

Two-beam hologram encoding two images of the test object taken 50fs apart, see page 2.

## FEL science takes off

International collaboration is essential

Science at X-ray free electron lasers (FEL) has gained enormous momentum during the last years. About 200 research projects have been conducted so far at the first two facilities of this kind, FLASH in Germany and LCLS in the US, that have been in routine user operation since 2005 and 2009, respectively. They resulted in numerous publications in high-impact journals, and several made it on cover pages of the prestigious Nature journals and Physical Review Letters.

New FEL facilities in Italy (FERMI) and Japan (SACLA) have recently become operational, demonstrating the maturity of single-pass free electron lasers together with significant advancements in FEL technology. This tremendous success has established X-ray FELs as new research tools complementing optical lasers and synchrotron radiation sources and opening new research opportunities for a wide range of scientific disciplines, including physics, chemistry, materials and life science.

The growing interest in the science community goes along with heavy overbooking of experimental stations, but has also driven the extension of existing and the construction of new facilities worldwide. At this point, close international collaboration is crucial: collaboration of user groups in order to maximize their use of the limited number of experimental stations for specific research areas, collaboration of facility operators to advance the technology in an efficient way and to provide state-of-the-art facilities for the science community, and close interaction between the facilities and the user community to promote new developments and to balance demand and supply.

In this regard, an important milestone will be the signing of a memorandum of understanding between EuroFEL partners and the European XFEL. The MoU is based on the core activities defined by EuroFEL's preparatory phase project, IRUVX-PP; the signing of the document is planned at the ERF meeting at DESY end of May. *JF*

### Invitation

Science at FELs, a SRI 2012 Satellite Meeting, is jointly organized by DESY and European XFEL from July 15-18, 2012 in Hamburg. A number of free-electron laser facilities for the VUV and hard X-ray range are now in operation in Asia, Europe and the US, and their performance exceeds the initially proposed radiation properties.

The meeting will present science highlights achieved in the first seven years of operation of short-wavelength FELs. Applications from quantum optics to life sciences and systems from atoms to complex solids will be featured. A focus will also be placed on new directions in science at FELs and challenges to scientific instrumentation. Visits of the FLASH facility at DESY and the European XFEL construction site will be included in the meeting programme.

New FEL schemes are emerging and will lead to further improvements in performance. A workshop to discuss new science opportunities using seeded FEL radiation at the European XFEL will follow the Science at FELs Meeting from July 19-20, 2012.

All the best,

Elke Plönjes  
for the local organising committee

### IN THIS ISSUE

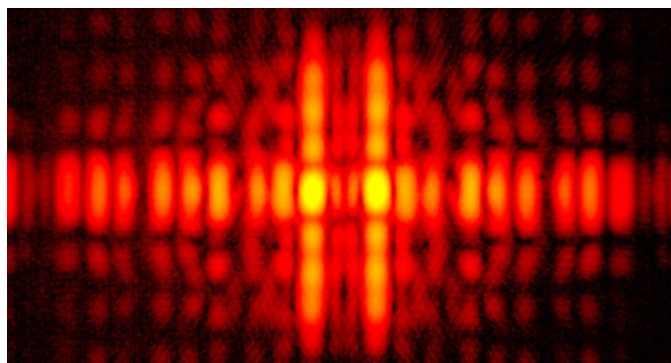
Scientific Highlights .....	02
FEL Projects in Europe.....	03
International Cooperations .....	06
Interaction with Users.....	08

### Femtosecond sequential X-ray imaging

Femtosecond snapshot imaging is well established at Free Electron Lasers. How about ultrafast image sequences as in a movie?

X-ray Free Electron Lasers (FELs) provide bright femtosecond pulses at short wavelength. Snapshot X-ray imaging of ultrafast processes on short length scales is thus an obvious application, which is currently opening new scientific fields. Beyond a single image, time resolved spatial information can be obtained in pump-probe experiments for triggerable, deterministic processes. A complementary approach of recording independent images with only femtosecond separation was demonstrated recently at FLASH<sup>1</sup>.

Holography allows to encode more than one image in a single hologram – on the order of a dozen images per single shot exposure have been recorded via Fourier Transform Holography at FLASH and LCLS so far. In conjunction with a two-pulse illumination of a test object via splitting and delaying a single FEL pulse, a particular variant of this trick was exploited to encode images of a test object seen at two illumination times in one hologram. In this fashion, two independent images were recorded only 50 fs apart and stored in a single exposure on a CCD camera (see figure) mapping the temporal illumination sequence into a modulation pattern in the hologram. This circumvents the funda-



mental read-out time limitations of 2D detectors required for image formation, as no readout in between the subsequent scattering events is necessary. In the future, the method will allow the investigation of untriggered and not necessarily repetitive dynamics on the nanoscale.

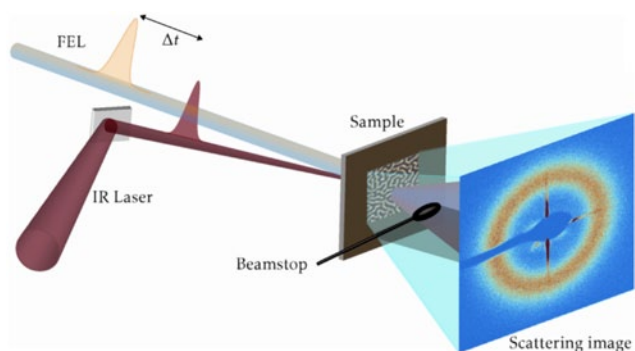
Beyond optical schemes to split and delay the photon beam, FEL accelerator based approaches to generate staggered electron bunches in the pico- and femtosecond regime may be an efficient way to generate the required consecutive X-ray pulses, possibly allowing for more image frames or even multi-color experiments in the future<sup>2</sup>. [SE](#)

<sup>1</sup> C. M. Günther et al., Nature Photonics 5, 99 (2011).

<sup>2</sup> B. Pfau et al., New J. Phys 12, 095006 (2010).

### Tackling the ultimate time scale of magnetization dynamics

Resonant magnetic small angle scattering pump-probe type experiments have been conducted at FLASH (DESY, Hamburg) and the LCLS (SLAC, Stanford, US) SXR beamline. After first prosperous proof of principle experiments at FLASH showing the feasibility to detect non-destructively magnetic scattering at FEL



sources at the L (778 eV) as well as at the M edges (59 eV) of the transition metal element Cobalt,<sup>1,2</sup> a pump-probe scheme could be setup using an IR-femtosecond laser synchronized to the FEL as a pump and the FEL as a probe (see figure). As samples we used thin Cobalt/Platinum multilayers deposited via

ECR and magnetron sputtering on free-standing silicon nitride membranes<sup>3</sup>. The samples show an out-of-plane magnetic anisotropy with alternating up and down domains with an average width in the range of 100 nm. Prior to the FEL measurements an isotropic maze domain state is prepared by out-of-plane demagnetization. In the pump-probe experiments the unrivaled high brilliance of the FEL together with the intrinsically short pulse length allowed for the first time to study ultra-fast dynamics<sup>4</sup> in the magnetic system not only in the temporal but also in the spatial domain. Valuable information about the demagnetization process could be derived.

The experiments were accomplished in a large collaboration between DESY, HZB, Technical University Berlin, University of Hamburg, University Pierre and Marie Curie (Paris), Laboratoire d'optique appliquée (Palaiseau), ETH Zürich, and SLAC. [LM/GG](#)

<sup>1</sup> C. Gutt et al., Phys. Rev. B 79, 212406 (2009).

<sup>2</sup> C. Gutt et al., Phys. Rev. B 81, 100401(R) 2010.

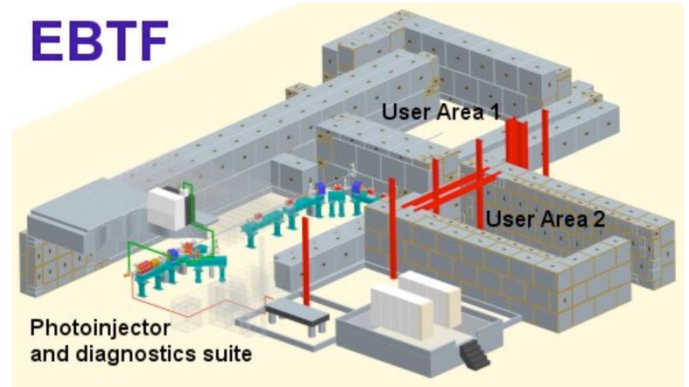
<sup>3</sup> M. Wellhöfer et al., J. Magn. Magn. Mater. 292, 345 (2005).

<sup>4</sup> E. Beaurepaire et al., Phys. Rev. Lett. 76, 4250 (1996).

## Recent developments at Daresbury Laboratory / United Kingdom

The coherent infrared light of ALICE was combined with a Scanning Near-field Optical Microscope to take images of diseased cells demonstrating a potential means of spotting early stage oesophageal cancer. Spatial variations in DNA spectra show diseased cells may be detectable leading to improved diagnosis and prognosis. A new superconducting RF cavity with a high quality factor optimised for applications on energy recovery linacs (ERLs) will be tested on ALICE in the coming year. Construction has begun for an Electron Beam Test Facility, EBTF, aimed at developing new technologies that could revolutionise cost and compactness of accelerator-based systems. This could also form the front end of a future FEL test facility – CLARA. *GBW*

<http://www.stfc.ac.uk/ASTeC/News+and+events/38145.aspx>



## The LUNEX5 project / France

LUNEX5 (free electron Laser Using a New accelerator for the Exploitation of X-ray radiation of 5th generation), a new advanced FEL project proposed by a consortium of laboratories in France, aims at investigating the production of ultra-short (fs), intense, and coherent pulses in the soft X-ray region (20 - 4 nm). It consists of a single FEL line designed for the seeded configuration (high order harmonic in gas seeding and echo enabled harmonic generation)

including in-vacuum undulators with two accelerators: a 400 MeV linac or a 0.4-1 GeV laser wake field accelerator, and experimental stations for time-resolved pilot user experiments on gas phase species and magnetic samples. After completion of the conceptual design report followed by a project review, complementary studies to be coupled to further R&D activities have been started. *MEC*

LUNEX5 (SOLEIL test facility, France)



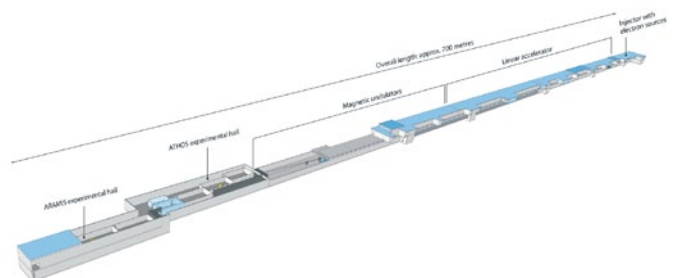
## FERMI & Seeding / Italy

The first call for experiments at the FERMI@Elettra Free Electron Laser, run by Sincrotrone Trieste and located in Italy, was issued last December 2011, providing the users with a novel and unique light source. It operates in the extreme ultra-violet wavelength range with unprecedented spectral and temporal stability, and transverse and longitudinal coherence, generating close-to-transform-limited pulses, carrying tens of microjoules, in the spectral range between 60 and 20 nm. The FERMI free-electron laser is based on the so-called high-gain harmonic generation configuration in which an external laser is used to initiate the emission process overcoming typical limitations of schemes based on self-amplified spontaneous emission: a ground-breaking achievement that pierces the frontiers for the next generation light sources. *EA/LBP*



## SwissFEL / Switzerland

An important political milestone for the realization of the new SwissFEL facility was reached on the 23th of August 2011, the "Grossrat" of the Kanton Aargau voted in favour of the SwissFEL building site. This means that the legally valid building permit for SwissFEL can be expected by the end of May 2012. The project is progressing well. The new SwissFEL facility will open the door to discoveries in many areas of current research that cannot be obtained using existing methods, and will also provide the basis for a vast range of technical and scientific developments.



The collection of user input for the design of the initial set of instruments at the SwissFEL hard X-ray „ARAMIS“ undulator



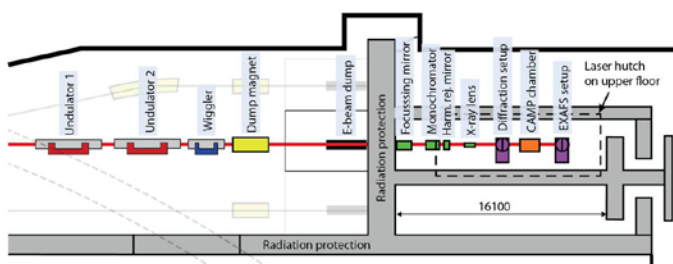
beamline was started with two scientific workshops on hard X-ray instrumentation with the SwissFEL, held in 2011. The first workshop concentrated on spectroscopic experiments, and the second workshop focused on scattering and diffraction experiments. The results of the workshops are available under <http://www.psi.ch/swissfel/swissfel-workshops>. The next step in the instrument design process will be four focused workshops, to be held at PSI. *MvD*

### **The MAX IV project, the Short Pulse Facility and FEL development / Sweden**

In Lund in Sweden MAX-lab is transformed into the MAX IV laboratory with the construction of the ultralow emittance ring MAX IV. More interesting from a EuroFEL perspective is the full energy linac injector and the Short Pulse Facility (SPF) (see figure).

The SPF will use pulses from the linac compressed to 100 fs. The photon energy range will be 2-20 keV and the flux  $10^9$  photons/s in 1% bandwidth (better than slicing sources). The focus of this source is structural dynamics with the fundamental timescale of a vibration period.

The construction of the MAX IV is well under way. The linac tunnel and SPF hall are taking form. The tunnel will be completed and accelerator installations commence in mid 2013.



Schematic layout of the SPF undulator and experimental hall for the MAX IV laboratory.

The injector in the MAX IV is also designed such that it can be used for a FEL. A plan for the continued development is currently being outlined. The department for accelerator physics at Lund University and the MAX IV laboratory will start design work for a FEL on the linac. In parallel the MAX IV laboratory, the Lund Laser Center (LLC) and the FEL center in Stockholm-Uppsala will jointly commence the study for a scientific case of FELs in Sweden. *SW*

### **FLASH2 under construction / Germany**

In September 2011 the civil construction for the second FEL beamline FLASH 2 at DESY has started, requiring a 3.5 months shutdown of FLASH until the end of 2011 and a 1.5 months shutdown of the PETRA storage ring at the beginning of 2012. The construction work is now pressing ahead without major disruption of FLASH and PETRA III operation during 2012. A second FLASH shutdown is scheduled for early 2013, when the existing FLASH accelerator is connected to the new FLASH2 undulator beamline. The goal is to complete the new tunnel and install its major components until spring 2013 and be ready for first experiments in 2014.

The extension of FLASH will in the future double the number of endstations and the throughput of experiments, and new beam qualities will become available. The new science opportunities were discussed with the user community on a three day workshop with over 150 participants in October 2011 (<https://indico.desy.de/conferenceDisplay.py?confId=4425>). The main part of the workshop was devoted to new scientific achievements at FLASH and novel ideas for FLASH instrumentation and experimental setups, which were presented by the user community in 20 contributed talks and a poster session with over 40 contributions. A special focus was given to proposals for long-term experimental end stations of user collaborations. *EP/JF*



FLASH 2 construction in November 2011. Meanwhile this part is completed, the old tunnel (on the left, with the experimental hall in the back) covered again with sand and the FLASH 1 FEL is back in operation. <http://flash2.desy.de>

### **European XFEL construction in full swing**

The construction of the European XFEL is progressing rapidly. End of February 2012 the 2 km long accelerator tunnel was handed over by the construction company and infrastructure installation has been started. Until summer 2012 the tunneling

work will be completed and shafts and surface buildings will follow. The accelerator module test facility (AMTF) will start operation in 2012. Here testing of the niobium accelerator cavities and of the assembled accelerator modules will take place and the wave guide systems will be installed on the accelerator modules. Pre-series undulator segments have arrived for magnetic measurement and the series production of undulator segments starts early 2012. Three development projects for 2D area detectors dedicated to high repetition rate X-ray FEL experiments passed intermediate review and have entered now the prototype phase.

With new project parameters, based on an improved electron beam emittance (confirmed by measurements at PITZ@DESY and LCLS) and flexible electron bunch duration, the European

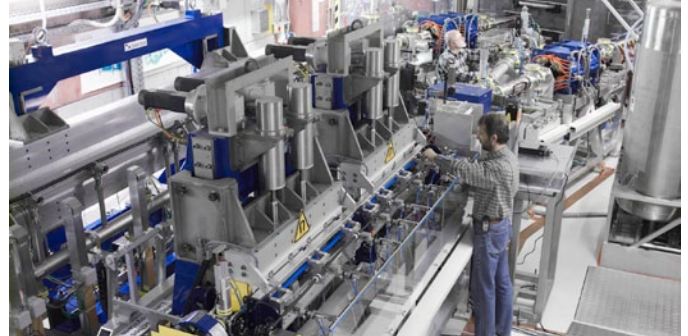


Survey works in February 2012 in one of the future undulator tunnels of the European XFEL after completion of civil construction.

XFEL will now span an even larger photon energy range, from the carbon K-edge to very hard X-rays beyond 20 keV, and will enable time resolved studies from single femtoseconds to microseconds. Conceptual design reports of the X-ray beam transport and four of the prioritized six instruments have been published in 2011 and are available on [www.xfel.eu](http://www.xfel.eu) under Technical Reports. Staffing of the European XFEL GmbH proceeds according to plan and exceeds already 50% of its final target. The overall schedule foresees the first electron beam in the linear accelerator in the autumn of 2015 and the start of user operation in 2016. *TT*

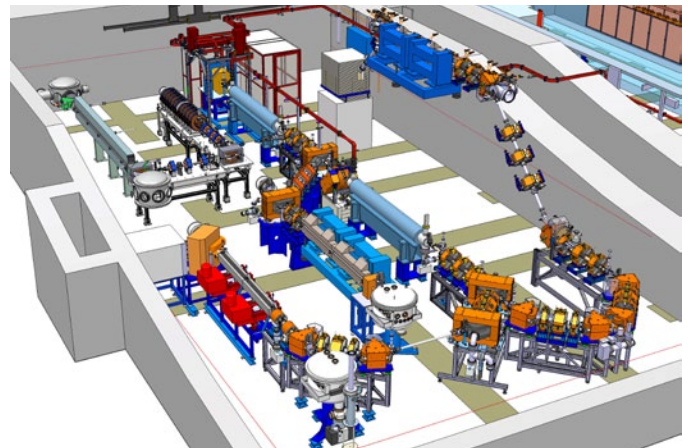
### **Operating infrared FEL user facilities CLIO, FELIX and FELBE / France, Netherlands, Germany**

All European infrared FEL facilities, namely CLIO near Paris, the Dutch facility "FELIX" comprising the free electron lasers FELIX/FELICE and FLARE, and FELBE at Dresden deliver picosecond radiation pulses in the mid- and far-infrared spectral range (3 – 150  $\mu\text{m}$  for CLIO, 3 – 1500  $\mu\text{m}$  for the FELIX facility, 4 – 250  $\mu\text{m}$



FELBE, the IR-FEL at HZDR, Dresden, Germany

for FELBE). The pulse energies are in the 1-100  $\mu\text{J}$  range. All facilities offer tabletop laser systems synchronized to the FELs for two-color experiments. To mention some specific features, FELICE is dedicated to high-power intra-cavity experiments, the terahertz laser FLARE (100 – 1500  $\mu\text{m}$ ) will also operate in a spectroscopic mode with  $\mu\text{s}$ -long pulses offering a spectral resolution of  $\Delta\lambda/\lambda < 10^{-5}$ . FELBE is the only facility able to operate in a quasi-cw mode, with a continuous pulse train at 13 MHz repetition rate. Furthermore, the Dutch facility and FELBE are connected to high-magnetic-field laboratories which provide static and pulsed magnetic fields up to 35 T and 70 T, respectively, and are partners in the ESFRI Roadmap project EMFL ([www.emfl.eu](http://www.emfl.eu)). Typical experiments at the infrared FELs range from pump-probe



The new FELIX layout, Nijmegen, Netherlands

studies in solids (CLIO, FELIX and FELBE) to near-field microscopy (FELBE and CLIO) and molecular dynamics (FELIX and CLIO). FELIX and FELICE are currently moving from near Utrecht to Nijmegen (location of FLARE). *MH*

CLIO [http://clio.lcp.u-psud.fr/clio\\_eng/clio\\_eng.htm](http://clio.lcp.u-psud.fr/clio_eng/clio_eng.htm)

FELBE [www.hzdr.de/felbe](http://www.hzdr.de/felbe)

FELIX <http://www.differ.nl/felix>

### **Status of SACLA: Japanese XFEL facility**

The SPring-8 Angstrom Compact free electron LASer (SACLA) achieved laser amplification at 10 keV photon energy on June 7, 2011. This is the world's second accomplishment of a X-ray FEL after LCLS at the SLAC national accelerator laboratory in the US.

SACLA is the first "compact" XFEL facility in the world with a total length of 700 m. Three unique technologies, a low-emittance thermionic cathode, an 8-GeV C-band linac system, and short-period in-vacuum undulators with 18-mm magnetic period, have been combined for realizing this concept. Notably, SACLA is adjacent to the SPring-8 synchrotron radiation facility; SACLA XFEL radiation and SPring-8 undulator X-rays can be simultaneously guided onto samples, and the SACLA linac is capable of serving as a low-emittance electron beam injector to the SPring-8 storage ring.

SACLA lasing was achieved only three months after the first injection of the electron beam to the accelerator. Experiences at the SPring-8 Compact SASE Source (SCSS) with 250 MeV beam energy, which was built in 2005 as a prototype of SACLA, played crucial roles for realizing this launch.

SACLA starts user operation in March 2012. In the period 2012A (March to July), 25 proposals from domestic/international universities, research institutes, and industry will be conducted. In parallel with user operation, SACLA will continue to upgrade the performance (expansion of wavelength range, seeding, increase of beamline number etc.), to develop novel experimental methodologies, and to cultivate scientific frontiers. *MY*



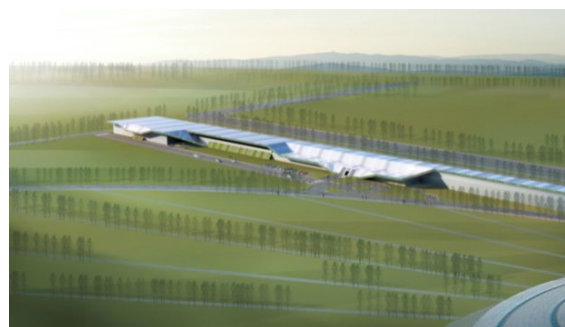
Aerial view of SACLA at the SPring-8 site.

### **FELs at Shanghai Institute of Applied Physics (SINAP)**

The Shanghai Deep Ultra Violet (SDUV) FEL continues to conduct experiments exploring the potential of seeded FEL schemes. The first lasing of the Echo-Enabled Harmonic Generation (EEHG) FEL was successfully achieved on SDUV in 2011. The EEHG proposed by G. Stupakov in 2009 promises significantly larger bunching factors at high harmonics making it possible to generate a large amount of frequency up-conversion starting from the laser seed in a single stage of harmonic generation. The experimental setup includes two modulator undulators, two laser seeds and a long undulator section as the radiator. The FEL signals produced by EEHG especially the spectral properties are carefully distinguished from the typical HGHG FEL output.

The design of the Shanghai Soft X-ray Free Electron Laser (SXFEL) has well advanced in 2011. The construction will start mid-2012. The facility will be built next to the existing Shanghai Synchrotron Radiation Facility, a 3.5 GeV third generation light source. With a total length of 295 meters, SXFEL consists of a photo-injector, an electron linac with S-band and C-band structures, an undulator array and a beamline for FEL diagnostics. The commissioning is scheduled in 2015.

*DW*



SXFEL is a test FEL facility in the soft X-ray regime.



### 3-site XFEL meeting at SACLA

On October 31 – November 2, 2011, the 4th XFEL 3-site meeting was organized by SACLA, the new Japanese XFEL at the SPring-8 site. The main objective of these regular collaboration meetings is to exchange experience in design, construction and operation of X-ray Free Electron Lasers (XFEL) and to initiate specific activities addressing common issues in electron beam dynamics and start-to-end simulations, electron and photon beam diagnostics, synchronization and stabilization, high precision optics, seeding and other areas. For the first time, also the new XFEL projects in Korea (PAL XFEL) and Switzerland (SwissFEL) participated in the meeting and presented the status of their projects. The next meeting will take place in the United States. **JF**



### LCLS-II moves forward

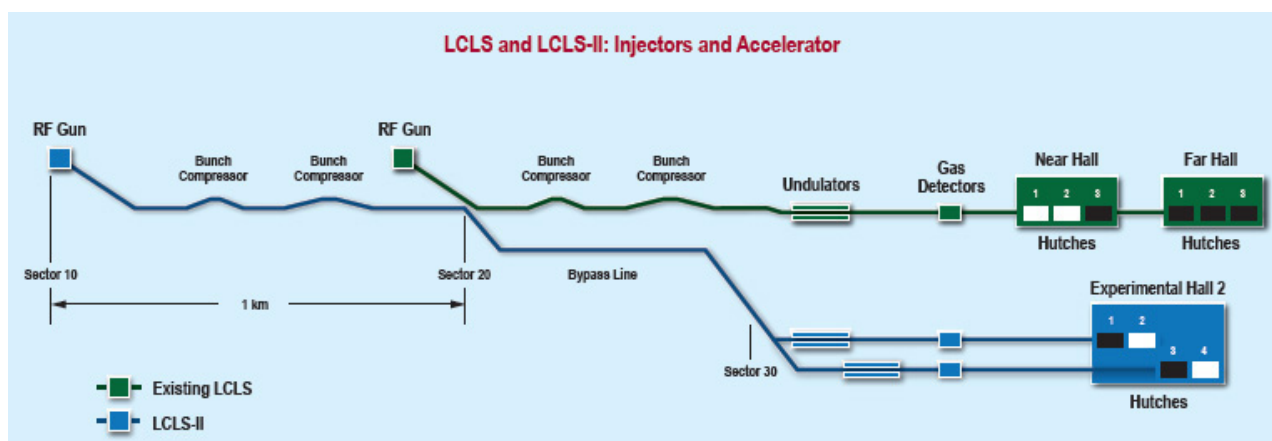
Building on the success of the world's most powerful X-ray laser – the Linac Coherent Light Source (LCLS), whose beams are a billion times brighter than any other X-ray light source – SLAC National Accelerator Laboratory in the US is planning an upgrade, LCLS-II, which will enhance and expand the facility's avenues for scientific discovery.

The LCLS is in such high demand that only one out of four experimental proposals can be approved. By adding two new X-ray laser beams and room for four new instruments, LCLS-II will triple the number of experiments run per year. Long-term plans call for additional expansion through 2025, accommodating up to 2,000 scientists per year at up to a dozen experimental stations.

LCLS-II will provide an expanded range of X-ray wavelengths, allowing researchers to home in on carbon atoms

involved in chemical and biological processes, peer inside thick three-dimensional materials, and see intricate details of the structure of macromolecular assemblies and the evolution of orientational and crystallographic order from atomic disorder. It will also set the stage for increasing the intensity of the X-ray laser pulses 20-fold with control of pulse length and polarization. We expect to whittle the pulse length down to about 1 femtosecond without loss of intensity.

Current plans call for defining the project's cost and schedule and starting construction of the LCLS-II Injector Complex in 2012. Fiscal year 2013 would see construction start on undulators and technical hardware and the awarding of a contract for tunnel construction. User assisted commissioning is projected to begin by summer 2019. **GC**



### Joint users meeting of the European XFEL and DESY's light sources with 680 participants

About 680 participants from 28 countries attended the annual joint European XFEL and DESY HASYLAB Users' Meeting on 25–27 January 2012 in Hamburg, a new record. In a 3-day programme, current and future users of the DESY light sources FLASH, DORIS and PETRA III and of the X-ray laser European XFEL met to discuss new developments and opportunities.

On the first day, Massimo Altarelli, Chairman of the European XFEL Management Board, and team leaders updated on the progress of the European XFEL construction. European XFEL scientists presented the central points of their conceptual design reports for the planned four scientific instruments and the X-ray beam transport systems and discussed their ideas with the audience. A science session in the afternoon focused on applications of FELs towards structural biology.

The second day started with status reports of three FEL facilities: FLASH and its ongoing extension in Hamburg, Germany, the new X-ray FEL SACLA in Japan and the first seeded FEL FERMI at ELETTRA in Italy. Then representatives of different user groups presented recent results they had obtained in different science areas at FLASH in Hamburg and LCLS in Stanford, US.

The last day featured a poster session with 300 posters, about 75 of them on FEL science, and a vendor exhibition with 60 companies. *UK/JF*

E. Allaria presenting the status of FERMI@Elettra on the users meeting



### UPCOMING EVENTS

#### CALL FOR PROPOSALS

##### FERMI@Elettra

For user period: 1 July – 30 December 2012.

Deadline: March 30th, 2012

<http://www.elettra.trieste.it/UserOffice/index.php?n=Main.FermiDeadlineForProposalSubmission>

#### CRISP 1st Annual Meeting,

23 – 24 April, 2012, FORTH,

Heraklion, Greek

<http://www.crisp-fp7.eu/>

#### The Socio-Economic Relevance of Research Infrastructures ERF Workshop

31 May – 01 June 2012, DESY Hamburg, Germany

<http://erf.desy.de/workshop/>

#### The 4th Intern. WS on Metrology for X-ray Optics, Mirror design & Fabrication

##### SRI 2012 Satellite Meeting

4 – 6 July 2012, Barcelona, Spain

<http://iwxm.cells.es>

#### X-Ray Detectors

##### SRI 2012 Satellite Meeting

5 – 7 July 2012, Zurich, Switzerland

[www.psi.ch/csx2012](http://www.psi.ch/csx2012)

#### SRI 2012

9 – 13 July 2012, Lyon, France

<http://sri2012.org/>

#### Science at FELs

##### SRI 2012 Satellite Meeting

15 – 18 July 2012, DESY / European XFEL, Hamburg, Germany

[www.science-at-FELs-2012.desy.de](http://www.science-at-FELs-2012.desy.de)

#### Science with seeded FEL beams

19 – 20 July 2012, European XFEL, Hamburg, Germany

<https://indico.desy.de/conferenceDisplay.py?ovw=True&confId=5665>

#### 34<sup>th</sup> International FEL conference

27 – 31 August 2012, Nara, Japan

<http://fel2012.spring8.or.jp/>

#### IMPRINT

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Images: page 1 S. Eisebitt; page 2/3 S. Eisebitt, L. Müller, PSI, FERMI, STFC, SOLEIL; page 4/5 MAX-lab, DESY, European XFEL, HZDR, DIFFER; page 6/7 Spring-8, SINAP, SLAC; page 8 DESY

#### Partners of IRUVX-PP – the preparatory phase of EuroFEL

