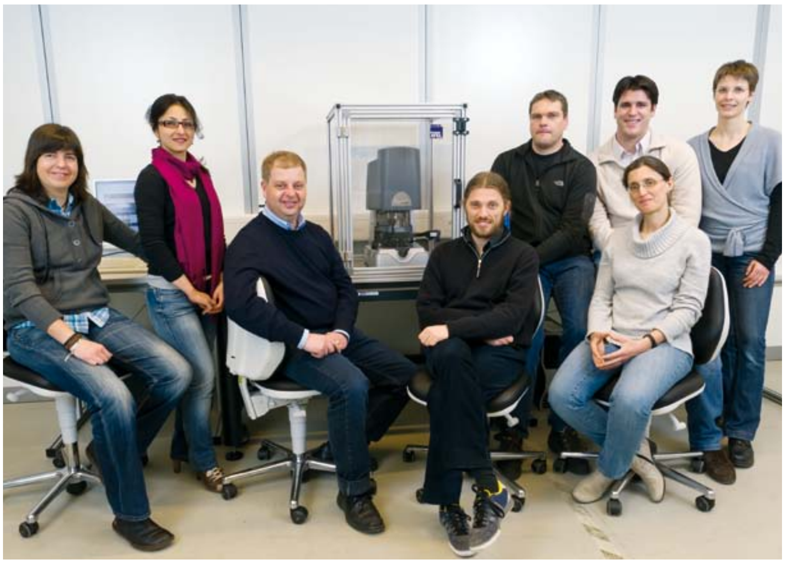
Apart from FEL radiation, the undulators also generate spontaneous radiation, leading to heat loads that can exceed the FEL power. However, this radiation is spread out over larger solid angles and higher photon energies up to around 200 keV. Because this very hard X-ray radiation will not be reflected by the mirrors, it leads to static and dynamic deformation of the first mirror in each beamline. Finite elements analysis (FEA) calculations for the first mirrors in the SASE1 and SASE2 beamlines indicate that static deformations can be reduced to about 10 nm, plus a 2 to 3 nm dynamic deformation of the mirror surface, if the spontaneous radiation is carefully apertured and the cooling geometry optimized.

Maintaining wavefront properties

Despite thermal deformations, requirements on mirror surfaces to preserve the wavefront and a homogeneous intensity distribution of the FEL radiation are extremely demanding: a peak-to-valley profile error of 2 nm or better over a mirror length of 800 mm is required to keep distortions within acceptable levels. To control the beam size throughout the beam transport system and to compensate for static heat-load deformations, the curvatures of the second offset mirrors and distribution mirrors have to be controlled with nanometre accuracy as well. All mirror deflections of the beam transport systems are chosen in the horizontal scattering plane to minimize distortions from gravitation and also to enable focusing onto the distribution mirrors.

Focusing beams

The experiment hall is located about 1 000 m from the SASE1 and SASE2 undulators and about 400 m from SASE3. This location results in relatively large beam diameters at the experiments, ranging from about 1 mm in diameter at the highest X-ray energies to more than 10 mm for the longest wavelengths at SASE3. Because most experiments will require a focused beam, developing focusing optics with large spatial acceptance will be a major challenge for the X-ray optics. Besides long Kirkpatrick-Baez-type (ellipsoidal) mirror systems, the use of multilayer optics and single-crystal optics could provide possible solutions. To enable sub-micrometre focusing, diamond-based zone plates with large apertures are currently being developed as a Swedish in-kind contribution from the KTH Royal Institute of Technology in Stockholm.



Group members
Idoia Freijo-Martín, Shafagh Dastjani Farahani, Harald Sinn (group leader), Jérôme Gaudin, Martin Dommach, Germano Galasso, Liubov Samoylova, Antje Trapp, Nicole Kohlstrunk (not shown), and Fan Yang (not shown)

X-RAY PHOTON DIAGNOSTICS

To perform most experiments, it is essential to know the properties (for example, intensity, position, and timing) of each incoming photon pulse. This knowledge is especially important when working at a self-amplified stimulated emission (SASE) free-electron laser (FEL) source, where each pulse is different because the SASE process originates from noise. The task of the X-Ray Photon Diagnostics group is to design, build, and later operate the devices to measure these photon pulse properties.

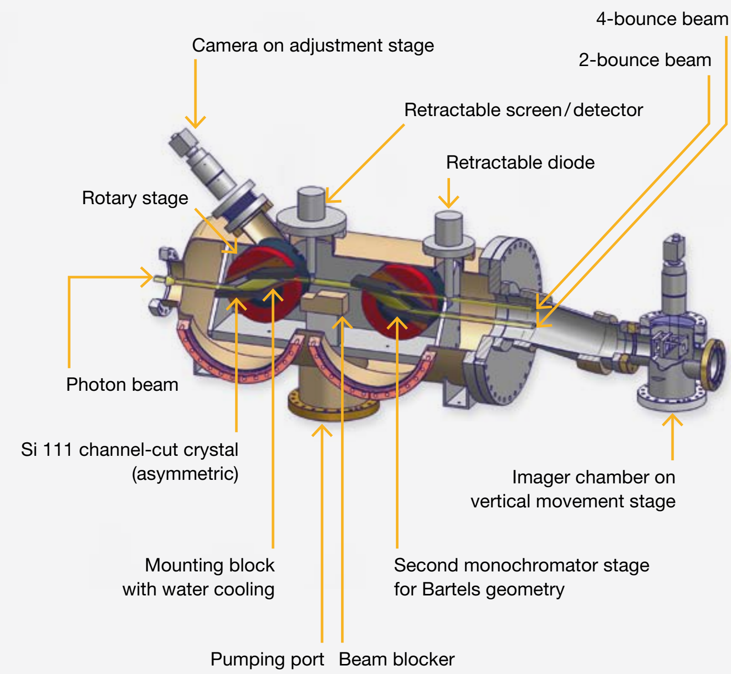


Figure 1 Conceptual design of the undulator commissioning spectrometer

Conceptual design of the undulator commissioning spectrometer

Photon-based commissioning of the European XFEL undulators will require a precise adjustment of the *K* parameters of all undulator segments and of their relative phasing. To achieve this, the undulator commissioning spectrometer must cover a large wavelength range because of the large gap setting range of the undulators and variable electron energy working points. It will analyse spontaneous radiation either from individual segments, or from multiple segments to all segments. To apply the spectrometer to the soft X-ray region of SASE3, the use of third- and fifth-order harmonics is planned.

Setup of the spectrometer:
Two channel-cut silicon (111) crystal pairs mounted on high-precision in-vacuum rotary stages (Figure 1) select the wavelength of the incoming beam. The use of higher-order crystal reflections (333 and 444) increases the usable wavelength range and energy resolution. In front of the spectrometer, attenuators for intensity adaptation and energy filters (*K*-edge absorption) for energy calibration are foreseen.

International workshop on X-ray photon diagnostics

In February 2010, an international workshop was organized in Ryn, Poland, by the European XFEL, with the support of the Pre-XFEL European grant, to bring together X-ray diagnostics experts and the user community. Parameters, requirements, and methods were reviewed.

To see the results of the discussions documented in three working group reports, go to the following location:

www.xfel.eu/events/workshops/2010
/x_ray_diagnostics_and_scientific_application_workshop

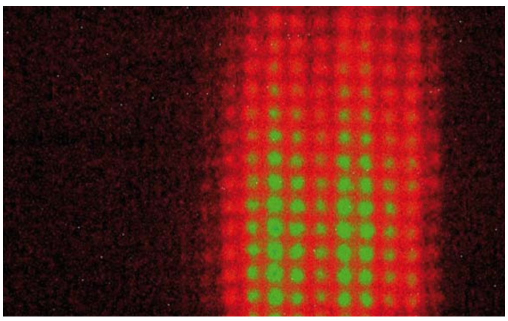


Figure 2 Photon beam image using an interferometer with a 2D grating

Figure 3 Joint SLAC, PSI, and European XFEL team of the LCLS beamtime L221 at XPP

Single-shot wavefront sensing using a grating interferometer

Using a Moiré technique, complete wavefront information can be recorded with an angular sensitivity down to 10 nrad, corresponding to hard X-ray wavefront distortions smaller than $\lambda/10$. In collaboration with the X-Ray Optics and Beam Transport group, as well as the team of Christian David at the Paul Scherrer Institute (PSI) in Switzerland, we applied this technique at the X-ray pump-probe (XPP) instrument of the Linac Coherent Light Source (LCLS) at SLAC National Accelerator Laboratory in the USA to determine the wavefront of the FEL itself, evaluate disturbing effects of additional optics, and calculate the transverse and longitudinal photon source position in the undulator. By measuring the divergent beam behind a refractive focusing device, the focal spot size and the wavefront in the beam waist can be established. It is important to emphasize that this technique works even for single FEL shots.

XGMD at LCLS and SCSS

In September 2010, a contract was signed that formally established the ongoing collaboration between the European XFEL and the Hamburg Synchrotron Radiation Laboratory (HASYLAB) at Deutsches Elektronen-Synchrotron (DESY) in the domain of photon diagnostics. The team at HASYLAB led by K. Tiedtke will build gas-based intensity and position monitors—X-ray gas monitor detectors (XGMD) and X-ray beam position monitors (XBPM)—for the European XFEL facility. The last two years saw the commissioning of the test accelerator EUV-FEL of the Super Photon ring-8 GeV (SPring-8) Compact SASE Source (SCSS) in Japan and the X-ray free-electron laser LCLS in the USA. These commissionings triggered a series of round-robin tests by the HASYLAB group, comparing the Free-Electron Laser in Hamburg (FLASH), LCLS, and SPring-8 pulse intensity detectors. The 2010 comparison at SCSS was carried out between the new stand-alone upgrade of the FLASH gas monitor detector and the Japanese National Institute of Advanced Industrial Science and Technology (AIST) cryogenic radiometer, revealing that average radiant power values obtained with the two detectors agree within 3.6%. This percentage is well below their combined relative standard uncertainty, which varies from 4.1% to 5.5%.

Diamond detectors at SLS

Single-crystal chemical vapour deposition (CVD) diamond is a promising material not only for X-ray FEL optics (for example, monochromators), but also as a transmissive diagnostic detector, thanks to its excellent electronic properties and the high transmission at X-ray FEL energies. Its electron mobility (4 500 cm^2/Vs) is the highest among all wide-band-gap semiconductors. In collaboration with the French Atomic Energy Commission (CEA) in Saclay, two devices were tested in the µXAS beamline at the Swiss Light Source (SLS) at PSI.

Photon-based commissioning of the European XFEL undulators will require a precise adjustment of the *K* parameters of all undulator segments and of their relative phasing. To achieve this, the undulator commissioning spectrometer must cover a large wavelength range.

An I_0 monitor recorded the incoming X-ray intensity in transmission, in a mode uncommon to most synchrotron experiments: time-resolving a

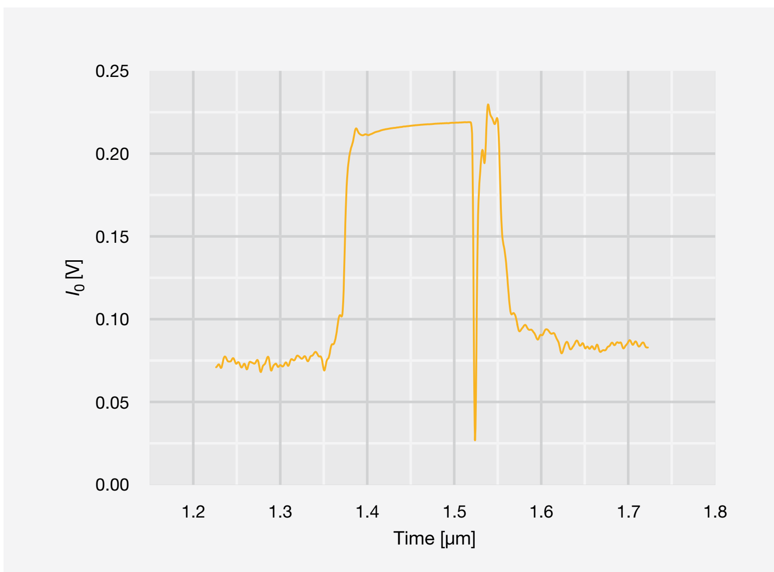


Figure 4 X-ray intensity signal measured by a partially transmissive diamond detector, nicely resolving the single "cam shaft" (with 200 MHz bandwidth pre-amplifier)

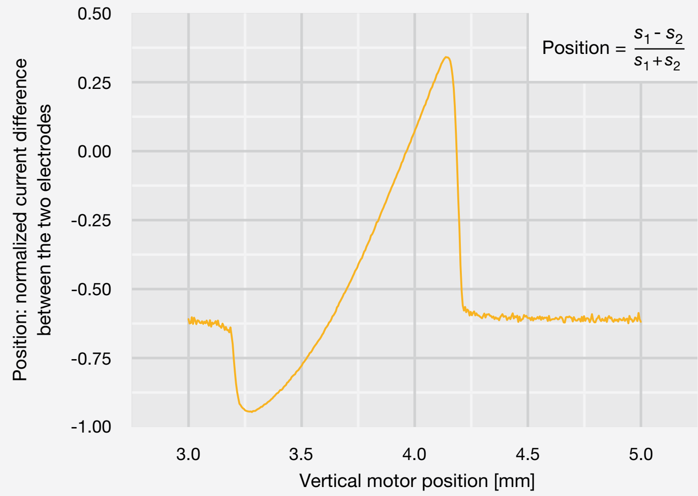


Figure 5 Signal of the position-sensitive detector (PSD): normalized current difference in the two electrodes during motor movement ($s_{1,2}$ = currents in the electrodes)

single bunch (Figure 4). A position-sensitive device (PSD) monitored the position of the X-ray beam by the ratio of electric current at two opposite electrodes (Figure 5). Thanks to their high X-ray transmission, both devices could be operated in front of and simultaneous to the actual experiment. ■

Group members
Wolfgang Freund, Bin Li, Jan Grünert (group leader), Cigdem Ozkan (since February 2011), and Jens Buck

05

SCIENTIFIC INSTRUMENTS

■ In its startup version, the European XFEL facility will comprise six scientific instruments. Leading positions for three of the groups in charge of these instruments have been filled: the Femtosecond X-Ray Experiments (FXE) instrument, the Single Particles, Clusters, and Biomolecules (SPB) instrument, and the Small Quantum Systems (SQS) instrument. The recruiting process for the other instruments continues.

SCIENTIFIC INSTRUMENT FXE

The Femtosecond X-Ray Experiments (FXE) instrument is designed to perform time-resolved pump-and-probe experiments on an ultrafast time scale. The FXE group is currently using laboratory laser sources, synchrotron sources, and the Linac Coherent Light Source (LCLS) at SLAC National Accelerator Laboratory to test new strategies and acquire hands-on experience with FEL X-ray pump-and-probe measurements.

Preparing the way

The mission of the FXE group is to identify and implement the best possible instrumentation that will permit groundbreaking research after inauguration of the FXE instrument in 2015.

For this ambitious goal, the FXE group needs to do the following:

- Collaborate with leading science groups worldwide.
- Develop and maintain world-class expertise in the field of chemical dynamics.
- Identify future problems in chemical and biological dynamics and ultrafast research that can be tackled at the European XFEL in 2015 and beyond.
- Exploit the unique properties of the European XFEL facility, unmatched by current and upcoming sources of X-ray free-electron laser (FEL) radiation.

Setting up the laser lab

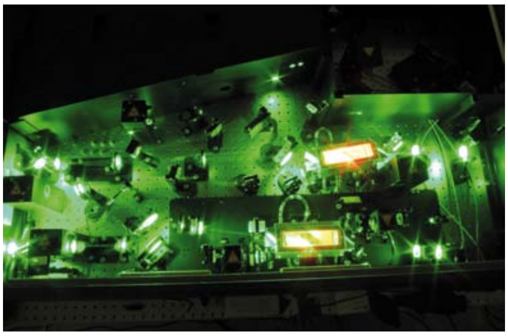


Figure 1 Amplification stage of the 3 kHz femtosecond laser system

In 2010, the FXE group was established with three members, who, together with the X-Ray Optics and Beam Transport group, began setting up the new European XFEL laser laboratory in the PETRA III experiment hall. The laser lab, which is operated together with the Small Quantum Systems (SQS) group, now includes 60 m^2 of surface area, air conditioning, lights, electricity, a functioning 3 kHz / 3 mJ Ti:Sapphire femtosecond laser system (Figure 1), and some associated optics and equipment. Early in 2011, it will be equipped with an optical parametric amplifier (OPA) for wavelengths covering the entire UV/vis-NIR range. This complementary research with femtosecond lasers is vital to the mission of the FXE group. Next to the mandatory laser characterization under the pump-probe conditions utilized later at pulsed X-ray sources, it is also important to apply ultrafast optical laser sources to obtain the complementary information about ultrafast processes that do *not* require X-ray FEL radiation.

Combining structural tools

A scientific workshop was held in December 2009 to identify key research fields of interest for the future FXE instrument. One targeted outcome was to investigate in detail the elementary steps in photochemical reactivity in disordered systems. The workshop participants presented different structural tools, such as X-ray diffraction (XRD), X-ray absorption (XAS), and X-ray emission (XES).

Each tool reveals a different property in the system under investigation: that is, the global geometric structure (XRD), the local geometric and electronic unoccupied valence structure (XAS), and the local electronic occupied valence structure together with the spin state (XES). Combining such tools in one single scientific instrument could thus boost our understanding by delivering a uniquely rich "motion picture" of the elementary steps in chemical activity, which is a prime goal for the FXE instrument. As a first step, the FXE group performed and published, in collaboration with its external partners, the first sub-nanosecond time-resolved X-ray emission spectrum of a light-driven spin transition process [1], which proves that the methodology can be extended into the ultrafast time domain.

Combining different structural tools—such as X-ray diffraction (XRD), X-ray absorption (XAS), and X-ray emission (XES)—in one single scientific instrument could boost our understanding by delivering a uniquely rich "motion picture" of the elementary steps in chemical activity, which is a prime goal for the FXE instrument.

From January to May 2010, a collaboration—which included research groups at the University of Copenhagen and Lund University—was initiated on the topic of ultrafast dynamics exploiting complementary structural tools (UDECS). This collaborative group held two meetings, in May and December 2010, to prepare joint proposals at the X-ray pump-probe (XPP) instrument of LCLS, and to coordinate joint experiments at PETRA III, Beamline P011, and at the Advanced Photon Source (APS), Sector 7.

These experiments, which will commence in 2011, seek to combine XRD with X-ray spectroscopy tools to investigate the local and more global structural changes in photo-excited molecular systems. The experiments aim to further our understanding of the elementary processes happening in these systems from the femtosecond to picosecond time scales. But they also help to fine-tune the interpretation of the data recorded with each methodology. Indeed, it is not yet clear to what extent each structural tool—when implemented in the ultrafast time domain in a pump-probe configuration—is capable of extracting precise quantitative information. It is therefore of paramount importance to perform key experiments that exploit these tools.

The knowledge coming out of these time-resolved studies will naturally flow into the FXE instrument design. For this purpose, the UDECS group submitted a proposal to LCLS, which was granted beamtime for 2011, to study a correlated spin transition in a solvated complex by using XAS, XES, and XRD.

To exploit solid-state samples, a preparatory study at the microXAS beamline of the Swiss Light Source (SLS) in June 2010 sought to explore the capability of performing time-resolved studies in molecular SCO crystals. So far, it seems that these solid-state systems easily suffer additional radiation damage. For this reason, solution phase systems appear more promising for time-resolved studies.

Exploiting the burst mode

Exploiting the unique beam properties at the European XFEL facility also requires new strategies to use its specific burst-mode operation (up to 3 000 pulses enter the sample at a 4.5 MHz repetition rate), in terms of radiation damage as well as smart and fast data acquisition schemes. For this purpose, a 5 MHz laser system (20 W, 270 fs) was purchased and will be tested at ID26 of the European Synchrotron Radiation Facility (ESRF) in 2011 (Figure 2), before it is moved to Hamburg. This strategy offers the opportunity to test the FXE concept, namely to combine X-ray spectroscopies with X-ray scattering tools, at an advanced beamline equipped with secondary spectrometers, as required for X-ray emission spectroscopy and advanced variants thereof. These activities naturally include the UDECS collaboration efforts exploiting diffuse scattering and XAS/XES, and they also invite new ideas from other leading research groups interested in the concept. In addition, the MHz laser will also serve to implement and test sensitive data acquisition (DAQ) schemes at repetition rates matching the burst mode of the European XFEL.

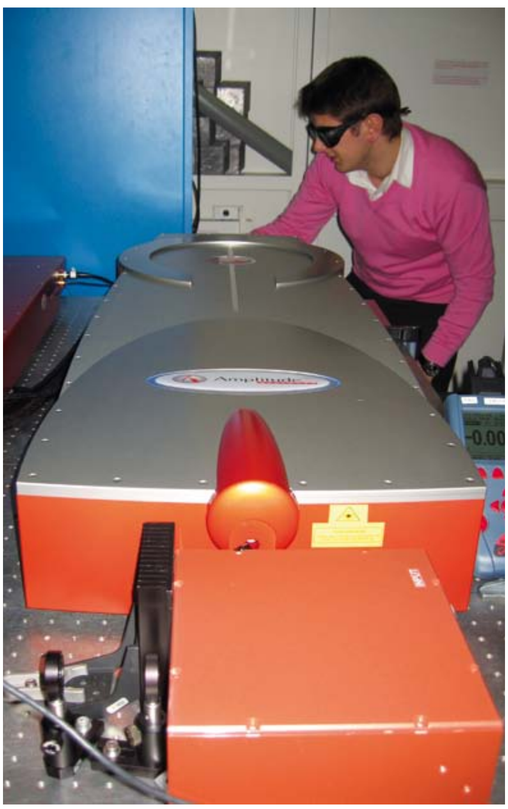


Figure 2 Installing the FXE MHz laser system at beamline ID26 of the ESRF

Testing XANES measurements at SASE FEL sources

In October 2010, the FXE group participated in an XPP commissioning experiment. This five-day beamtime was divided into three days of preparation and setup, and two days of data collection on three different samples: $Fe(bpy)_3$, $Fe(phen)_2$, and a Ni compound, of which only the first two samples delivered femtosecond pump-probe signals. This campaign was very successful for several reasons. It demonstrated that femtosecond XANES measurements are indeed feasible at SASE FEL sources, a fact that was questioned from the very beginning in X-ray FEL technology. From this success, we can already extrapolate that femtosecond EXAFS studies, which require tuning the SASE radiation by up to 1 000 – 2 000 eV, may no longer be mere fiction in 2015. This experiment also showed that, even in the commissioning phase, we are capable of extracting new information about the elementary steps in photochemical reactivity—information that, until now, remained in the dark when exploiting the weaker femtosecond X-ray sources available before the advent of LCLS. Figure 3 demonstrates the basic capability to record high-quality XANES with femtosecond time resolution. The new information can be extracted from the wealth of data available and is currently under analysis.

Encouraging synergy

The future FXE instrument will strongly benefit from the proactive approach taken by the FXE group. From the very beginning, the group decided to add more structural dynamics tools to the investigation of dynamic properties of matter. This strategy is starting to be adopted by

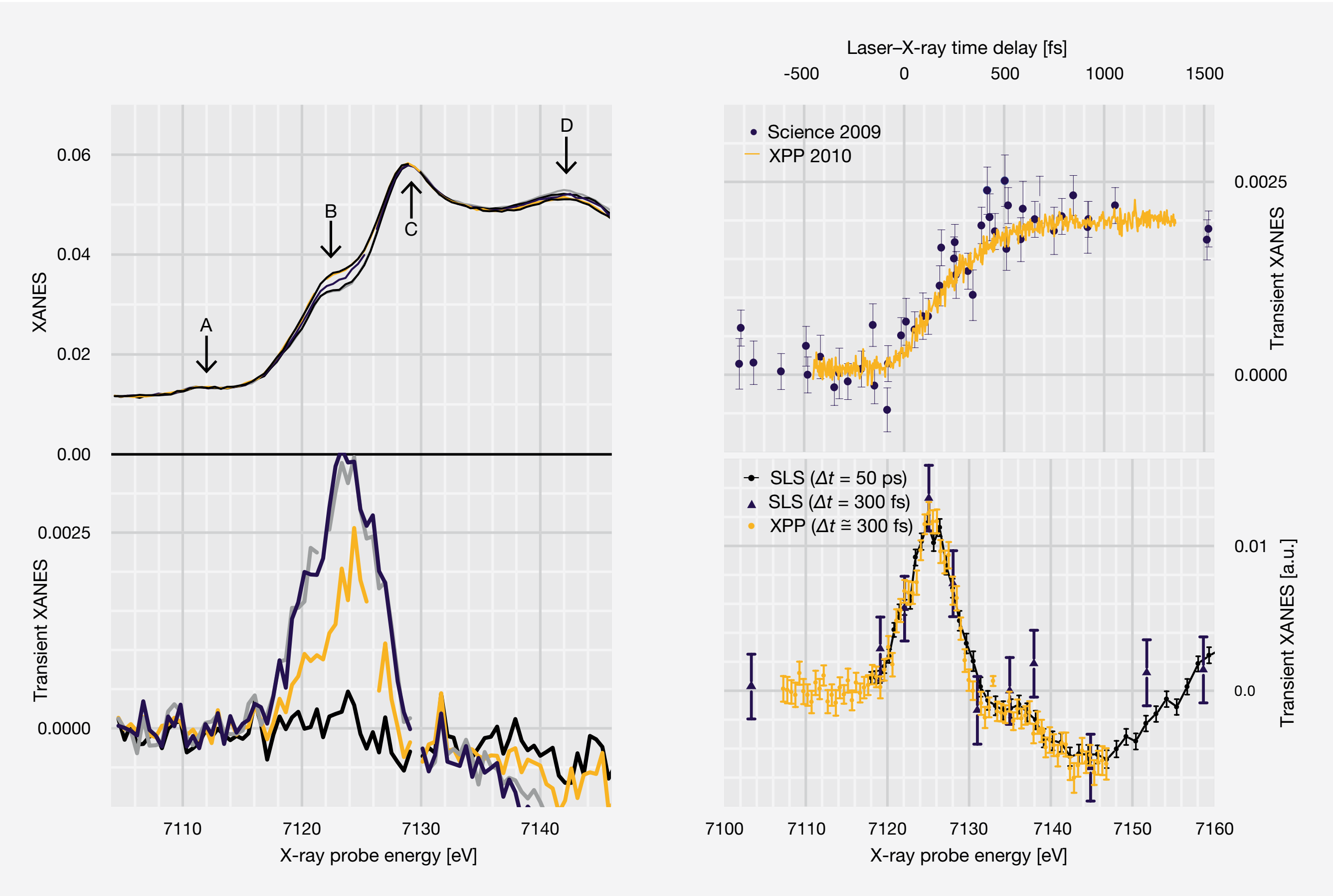


Figure 3 Upper left XANES spectra of aqueous $Fe(bpy)_3$ recorded at selected time delays around time zero.
Lower left Transient XANES reconstructed from the spectra in the upper left.
Upper right Time-delay scan of photo-excited $Fe(bpy)_3$ recorded at the B feature (indicated in the upper left) from the SLS slicing source (blue data points with error bars) [2], and during a single 10 min scan at XPP (red trace).
Lower right Transient XANES after 50 ps recorded with 50 ps pulses at SLS (black data points), after 300 fs using the SLS slicing source (blue data points with error bars), and during a single XPP scan (red data points).
Data from [2] and unpublished data from XPP/LCLS

the scientific community, as observed by the FXE group members during several conferences and workshops in the past year. As can be seen, presenting and repeatedly advertising the new possibilities at the future European XFEL is another vital step in awakening the broader scientific community to the exciting prospects that will become available in 2015. ■

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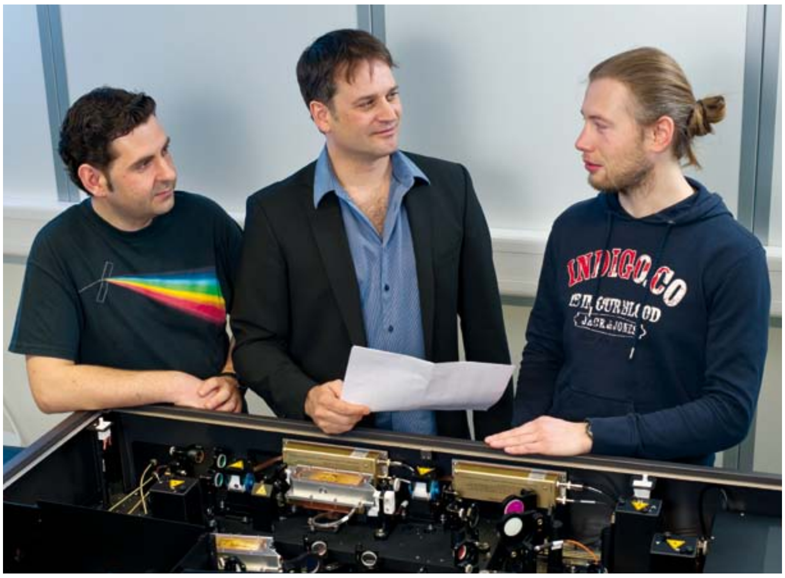

Group members
Wojciech Gawelda, Christian Bressler (group leader), and Andreas Galler

SCIENTIFIC INSTRUMENT SPB

The Single Particles, Clusters, and Biomolecules (SPB) instrument is a hard X-ray instrument for imaging single nanoscale samples. Its ultimate goal is to enable users to analyse the 3D structure of individual biological macromolecules, in particular, those that cannot be seen by conventional methods.

Launching the SPB group

The year 2010 saw the start of rapid progress on the SPB instrument. The leading scientist for the instrument was appointed and began work at the European XFEL at the start of September 2010. His background is in coherent X-ray diffractive imaging, which is the dominant imaging modality that SPB will exploit. Even before his appointment, he was working towards understanding the fundamental properties of X-ray free-electron laser (FEL) beams by studying the transverse coherence properties of existing FEL sources, such as the Free-Electron Laser in Hamburg (FLASH) and the Linac Coherent Light Source (LCLS) at SLAC National Accelerator Laboratory.

The SPB team is growing. At the time of this writing, the group is advertising for a post-doctoral researcher to expand its capacity for research and to contribute to the design of its unique instrument. There are plenty of challenges ahead as the group moves toward its goal of single-particle imaging. The hope is to build a core group of highly skilled and dedicated professionals to make that happen.

The SPB group will continue to perform vigorous research on both the fundamental nature of FEL beams and imaging with FELs as we move toward delivering our instrument for the user community.

Studying FEL beam properties at FLASH and LCLS

In the lead-up to the delivery of photons at the European XFEL in 2015, the SPB group is studying the fundamental nature of FEL beams at FLASH and LCLS. In particular, the group is investigating FEL beam single-shot transverse coherence properties and wavefront characteristics. Both properties (and more) influence how we can best use the beams for imaging. Successful measurements of the transverse coherence at FLASH and LCLS have been performed by the SPB group with assistance from a wide range of collaborators in 2010. Work to understand the wavefront properties of FEL beams is planned for 2011 in collaboration

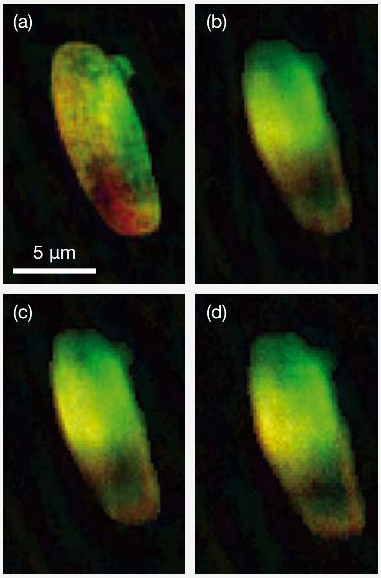

Figure 1 (a) A reconstruction of a *Navicula perminuta* diatom from coherent diffraction data collected at FLASH.
(b) – (d) Reconstructions of the same diatom using data collected from three different individual pulses of the FLASH beam. This figure was first published in [1], and appeared in the New Journal of Physics "Best of 2010" collection.

with Garth Williams of the Coherent X-Ray Imaging (CXI) instrument at LCLS. The SPB group will continue to perform vigorous research on both the fundamental nature of FEL beams and imaging with FELs [1] as we move toward delivering our instrument for the user community. An example of recent imaging work at FLASH is shown in Figure 1.

Defining the SPB instrument

In its brief existence, the SPB group has laid the groundwork for defining the SPB instrument by attending workshops in Europe and abroad, as well as by canvassing the opinions of future users through personal communication. One of the most promising revelations of the year in the coherent imaging community was the successful demonstration of femtosecond nanocrystallography using an X-ray FEL [2]. This exciting discovery broadens the scope of what we can investigate with instruments like the SPB instrument of the European XFEL by showing that it is possible to determine the structure of biomolecules from crystals that are only hundreds of nanometres in size.

The SPB group is involved in attempting to make structure determination using FELs more accessible. In partnership with the Biostruct-X consortium, and, in particular, with the group of Henry Chapman of the Center for Free-Electron Laser Science (CFEL), we hope to broaden the applicability of existing protein crystallography codes to FEL sources.

The year 2011 will see the conceptual design of the SPB instrument take shape using the knowledge gleaned from a close association with the future user community. We look forward to designing an instrument that capitalizes on the very rapid progress currently being made in the field of coherent imaging. ■

Group member
Adrian Mancuso (group leader)

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H. Chapman et al, Nature 470, 73–77, 2011

SCIENTIFIC INSTRUMENT SQS

The Small Quantum Systems (SQS) instrument at the European XFEL will be devoted to the study of atomic, molecular, and cluster systems. These are relatively simple objects. As such, they are ideal samples for scientists who aim to identify and study new effects in the interaction of matter with the ultrashort and highly intense X-ray pulses of the European XFEL.

Defining the instrument

In 2010, the SQS group concentrated on defining and preparing the SQS instrument, focusing in particular on the preparation of its conceptual design report.

The activities included the following:

- Several experimental campaigns at the new XUV and X-ray free-electron laser (FEL) sources (LCLS and FLASH)
- More specific experiments and preparatory work at synchrotron radiation sources (SOLEIL and BESSY) and in the new European XFEL laser laboratory in the PETRA III experiment hall
- Workshops and meetings with the user community

In 2010, the SQS group concentrated on defining and preparing the SQS instrument, focusing in particular on the preparation of its conceptual design report. Activities included several experimental campaigns and preparatory work, as well as workshops and meetings with the user community.

Testing general concepts at LCLS and FLASH

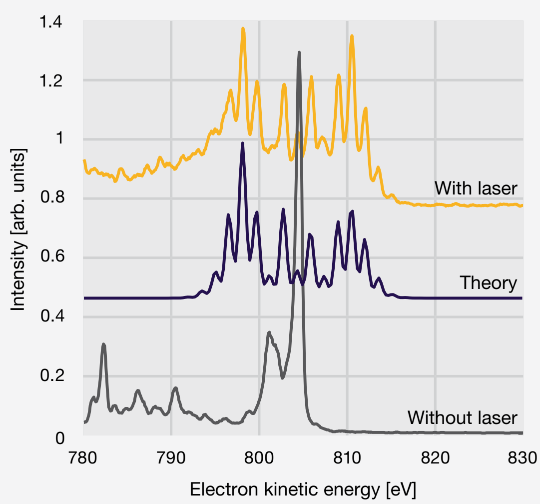
During 2010, the SQS group coordinated one experimental campaign and participated in two additional campaigns at the Linac Coherent Light Source (LCLS) at SLAC National Accelerator Laboratory using the Atomic, Molecular, and Optical Science (AMO) instrument. The AMO instrument is very similar to the SQS instrument with respect to the photon energy range and main scientific scope. Our experiments at LCLS, as well as our discussions with scientists at this new facility—the world’s first operating X-ray FEL—enabled us to directly experience the new technical and scientific challenges (and limitations) of studies with intense, ultrashort FEL pulses in the XUV wavelength regime.

The results of an investigation of the laser-assisted Auger decay (LAAD) by angle-resolved electron spectroscopy are shown in Figure 1. For the experiments, we took advantage of the possibility at LCLS of producing coherent X-ray pulses with temporal widths of a few (2 to 5) fs. This duration coincides with the lifetime of core hole states governing the dynamics of the Auger decay and with the temporal width of one cycle of the electric field in the optical wavelength regime.

The conditions give rise to new interference phenomena caused by the coherent emission of electrons produced during one cycle of a superimposed optical dressing field, which can be observed by angle-resolved Auger spectroscopy. At an emission angle of 60°, one observes a clear oscillation in the intensity distribution, which is almost perfectly reproduced by theory when the experimental geometry (for example, the extent of the optical focus) is taken into account in the simulations.

The results demonstrate that new exciting phenomena show up in the short wavelength regime. Experimentally, the main challenge for this type of experiment, which combines the FEL pulses with those of an optical laser, lies in the synchronization of both sources, which is still limited to about 100 fs, but should be improved in the future to values of 10 fs or less.

In addition to the experiments at LCLS, we continued our investigations of two-colour photoionization processes in the gas phase [1] and



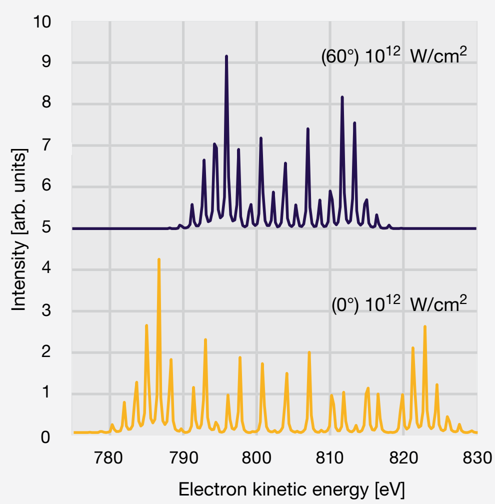


Figure 1 Left Experimental spectrum of the laser-assisted Auger decay in atomic Ne recorded under an angle of 60° upon photoionization with ultrashort (few fs) X-ray pulses of LCLS with (top) and without (bottom) an additional optical dressing field (about 10^{12} W/cm^2). Corresponding theoretical simulation (middle) calculated for a finite distribution of the optical field (0.5 – 0.8 x 10^{12} W/cm^2) in the interaction volume.
Right Theoretical spectrum obtained for an optical dressing field of 10^{12} W/cm^2 and observation angles of 0° (bottom) and 60° (top).

performed some studies of non-linear phenomena at FLASH (for example, resonant two-photon excitation (Figure 2) as well as direct and sequential two- and multiple-photon ionization) using a microfocus (less than 5 μm) of the XUV beam. The main challenge of these experiments consists in finding conditions to obtain energy-resolved electron spectra that are not perturbed by space charge effects arising from the high intensity necessary to drive the non-linear processes. The problem of space charge will be similar for the SQS instrument because it is mainly caused by the huge number of created electrons and (primarily) not related to their kinetic energies, which are higher for experiments at the European XFEL.

Testing specific components at SOLEIL, BESSY, and PETRA III

To test and specify the characteristics of specific parts (analysers, detectors, electronics, and so on) of the SQS instrument, the SQS group, together with the Femtosecond X-Ray Experiments (FXE) group, set up a new kHz laser system in the European XFEL laser laboratory inside the PETRA III hall. The laser (Coherent Legend Elite) provides 800 nm pulses of about 25 fs duration, a 3 kHz repetition rate, and about 3 mJ of pulse energy. These specifications will be used to produce a beam of VUV photons by generating higher-order harmonics (HHG) in rare gases, enabling us to perform experiments on atomic or molecular targets. Beside some scientific applications, this setup will be the main tool to

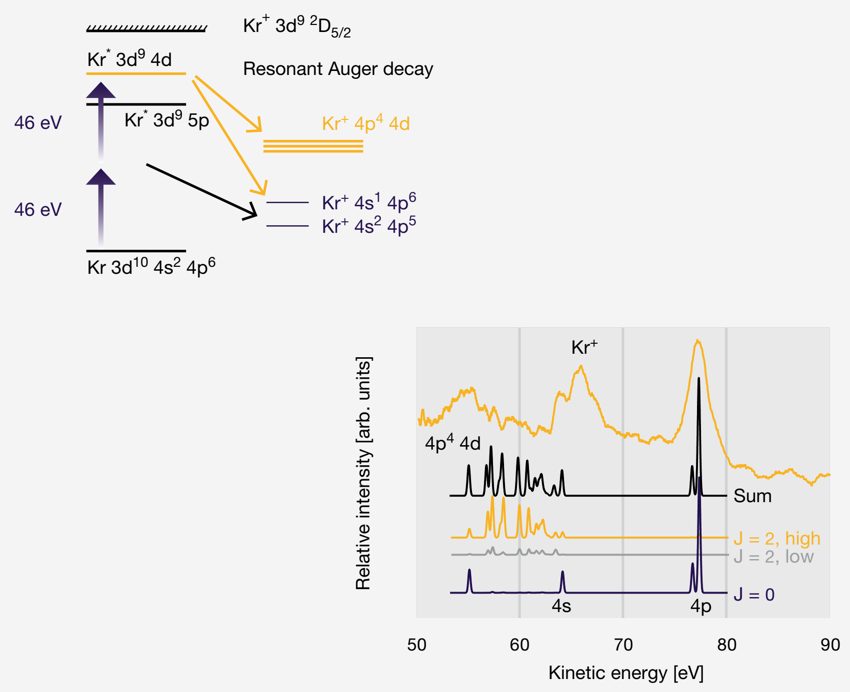


Figure 2 Top Energy level diagram and excitation scheme for the resonant two-photon 3d → 4d excitation in atomic Kr. **Bottom** High-resolution electron spectrum of atomic Kr recorded at FLASH upon excitation with intense (5 x 10^{12} W/cm^2) FEL radiation of 46 eV photon energy. The experiment is compared to the theoretical spectrum obtained by taking into account the relative probabilities for the excitation of different $3d^{-1}4d$, J = 0, and J = 2 resonances and their decay rates to the Kr^+ $4p^44d^{2,4}L_J$ final states. The structure at around 65 eV in the experimental spectrum corresponds to the 4p above-threshold ionization (ATI) in the Kr^+ ion [2].

characterize new analysers, such as high-resolution time-of-flight (TOF) spectrometers and velocity-map imaging (VMI) analysers, which are foreseen for the SQS instrument, and to test and acquire experience with femtosecond timing diagnostics, fast electronics, data acquisition systems (kHz repetition rate), especially for coincidence experiments, and spatial alignment procedures.

Parallel to building up this HHG setup, the SQS group leveraged an experimental campaign at the French national synchrotron facility, SOLEIL, to gain experience with the VMI spectrometer, which was used in coincidence with an ion TOF in two-colour experiments on atomic Xenon. The results are very promising and demonstrate the feasibility of such studies. They also show the necessity of a well-defined, not-too-large interaction volume for maintaining the high performances of the device.

Particular attention should be given to the development of experiments that make use of the high repetition rate of the European XFEL, the main advantage over other X-ray FELs. One main focus in the design of the SQS instrument will therefore be on measurements of multiple coincidences between photons, electrons, and ions, to allow the complete characterization of the interaction between the X-ray pulse and the target.

Getting feedback from the user community

The general layout of the SQS instrument, and the technical requirements it should meet to fully exploit the specific characteristics of the European XFEL, were discussed during a two-day workshop, titled “Soft X-Ray Instrumentation at the European XFEL”, in Trieste in December 2010. After the first “International Workshop on the Science with and the Instrumentation for Small Quantum Systems (SQS) at the European XFEL”, which was held in Aarhus in October 2008, and a “Work Meeting on SQS Science” in January 2009 in Hamburg, this was the occasion to inform the user community about the progress in the preparation of the SQS instrument, to gather suggestions for its final layout in light of the latest experiments at LCLS (especially at AMO), and, if necessary, to revise its scientific scope.

In general, the proposed layout of the SQS instrument was accepted by the user community and will now be used as the basis for the conceptual design report, which will be released in April 2011. More specifically, it was pointed out that particular attention should be given to the development of techniques and experiments that make use of the high repetition rate of the European XFEL (27 000 pulses per second), the main advantage over other X-ray FELs. One main focus in the design of the SQS instrument will therefore be on measurements of multiple coincidences between photons, electrons, and ions, to allow the complete characterization of the interaction between the X-ray pulse and the target. In addition, the need for a perfectly synchronized (better than 10 fs) pump-probe laser, as well as the option to use circularly polarized FEL radiation, was underlined and will be considered for the conceptual design report. ■

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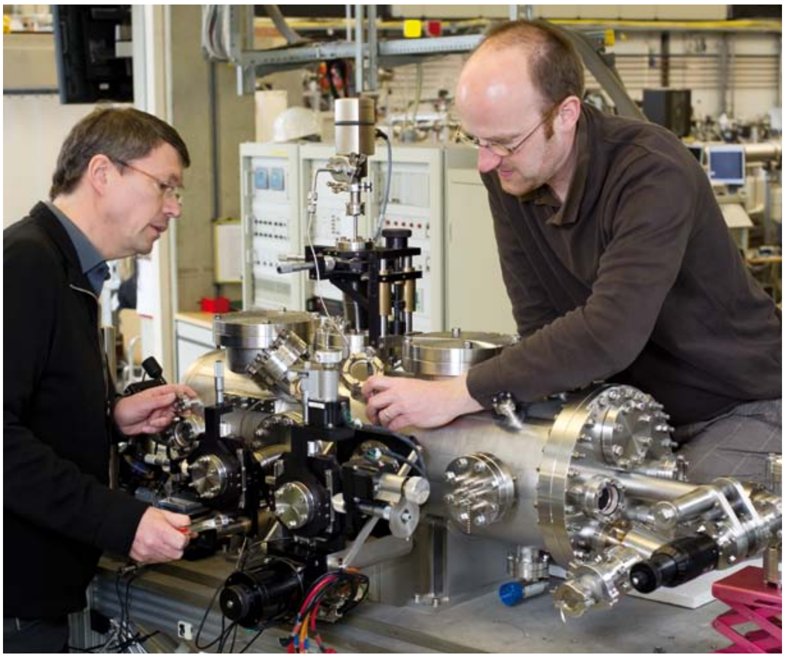
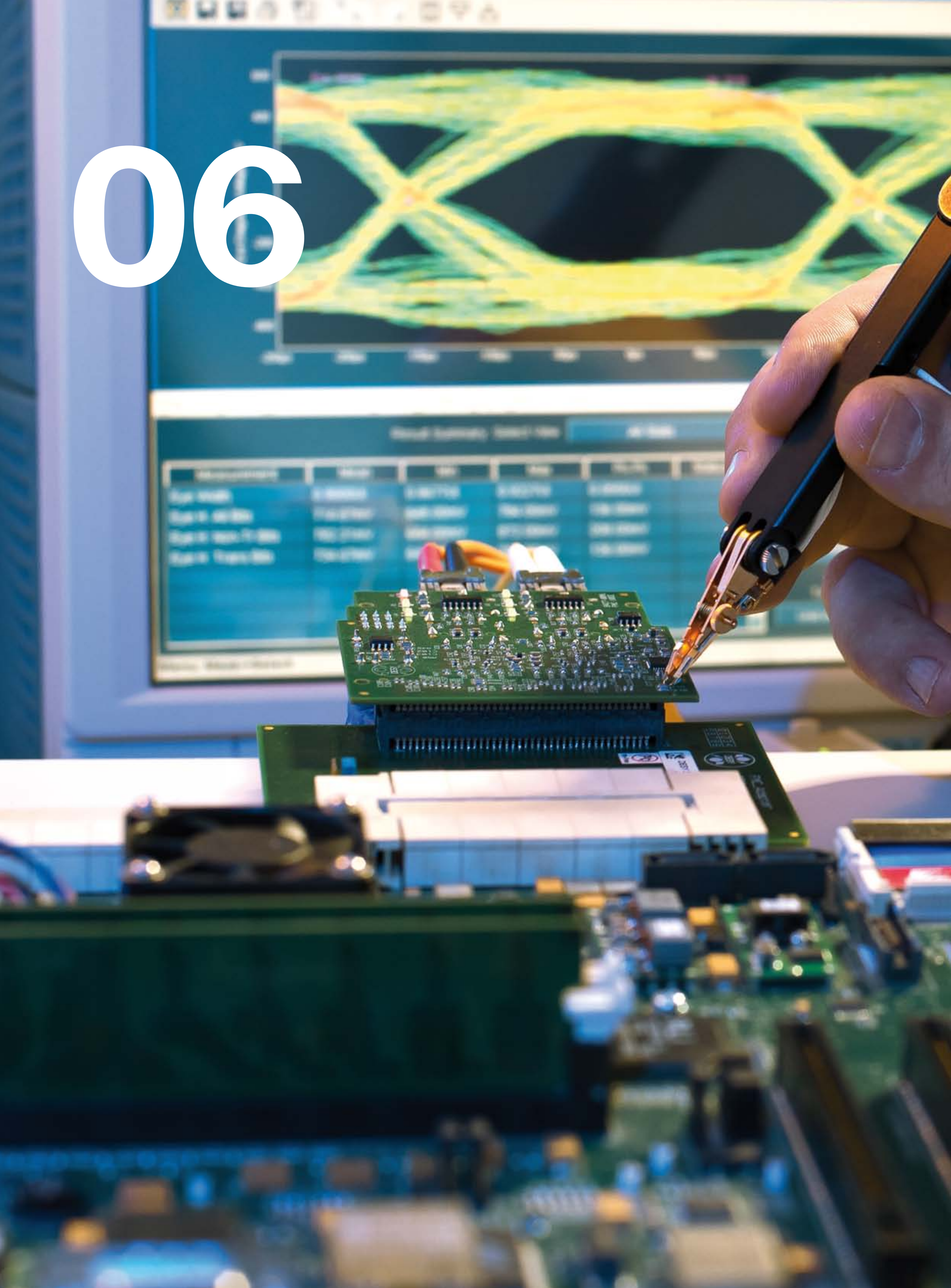
M. Meyer, D. Cubaynes, V. Richardson, J.T. Costello, P. Radcliffe, W.B. Li, S. Düsterer, S. Fritzsche, A. Mihelic, K.G. Papamihail, P. Lambropoulos
Phys. Rev. Lett. 104, 213001 (2010)



Group members
Michael Meyer (group leader), Paul Radcliffe, and Nicolay Kabachnik (visiting scientist, not shown)

06



DETECTORS AND DATA ACQUISITION

■ To make optimal use of the unprecedented capabilities of the European XFEL, the company established a Detector Development group, which began devising the detector instrumentation for the facility. At the same time, the DAQ and Control Systems group started developing the data acquisition, data management, control hardware, and control systems required to operate the scientific instruments and facilitate data analysis.

DETECTOR DEVELOPMENT

The feature that singles out the European XFEL from competing facilities is the large number of pulses per second: up to 27 000. To make use of this high repetition rate, suitable instrumentation must be developed for data acquisition at the experiments. The task of the Detector Development group is to develop the detector instrumentation for the new facility.

Detector requirements

The European XFEL will provide as-yet-unrivalled peak brilliance and ultrashort X-ray pulses with a pulse length of less than 200 fs. Its time structure will be unique: The X-ray pulses will be delivered in trains lasting 0.6 ms each. Every train will contain up to 2 700 X-ray pulses that are 222 ns apart. The facility will deliver 10 trains—that is, 27 000 pulses—every second. This time structure will allow the study of ultrafast phenomena, for which adequate instrumentation must be developed.

Some experimental techniques foreseen for the European XFEL will require two-dimensional integrating X-ray detectors with a large dynamic range. These imaging detectors should also provide single-photon sensitivity. Other experiments will make high demands in terms of angular resolution, detector area, and the storage capacity of as many images as possible, up to 4.5 MHz frame rates.

Developing optimal detectors

To make optimal use of the unprecedented capabilities of the European XFEL and master these vast technological challenges, the European XFEL GmbH started a detector R&D programme and began building up a dedicated Detector Development group to take over the central coordinating role.

The primary goals of the Detector Development group include:

- Developing 2D pixel detectors optimized for the requirements of imaging experiments
- Setting up infrastructure in the construction phase (until 2014 or 2015)
- Preparing the detector-related infrastructure (clean room, measurement equipment, calibration equipment, and so on) in Schenefeld
- Planning the workforce build-up for the group over the next few years

Figure 1 LPD super-module mechanical support frame. One super-module is the smallest LPD detector subunit. It houses the LPD sensor, cooling, power, and parts of the data acquisition system.

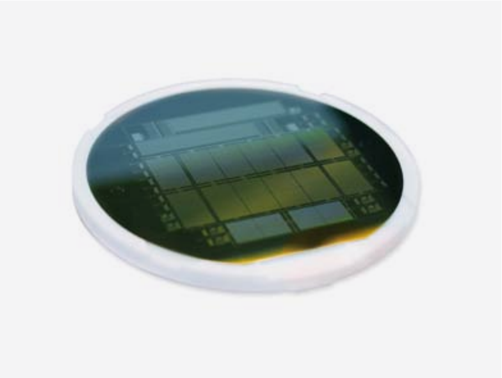


Figure 2 DSSC dummy wafer used for bump-bond tests. The two large central rectangular structures represent one DSSC sensor chip with 128 x 256 pixels. The chip is subdivided into 64 x 64 pixel blocks with separate readout chips.

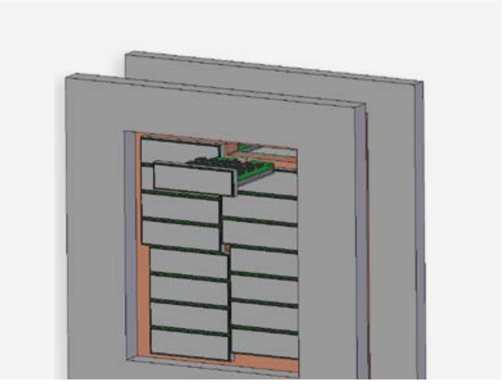


Figure 3 Current design of the one-megapixel AGIPD detector

Starting three detector projects

In 2007, the European XFEL project team started three independent multinational detector development projects, with the primary goal of overcoming the technological challenges for imaging detectors posed by the European XFEL burst-mode frame rate and the required high dynamic range. The detector concepts of each of the three multinational consortia are complementary in their performance (for example, optimizing either the sensitive energy range of the sensor or the specific scientific applications of one detector).

The Adaptive Gain Integrating Pixel Detector (AGIPD) project—led by DESY and conducted in collaboration with the Paul Scherrer Institute (PSI, Switzerland) and the Universities of Hamburg and Bonn—and the Large Pixel Detector (LPD) project—managed by the detector group of the Rutherford Appleton Laboratory (RAL, UK), and carried out in conjunction with the University of Glasgow—both implement a multiple-gain readout concept to realize a large dynamic range of the order of 10^4 (Figure 1).

The Depleted P-Channel Field Effect Transistor (DEPFET) Sensor with Signal Compression (DSSC) project is managed by the MPI Halbleiterlabor (MPI HLL) in Munich, with contributions from the Politecnico di Milano, DESY Hamburg, and the Universities of Heidelberg, Siegen, and Bergamo. This detector concept follows a fundamentally different idea. The realization of a large dynamic range of the sensor is based on the intrinsic non-linear response of each sensor cell (Figure 2).

Tracking detector progress through the DAC

The European XFEL Detector Advisory Committee (DAC) was established by the European XFEL GmbH as an independent international steering and review committee for the detector development programme. In 2010, the DAC met in April and November. In the latter meeting, the three detector consortia described the progress in the design and prototyping of the 2D detector systems. In addition, reports were delivered about the latest investigations of external groups at the Weierstrass Institute in Berlin and at the University of Hamburg. These groups studied the radiation damage effects of the silicon sensors and the effects of the quasi-instantaneous deposition of a very large number of 12 keV photons in a single pixel on the signal development time, the charge spread function, and the positioning accuracy. The results of experimental measurements, in combination with simulations, indicate that charge-spreading effects on pixel level will not limit or deteriorate the performance of the imaging sensors. The study of the radiation damage effects is still continuing and is providing results that will be taken into account in the final sensor and application-specific integrated circuit (ASIC) design. The DAC scrutinized and reviewed the developments in data acquisition and control systems, as well as test results of the first prototype ASIC chips and the management of the large data streams that will be produced at the highest frame rates by the 2D megapixel cameras. The overall progress was deemed satisfactory and detailed suggestions were made in various areas and for all consortia.

In 2007, the European XFEL project team started three independent multinational detector development projects, with the primary goal of overcoming the technological challenges for imaging detectors posed by the European XFEL burst-mode frame rate and the required high dynamic range.

The AGIPD detector project (Figure 3) had to surpass the first "go/no go" analysis of their progress in November 2010. These early milestones were fixed in the contracts with all three consortia to enable flexibility in deciding whether to terminate or continue a particular development, depending on the amount of progress reported. The AGIPD consortium passed the first "go/no go" analysis and was encouraged to continue on the path described at the meeting. Early in 2011, the LPD project will, in turn, undergo an in-depth review, followed by the DSSC project at the end of 2011.

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Group member (European XFEL, after November 2010)
Markus Kuster (group leader, pictured)
Group members (DESY HASYLAB, before November 2010)
Heinz Graafsma (group leader) and Stefanie Jack

DAQ AND CONTROL SYSTEMS

In collaboration with international partners and other European XFEL work package groups, the DAQ and Control Systems group develops the data acquisition (DAQ), data management (DM), control hardware, and control systems required to operate the photon beamline instruments and facilitate data analysis. The computing technical design report finalized in autumn 2009 defines the mission statement of the group. In 2010, DAQ development concentrated on the readout and synchronization systems required for operating the large-area cameras to be used at the facility. DM software development was initiated, as were tests of data archiving. Following a review of systems used at other facilities, the development of beamline and experiment control systems was launched. At the same time, the group submitted proposals to European Union (EU) funding organizations.

DAQ

The development of DAQ systems for the large-area cameras being designed by the AGIPD, DSSC, and LPD consortia (see previous article) to operate at the European XFEL took a major step forward with the signing of collaboration agreements with University College London (UCL) and the Science and Technology Facilities Council (STFC) to develop sequencing and readout systems, respectively. Custom camera and DAQ developments are needed because of the demanding timing requirements of photon delivery at the European XFEL. An important feature of both developments is the large-scale use of field-programmable gate array (FPGA) digital signal processing on electronics boards hosted in telecommunications computing architecture (TCA) industrial standard crates.

The clock and control sequencing system is required to interface to the linac timing system; generate and distribute fast signals, clocks, and vetoes to the front-end readout interfaces (RI) of the cameras; receive error signals; and ensure system synchronicity. The hardware implementation of the design was finalized and uses the small-board MTCA.4 standard (PICMG Specification MTCA.4 R 1.0 Draft 0.9w) recently developed for use in physics applications. An X-ray free-electron laser (FEL) timing receiver (TR) system board (European XFEL timing board, Stockholm University and DESY-MCS4) provides access to timing and telegram configuration information of the linac over the backplane. A DAMC2 FPGA board (DAMC2 FPGA carrier board, DESY-FEA) provides signal processing to drive RIs connected by custom rear transition modules. Towards the end of 2010, initial firmware development was made using evaluation boards and small test boards in preparation for the arrival of DAMC2 and TR boards.

The train builder readout system is required to sink frame data coming for camera RIs, build contiguous-frame-ordered blocks from a specific train, and output blocks to a downstream computing layer. The hardware implementation of the design uses the large-board ATCA crate standard, 10 Gbps fibre data IO connections, DDR2 memory banks controlled from FPGAs, and a large cross-point switch for frame and train building. During 2010, three development steps prior to the design of an initial demonstrator board were completed. FPGA evaluation boards were used to investigate and prove the required memory concurrent r/w performance and the operation and performance of the switch. Additionally, the dual 10 Gbps fibre connection FMC mezzanine board (Dual Fibre 10 Gbps FMC link, DESY-FEA) development was completed and first boards were shipped. A schematic showing camera, clock, control, and train builder connectivity is shown in Figure 1.

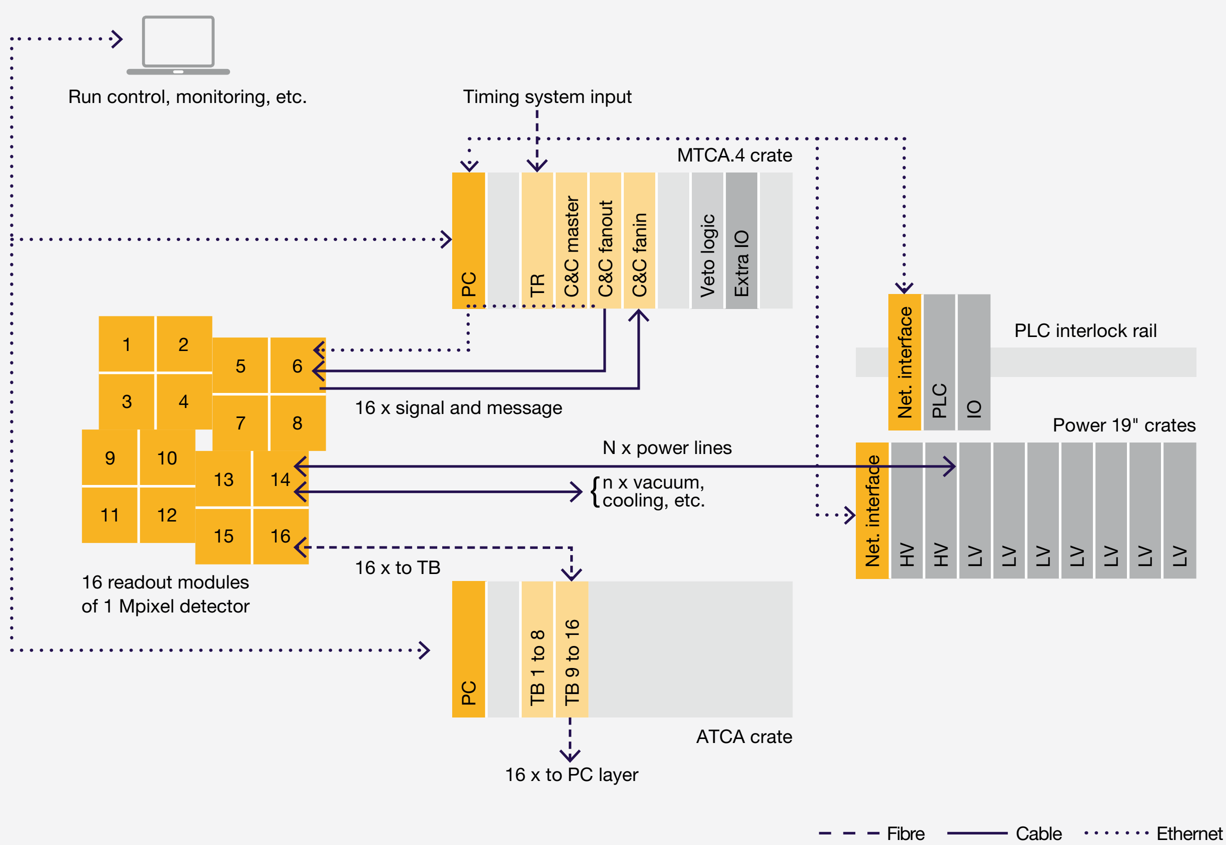


Figure 1 Schematic showing one-megapixel area camera DAQ and control subsystems

During 2010, it became clear that the MTCA.4 standard could provide the basis for small single-crate DAQ systems incorporating both sequencing and DAQ. The development of a prototype system to read out a small number of analogue input channels was started using a commercial FADC board (SIS8300 FADC MTCA.4, Struck Innovative Systems GmbH) and a custom development to shape the incoming signal.

The development of DAQ systems for the large-area cameras being designed by the AGIPD, DSSC, and LPD consortia to operate at the European XFEL took a major step forward with the signing of collaboration agreements to develop sequencing and readout systems.

Control

A review of the control systems used at light sources was started with visits to the Linac Coherent Light Source (LCLS) at SLAC National Accelerator Laboratory, USA, the European Synchrotron Radiation Facility (ESRF) in Grenoble, France, the ALBA Synchrotron Light Facility in Barcelona, Spain, the Paul Scherrer Institute (PSI) in Villigen, Switzerland, and the Diamond Light Source in Oxfordshire, UK. The aim of the review was to identify software and hardware developments that can be used in the photon beamline control systems (PLCs, motion control, cameras, and so on). Preliminary ideas on software development for the DAQ systems relating to messaging and graphical user interfaces that were tested during 2010 will require modification in view of potentially interfacing other control systems to allow reuse of hardware device servers.

DM and software framework

The DM concept, policies, and the major services required are described in the computing technical design report, which was released in October 2009. The data access model currently envisaged for the European XFEL is that the bulk of experiment data is analysed on site, close to the data storage system in computing clusters with batch job submission and data organization tools developed in the context of the European e-Infrastructure initiative. Lightweight client access allowing small amounts of data to be transferred over a wide area network (WAN) to home institutes for final analysis or algorithms tuning are foreseen.

The key components of the DM system, as well as its characteristics and functionality, can be summarized as follows:

- Secure tape archive will be used for long-term data storage.
- Data from unsuccessful experiment runs will not be stored, filtering of bad data will be applied as early as possible.

- Data compression will be applied whenever possible.
- Raw data stored in the archive will remain immutable.
- Disk storage system (dCache) will be used as the front end to the tape archive.
- Data archive and disk cache system will be integrated with the e-Infrastructure.
- Computing clusters close to the data archive will be used for offline data analysis.
- Data will be protected using global authentication and authorization services.
- Metadata services will be used to describe the content of the archive.
- Grid services will be provided for transferring data to offsite locations.
- User-friendly interfaces will be provided to access data and metadata services remotely.

The data access model currently envisaged for the European XFEL is that the bulk of experiment data is analysed on site, close to the data storage system in computing clusters with batch job submission and data organization tools developed in the context of the European e-Infrastructure initiative.

The following policy decisions relating to DM usage were defined:

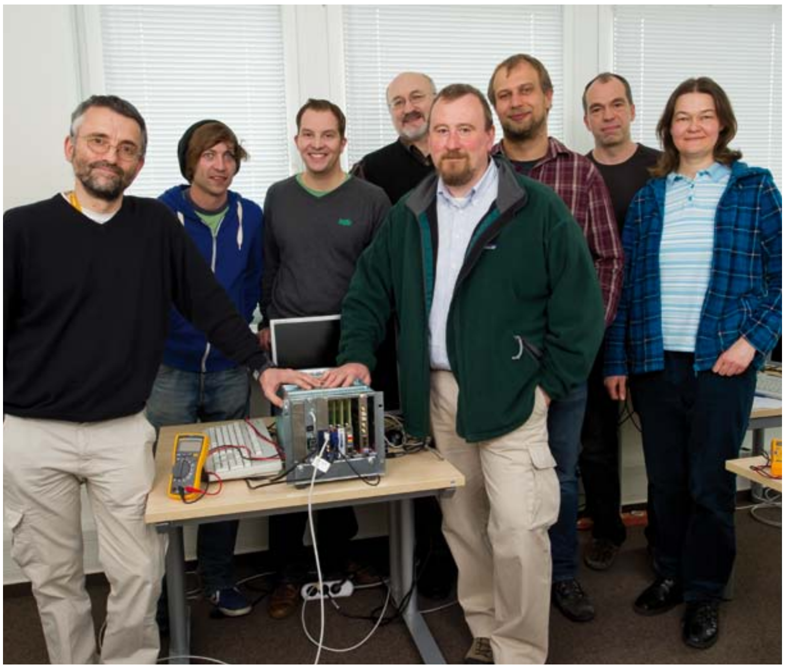
- Initial size of the data storage system will be 10 PB.
- Data will be archived for at least one year before deletion.
- Reasonable amount of archive storage will be provided to experiments.
- Reasonable amount of computing power will be provided to experiments.

During the year, first functionality and performance tests were conducted for the data archiving service using dCache. A data transfer rate of up to 200 MB/s was achieved over a 2 x 1 Gbps link. No limits from dCache or servers were observed below the network bandwidth. Further tests are required and planned using a 10 Gbps interface. WAN data transfer tests have been performed using the data recorded at SLAC. An average transfer rate of 24 MB/s over three months was observed. The results support the model where data is analysed on site.

Work on software for data processing was initiated. This work included setting up the environment and infrastructure for software developments (source code repository, procedures for building, testing, and installation). The design and development of core software components in C++ was started and advanced significantly towards the end of the year. In particular, the following software components were implemented: flexible objects configuration, logging, IO interfaces, and an application framework allowing for pluggable software modules. The work on Python interfaces and a graphical user interface was also advanced.

EU funding calls

During the year, the group submitted proposals to various EU funding organizations. Although its proposal to the Robust Scientific Communities for European Grid Infrastructure (ROSCOE) project was rejected early in the year, the group is hopeful that additional funding may result from its submission to the Cutting Edge Reconfigurable ICs for Stream Processing (CRISP) project.



Group members
Christopher Youngman (group leader), Dana Wilson, Burkhard Heisen, Sergey Esenov, Nicola Coppola, Krzysztof Wrona, Manfred Knaack (since April 2011), Irina Kozlova, and Bartosz Poljancewicz (not shown)

07

FACTS AND FIGURES

- As a new research facility, the European XFEL benefits directly from the numerous collaborations that it has established with related laboratories, scientific institutions, and universities worldwide. The facility also requires a highly professional administrative infrastructure, most of which was in place by the end of 2010.

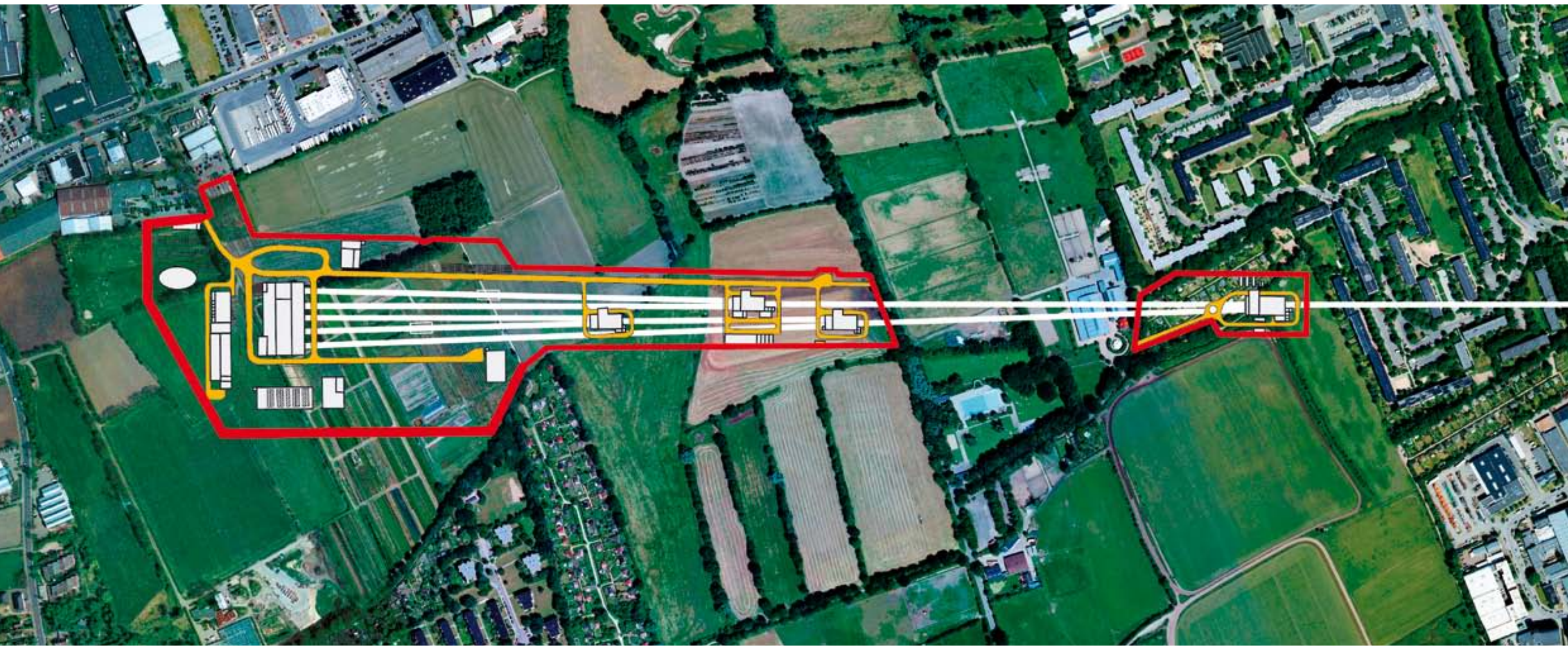


Figure 1 Aerial view of the European XFEL facility. **Right to left** Site DESY-Bahrenfeld, site Osdorfer Born, site Schenefeld

AT A GLANCE

The European XFEL is a new research facility currently under construction in Hamburg and Schleswig-Holstein in northern Germany. Starting in 2015, the 3.4 km long X-ray free-electron laser (FEL) will generate ultrashort X-ray flashes for photon science experiments using the self-amplified spontaneous emission (SASE) process.

Light source for superlatives

With its repetition rate of 27 000 pulses per second and a peak brilliance a billion times higher than that of the best synchrotron X-ray radiation sources, the European XFEL will open up new research opportunities for scientists and industrial users. Thanks to its ultrashort X-ray flashes, the facility will enable scientists 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 such as those occurring deep inside planets.

The European XFEL will be located mainly in underground tunnels accessible from three sites, 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 Schenefeld site will host the research campus.

European XFEL GmbH

The international partners entrusted the construction and operation of the European XFEL to a non-profit limited liability company under German law, named the European X-Ray Free-Electron Laser Facility GmbH, which was established in October 2009. This company will ultimately have a workforce of about 250 people.

As of December 2010, 12 countries are participating in the European XFEL project: Denmark, France, Germany, Greece, Hungary, Italy, Poland, Russia, Slovakia, Spain, Sweden, and Switzerland.

Construction

The European XFEL is being realized as a joint effort of many partners. The European XFEL GmbH cooperates closely with the DESY research centre and other organizations worldwide. Construction started in early 2009. The beginning of commissioning is planned for early 2015. User operation with one beamline and two instruments will start in 2015.

Costs

The construction costs of the facility, including commissioning, amount to 1082 million euro (at 2005 price levels). As the host country, Germany (that is, the federal government, the city-state of Hamburg, and the state of Schleswig-Holstein) covers 54% of these costs. Russia bears 23%, and the other international partners between 1% and 3.5% each. To a great extent, the European XFEL facility will be realized by means of in-kind contributions by shareholders and partners. ■

COOPERATION

As a new research facility, the European XFEL benefits directly from collaborations and agreements with related laboratories, scientific institutions, and universities. Since the foundation of the European XFEL GmbH in October 2009, a number of such formal associations have been established.

STFC and University College London

To record the diffraction images of small crystals and single molecules at the extremely high repetition rate of the European XFEL, novel 2D imaging detectors need to be developed. To this end, the European XFEL management has set up agreements with expert teams in the UK.

The Science and Technology Facilities Council (STFC) in the UK is developing one of these 2D imaging detectors—the Large Pixel Detector (LPD)—as well as hardware elements for the readout and data acquisition architecture. Because the UK has decided not to become a full member of the European XFEL at this time, a Memorandum of Understanding (MoU) has been set up with the STFC to govern collaboration on LPD and data acquisition developments. The work on the LPD and the train-builder hardware is regulated by separate contracts. In addition, a similar contract for the clock and control hardware has been set up with University College London.

DESY

Another 2D detector project—the Adaptive Gain Integrating Pixel Detector (AGIPD) launched by the European XFEL project team in 2007—is located at Deutsches Elektronen-Synchrotron (DESY), Germany. A contract for studies on photon diagnostics was signed in September 2010.

SLAC

Contacts with the SLAC National Accelerator Laboratory at Stanford University in the USA led to the temporary assignment of European XFEL scientist Oleg Krupin (Figure 1) to the Soft X-Ray Materials Science (SXR) instrument of the Linac Coherent Light Source (LCLS). A general MoU on close collaboration in X-ray laser research has been in place between DESY and SLAC since 2002. An addendum to this MoU, which covers the collaboration on the SXR instrument, is ready to be signed. It provides an important opportunity for the European XFEL GmbH to gain hands-on experience at the world’s only X-ray free-electron laser (FEL) currently in operation.

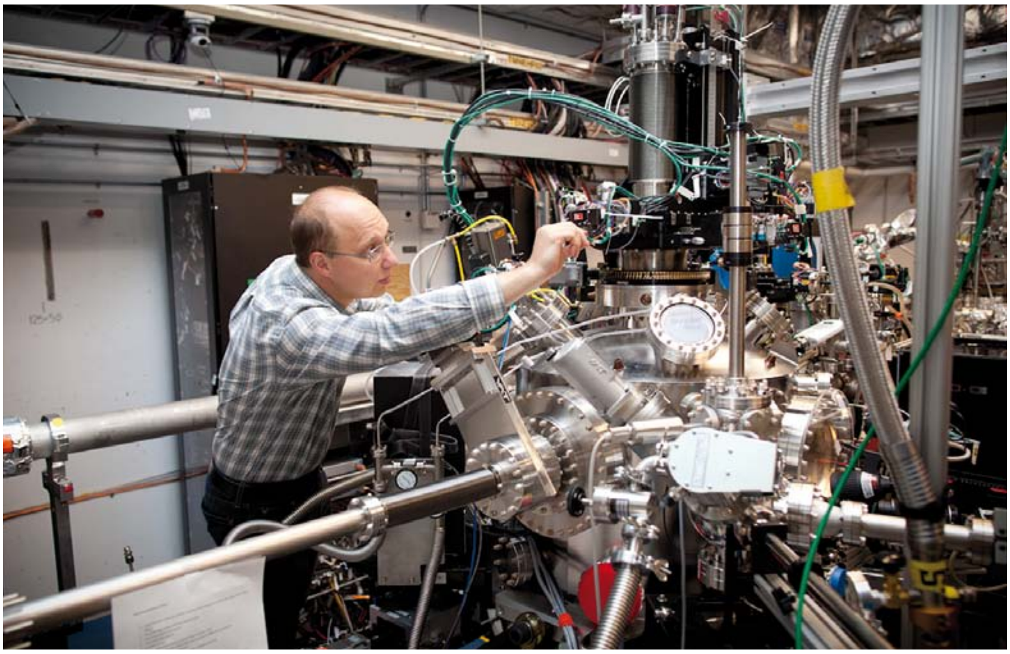


Figure 1 European XFEL scientist Oleg Krupin at the SXR instrument of LCLS

Helmholtz-Zentrum Berlin

An MoU for a generic collaboration was signed with the Helmholtz-Zentrum Berlin (HZB), Germany, formerly Berliner Elektronenspeicherring-Gesellschaft für Synchrotronstrahlung (BESSY). The goal of the MoU is to establish specific collaborations in soft X-ray optics, a field in which the HZB has considerable expertise. The agreement foresees a collaboration in the development of optical components, especially with respect to the outstanding expertise and the availability of sophisticated instrumentation at the BESSY synchrotron on precision mirror and grating fabrication and characterization.

FERMI@ELETTRA

Contacts are also in progress with the FERMI@ELETTRA project. The Free Electron Laser for Multidisciplinary Investigations (FERMI) is a FEL user facility located next to the third-generation synchrotron radiation facility ELETTRA in Trieste, Italy. Possible cooperations were further discussed at a European XFEL workshop, which took place in Trieste on 16–17 December 2010. The workshop was part of a series sponsored by the Pre-XFEL grant.

University of Hamburg

The European XFEL GmbH joined the University of Hamburg, DESY, and several Max Planck Institutes in an application to the Max Planck Society for creation of an International Max Planck Research School for Ultrafast Imaging and Structural Dynamics. This proposal, which was approved and is now operational, will provide funds for attracting international graduate students to Hamburg to pursue doctoral studies on topics closely related to the mission of the European XFEL, such as the development of experimental methods and instrumentation.

In addition, European XFEL scientists participated in a proposal led by the University of Hamburg for a long-term grant by the German Research Foundation (DFG) and a continuation proposal for a post-graduate programme in “Physics with New Advanced Coherent Radiation Sources”, also supported by DFG.

University of Uppsala

In October 2010, an agreement to cooperate closely in the field of X-ray science with a focus on structural biology was signed by representatives of Uppsala University in Sweden and the European XFEL GmbH (Figure 2). In particular, the agreement stipulates the secondment of Janos Hajdu, an internationally renowned expert in structural biology, to the European XFEL GmbH for half of his working time. Hajdu will act as a senior advisor to the scientific directors of the European XFEL GmbH and contribute his expertise to the construction of the scientific instruments and the realization of experiments. He will also strive to establish and promote connections to the Swedish scientific community and other structural biology institutions throughout the participating countries and beyond. The secondment of Hajdu and a research engineer counts as an in-kind contribution of the Swedish Research Council, which is one of the shareholders of the European XFEL GmbH, to the realization of the project.

Figure 2 Signing of the agreement between Uppsala University and the European XFEL GmbH.
Left to right Massimo Altarelli, managing director of the European XFEL GmbH; Andreas Schwarz, scientific director of the European XFEL GmbH; Anders Hallberg, vice chancellor of Uppsala University; Thomas Tschentscher, scientific director of the European XFEL GmbH; Joseph Nordgren, vice rector of the Disciplinary Domain for Science and Technology at Uppsala University; and Karl Witte, managing director of the European XFEL GmbH.

Southern Federal University

In an exchange of letters, the management of the European XFEL GmbH and the vice rector for research at Southern Federal University in Rostov, Russia, stated their interest in establishing a joint programme.

EIROforum

In November 2010, the European XFEL GmbH became the eighth member of EIROforum, a partnership of European intergovernmental research organisations with large research infrastructures that combine their resources, facilities, and expertise to support European science in reaching its full potential (Figure 3).

The other members of EIROforum:

- European Fusion Development Agreement (JET-EFDA)
- European Molecular Biology Laboratory (EMBL)
- European Organization for Nuclear Research (CERN)
- European Southern Observatory (ESO)
- European Space Agency (ESA)
- European Synchrotron Radiation Facility (ESRF)
- Institut Laue-Langevin (ILL)

The directors general of the EIROforum institutions meet twice a year to discuss common problems and issues of the international research organizations in Europe, as well as to coordinate actions related to the European Commission, the European public, and so on, with the aim of promoting the quality and impact of European research. Five working groups address specific topics: international relations, outreach and education, human resources, instrumentation, and IT.

Figure 3 Signing the declaration of accession to EIROforum. **Front** Massimo Altarelli, managing director of the European XFEL GmbH (left) and Francesco Romanelli, JET-EFDA and chairman of EIROforum (right). **Back (left to right)** Francesco Sette (ESRF), Felicitas Pauss (CERN), Iain Mattaj (EMBL), Richard Wagner (ILL), Rowena Sirey (ESO), and David Southwood (ESA).

Physics on Accelerators and Reactors of West Europe

In November 2010, the European XFEL joined the “Physics on Accelerators and Reactors of West Europe” programme of the Russian Ministry of Science and Technology. The goal of this programme is to enable research stays of Russian scientists at large leading European research facilities. In the summer of 2010, the European XFEL work package leaders submitted their proposals for research programmes within this framework programme. Most of these proposals were approved and five Russian scientists came to Hamburg in 2010. Further secondments will be considered within the budget of this programme in 2011.

FEL three-site meeting

From 29 September to 1 October 2010, the third “FEL three-site meeting” took place in Hamburg. This is a meeting between the LCLS, the Japanese SPring-8 Compact SASE Source (SCSS), and the Hamburg FEL projects (FLASH and European XFEL). The series enables attendees to share information about different projects and to identify topics of common interest on which collaborations can form.

The third meeting provided a good opportunity to hear about the progress of the Japanese facility, which looks very much on time to produce first beams in the spring of 2011. The LCLS colleagues confirmed the ambitious plan known as “LCLS II” for a multiple-undulator facility with variable-polarization soft and hard X-ray beams and even an emerging “LCLS III” scenario contemplating the use of the full SLAC linac at 28 GeV for terawatt peak power level FEL beams.

Following an invitation by representatives of the Japanese SPring-8 project, it was agreed that the next meeting should take place in the autumn of 2011 at the Japanese site. At that time, the SPring-8 X-ray FEL will be operating and some data will be available. ■

PRESS AND PUBLIC RELATIONS

To establish a large, new research facility like the European XFEL—and to ensure its long-term acceptance locally, nationally, and internationally—it is essential to provide open, honest, and comprehensive information to the public. A dialogue with the public was initiated by the DESY public relations department as soon as the project of an X-ray free-electron laser facility in the Hamburg region first took shape. Since early 2008, this dialogue has been deepened by a dedicated European XFEL Press and Public Relations (PR) group.

The PR group serves as the interface between the public and the European XFEL GmbH. The team fosters contact with local, national, and international media, publishes the European XFEL web portal and other information materials for various target groups, and represents the European XFEL at selected events. During the construction phase of the facility, strong emphasis is also being placed on neighbourhood work.

Even before the foundation of the European XFEL GmbH, the PR group developed a corporate design—comprising a logo, colour scheme, and fonts for templates of various publication media—to ensure a uniform appearance and high recognizability of the new institution (Figure 1). Another major element of PR activities is the web portal (www.xfel.eu), which is published in English and German. The web portal provides both general and in-depth information about the European XFEL, separated into four categories: overview, research, organization, and construction project. Special-interest groups—neighbours, journalists, scientists, and European XFEL employees—can access specific information using dedicated links. The homepage also features a list of news, workshops and seminars, job offers, and a media database with images and videos.

Figure 1 Elements of the European XFEL corporate design

Figure 2 Neighbourhood “tunnelfest” at the information point FELIX on the Schenefeld construction site (30 June 2010)

Major events are communicated to the media through regular press releases. In addition, the PR group publishes an email newsletter, in English and German, to inform more than 800 subscribers about the latest events at the European XFEL. This newsletter also includes a feature article about a special topic, lists job offers, and spreads information about upcoming events.

Because the European XFEL facility is located in a predominantly residential area, during the civil construction phase (2009–2014), major emphasis is being placed on neighbourhood work. The neighbourhood office, which was initially created by DESY in 2005, 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 email, phone calls, and even personal visits. An information point, named FELIX, near the entrance of the future Schenefeld campus, provides residents and visitors with a good view of construction activities on the site. Information boards and a poster exhibition present an overview of the facility, research opportunities, and construction work. In addition, local residents and members of citizen committees are invited to special events, such as the neighbourhood party that took place on 30 June 2010 to mark the official christening of the first tunnel boring machine (Figure 2). The event attracted nearly 300 visitors from the Hamburg and Schenefeld neighbourhoods. ■

SAFETY

Protecting employees, guests, and the environment are high-priority goals for the European XFEL GmbH. In 2010, the company took major steps to prevent on-the-job injuries, occupational diseases, and incidents leading to environmental or safety problems.

Safety first

Safety is the top priority of the construction project and the company:

- **Construction project**
  The construction project has to comply with the health and safety regulations of the plan approval order (PAO). Ensuring that these issues are properly dealt with is the task of the General Safety work package within the construction project structure.
- **Company**
  As an employer, the European XFEL GmbH is required by law to take all necessary measures to protect its employees and guests from work accidents, occupational diseases, and harmful influences originating in the work environment.

General Safety work package

The General Safety work package is in charge of the following tasks:

- Assessing risk and analysing hazards for the overall facility installation and later operation
- Creating a health, safety, and environmental concept as well as an emergency organization for the installation and operation phases
- Tracking the PAO: verifying the completeness, consistency, and compliance of the individual items; obtaining operations permits; organizing safety inspections by regulatory authorities; and documenting fulfilment of all PAO items
- Updating the safety expertise provided by the German Research Association for Underground Transportation Facilities Ltd. (STUVA)
- Cooperating with regulatory authorities
- Planning an access control system for the facility buildings, notably the underground areas
- Advising all work package groups about health, safety, and environmental issues

The work package leader in charge of these tasks is the head of the DESY safety group. In accordance with the cost book for the startup configuration of the facility, the budget assigned to general safety amounts to 6.3 million euro (at the 2005 price level).

Safety administrators

Within the company, the European XFEL Managing Directors are responsible for setting up and implementing safety measures. In accordance with the legal framework defined by the German Labour Protection Law (*ArbSchG*) and the German Social Welfare Code, Book VII

(*SGB VII*), the managing directors have delegated these duties to safety administrators (*Sicherheitsverantwortliche*).

For the time being, three safety administrators have been appointed, one for each of the three locations where European XFEL employees work:

- Office building at Albert-Einstein-Ring 19
- Undulator lab in DESY Hall 36
- Preparation and laser labs situated in the PETRA III hall

In addition, given that several powerful optical lasers will be installed—initially for testing in the preparation labs, later in the experiment hall—one employee has been made responsible for laser safety.

Safety officers and engineer

In addition, three experienced employees have been appointed as safety officers, one for each of the three locations where employees work. Safety officers assist the safety administrators in implementing occupational safety, in particular by alerting them to safety hazards.

In 2011, the managing directors plan to hire a safety engineer, who will advise the directors and all employees in matters of occupational safety, accident avoidance, health protection, and environmental protection. Pending this recruitment, the tasks of the safety engineer are being carried out by the technical coordinator in consultation with the DESY safety group.

Occupational safety expert and company doctor

In January 2010, the DESY safety group leader was also appointed as the company's expert for occupational safety (*Fachkraft für Arbeitssicherheit*). At the same time, a contract was signed with a company doctor, who is also in charge of DESY personnel.

Occupational safety committee

A committee for occupational safety (*Arbeitsschutzausschuss*) has been established, consisting of:

- Administrative director (or representative)
- Occupational safety expert
- Company doctor
- One security administrator

During 2010, the committee met three times. At its August meeting, the committee undertook a thorough inspection of all workplaces at Albert-Einstein-Ring 19.

At the proposal of the committee, three first-aid volunteers were nominated for the three work locations.

Technical emergency services

In 2010, the management board also developed a first concept for technical emergency services on the Schenefeld campus. To benefit from organizational synergy, close cooperation with the corresponding DESY service was sought.

Safety of equipment

An intense discussion has taken place on the safety of all of the equipment to be installed and further integrated in the accelerator complex and the scientific instruments, including their appropriate certification. A solution, suited to the specific situation at research laboratories, is being investigated by colleagues at DESY in the framework of the Helmholtz Association. ■

SERVICES

An advanced scientific facility like the European XFEL requires a highly professional administrative infrastructure to operate smoothly and efficiently. Even before the formal creation of the European XFEL GmbH, essential administrative structures were put in place. Since the foundation of the company in the autumn of 2009, the recruitment of personnel has proceeded at full speed, enabling most of the administrative positions to be filled by the end of 2010.

Personnel development

The European XFEL GmbH was formally created in October 2009. Before then, the build-up of personnel proceeded rather slowly due to continuing uncertainty about the exact date of the signing of the company convention and the founding of the GmbH. Thanks to the EU-funded Pre-XFEL project, which started in 2007, and the generous help of Deutsches Elektronen-Synchrotron (DESY), it was possible to recruit key personnel beforehand. Employees were hired by DESY with fixed-term contracts ensuring a “safety net” until the founding of the company enabled the management to offer contracts with the European XFEL GmbH. In addition, pre-existing contracts with DESY were taken over by the company on 1 January 2010.

After the GmbH was founded, hiring activities increased in intensity. Today, these activities continue at full speed. As of December 2010, the company has 74 employees, as shown in Figure 1. The staff consists of 47% scientific, 33% administrative, 19% engineering, and 1% technical staff. While hiring for the administrative staff is almost complete, the scientific, engineering, and technical contingent will continue to grow.

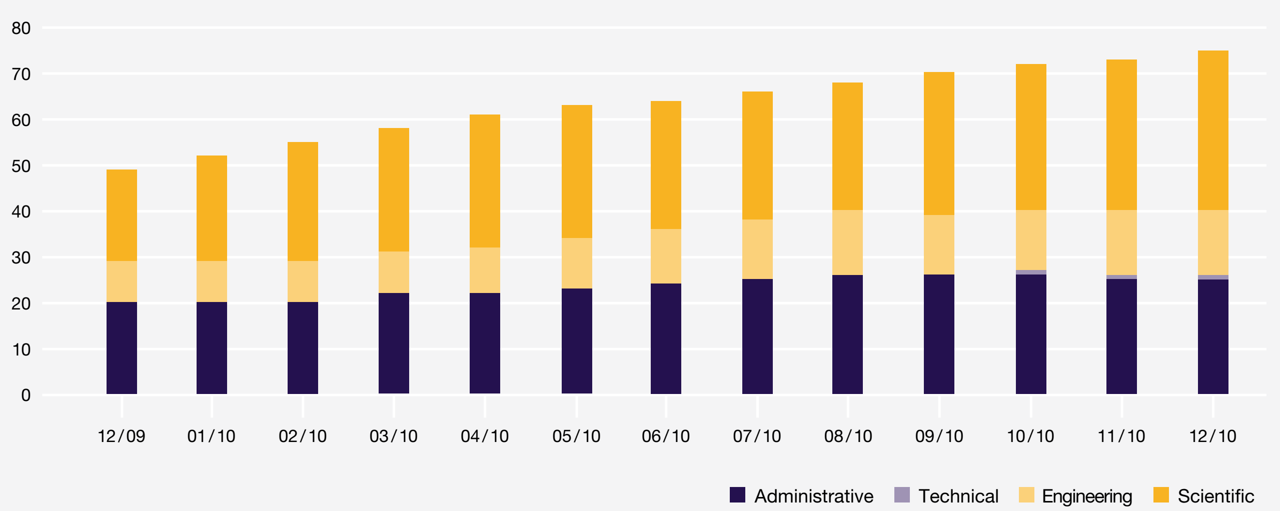


Figure 1 Build-up of staff since the founding of the company

For 39 advertised open positions between December 2009 and December 2010, 867 applications were received and processed, as shown in Figure 2.

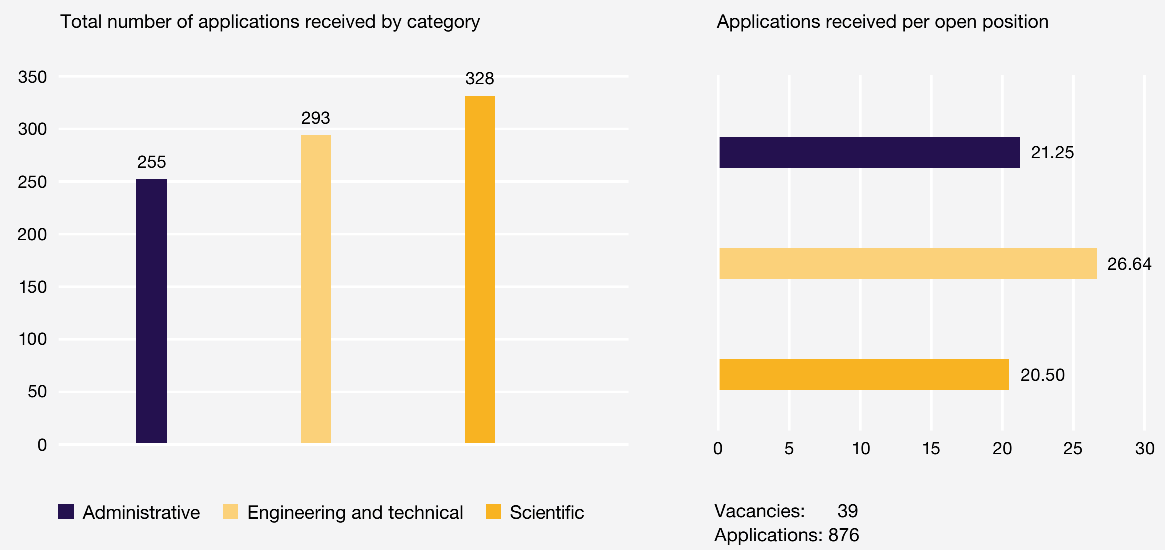


Figure 2 Hiring process from December 2009 to December 2010 for administrative, engineering and technical, and scientific positions

As of December 2010, employees of the European XFEL come from 17 countries: Australia, Canada, China, Croatia, Denmark, France, Germany, India, Indonesia, Iran, Italy, Poland, Russia, Spain, the UK, Ukraine, and the USA. The percentage of non-German nationals is markedly higher among the scientific staff (62%) than among the non-scientific staff (26%). The distribution of nationalities among the scientific staff is shown in Figure 3. Staff members are listed on page 114 and pictured on page 115.

Currently, the staff is 68% male and 32% female. To provide a contact point on equal-opportunity issues for all employees, the European XFEL Management Board established an equal-opportunity policy for the company in 2010, thereby ensuring compliance with European and German equal-opportunities legislation. The elections of the first two spokespersons will take place in February 2011.

The company management continues to focus on building up a workforce that is highly qualified and diverse with respect to nationality and gender. The introduction of the company pension scheme is an additional valuable contribution to the attractiveness of the working conditions.

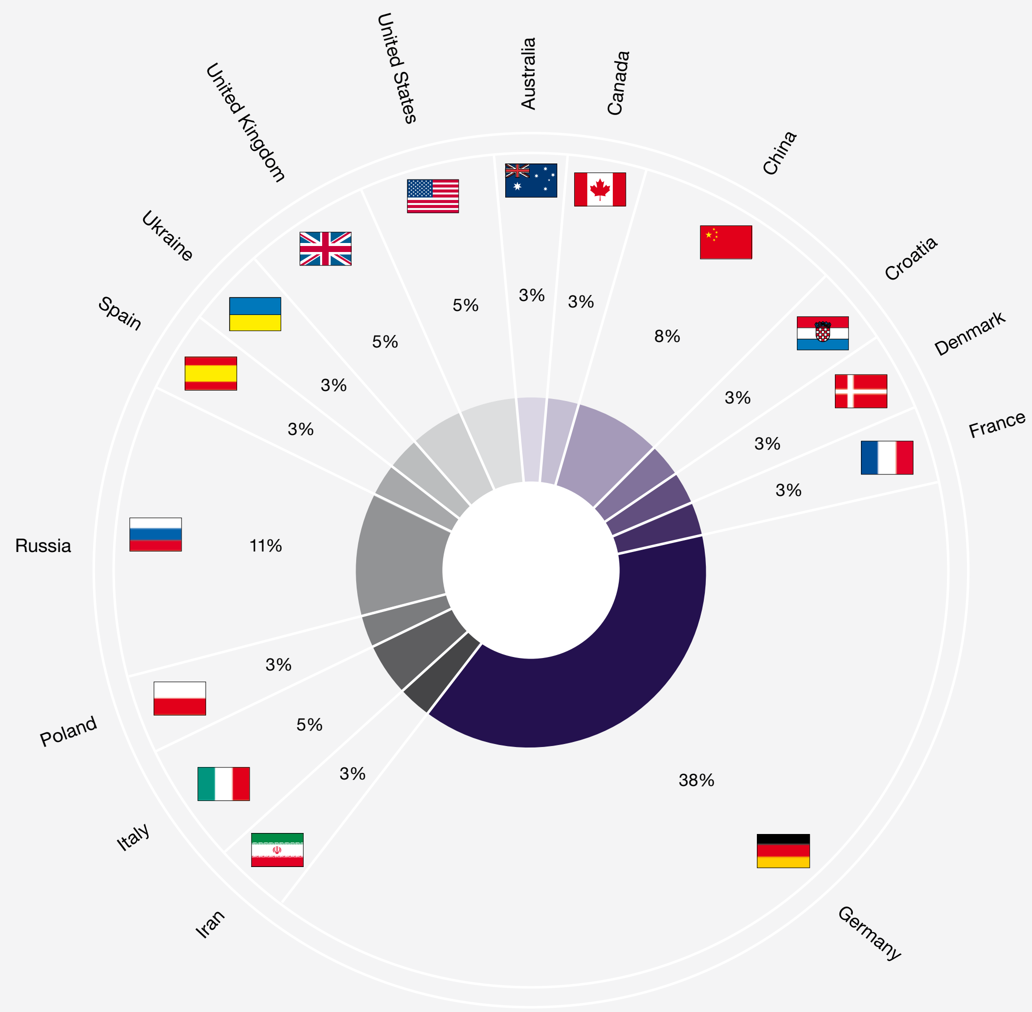


Figure 3 Distribution of nationalities among scientists at the European XFEL GmbH (December 2010)

Regulations and communication

During 2010, the European XFEL Council, on the recommendation of the Administrative and Finance Committee, amended the financial rules of the company and approved internal financial regulations, which further specify the financial and contolling practices and procedures for internal use within the company.

The staff rules were amended slightly, essentially to follow the collective agreements for German public service employees. At the end of 2010, the company concluded an agreement on an occupational pension scheme, which provides an add-on to the statutory national pension scheme in Germany.

The discussion of the procurement rules continued throughout the year. In addition, the council agreed on various bylaws, such as its own rules of procedure as well as the rules of procedure for the management board.

In accordance with the requirements of the German commercial code, the management board adopted a risk management handbook that sets out internal procedures for identifying, monitoring, preventing, and mitigating risks at the European XFEL GmbH.

The management board also established "Rules to ensure good scientific practice", which are annexed to the employment contracts with scientists. In addition, a policy covering scientific publications by all employees working for the European XFEL was developed and published. This policy instructs employees to archive post-print versions of their published scientific manuscripts in the Open Access archive (arXiv). For all company staff, a policy was put in place that enables all employees to apply for official company business trips and receive reimbursement for travel expenses.

To improve communication among the staff, an internal news bulletin is sent by email to all employees on a weekly basis. Once a month, a general staff meeting is held to facilitate the direct exchange of news and views between all staff members and the management board. In addition, group leaders have been meeting once a month since late 2010. ■

Staff of the European XFEL GmbH (December 2010)

Altarelli, Massimo
Ament, Kurt
Bearzotti, Chiara
Bressler, Christian (not shown)
Budrovic, Zeljka
Coppola, Nicola (not shown)
Dastjani Farahani, Shafagh
Deron, Georg
Desai, Abhishek
Englisch, Uwe
Esenov, Sergey
Flammer, Meike (not shown)
Folkerts, Petra
Freijo-Martin, Idoia
Freund, Wolfgang
Galasso, Germano (not shown)
Galler, Andreas (not shown)
Gaudin, Jérôme (not shown)
Gawelda, Wojciech (not shown)
Geloni, Gianluca
Gembalies, Imke
Glauß, Christian
Grünert, Jan (not shown)
Guhlmann, Florian
Haas, Tobias
Halimah, Halimah
Heeßel, Gabriela
Heisen, Burkhard
Karabekyan, Suren
Knoll, Martin
Kohlstrunk, Nicole
Kozlova, Iryna (not shown)
Krupin, Oleg (not shown)
Kunz, Marc
Kuster, Markus (not shown)
Laub, Malte
Lederer, Maximilian (not shown)
Li, Bin
Li, Yuhui
Liebram, Axel (not shown)
Madsen, Anders
Mancuso, Adrian (not shown)
Mergen, Julia (not shown)
Meyer, Michael (not shown)
Molodtsov, Serguei (not shown)
Mulá Mathews, Gabriella
Nawrath, Gunther (guest scientist, not shown)
Osterland, Christiane
Pannier, Reik
Pflüger, Joachim
Poljancewicz, Bartosz (not shown)
Poppe, Frank
Prat, Serge
Raciniewski, Magdalena
Radcliffe, Paul (not shown)
Röhling, Maike
Rychev, Mikhail (not shown)
Samoylova, Liubov
Sauermann, Wolf-Ulrich
Schmidt, Sven-Oliver
Schulz, Carola
Schwarz, Andreas
Sinn, Harald
Smolyakov, Nikolay (guest scientist)
Suhr, Stephanie
Tomin, Sergey (guest scientist)
Trapp, Antje
Tschentscher, Thomas (not shown)
van Hees, Brunhilde (not shown)
Witte, Karl
Wilson, Dana (not shown)
Wolfarth, Svenja
Wrona, Krzysztof
Yang, Fan (not shown)
Youngman, Christopher (not shown)

Forty-nine employees of the European XFEL GmbH (15 December 2010)

SHAREHOLDERS

The European XFEL is organized as a non-profit company with limited liability under German law (GmbH) 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 2010)	
Denmark	DASTI (Danish Agency for Science, Technology and Innovation)
Germany	DESY (Deutsches Elektronen-Synchrotron)
Hungary	NKTH (National Office for Research and Technology)
Poland	IPJ (Andrzej Soltan Institute for Nuclear Studies)
Russia	RUSNANO (Russian Corporation of Nanotechnologies)
Slovak Republic	Slovak Republic, represented by the Ministry of Education
Sweden	VR (Vetenskapsrådet, 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 Science and Innovation

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 shareholders' assembly and decides on important issues of company policy.

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

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 Ødegaard (Danish Agency for Science, Technology and Innovation, Copenhagen) and Martin Meedom Nielsen (Technical University of Denmark)
Germany	Helmut Dosch (DESY, Hamburg) and Beatrix Vierkorn-Rudolph (Federal Ministry of Education and Research BMBF, Bonn)
Hungary	Dénes Lajos Nagy (KFKI Research Institute for Particle and Nuclear Physics, Budapest)
Poland	Grzegorz Wrochna (Andrzej Soltan Institute for Nuclear Studies, Świerk/Otwock)
Russia	Mikhail Kovalchuk (Kurchatov Institute, 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	
	Stephanie Suhr (European XFEL GmbH, Hamburg, Germany)

European XFEL GmbH Management Board	
Chairman	Massimo Altarelli
Administrative Director	Karl Witte
Scientific Director	Serguei Molodtsov
Scientific Director	Andreas Schwarz
Scientific Director	Thomas Tschentscher

Administrative and Finance Committee (AFC)	
Chairman	Andreas Werthmueller (State Secretariat for Education and Research, Bern, Switzerland)
Vice chairman	Mikhail Rychev (RRC Kurchatov Institute, Moscow, Russia), until December 2010
Delegates	
Denmark	Anders Ødegaard (DASTI, Copenhagen) and Troels Rasmussen (DASTI, Copenhagen)
Germany	Sebastian Jester (Federal Ministry of Education and Research BMBF, Bonn) and Christian Scherf (DESY, Hamburg)
Hungary	Barbara Vizkelety (NKTH, Budapest)
Russia	Alexey Raykevich (RUSNANO, Moscow) and Valeriy Nosik (RRC Kurchatov Institute, Moscow)
Slovak Republic	Pavol Sovák (P.J. Šafárik University, Košice)
Sweden	Inger Andersson (Swedish University of Agricultural Sciences, Uppsala) and Leif Eriksson (Swedish Research Council, Stockholm)
Switzerland	Peter Allenspach (Paul Scherrer Institute, Villigen)
Secretary	
	Meike Flammer (European XFEL GmbH, Hamburg, Germany)

Machine Advisory Committee (MAC)	
Chairman	Mikael Eriksson (MAX-lab, Lund, Sweden)
Members	
	Hans-Heinrich Braun (Paul Scherrer Institute, Villigen, Switzerland)
	Paul Emma (LCLS/SLAC, Stanford, USA)
	Massimo Ferrario (INFN, Frascati, Italy)
	Jacek Krzywinski (SLAC, Stanford, USA)
	Gennady Kulipanov (BINP, Novosibirsk, Russia)
	John Mammosser (Jefferson Lab, Newport News, USA)
	Alban Mosnier (CEA, Saclay, France)
	Felix Rodriguez Mateos (CERN/ITER, Switzerland/France)
	Richard Walker (DIAMOND, Oxfordshire, United Kingdom)
Secretary	
	Gianluca Geloni (European XFEL GmbH, Hamburg, Germany)

Scientific Advisory Committee (SAC)	
Chairman	Gyula Faigel (RISSPO – Hungarian Academy of Sciences, Budapest, Hungary)
Vice chairman	Salvador Ferrer (CELLS/ALBA, Cerdanyola del Vallès, Spain)
Members	
	Rafael Abela (Paul Scherrer Institute, 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, Stanford, USA)
	Krystina 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, Russia)
	Franz Pfeiffer (TU Munich, Germany)
	Aymeric Robert (LCLS, Stanford, USA)
	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 GmbH, Hamburg, Germany)

In-Kind Review Committee (IKRC)	
Delegates	
Denmark	Søren Schmidt (Risø DTU)
France	Alex Mueller (CNRS, Paris)
Germany	Thomas Hott (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 (Andrzej Soltan Institute for Nuclear Studies, Świerk/Otwock)
Russia	Leonid Kravchuk (Institute for Nuclear Research of the Russian Academy of Sciences, Moscow)
Slovak Republic	Stefan Molokac (CRYOSOFT LTD, Košice)
Spain	Teresa Martínez De Álvaro (CIEMAT, Madrid)
Sweden	Håkan Danared (European Spallation Source ESS AB, Lund)
Switzerland	Volker Schlott (Paul Scherrer Institute, Villigen)
European XFEL GmbH	Andreas Schwarz (for the accelerator) and Thomas Tschentscher (for the beamlines)
Secretary and Lawyer	
	Serge Prat (European XFEL GmbH, Hamburg, Germany)
	Malte Laub (European XFEL GmbH, Hamburg, Germany)

Detector Advisory Committee (DAC)	
Chairman	Peter Siddons (NSLS/BNL, Upton, USA)
Members	
	Nigel Allinson (University of Lincoln, United Kingdom)
	Niels van Bakel (NIKHEF, Amsterdam, Netherlands)
	Michael Campbell (CERN, Geneva, Switzerland)
	Pablo Fajardo (ESRF, Grenoble, France)
	Karl-Tasso Knöpfle (MPI für Kernphysik, Heidelberg, Germany)
	Jörg Klora (CELLS/ALBA, Cerdanyola del Vallès, Spain)
	Tim Nicholls (Rutherford Appleton Laboratory, Oxfordshire, United Kingdom)
	Paul O'Connor (BNL, Upton, USA)
	Amedeo Perazzo (SLAC, Stanford, USA)

MANAGEMENT BOARD

- **Chairman, Managing Director** Massimo Altarelli
- **Managing Director** Karl Witte
- **Scientific Director** Serguei Molodtsov
- **Scientific Director** Andreas Schwarz
- **Scientific Director** Thomas Tschentscher

MB Assistant Stephanie Suhr

ADMINISTRATION – Karl Witte

- **Central Services** TBD ▪
- **Finance** Christian Glauß ▪
- **Human Resources** Wolf-Ulrich Sauermann ▪
- **Law Office**
- **Procurement** TBD ▪

SCIENTIFIC UNIT – Serguei Molodtsov

- **Simulation of Photon Fields** (WP-72) Gianluca Geloni ▪
- **X-Ray Photon Diagnostics** (WP-74) Jan Grünert ▪
- **Exp. Hall and Instrument Environment** (WP-79) TBD ▪
- **Scientific Instrument SQS** (WP-85) Michael Meyer ▪
- **Scientific Instrument SCS** (WP-86) TBD ▪

SCIENTIFIC UNIT – Andreas 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** (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) TBD ▪
- **Scientific Instrument SPB** (WP-84) Adrian Mancuso ▪

Staff functions

- **Controlling** Chiara Bearzotti ▪
- **In-Kind Contributions / Quality Assurance** Serge Prat ▪
- **Internal Audit** TBD ▪
- **Press & Public Relations** Petra Folkerts ▪
- **Secretariat** Stephanie Suhr ▪
- **Technical Coordination** Tobias Haas ▪

External staff

- **Company Doctor** Katharina Bünz
- **Data Protection** Carsten Porthun
- **Safety Specialist** Andreas Hoppe

Director — External staff — ▪ Group Leader / Supervisor

European X-Ray Free-Electron Laser Facility GmbH (December 2010)

08

SCIENTIFIC RECORD

■ Thanks to the dedication of everyone involved in the European XFEL, the scientific record of the facility is already impressive. Between October 2009 and December 2010, the company hosted the 4th European XFEL User's Meeting, half a dozen international workshops, and a dozen onsite seminars featuring scientists from around the world. During the same period, staff members published over 40 scientific articles and technical reports.

EUROPEAN XFEL USERS' MEETING

27–29 January 2010
Deutsches Elektronen-Synchrotron (DESY), Hamburg, Germany

The European XFEL Users' Meeting is an annual opportunity to strengthen the interaction between the European XFEL project and the scientific user community. As in previous years, the fourth such meeting saw an increase in the number of potential users of the facility. More than 280 scientists from 21 countries—including all European XFEL partner countries, as well as Australia, Austria, Belarus, Belgium, the Czech Republic, Gabon, India, Ireland, Japan, the Netherlands, the UK, and the USA—travelled to Hamburg for the meeting. The early successes at the Linac Coherent Light Source (LCLS) at SLAC National Accelerator Laboratory, which went into operation in 2009, seem to have actually increased the excitement about the possibilities of the European XFEL.

The 4th European XFEL Users' Meeting focused on the following:
- Selected science applications
- Progress and current status of the European XFEL X-Ray Photon Diagnostics group to study photon-beam-based alignment (PBBA) procedures
- Results of 2009 technical and scientific workshops
- Current developments in the field of X-ray free-electron laser (FEL) facilities
- Job opportunities at the European XFEL

Figure 1 Impressions of the 4th European XFEL Users' Meeting (January 2010)

INTERNATIONAL SCHOOL FOR YOUNG SCIENTISTS

11–13 November 2009
Advanced research in photon sciences—Experimental capabilities of the European XFEL
Shubnikov Institute of Crystallography of the Russian Academy of Sciences (IC RAS), Moscow, Russia

At the initiative of the Russian science community, an international school for young scientists was held in Moscow in November 2009. The aim of the school was to educate young scientists in state-of-the-art research in photon science using FEL radiation. The school provided general tutorial presentations on physics and FEL techniques, as well as scientific talks on experiments to be performed at the European XFEL. The lectures were held by more than 15 leading scientists from around the world with expertise in various fields of FEL-related research. In addition, Russian lecturers reviewed the interests and achievements of the Russian scientific community.

WORKSHOPS

You will find a list of all European XFEL workshops, including the speakers' presentations and workshop reports, at the following location:

www.xfel.eu/events

The meetings presented below for the Materials Imaging and Dynamics (MID) and Femtosecond X-Ray Experiments (FXE) instruments were the last in a series of six workshops that discussed the scientific cases and designs of the European XFEL scientific instruments. The series started with the Small Quantum Systems (SQS) and Single Particles, Clusters, and Biomolecules (SPB) instruments in October and November 2008, respectively. The High-Energy Density (HED) matter experiments and Spectroscopy and Coherent Scattering (SCS) instruments followed in March and June 2009, respectively. All six workshops featured a number of invited lectures on scientific and technical aspects, followed by group sessions that provided opportunities for extended discussions from broad user communities on the construction of the instruments and on their capabilities.

28–29 October 2009
MID workshop 2009: International workshop for the Materials Imaging and Dynamics instrument at the European XFEL
European Synchrotron Radiation Facility (ESRF), Grenoble, France

The goal of the Materials Imaging and Dynamics (MID) instrument at the European XFEL is to investigate nanosized structures and nanoscale dynamics using coherent radiation. Applicability to a wide range of materials—from hard to soft condensed matter and biological structures—is envisaged.

The workshop was attended by 71 scientists from 10 countries (Figure 2). Presentations described the scientific case of the MID instrument before focusing on the technical specifications.

In particular, the lectures addressed the following topics:

- Source properties (energy range, polarization)
- Experimental infrastructure (sample chamber, temperature range, magnetic field, and pump laser)
- 2D detector system
- Diagnostics and synchronization

Figure 2 Participants of the MID workshop (October 2009)

9–11 December 2009
FXE workshop 2009: International workshop on the science and instrumentation for femtosecond X-ray experiments at the European XFEL
Hotel Benczur, Budapest, Hungary

The Femtosecond X-Ray Experiments (FXE) instrument will exploit the unique time structure and intensity of the European XFEL for structural dynamics studies of molecules, biological species, and solid-state materials. This instrument will enable investigations of electronic and atomic structure changes that are not possible today. It will thereby supplement several fields of contemporary research, including chemical and biological dynamics as well as solid-state physics. Advanced X-ray spectroscopy and scattering methods will be implemented with femtosecond time resolution, as will techniques that require the intense average X-ray FEL flux. Ninety-three scientists from 17 countries participated in the workshop.

14–17 February 2010
International workshop on X-ray diagnostics and scientific applications of the European XFEL
Ryn, Poland

This workshop, which was organized by the European XFEL with support from the Pre-XFEL grant, brought together X-ray diagnostics experts and the future user community of the facility. The main goals were to present the initial diagnostics concept to the users and to get their feedback for improvements. The workshop was attended by 62 scientists from 9 countries.

Presentations on X-ray diagnostics and scientific applications were followed by sessions of topical working groups, which reviewed parameters, requirements, and methods.

These working groups were dedicated to the measurement of the following photon beam properties:
- Spatial profiles, wavefront, and coherence
- Spectral properties
- Temporal properties

16–17 December 2010, Trieste, Italy

International workshop on soft X-ray science and instrumentation at the European XFEL

Abdus Salam International Centre for Theoretical Physics (ICTP), Trieste, Italy

Soft X-ray instrumentation at the European XFEL undulator SASE3 includes two instruments:

- **Small Quantum Systems (SQS)**
  Deals with the investigation of atoms, ions, molecules, and clusters in intense fields and of non-linear phenomena
- **Spectroscopy and Coherent Scattering (SCS)**
  Aims at studies of the electronic and atomic structure and dynamics of hard, soft, and biological nanoscale objects

Following two previous instrumentation workshops on SQS in Aarhus (2008) and SCS in Villigen (2009), this workshop was designed to bring the soft X-ray scientific community together to coordinate and synchronize its activity. Another major aim was to inform attendees about new results obtained at different FEL facilities and about recent developments at the European XFEL. The workshop was organized together with the Sincrotrone Trieste.

More than 90 scientists from 10 countries around the world participated in the workshop (Figure 3). Several participants came from countries that attended the European XFEL instrumentation workshops for the first time, such as Austria, China, and Serbia.

Figure 3 Participants of the soft X-ray science and instrumentation workshop (December 2010)

The introductory project status report was followed by presentations of new results obtained at the two operating X-ray FEL facilities (FLASH and LCLS) in all the application areas of the European XFEL soft X-ray instruments identified by the user working groups at the previous SQS and SCS workshops. Each session was concluded by a corresponding report describing the updated user requirements. The general discussion at the end of the workshop confirmed the European XFEL considerations concerning the scientific scope of the instruments. The conceptual design of SQS and SCS will now be finalized and presented to the user community.

SEMINARS

25 September 2009
Time-resolved XANES measurements of warm dense matter using ultrashort laser-plasma X-ray source
Fabien Dorchies, University of Bordeaux, CNRS, CEA, France

11 March 2010
CVD diamond detectors for X-ray beam monitoring
Michal Pomorski, Laboratoire Capteurs Diamant, CEA, France

25 March 2010
Parallel X-ray femtosecond spectrometer
Alexei Erko, Helmholtz-Zentrum Berlin, Germany

19 April 2010
Set up and operation of high-resolution monochromators
Rolf Follath, Helmholtz-Zentrum Berlin, Germany

22 April 2010
Ultrafast photoreactions in biomolecules studied by femtosecond laser spectroscopy
Stefan Haacke, University of Strasbourg, France

28 April 2010
Ultrafast photophysics of protochlorophyllide a
Benjamin Dietzek, University of Jena, Germany

29 April 2010
Disentangling thermal and non-thermal excited states in a charge-transfer insulator by ultrafast optical spectroscopy
Goran Zgrablic, Sincrotrone Trieste, Italy

20 May 2010
DiProI project at FERMI@ELETTRA: present status and research perspectives
Maya Kiskinova, Sincrotrone Trieste, Italy

20 May 2010
Science frontiers with the FERMI@ELETTRA free-electron laser
Fulvio Parmigiani, Department of Physics, University of Trieste,
and FERMI@ELETTRA Laboratory, Sincrotrone Trieste, Italy

4 June 2010
High-energy X-ray spectroscopy at high-energy laser facilities
Csilla Szabo, Naval Research Laboratory, Washington, DC, USA

15 June 2010
Experience with commissioning of the LCLS undulator system
Heinz-Dieter Nuhn, SLAC LCLS, Stanford University, Palo Alto, USA

9 July 2010
Engineering seminar: Thin-film mechanical stability and fracture prevention
Alex A. Volinsky, University of South Florida, Tampa, USA

19 July 2010
WAVE: A general-purpose code for synchrotron radiation
Michael Scheer, Helmholtz-Zentrum Berlin, Germany

27 July 2010
Engineering seminar: Simplified quantum mechanics for engineers
Alex Volinsky, University of South Florida, Tampa, USA

9 September 2010
An X-ray emission spectrometer with unique capabilities at CLÆSS beamline of ALBA synchrotron
Konstantin Klementiev, Experiments Division, ALBA Synchrotron Light Facility, Barcelona, Spain

16 September 2010
Engineering seminar: Advanced design concepts for high-precision X-ray optics
Tino Noll, Helmholtz-Zentrum Berlin, Germany

17 September 2010
Quantum chemical study of spin crossover in Fe(II) complexes
Coen de Graaf, University of Tarragona, Spain

23 September 2010
X-ray grating interferometry for wavefront sensing applications
Timm Weitkamp, Synchrotron SOLEIL, Gif-Sur-Yvette, France

7 October 2010
Ultrafast electron kinetics in semiconductors and metals irradiated with VUV-XUV femtosecond laser pulse
Nikita Medvedev, University of Kaiserslautern, Germany

3 November 2010
Quality and project management system at SOLEIL
Hélène Rozelot, Synchrotron SOLEIL, Gif-sur-Yvette, France

2 December 2010
X-ray tomography on laboratory sources with micrometre resolution
Alexey Buzmakov, Shubnikov Institute of Crystallography, Moscow, Russia

16 December 2010
Resonant coherent excitation of relativistic HCIs in crystals as a model for polarization XFEL studies in the keV region
Vsevolod Balashov, Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University, Moscow, Russia

PUBLICATIONS

JOURNALS

Coherence properties of the European XFEL
G. Geloni, E. Saldin, L. Samoylova, E. Schneidmiller, H. Sinn, Th. Tschentscher, M. Yurkov
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Cascade self-seeding scheme with wake monochromator for narrow-bandwidth X-ray FELs
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Circular polarization control for the LCLS baseline in the soft X-ray regime
G. Geloni, V. Kocharyan, E. Saldin
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Control of the amplification process in baseline XFEL undulator with mechanical SASE switchers
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Generation of doublet spectral lines at self-seeded X-ray FELs
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Scheme for femtosecond-resolution pump-probe experiments at XFELs with two-color ten GW-level X-ray pulses
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Scheme for generation of fully-coherent, TW power level hard X-ray pulses from baseline undulators at the European X-ray FEL
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Way to increase the user access at the LCLS baseline
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