INSIS is a new international school aimed at providing a comprehensive training in the fundamental concepts of instrumentation for neutron scattering experiments.

2012 School: 15th-27th of July 2012, Rome Laboratori Nazionali di Frascati (INFN), Italy

The INSIS school is aimed at PhD students, post-doctoral researchers and early career scientists who wish to be involved in the design and development of novel instrumentation and components at present and future neutron sources. The course will provide basic and advanced lectures, simulation activities and tutorials about neutron scattering instrumentation. The school is intended as a ‘pipeline’ initiative, to promote increased activities in instrument design and develop the next generation of instrument designers with a target audience of about 25 students. The school is composed of two distinct parts: the first week (15th – 20th July) will introduce basic instrumentation and components used in neutron scattering research; and the second week (22nd – 27th July) will provide a more in depth insight into neutron detector technologies. Students may participate in the first week, the second week, or both.

This school is partially supported by the U.S. National Science Foundation and the European NMI3, CNR and INFN.

Application Deadline: June 7, 2012

Outline of the first week
- Introduction to neutron instrumentation
- Comparison with other techniques
- Neutron sources
- Optical components
- Instrumental Resolution and background
- Polarized neutrons
- Larmor labeling and beam modulation
- Coherence and Focusing
- Neutron detectors
- Monte Carlo simulation methods
- Data acquisition and treatment
- Interfacing with sample environments
- Materials and constructability
- Cost evaluation

Outline of the second week
- Fundamental detector concepts
- Front-end electronics
- Data acquisition and data processing
- (3He) Gas detectors
- Non 3He gas detectors
- Gas detectors readout strategies
- Semiconductor detectors
- Scintillators
- Light sensors
- Scintillation detector readout strategies
- Imaging detectors
- Simulations

Information at web site http://neutrons.ornl.gov/conf/insis2012

Members of the organizing group: Ian Anderson, Carla Andreani, Masa Arai, Andrew Harrison, Robert McGreevy and Roger Pynn (School Chair)
The picture shows a simulated diffraction pattern of the European XFEL logo. When user operation starts in 2016, the detectors at European XFEL will register thousands of diffraction patterns from objects like protein nanocrystals. The original shape of the object under investigation can be deduced by Fourier transform from the recorded patterns. (Image courtesy of B. Ebeling, XFEL.)
ESRF Upgrade Programme Reaches Halfway Mark

In 2012, the ESRF reached the peak activity of the first phase of its Upgrade Programme. This included a 5-month shutdown until May 2012, the first time ever in 18 years that the user operation was shut down for such an extended period of time. The first new beamlines are now available for user operation, and many more will become operational until the end of Phase I of the upgrade in 2015. Remarkably, the performance of the ESRF for its users did not drop significantly despite a period of heavy works. The X-ray source performs better than ever, with record values for the mean time between failure and availability.

Plan of the ESRF experimental hall showing the location of the beamlines at the end of Phase I of the ESRF Upgrade Programme. refurbished and Upgraded beamlines are marked in green; new buildings are outlined in red. (Image credit: ESRF/M. Collignon).
Although the number of hours of user operations is slightly lower than in the past years due to the construction-related shutdown periods, the interest in the ESRF remains high, and the number of proposals did not decrease, on the contrary!

Upgrade Beamlines

Eight Upgrade Beamline Projects are a core deliverable of the Upgrade Programme. These are now all under development, and most of them are already under construction. Together, the eight Upgrade Beamline Projects actually comprise 11 different new beamlines with 15 independently operable end stations.

In the following, short descriptions are given of these eight projects, including the opening dates of the end stations for users and whom to contact for any enquiry:

**ID01 Diffraction imaging for nano-analysis**
Long beamline for nano-X-ray diffraction across a wide energy range (2.2–50 keV), offering coherent imaging of individual nanostructures as well as basic surface diffraction and small-angle scattering. Combines X-ray diffraction with atomic-force microscopy to allow investigation of the structure–function relationships at the nanoscale. Targets the study of properties of device-like structures in unprecedented detail. Open late 2014, scientist in charge: Tobias Schulli, schulli@esrf.fr

**ID31 High-energy beamline for buried interface structures and materials processing** (previously ID15)
Long beamline covering energies 30–150 keV for the study of working devices in situ, with new optics allowing the beam size to be reduced to 200 nm at the push of a button. The smaller spot size will allow users to study less perfect, more realistic, interfaces to understand the interplay between microscopic material properties and macroscopic device performance – in particular concerning advanced materials for fuel cells, organic solar cells, rechargeable batteries and catalytic materials. Open early 2015, scientist in charge: Veijo Honkimäki, honkimak@esrf.fr

**ID16 Nano-imaging and nano-analysis** (previously ID22)
Long, high-brilliance beamline providing nanofocused beams for two end stations. Operated in a cryogenic environment, the nano-imaging end station will focus hard X-rays at specific energies to a spot size as small as 15 nm and combine fluorescence analysis and nanotomography. The nano-analysis end station will provide a monochromatic beam tunable in a large energy range, offering a multianalysis nanoprobe for spectroscopic studies. ID16 will focus on biomedical research, for instance allowing subcellular processes to be studied, as well as environmental sciences, energy and nanotechnology. Open February 2014, scientist in charge: Peter Cloetens, cloetens@esrf.fr

**ID20 Inelastic hard X-ray scattering for electronic spectroscopy** (previously ID16)
Two end stations offering a spectroscopic tool with all the advantages of a hard X-ray probe – bulk information, high-penetrating power and elemental and spin sensitivity – designed to enhance the ESRF’s inelastic scattering programme. The upgrade will decrease the size of the beam from around 100 microns to 10 microns, allowing experiments in extreme conditions, for example at very high pressure. The energy range will also increase from 6–10 KeV to 5–20 KeV, enabling resonant experiments at a large number of absorption edges with increased compatibility with more complex sample environments. Finally, more luminous spectrometers will broaden the scientific impact of inelastic X-ray scattering. Open March 2013, scientist in charge: Giulio Monaco, gmonaco@esrf.fr

**ID32 Soft X-rays for magnetic and electronic spectroscopy** (previously ID08)
State-of-the-art facility for soft X-ray absorption spectroscopy and very high-energy resolution resonant inelastic X-ray scattering, with sophisticated sample environments and tunable X-ray beam sizes ranging from microns to hundreds of microns. The beamline will provide new facilities for users to study the electronic and magnetic properties of materials, offering magnetic dichroism techniques and soft resonant inelastic X-ray scattering to meet the demands of an expanding user community. Open August 2014, scientist in charge: Nick Brookes, brookes@esrf.fr

**ID02/ID09 Time-resolved experiments** (previously ID02/ID09B)
Two independent beamlines. The long beamline ID02 will extend SAXS to ultra-small (microradian) angles with sub-millisecond time resolution, pushing the technique’s applicability to systems ranging from colloidal plasmas to highly self-assembled biomimetic systems. ID09 is dedicated to time-resolved diffraction and scattering, with picosecond laser pulses initiating structural changes in the sample that can then be probed with ultrashort X-ray pulses. Open: ID02 April 2014, scientist in charge: Theyencheri Narayanan, narayan@esrf.fr ID09 operational, scientist in charge: Michael Wulff, wulff@esrf.fr
ID30/BM29 Massively automated sample selection integrated facility for macromolecular crystallography
A unique resource based on second-generation automation for macromolecular crystallography experiments, designed to help structural biologists tackle ever more ambitious projects, such as complex membranes. The hub of the project is a sample-evaluation and sorting facility (MASSIF), from which the most suitable crystals for data collection will be distributed to the best suited of seven end stations (MASSIF-1/2/3, ID23-1/-2, ID29 or ID30B). Such screening is vital to cope with the problem of inter- and intra-sample variations in modern macromolecular crystallography experiments.
Open: BM29A June 2012; ID30A May 2013; ID30B May 2014, scientist in charge: Christoph Mueller-Dieckmann, christoph.mueller_dieckmann@esrf.fr

ID24/BM23 Time resolved and extreme conditions X-ray absorption spectroscopy (previously ID24/BM29)
High-brilliance energy dispersive X-ray absorption spectroscopy (EDXAS) allows users to study the local and electronic structure of matter in real time and in situ; the behaviour of matter under extreme pressures and temperatures, such as those in the Earth’s core, or the structure–function relationship in industrially-relevant catalysts. Two independent end stations (EDXAS_S “small spot” and EDXAS_L “large spot”) on ID24 combined with the general purpose EXAFS station on BM23 will permit X-ray absorption spectroscopy in sample volumes 20 times smaller and with time resolution a 1000 times better than before.
Open: BM23 since November 2011; EDXAS_S May 2012; EDXAS_L Sep 2012, scientist in charge: Sakura Pascarelli, sakura@esrf.fr

Beamline Refurbishments
During the Upgrade, every ESRF beamline will undergo at least some form of refurbishment, and those with only light improvements will be candidates for Phase II of the upgrade beginning in 2015. The national “CRG” beamlines, which include the Italian GILDA beamline, do not receive ESRF funding, but they stand to benefit from improvements to the X-ray source, sample environments and larger experimental halls.
Major refurbishments to the beamlines ID19 and ID10 are now nearing completion, and they will boost ESRF’s imaging, soft-matter and interface science as of the summer of 2012:
Today, palaeontology represents more than 35% of the ID19 microtomography proposals. After more than ten years of operation, ID19 is currently undergoing an in-depth refurbishment with palaeontology as the science driver, but benefiting also other research areas such as materials science, engineering, environmental sciences and biology. ID19 will provide a high-flux pink beam allowing multi-scale imaging at sub-micron resolution of objects measuring up to 40 cm across.
The refurbishment will be complete by spring 2013. The neighbouring ID17 beamline will be equipped with a new sample stage for large fossil scanning plus a refurbished monochromator for higher-energy operation and eventually a new detector. Contacts: Paul Tafforeau, paul.tafforeau@esrf.fr (ID19) and Alberto Bravin, bravin@esrf.fr (ID17)
In parallel, the ID10 beamline complex – previously known as the Troika I, II and III beamlines – will restart in June 2012 after an in-depth refurbishment under the new name “soft interfaces and coherent scattering” (SICS). ID10A/C and ID10B have been transformed into one beamline with two end stations working in time-sharing mode. One station (SICS-CS) will be devoted to X-ray photon correlation spectroscopy and coherent X-ray
View of construction works for the Belledonne experimental hall extension area, May 2012. About 8500 m2 of new experimental halls, laboratory and office space is being created. The buildings are scheduled for completion by June 2013. (Image credit: ESRF/C. Argoud).

diffraction imaging, while the other (SICS-LSIS) will offer liquid surfaces and interfaces scattering based on X-ray reflectivity and grazing incidence scattering. Each station will benefit from independent optics and instrumentation optimised for each of the techniques, and will be served by two different silicon monochromators. Contacts: Oleg Konovalov, konovalo@esrf.fr (SICS-LSIS) and Yuriy Chushkin, yuriy.chushkin@esrf.fr (SICS-CS).

Instrumentation and Data Handling
Developing state-of-the-art instrumentation is another pillar of the Upgrade Programme. Driven by the projects for new beamlines, the need for new technologies was identified in the fields of X-ray mirror engineering, diamond technologies, nanofocusing optics, pixel detectors, on-line data analysis and high-rate data collection.

Handling the massive flux of data coming in particular from the latest generation of 2D detectors is a challenge which requires a coordinated approach between different groups at the ESRF. Today, the petabyte has become the standard unit for data-intensive facilities like the LHC at CERN (15 petabytes/year) or the ESRF (several petabytes/year).

Work has started to optimise the integration of the data flow from the detectors into the ESRF IT infrastructure in order to minimise bottlenecks between data collection and the actual data analysis. Already in 2011, a new data centre was inaugurated, equipped with state-of-the-art file servers capable of storing almost 1 petabyte of data, a tape-based archiving facility of several petabytes, computing clusters with a peak performance of 15 teraflops and an extensive 10 Gbit/s Ethernet infrastructure. This can easily be extended thanks to pre-installed power, cooling and networking resources, allowing a flexible response to changing demands of the users for storage, data analysis capacity and data backup, for many years to come.

Inauguration of Upgrade Beamline ID24 - Ribbons were cut during the inauguration ceremony on 11 November 2011 to mark the opening of two new beamline branches. Left: High-pressure/extreme conditions branch. Right: Chemistry branch.

From left to right: Francesco Sette, ESRF Director General, Sakura Pascarelli, Scientist in charge of ID24, Harald Reichert, ESRF Research Director.

From left to right: Michel van der Rest, vice-chairman ESRF Council, Geneviève Fioraso, Députée de l’Isère et Adjointe au Maire chargée de l’Economie, l’Emploi, l’Université, la Recherche, Rafael Abela, Chairman ESRF SAC. (Image credit: ESRF/C. Argoud).
Building a road map for tailoring multilayer polyelectrolyte films

Implant coatings, drug delivery are future applications for new polyelectrolyte layering studies at ORNL

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Researchers are moving a step closer to a definite road map for building layer-by-layer (LbL) assembled polyelectrolyte films, with the assistance of the Liquids Reflectometer at Oak Ridge National Laboratory’s Spallation Neutron Source, in Oak Ridge, Tennessee. Scientists using the liquids reflectometer have successfully taken snapshots in close to real time of these multilayered structures for different applications when they modify the structure and function parameters.

Polyelectrolytes are polymers that carry charge in aqueous solutions. They contain chemical groups that dissociate in water, making such polymers charged. Most polyelectrolytes are water soluble. They are important components in foods, soaps, shampoos, and cosmetics products. They show promise for such environmental work as oil recovery and water treatment.

Polyelectrolytes are compelling because researchers can chemically modify how they interact with water for multiple applications. When two types of polyelectrolytes of opposite charge are assembled at a surface in a sequential way using the LbL assembly technique, “the result is the forming of surface films, useful for coatings, biomedical implants and devices, controlling adhesion of biological molecules, and controlling delivery of therapeutic molecules from surfaces,” said Svetlana Sukhishvili of the Stevens Institute of Technology in New Jersey, the lead chemist on the collaboration.

“Medical doctors often prefer to deliver multiple therapeutic compounds from the coatings in a time-resolved manner,” Sukhishvili said. “To assist them, material scientists need to learn how to build coatings in which polymer layering will not be compromised when exposed to normal physiological conditions.”

“Being able to control these properties, understanding how what you do to the materials affects their properties, this allows you to apply them to situations where interacting with an environment is very helpful, whether in a biological context or any other kind of water soluble context,” said John Ankner, lead instrument scientist for the Liquids Reflectometer.

Ankner said that when several parameters are systematically altered, that allows researchers to map out the whole range of structures in the polymer. “This work really sets a road map for how to get started with synthesizing polyelectrolyte materials for specific applications. Then, one can say, ok, this methylated material, the one that is 30% charged, is going to be what we want to use for a particular application.”

The ORNL collaboration with the Stevens Institute has been conducting a series of experiments at the SNS to study layered film stratification in these polymers.

Researchers stitch the polyelectrolyte chains in the LbL films together through what is called ionic pairing and arrange them within fuzzy, ultrathin layers that lie parallel to a solid surface substrate. Exposure of these films to aqueous solutions that contain salt (i.e., conditions that imitate real life) can compromise this film layering, as the salt ions act to weaken the ionic pairing that binds such layers together. So salt solutions are of key interest in studying how to make such layers for use in human applications.

In the first research (see paper citation at end of article), Ankner, Sukhishvili and her student Li Xu looked at the effects of the layering of two types of LbL films of changing the charge density with a salt solution, and of blocking access to a charged site by nearby groups. The films were composed of positively charged variants of PDMA, a methyl polymer, and PDEA, an ethyl polymer. The other component of both systems is the ion exchanger polystyrene sulfonate (PSS) which features a fixed negative charge.

First, a silicon substrate was dipped into solutions of PDMA and PDEA in dilute sodium chloride for a fixed time. Depending on the deposition time and the concentration of the solution, a nanometer-thick monolayer of the polymer adsorbs to the silicon surface. The film buildup is then continued by depositing a layer of PSS, and the cycle is repeated. The PDMA (methyl)/PSS and PDEA (ethyl)/PSS films were then annealed in varying concentrations of aqueous salt solutions.

The chemists wanted to know if in these multi-layer cake-like assemblies, the structure can be systematically altered by varying

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the salt concentration, time in solution, and ultimately other
environmental parameters, such as temperature or pH.

Neutron reflectivity of the layered films exhibits the quality of the
layering, in particular the concentration of the layers and how in-
termixed they are with adjacent layers. In this research, neutron re-
fectivity data from films built from 10%, 40%, and 100% charged
PDMA or PDEA polyelectrolytes and 100% charged PSS were quan-
titatively compared to predicted, layered arrangements until the
models produced reflectivity patterns matching those of the data.

Subsequent annealing in varying sodium chloride solutions over
2, 6 and 12 hour time periods allowed researchers to observe
whether the initial, well-defined layers intermixed, and if they did,
how quickly they intermixed, as a result of the enhanced diffusion
of the polymer chains.

“The instrument is just ideal for parametric studies,” Ankner
said. “We varied the charge of the monomer units in assembled
polymers, we varied the architecture of the polymers, how many
carbons, i.e., are the materials bulky or compact, and we were able
to vary the salt concentration in the external solution.

“We actually probed a 3-dimensional space of parameters. Since
this instrument is faster at collecting data than any other here,
the researchers were able to do this experiment in one visit.”

In a second study conducted concurrently, the team went on
to probe how the polyelectrolyte chains diffused within the
multilayer films and in what direction diffusion occured. Using
the Liquids Reflectometer, they found that such diffusion was
highly anisotropic (i.e., directionally dependent on the sample's
characteristics), with the preferential chain motion running
parallel to the substrate on which the layers were deposited.

The degree of anisotropy was quantified by a combination of fluo-
rescence recovery after photobleaching and of neutron reflectom-
etry. They probed the chain diffusion in directions parallel to and
perpendicular to the substrate. They found that the chain mobility
was controlled by the ionic strength of the annealing solutions
and by the steric hindrance to ionic pairing of the interacting
polyelectrolytes.

As in the first experiment, this effect was demonstrated with two
PEM systems exposed to solutions at various salt concentrations.
Significant diffusion anisotropy was detected; researchers believe
it reflects a weak coupling between polymer chain diffusion in di-
rections parallel and perpendicular to the substrate and that non-
equilibrated LbL films experience long-lived metastable states.

The observed stronger persistence of film layering in the direction
perpendicular to the substrate (as compared with greater lateral
diffusivity) during salt annealing could have important ramifications for applications that rely on persistent stratification of LbL
films, Sukhishvili said. “Slower diffusion, perpendicular to the
substrate, as compared to that parallel to the substrate, sustains
chain layering. This is very good for us as it helps tailor these
materials for special applications.”

Further theoretical and experimental insights on the dynamic
behavior of layered PEMs will now be pursued. Their experi men-
tal findings to date provide a first confirmation for the signifi-
cance for such studies.

“So what we have now is kind of like a peanut butter and jelly
sandwich,” commented ORNL’s John Ankner. “We have the
sandwich. Now we will start putting in raisins and nuts and other
things. We are starting to move now from the road map of the
structure/function relationship, to specific initial applications that
would be the first steps towards people actually using these mate-
rials for new applications.”

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U. S. Department of Energy.

Pairing and Polyelectrolyte Interdiffusion within Multilayered
Films: A Neutron Reflectometry Study”, Macromolecules 44,

Li Xu, Veronika Kozlovskaya, Eugenia Kharlampieva,
John F. Ankner and Svetlana A. Sukhishvili, “Anisotropic
Diffusion of Polyelectrolyte Chains within Multilayer Films”,
ACS Macro Letters, accepted.
New, more efficient materials for spin valves—a device used in magnetic sensors, random access memories, and hard disk drives—may be on the way based on research using the magnetism reflectometer at Oak Ridge National Laboratory (ORNL). Spin valve devices work by means of two or more conducting magnetic material layers that alternate their electrical resistance depending on the layers’ alignment.

Giant magnetoresistance is a quantum mechanical effect first observed in thin film structures about 20 years ago. The effect is observed as a significant change in electrical resistance, depending on whether the magnetization of adjacent ferromagnetic layers is in a parallel or an antiparallel magnetic alignment.

“What we are doing here is developing new materials. The search for new materials suitable for injecting and transferring carriers with a preferential spin orientation is most important for the development of spintronics,” said Valeria Lauter, lead instrument scientist on the magnetism reflectometer at the Spallation Neutron Source (SNS), who collaborated on the experiment.

The researchers discovered that the conductivity of such materials is improved when an organic polymer semiconductor layer is placed between the magnetic materials. Organic semiconductors are now the material of choice for future spin valve devices because they preserve spin coherence over longer times and distances than conventional semiconductors.

While research into spin valves has been ongoing, research into organic semiconductors is recent.

Previous research has shown that a “conductivity mismatch” exists in spin valve systems in which ferromagnetic metal electrodes interface with such organic semiconductors as Alq3 (π-conjugated molecule tris(8-hydroxy-quinoline) aluminium). This mismatch limits the efficient injection of the electrons from the electrodes at the interface with the semiconductor material. However, lithium fluoride (LiF), commonly used in light-emitting diodes, has been found to enhance the injection of electrons through the semiconductor.

Researchers from the University of Alabama and ORNL used polarized neutrons at the magnetism reflectometer at SNS to investigate the electronic, magnetic, and structural properties of the electrodes in a novel system. In this system, the magnetic layers cobalt and Ni₈₀Fe₂₀ are interfaced with spacer layers composed of the organic semiconductor Alq₃. A coupling layer of LiF is inserted to separate the magnetized layers from the semiconductor.

“Alq₃ is an organic semiconductor material,” said Lauter. “Normally in these systems a first magnetic layer is grown on a hard substrate so that one can get the controlled magnetic parameters. Then you grow the organic semiconductor layer, followed by another magnetic material layer, such as cobalt.”

In addition to determining the effect of the LiF layers on the efficiency of the electron injection, the researchers wanted to determine the magnetic properties of the cobalt and Ni₈₀Fe₂₀ as well as the interfacial properties: whether there is interdiffusion of cobalt through the LiF layer to the semiconductor, for example.

The researchers used polarized neutrons at beam line 4A to probe the entire, layer-by-layer assembly of the system. “Reflectometry with polarized neutrons is a perfect method to study thin magnetic films,” Lauter said. “These thin films—if you put one on a substrate, you see it just like a mirror. However, this mirror has a very complicated internal multilayer structure. The neutrons look inside this complicated structure and characterize each and every interface. Due to the depth sensitivity of the method,
we measure the structural and magnetic properties of each layer with the resolution of 0.5 nm.”

The neutron scattering results found that inserting LiF as a barrier significantly improves the quality of the interface, increasing the injection of electrons from the magnetic layer through the organic semiconductor in the spin valve and enhancing the overall properties of the system. In related work the magnetic properties of the cobalt film and the permalloy Ni$_{80}$Fe$_{20}$ were characterized. Cobalt in particular needed attention, as it cannot be grown epitaxially (i.e., deposited) on an organic semiconductor film. Cobalt becomes polycrystalline or amorphous, and this affects its magnetic properties.

The data from the first experiment showed that the cobalt layer in the system “did not have typical magnetic properties,” Lauter said. “The results showed that the cobalt had low magnetization. To improve the efficiency, the cobalt magnetization should be much higher. So this experiment helped us to improve the growth conditions and to get a cobalt layer with better magnetic properties.”

In a subsequent experiment the researchers increased the magnetization of the cobalt, and a follow-up paper is in progress.

References

(Top) Specular neutron reflectivity data measured at 10 K in a 0.2 T in-plane magnetic field for the sample: Ni$_{80}$Fe$_{20}$(10 nm)/LiF(2 nm)/Alq$_3$(100 nm)/LiF(2 nm)/Co(4 nm)/Al(10 nm)/Si(100). The film thickness in parentheses represents the quartz crystal microbalance (QCM) value. (Middle) Nuclear scattering length density profile as a function from the distance to the surface, obtained from the fitting procedure. (Bottom) Magnetic scattering length density profile as a function from the distance to the surface, obtained from the fitting procedure.
Abstract

Oxygen is the only elemental molecule which carries a magnetic moment. Therefore, the different solid phases encountered on cooling show various degrees of magnetic order, and similar behavior is expected under compression. In a recent study we presented neutron diffraction data which reveal the magnetic ordering under high pressure in the δ-phase, i.e. in the range 6-8 GPa (60-80 kbar) and 20-240 K [1]. Such experiments have been made possible by the progress in high pressure neutron techniques. We show that δ-O₂ contains in total three different magnetic structures, all of them being antiferromagnetic and differing in the stacking sequence of spins along the c-axis. We explain this structural diversity by the quasi two-dimensional nature of δ-O₂ and the fact that the magnetic exchange interaction between O₂ molecules depends strongly on the mutual orientation between them. The results show that δ-O₂ is antiferromagnetic at room temperature. Oxygen appears to be a textbook example where the interplay between nuclear and magnetic structures can be studies on one of the simplest magnetic systems in nature.

Keywords: oxygen, high pressure, magnetism, neutrons.

Numerous experiments carried out within the last four decades have revealed the existence of five solid phases in oxygen in the 0-10 GPa range, denoted, α, β, δ, γ, and ε-oxygen, see Fig. 1. γ-oxygen is cubic where the orientation of the O₂ molecules is dynamically disorder. β-O₂ is hexagonal (rhombohedral, R₃m) with the O₂-molecules arranged in sheets on a perfectly triangular lattice and the molecular axis pointing along the c-axis. α- and ε-oxygen are c-centered monoclinic (C₂/m) whereas δ-O₂ is face centered orthorhombic (Fmmm)[2,3].

Magnetism in solid oxygen has been a subject of fundamental interest for at least a century and neutron diffraction has played a key role in identifying its magnetic structures. Phases γ, β and α exist at ambient pressure which has allowed detailed investigations of magnetic ordering in these solids: γ-O₂ is paramagnetic (without surprise given the rotational disorder) and converts at 44 K to β-O₂ which is magnetically short-range-ordered. This phase transforms at 24 K into fully antiferromagnetically ordered α-oxygen. α-O₂ is hence the only long-range ordered phase of oxygen at ambient pressure. It consists of an antiferromagnetic arrangement within the O₂-sheets with the spins pointing along the b-axis (Fig. 2). Given the nearest neighbor distances between two O₂ molecules

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Magnetism in solid oxygen by neutron diffraction
in adjacent layers is ≈ 4.2 Å compared to an in-plane nearest-neighbor distance of ≈ 3.2 Å, magnetism in α-O₂ is essentially two-dimensional with a weak antiferromagnetic coupling between the layers. α-oxygen can be regarded as the simplest antiferromagnetic system in nature: it consists of a single element, has a simple nuclear structure with only two molecules per unit cell, and has a magnetic ordering which is extremely simple.

As for δ-O₂ and ε-O₂, these phases can only be investigated under high pressure (see Fig. 1), and consequently our knowledge on magnetism in these phases is very sparse. This is due to the well-known technical difficulty to compress relatively large samples needed for neutron scattering to pressures in the 0-10 GPa range and collect diffraction patterns in situ. Indirect evidence of magnetic ordering has been derived from optical spectroscopy carried out by the Florence group in diamond anvil cells, but without revealing the nature of the ordering [4].

The only neutron diffraction measurement carried out so far suggests the absence of magnetism in ε-O₂ [5] as well as in δ-O₂ [6] above ≈ 120 K, but claims antiferromagnetic long range order below ≈ 120 K based on the observation of a single magnetic reflection. However these findings appear inconsistent with the spectroscopic data [4], and a comprehensive understanding of magnetic ordering in δ-O₂ was still lacking.

In a series of experiments [1] carried out at the ILL we have investigated magnetism in δ-O₂ using neutron diffraction and a high pressure technique which allows a sample volume of ≈ 70 mm³. The several orders of magnitude increased intensity compared to previous investigations [6] allowed us to visit most of the stability domain in a reasonable amount of time, i.e. from 20 K up to almost room temperature and pressures up to 8 GPa, the phase boundary with ε-O₂. It also permitted the use of Rietveld refinement methods to derive both the nuclear and magnetic structures simultaneously, and investigate their mutual interplay.

The experiments were carried out at the D20 diffractometer of the Institute Laue Langevin, Grenoble, France [7]. Oxygen (99.998\%) was condensed at 77 K into a specially built loading clamp and then transferred at 300 K to a VX5 Paris-Edinburgh cell for data collection. The rest of the experimental setup was identical to the one described in Ref. [8]. Several polycrystalline samples of δ-O₂ were then prepared by compressing the liquid at ≈ 240 K through phases γ and β (Fig. 1). The strong volume change at the γ−β transition produced reasonably good powders, though with some preferred orientation as revealed by the Rietveld fits. In two loadings data were collected on cooling (0.2 K/min) along P-T paths as indicated in Fig. 1. The pressure technique does not allow for cooling at strictly constant pressure. Instead, cooling is quasi-isochoric (as confirmed by the diffraction...
data shown further below), which leads to a small (≈ 5-10%) pressure drop due to the thermal contraction of the sample. Neutron powder diffraction patterns (Fig. 3) collected at high temperatures (up to 235 K) revealed immediately the presence of magnetic order due to a strong magnetic reflection at 2θ = 30 deg. This is, however, not consistent with the reported magnetic structure [6], but corresponds to a spin alignment which resembles the one in α-O₂ and which we call here HTC (high temperature commensurate) δ-phase. Upon cooling, this magnetic reflection disappears at 149 K and another magnetic peak appears at 2θ = 26.5 deg. This again cannot arise from the proposed magnetic order [6] either, but derives from an antiferromagnetic structure with a doubling of the c-axis, as explained further below, subsequently called ITC (intermediate temperature commensurate) magnetic phase. This structure is stable over only ≈ 20 K, and transforms at 132 K into a magnetic phase with a strong reflection at 2θ = 25 deg. which is then consistent with the previously observed [6] structure which we subsequently refer as LTC (low temperature commensurate) phase. We repeated these measurements with a different sample at 0.5 GPa lower pressure and found essentially the same results, except that the transitions were shifted to lower temperatures. Interestingly, none of these transitions have a detectable influence on the nuclear structure, i.e. there is no evidence of a pronounced coupling between the magnetic and nuclear degrees of freedom.

Figure 3 shows results from simultaneous Rietveld refinements of the patterns to the nuclear and magnetic structures. These were carried out using a minimal set of variables: i.e. a scale factor, background, lattice and profile parameters, the internal oxygen position, the magnetic moment and to some extent anisotropic atomic displacement factors. Magnetic form factors for oxygen were taken from Ref. [9], and the final refinements included a preferred orientation along <001>.

Whereas the fit to the nuclear structures is straightforward, the identification of the magnetic structures using at most three reflections is less obvious. The strategy in solving the magnetic structures was as following. The nuclear structures of phases α, β, and δ consist of weakly bonded sheets of O₂ molecules [3]. As stated above, neutron diffraction studies on solid α-oxygen show conclusively that the magnetic ordering between nearest neighbor molecules within the O₂ layers is antiferromagnetic [3]. Given the very close structural relationship with α-O₂ it is unquestionable that δ-O₂ adopts a similar in-plane spin arrangement. The problem of solving the magnetic structure of the δ-phase reduces hence to finding the spin direction in the sheets as well as the stacking sequence of the sheets along <001>. The absence of any detectable signal at positions of (00l) reflections signals that spins are indeed aligned in the (a-b) planes, or close to it, as expected. Pattern calculations and refinements show that the out-of-plane angle in LTC δ-O₂ cannot be larger than ≈ 25 deg., and is much smaller for the HTC phase. Since all these angles are close to their refined estimated standard deviation, and given the evidence from α-O₂, the z-component of the spins can be set to zero. With this setting, the orientation of the spins within the sheets is tightly constrained to be close to <010>. This is because the intensity of the reflections between 34 deg. and 44 deg. (Fig. 3) is extremely sensitive to the angle with respect to <010>, and their apparent absence (extreme weakness) is direct evidence of the spin alignment along b. To derive the stacking sequence of the sheets, the simplest conceiv-
able scenarios correspond to either ferro- or antiferromagnetic coupling of neighbouring sheets, i.e. (A-A-A) or (A-B-A) (Fig. 4). The first case produces the formerly proposed LTC structure, the latter the HTC structure. The excellent fits (Fig. 3) leave very little doubt on the correctness of these assignments. The assignment of the ITC structure is less obvious. The position of the peak at $\theta = 26.5$ deg. indicates $c = 6.767$ Å, i.e. doubling of the nuclear c-axis with respect to the LTC and HTC phases. This leaves four non-equivalent stacking possibilities: (A-B-B-B-A), (A-A-A-B-A), (A-A-B-A-A) and (A-A-B-B-A). Pattern calculations reveal strongly different intensities for these configurations, which can be easily distinguished by the experiment. This eliminates all but one possibility, (A-A-B-B-A), which corresponds to the fit in Fig. 3 and the ITC structure shown in Fig. 4.

It should be noted that the apparent lack/absence of magnetic Bragg peaks at high scattering angles is not due to the rapid decrease of the magnetic form factor, but mainly to the peculiar highly symmetric nature of all three magnetic structures which entails an almost or complete cancelation of most of the peaks up to $\theta \approx 45$ deg. In all three cases we find a magnetic moment of magnitude $m = 1.4 \pm 0.4 \mu_B$, which agrees within our uncertainty to the values reported from $\alpha$ and $\beta$-O$_2$ (1.64 $\pm$ 0.06 $\mu_B$ and 1.55 $\pm$ 0.03 $\mu_B$, respectively) [9].

As mentioned further above, there is very little evidence for changes in nuclear structures across the two magnetic transitions, and this is corroborated by the refined lattice parameters of data collected along trajectory 1 (Fig. 1). The magnetic transitions seem to have negligible influence on the nuclear structure; the transitions are virtually invisible in the temperature dependence of the lattice parameters and the molar volume, see details in ref. [1]. The data also demonstrate that the thermal expansion is negative in c-direction, and to a lesser extent also along b. The positive volume expansion arises hence solely from the strong positive thermal expansion along a. This is not unusual for solid oxygen: the $\alpha$ and $\beta$-phase both have negative thermal expansion along b and c, respectively. This phenomenon is most likely caused by a strongly anisotropic thermal motion. Although the values of our anisotropic thermal displacement parameters are not very reliable and scatter across the 3 samples and $\approx 100$ patterns collected in the different loadings, the refined thermal motion along the a-axis is systematically $\approx 3$ times larger than along c. In other words, the O$_2$-molecule librates, possibly with a preference around its spin direction (thereby avoiding canting), which naturally leads to a positive and negative thermal expansion along a and c, respectively.
To resume, these experiments show that δ-oxygen contains three different magnetic phases and that magnetic ordering in oxygen is hence considerably richer than has been presumed so far. Although we did not measure above 235 K, magnetic order is likely to exist up to room temperature given the spectroscopic evidence [4] and the fact that there is no detectable change of the magnetic moment over a temperature range of 200 K.

We suggested that the key to the understanding of these unusual transition sequences is the very strong dependence of the p-electron based exchange coupling on the orientation of O₂ molecules in neighboring sheets. It is abundantly clear that the magnetic phase diagram of solid oxygen can be described by a Heisenberg Hamiltonian which includes three coupling constants: J₁ (intra-plane, between parallel spins), J₂ (intra-plane, between antiparallel spins), and J₃ (inter-plane, nearest neighbour). Values for δ-O₂ are unknown, but have been derived for the closely related α-phase from both measurements and calculations [3]. Whereas J₁ and J₂ are large (58 and 14-28 K, respectively), reported values for J₃ are as expected very small in magnitude (<1 K), and either positive or negative, depending on the reference [3]. Van Hemert et al. [10] investigated the orientation and distance-dependence of coupling constants in an O₂-O₂ dimer, and find J₁ positive (ferromagnetic), hence consistent with the experimental finding in LTC δ-O₂, and close to the point where it changes sign. The important point here is that J₁ is in fact negative (antiferromagnetic coupling) for most of the mutual orientations, except the “parallel shifted” orientation found in δ and α-O₂ between nearest neighbour molecules in adjacent sheets (see Fig. 4). The thermal motion (libration) leads to sizeable temporal distortions from such orientations, as already pointed out earlier [11], where fluctuations of the molecular axis by ≈ 19° are reported, thereby approaching either the “T” (molecular axes perpendicular) or “parallel” (molecular axes parallel) orientations that both have strong antiferromagnetic coupling [10]. In other words, it is evident that the librational motion has a critical influence on the sign of the effective (i.e. motional averaged) magnetic exchange coupling constants, and in particular J₃ which governs the magnetic stacking sequence in the c-direction. If this is correct, the LTC-ITC-HTC transitions should approximately follow lines of constant librational fluctuations <u²>. From the Rietveld refinements and the pressure dependence of the libron frequency determined from light scattering experiments it is indeed possible to derive the slope of constant librational motion (∂T/∂P) <u²>, which gives:

\[(∂T/∂P)_{<u²>} ≈ 16 \text{ K/GPa}\]

This value is in very good agreement with the measured value of ≈ 15 K/GPa as shown in Fig. 5 and therefore supports the conjecture that the influence of the thermal motion on the exchange parameter J₃ is responsible for the peculiar magnetic transitions in δ-O₂.

From these data the following picture on the influence of magnetism on oxygen's phase diagram seems to emerge: The nuclear structures of phases α, β, and δ are all governed by the presence of the strongly antiferromagnetic intra-plane interactions. These lead for example to the distortion of the a-b plane from strictly hexagonal with a/b= 3½ = 1.73 in β-O₂ to orthorhombic with a/b ≈ 1.41 for α- and δ-O₂. On the contrary, the magnetic transitions...
found in our experiments within the δ-phase are governed by the much weaker inter-plane interaction. The experimental fact is, that within the same nuclear structure there are three different magnetic structures, and that HTC δ-O$_2$ and α-O$_2$ have strictly identical magnetic structures but nevertheless different nuclear phases. The assumption that solid oxygen is entirely ‘spin-controlled’, i.e. that its phase diagram is completely imposed by the various magnetic structures, does therefore not hold in general.

From an instrumental point of view, our study gives an instructive example on the state-of-the-art of high pressure neutron scattering on ‘difficult’ samples in the 0-10 GPa range, i.e. samples which are difficult to load, highly compressible and chemically reactive. It also demonstrates the key role of high-flux instruments for research on magnetism under strong compression. A major issue in these experiments was the possibility to study the interplay between magnetic and nuclear structures simultaneously which needs high resolution over a wide Q-range which is available on D20.

**Acknowledgments**

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**References**

The ESS is in a continuing flurry of activity. There are now about 150 staff working on the project, up from 45 in July 2010 when we became our own legal entity, ESS AB. We are in the process of designing the whole facility, from the ion source of the accelerator to the user laboratories and the neutron instruments.

The long-pulse nature of the ESS neutron source means that we often have to be innovative in our instrument designs, while achieving the right compromise...
between the novelty required to adapt to the long-pulse time structure and making the most of the accumulated wealth of experience throughout Europe in designing instruments for continuous and short-pulse sources. Sometimes we need to look at several alternative concepts to address a particular scientific need, sometimes the basic concept is already clear.

We need to play to our natural strengths in order to maximise the scientific impact of the instruments, while addressing as broad a range of science as possible and engaging with the full neutron user community. The instrument concepts currently being developed reflect all of these needs, both technical and scientific. A large number of the neutron laboratories and university groups working
Research Infrastructures

Instrument Design at the European Spallation Source

In neutron scattering in Europe are already engaged in the process of designing instruments for the ESS and the numbers are growing all the time. We are currently looking at about 40 different concepts for instruments, some pursued by researchers in partner countries and some by our own instrument scientists. The concepts are arranged into Instrument Classes, each of which is led by an ESS coordinator. We are always open for new ideas. If you have an instrument idea and want to get involved, feel free to contact the coordinator for the relevant instrument class.

In parallel with the instrument design work, we are now starting the process for choosing which instruments will go

Ken Andersen  
Overall manager for instrument design

Andrew Jackson  
Small-Angle Neutron Scattering

Hanna Wacklin  
Reflectometry

Axel Steuwer  
Materials and Engineering Diffraction

Markus Strobl  
Neutron Imaging

Pascale Deen  
Direct-Geometry Spectroscopy
through to construction. The first 3 instruments for construction will be chosen at the beginning of 2013 and new instruments will be chosen for construction every year after that. Our aim is to have 7 instruments to start commissioning in 2019 when first neutrons are expected, and to reach our full suite of 22 instruments in 2025. See http://www.ess-scandinavia.eu/ for more details.
The rise of X-ray Free-Electron Lasers: Outstanding characteristics and new opportunities

Abstract

X-ray Free-Electron Lasers (XFEL) will open up completely new research opportunities. They produce X-ray pulses with outstanding characteristics such as very short duration, high peak brilliance and a very high degree of transverse coherence. This article describes how these pulses are generated and then looks at applications in different scientific experiments, such as imaging of biomolecules in nanocrystalline or even single-molecule samples, and the time-resolved study of chemical reactions on the atomic scale (molecular movies). The European XFEL, which is described here in more detail, will be the largest and brightest XFEL when it starts operation in 2015.

Figure 1

Undulator foreseen for the European XFEL; © European XFEL

In order to achieve such values, undulators are extensively used as radiation sources in storage rings. An undulator is a set of two arrays of magnets subjecting the electrons to a vertical magnetic field varying with position in a sinusoidal manner (Fig. 1). The corresponding Lorentz force on the electrons results in an oscillating trajectory, with many bending points from which emission of synchrotron radiation occurs. In undulators, the broadband radiated power of bending magnet radiation, due to the interference of the different emission points along the trajectory, is concentrated in a spectrum of narrow lines, centered about the wavelengths:

\[ n\lambda = \left(\frac{\lambda_u}{2\gamma^2}\right)(1 + K^2/2) \quad (1) \]

Here \( n \) = 1,2,3... is the order of the harmonic, \( \lambda_u \) is the period of the undulator magnetic structure, \( \gamma \) is the electron energy, expressed in units of the electron rest energy, and \( K \) is the undulator parameter, a number of order 1 given by \( K = \gamma \theta \), where \( \theta \) is the maximum angular deviation of the electrons from their unperturbed trajectory, induced by the undulator magnetic field. It can be shown that Eq. (1) identifies the wavelength of the fundamental harmonic \( \lambda \) as the distance by which one electron lags behind the emitted photons after traveling over the distance \( \lambda_u \) from the emission point.
Another important condition to reach high brilliance in a storage ring is the reduction in the phase-space volume of the circulating electrons in the two transverse directions (the horizontal and vertical directions perpendicular to the average orbit). These quantities are called horizontal (vertical) emittances and are roughly speaking a measure of the horizontal (vertical) size of the electron bunch times the angular divergences of the corresponding velocity vectors projections. Progress in accelerator physics has allowed reduction of the horizontal emittance to values of order or below 1 mm rad, as presently achieved by the 6 GeV Petra III ring at DESY [2]. The properties of small dimension and high collimation of the electron beam translate into corresponding attributes of the radiated photons, and therefore in higher brilliance. A substantial further reduction of emittance values towards the fundamental limits is presently the subject of extensive research on the so-called "ultimate" storage ring source [3].

Storage rings are also limited concerning the bunch length, i.e. the duration of the light pulses. Typically, pulse duration in storage rings is limited to some 30 ps. Substantially shorter pulses can only be achieved at the expense of dramatic reductions of the radiated intensity. This poses a limitation to the time scales which can be explored by time-resolved experiments with synchrotron sources: at full power they are limited to the ≃ 50 ps time scale; access to the scale of atomic motions and rearrangements (typically, sub-ps), is only possible by techniques such as "bunch slicing", which produce pulses of 100 fs, but with intensities limited to ≃ 10^3 photons per pulse, and a few kHz pulse repetition rate [4]. On the other hand, there is a high demand for ultrafast experiments capable to explore atomic motions and configuration changes on a sub-ps time scale. The development of fs lasers in the infrared, the visible and near UV has shown a variety of interesting phenomena essential for the understanding of chemical reactions, phase transitions, etc.; only shorter wavelengths, however, can resolve smaller and smaller distances, and ultimately only x-rays can provide us with atomic position information. Progress in the realization of x-ray FEL (free-electron laser) sources, based on linear accelerators, allows generation of transversely coherent ultrashort (typically 10 – 100 fs) pulses, with a spectacular increase of some nine orders of magnitude in peak brilliance with respect to third-generation synchrotron sources (Fig. 2). The linear accelerator allows
indeed to obtain very low emittances, and, in addition, is a singlepass machine, in which the electron bunches run only once through the undulator, keeping the original bunch length (Fig 3).

The SASE process and single-pass Free-Electron Lasers

In the undulators of a synchrotron source, electrons are forced to follow a zigzag trajectory by the device magnetic field. There is a definite phase relationship between the radiation emitted by the same electron at different points of the trajectory, and there is an interference, which is constructive only for the wavelengths described by Eq. (1). However, under such circumstances all interference between the fields radiated by different electrons is averaged out, as no definite phase relationship occurs between them. In order to have such interference, electrons should be spatially ordered. For simplicity, let us consider two electrons: If the longitudinal coordinate (projection on the undulator axis of the position) of the second lags behind that of the first by an integer number of wavelengths, the corresponding radiation fields will superpose in phase after the electrons have run through an integer number of undulator periods. Remember that the light radiated by the second will "catch up" with the first, getting closer to it at the rate of one wavelength $\lambda$ per undulator period $\lambda_u$. The intensity radiated from the two electrons will be four times larger than that of one single electron. Thus, coherence effects between different electrons can arise when the density in the bunch (integrated over the transverse directions) has a Fourier component at the wavelength of the radiation, i.e. when this density shows a modulation at the radiation wavelength. The intensity of the radiation in such cases is proportional to the square of the number of electrons involved in the modulation.

Figure 3

In free-electron lasers, electrons are first brought to high energies in a superconducting accelerator. They then fly on a slalom course through undulators, in which they emit laserlike flashes of radiation; © DESY
For wavelengths in the nm range or below, controlling the electron density on that scale may appear extremely difficult. However, in a certain sense, the radiation does it for us. A microbunching phenomenon occurs because the electric field of the radiation has a small component parallel (or antiparallel) to the electron velocity (Fig. 4), which tends to accelerate some electrons and decelerate those which are positioned one half radiation wavelength ahead or behind, leading to bunching on the radiation wavelength scale (Fig. 5). Whenever shot-noise fluctuations in the electron bunch introduce a Fourier component of the appropriate wavelength in the electron density, the coherence effect between electrons described above increases the radiated intensity. For a sufficiently low-emittance and high peak-current electron beam in a sufficiently long undulator, the stronger radiation field, reinforces the density fluctuation via the microbunching process. This runaway process leads to exponential amplification of the radiated intensity. The amplification proceeds until saturation, which occurs when the intense radiation and subsequent recoil effects lead to a degradation of the electron beam quality that prevents further amplification. This single-pass process, known as Self-Amplified Spontaneous Emission (SASE) was theoretically identified many years ago, long before electron beams of sufficient density and quality were technologically feasible [5], [6], [7]. To trigger the SASE process, the linear accelerator (linac) geometry is essential in allowing the low emittance and the high peak current required.

The first experimental demonstration was in the visible range, at the LEUTL facility at Argonne National Laboratory [8], and later pushed to lower and lower wavelengths (down to 4.2 nm) at the 1.2 GeV FLASH facility at DESY, in Hamburg [9], [10]. The 2009 results [11] at the 14 GeV Linac Coherent Light Source (LCLS) at SLAC in Stanford, California, demonstrated SASE lasing at 0.15 nm, opening the era of hard x-ray FELs. In spring 2011, SASE amplification at 0.12 nm was observed at the 8 GeV SACLA facility at SPring-8 in Japan [12], and more recently down to 0.08 nm.

**Applications of hard X-ray Free-Electron Lasers**

The most important features of the x-ray pulses of Free-Electron Lasers (FELs) are the short duration, typically on a few 10 fs time scale, the high peak brilliance, translating into a number of photons per pulse in the $10^{11} - 10^{12}$ range; the very high degree of transverse coherence [13]; and a typical bandwidth of the pulses in the $\Delta \lambda / \lambda \approx 10^{-3}$ range. This means that the number of photons, that typically reach the sample in one second in an experiment on the best synchrotron beamlines, can be delivered in some $\approx 30$ fs in an FEL experiment. The very short duration of pulses and the high degree of coherence are beginning to deliver a big scientific payoff in x-ray structural experiments. In traditional crystallography, x-ray diffraction is used to unveil the electron density, for example in a molecule, by analyzing the intensity distribution of the Bragg peaks in the diffraction pattern of a crystal. This is done because the signal is enhanced by the coherent superposition process at the origin of Bragg reflections (scattering power growing with $N^2$ rather than $N =$ number of molecules) and also because the large number of photons needed to acquire the signal is distributed between many molecules, limiting the effects of radiation damage. On the other hand, the spatial periodicity of the crystal is not an indispensable route to the acquisition of sufficient information to recon-
The rise of X-ray Free-Electron Lasers: Outstanding characteristics and new opportunities

...struct the electronic density of a system. This applies to both general non-periodic objects and to very small crystals, smaller than the illuminated volume, in which periodicity is broken by the sample surfaces. In principle, delivering some photons to such a sample, reconstruction is possible. However, the problem of radiation damage imposes very tight constraints, especially for biological samples. Here, the short duration of the FEL pulse, however, brings a decisive advantage: data collection takes place on a time scale too fast for the atoms to move, the observed structure is therefore unperturbed, even if the sample is completely destroyed in the process. The first experimental demonstration of this principle was the single-pulse coherent diffraction imaging by Chapman et al. [14], in which a diffraction pattern sufficient to reconstruct an image by standard iterative algorithms was acquired using a single FLASH pulse of 25 fs duration (Fig. 6).

One of the chapters of the scientific case for hard x-ray FELs is the hope to be able to image non-periodic biological objects (from individual cells down to large macromolecules), with resolution approaching the atomic scale, without the need for crystallization – which is a major hurdle in structural biology studies (Fig 7). Very significant steps towards this goal were achieved at the LCLS, where images of single large viruses were acquired and reconstructed [15], and sub-nm resolution structures of biomolecules were obtained from nanocrystalline samples, dispersed in aqueous solution [16]. Other fields in which the possibility to acquire images on an ultra-fast time scale can be important are for example in the study of liquids with x-rays. So far, the acquisition time has always been much larger than that of the disordered translational and rotational molecular motions that permanently rearrange the configuration. With an FEL source one can take snapshots of instantaneous configurations and think of questions such as the statistics of configurations in a liquid versus in the amorphous solid; or a real time observation of nucleation phenomena at the liquid-solid boundary. The possibility of single-shot structural information opens the door to the study of time-dependent phenomena on the atomic scale: One could dream of following the evolution of chemical reactions in time, e.g. biochemical processes, catalytic mechanisms, and so on. However, the sample destruction by a single shot manifestly interrupts the time evolution one would like to investigate. There is a way out, though, as long as the object of investigation (the molecules of the reagents, for example) is available in many indistinguishable copies, and if there is a possibility of fast "triggering" of the process. For example, for a photochemical reaction triggered by an IR laser flash, the "pump and probe" experimental strategy can be used: We repeat the experiment on many copies of the system, each time enforcing a different time delay between the start of the process and the interrogation by an FEL pulse. Each acquisition is like one snapshot of a movie, and when they are put together, they deliver the time evolution of the phenomenon (Fig 8). There are limits to the precision of determining the time delay of an IR laser pulse and an FEL pulse, but the experience so
When biomolecules are hit by intense X-ray radiation, they “explode”. In order to obtain an image of the biomolecule, the image must be recorded before destruction occurs.

So far acquired at FLASH and LCLS shows that an accuracy of the order of one or a few hundreds of fs (see for example [17]) can be achieved. This is still one order of magnitude longer than the duration of either pulse, but it is an interesting time scale for a variety of photochemical processes. So far only measurements of structural quantities such as the charge density were discussed. We know, on the other hand, that other important observables and order parameters, such as magnetic moments, and other electronic order parameters such as orbital ordering are also accessible to x-ray investigations, especially in the resonant scattering regime. Recent experiments demonstrated the possibility of pump-probe studies of these order parameters (see [17]). In addition, the remarkable transverse coherence can be used to probe fluctuation dynamics by X-ray Photon Correlation Spectroscopy, with much increased possibilities with respect to those achievable in a synchrotron source. Other uses of powerful FEL pulses are envisaged in plasma physics and more generally in the study of high energy-density states of matter.

The European XFEL opens the door to studying the evolution of very fast processes such as chemical reactions. To take such “molecular movies”, a chemical reaction would be triggered by a laser flash. A second laser pulse would then take instantaneous snapshots of the changes that have occurred in the molecule at varying time intervals after the first one. © DESY
The rise of X-ray Free-Electron Lasers: Outstanding characteristics and new opportunities

**Table 1**

<table>
<thead>
<tr>
<th>Project</th>
<th>LCLS</th>
<th>SACLA</th>
<th>European XFEL (SASE1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. Electron Energy (GeV)</td>
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<td>8.0</td>
<td>17.5</td>
</tr>
<tr>
<td>Min. Photon Wavelength (nm)</td>
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<td>0.05</td>
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<tr>
<td>Photons/pulse</td>
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<td>$2 \times 10^{11}$</td>
<td>$\sim 10^{12}$</td>
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<tr>
<td>Peak Brilliance</td>
<td>$1.5 \times 10^{33}$</td>
<td>$1 \times 10^{33}$</td>
<td>$5 \times 10^{33}$</td>
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<tr>
<td>Average Brilliance</td>
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<td>$1.5 \times 10^{23}$</td>
<td>$1.6 \times 10^{25}$</td>
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<tr>
<td>Pulses/second</td>
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<td>60</td>
<td>27,000</td>
</tr>
<tr>
<td>Date of first beam</td>
<td>2009</td>
<td>2011</td>
<td>2015</td>
</tr>
</tbody>
</table>

**Figure 9**

The European XFEL and its underground tunnels running from the northwest of Hamburg to the neighbouring town of Schenefeld; European XFEL.
New snapshots of the nanoworld: The European XFEL

There are at present three major XFEL projects worldwide, one in the USA (the Linac Coherent Light Source, LCLS, in Stanford, California [18]) which obtained the first beam at 0.15 nm in April 2009; one in Japan (the SACLA, SPring-8 Angstrom Compact Laser, at SPring-8 [19]), currently completing its commissioning and expecting the first users soon; and one in Europe (the European XFEL in Hamburg, currently under construction [20]); all of them target wavelengths of the order or smaller than suitable for experiments determining structural properties with atomic resolution. More recently projects in Switzerland (SwissFEL) and in South Korea (PAL XFEL) were started. The European X-ray Free-Electron Laser Facility (European XFEL), which started construction in January 2009 in Hamburg, is deriving its basic technical choices from the successful FLASH experience. The 1.7 km long accelerator, located in an underground tunnel (Fig. 9), can provide electrons up to 17.5 GeV energy, and feed them into two beamlines according to the scheme displayed in Fig. 10 [20].

The first beamline contains a hard x-ray undulator (SASE1), for coherent photons and a soft x-ray one (SASE3), which can sometimes make use of the “spent” beam resulting from saturation of SASE1 to generate soft X-rays in the 0.4 to 1.6 nm range (at 17.5 GeV electron energy: softer x-ray radiation is of course obtained if the electron energy is reduced). The second beamline contains a second hard x-ray undulator (SASE2), identical to SASE1, and two tunnels downstream in which two further undulators can be located. In the baseline design for the initial phase of the facility, each of the three SASE undulators will feed into two instruments. There are six instruments foreseen to be available in 2015: 4 hard x-ray instruments and 2 soft x-ray instruments. The hard X-ray instruments are:

1. The Materials Imaging and Dynamics (MID) instrument; to explore dynamic fluctuations in matter, accessing unprecedented length and time scales.
2. The X-ray Femtosecond Experiments (FXE) instrument to explore ultrafast phenomena in the physics and chemistry of solids, liquids and soft-matter systems.
3. The Single Particle, Cluster and Biomolecular Imaging (SPB) instrument devoted to the pursuit of structural studies in non-periodic systems, especially in structural biology.
4. The High Energy-Density Science (HED) instrument to explore regions of the phase diagram not easily accessible in the laboratory. FEL pulses will
The rise of X-ray Free-Electron Lasers: Outstanding characteristics and new opportunities

be used to bring a target to extremely high values of temperature.

The soft X-rays instruments are:
1. The Small Quantum Systems (SQS) instrument to continue and extend to higher photon energy the innovative experiments pioneered at FLASH on ions, atoms and molecules.
2. The Soft X-ray Coherent Scattering and Spectroscopy (SCS) instrument; a multi-purpose device on which different end-stations could be mounted for a variety of techniques in the soft X-ray analysis of materials, such as RIXS, absorption, photoemission, etc.

The use of the superconducting technology is a formidable advantage of the European facility: it allows a very wide flexibility in the operating conditions; in particular, it allows to fill each RF pulse with a very large number of electron bunches. Fig 11 shows a cavity used in a superconducting accelerator. In the European XFEL it is foreseen to have a train of up to 2,700 bunches in each of the 10 RF pulses (of 600 μs duration) per second. It will be possible to switch the electrons from one beamline to the other during each bunch train. The possibility to use such a large number of bunches, with a spacing of 220 ns, implies considerable development work in the field of detectors, as well as in the lasers for pump-probe experiments, which should be able to follow the time structure of the XFEL pulses. This is already in progress.

The average brilliance, corresponding to this large number of X-ray pulses per unit time, could prove very important in experiments such as coherent diffraction of nonperiodic objects, where hits of the FEL pulses with a molecule are expected to be very rare, but a large number of them needs to be accumulated in order to achieve a satisfactory signal-to-noise ratio.

At present, a Convention concerning the Construction and Operation of a European X-ray Free-Electron Laser Facility was signed by representatives of twelve countries (Denmark, France, Germany, Greece, Hungary, Italy, Poland, Russia, Slovakia, Spain, Sweden, Switzerland). The largest contributors to the construction costs are Germany and Russia. The Convention foresees the creation of a limited liability company under German law, which exists, under the name European X-ray Free-Electron Laser Facility GmbH, since September 2009, and is in charge of the project.
Figure 11
Superconducting niobium cavity, © DESY
Future perspectives

We have so far mentioned the transverse coherence properties of SASE FEL radiation, but did not address the issue of its longitudinal (or temporal) coherence. In point of fact, longitudinal coherence is very poor, and a SASE x-ray pulse is composed of a very large number of incoherent spikes (Fig. 12). In order to improve the longitudinal coherence, that is to obtain a smooth single-mode lineshape instead of this ragged pattern, various seeding schemes are possible. The idea behind seeding is to start the amplification process not by random shot noise fluctuations in the bunch electron density distribution, but by a controlled radiation pulse. In longer wavelength FELs the external pulse is provided by an IR or visible laser, that is used to generate suitable harmonics, either in a non-linear medium, or in an additional undulator. This is the principle of seeding schemes, as tested in Japan [21] and adopted in soft x-ray facilities such as FERMI@Elettra in Trieste [22]. In hard x-ray facilities, generation of laser harmonics is not going to work, as the order of the harmonic would be too high. Therefore various versions of self-seeding are being thought of, in which the seeding radiation is produced in a short undulator with the same parameters as the long SASE one that follows. The radiation from the first undulator is monochromatized and superposed again to the electron bunch in the SASE undulator. The most promising self-seeding scheme was proposed in [23]. A self-seeded x-ray FEL could have a \( \Delta \lambda/\lambda \) between 10\(^{-4}\) and 10\(^{-5}\), with an enhancement of the peak power in the \( \approx 1 \) GW range and would be a remarkable progress in the field.

As we tried to illustrate briefly, this is a very exciting time in the development of accelerator based light sources, as many new and revolutionary facilities are starting operation. Their promise is great, and the scientific user community should accordingly prepare for them. The scientific pay-off of the new facilities, in fact, will to a large extent be determined by the progress of instrumentation for experiments. The new extremely bright and ultrafast sources require, for their full exploitation, corresponding progress in optics, diagnostics, and above all detectors and data acquisition strategies. They might also imply a change in the size and composition of the experimental teams. The early attention to instrumental issues and a close relationship with potential users from the very beginning may turn out to be a factor of importance for the success of the new generation of light sources.

Figure 12
Simulation of the temporal structure of the radiation pulse from SASE 1 at 0.1 nm radiation wavelength (Courtesy of M.V. Yurkov)
References

[18] For updated information, see http://lcls.slac.stanford.edu/
[19] For updated information, see http://xfel.riken.jp/eng/
The School of Neutron Scattering, http://www.sonsfpricci.org, named after the late Francesco Paolo Ricci, prominent scientist in neutron scattering and one of the founding fathers of the Italian neutron scattering community, has become a fix appointment of the international scientific calendar, and has steadily grown in prestige and international standing over the years. It is held every second year and provides students a comprehensive training in the fundamental concepts of neutron scattering and educates them on the utilization of major neutron facilities, in neutron scattering techniques, instrumentation and data collection, analysis and interpretation. The XI edition, we had the privilege to co-direct, was co-funded by the Association “School of Neutron Scattering Francesco Paolo Ricci”, the CNR, Universities of Messina, Milano Bicocca and Rome Tor Vergata, NMI3 and a number of Italian institutional sponsors. It was held at the superb setting of Palazzo Duchi di S. Stefano in the town centre of splendid Taormina (Messina, I) in May 22-27 2006. This edition addressed the theme “structure and dynamics of biosystems”, as investigated with a variety of neutron scattering tools. Emphasis was placed on theory and practice, with a mix of introductory lectures, specialised lectures providing the theoretical basis, scientific seminars on topical subjects.

The School started on Monday afternoon with introductory lectures on Neutron, Neutron Sources (C. Andreani, University of Rome Tor Vergata) and theory of neutron scattering (S. Magazu, University of Messina), which were followed by interesting lectures and examples on diffraction, by Silvia Capelli (ILL), who initiated the students on the intricacies of neutron diffraction. A detailed insight into neutron instrumentation at pulsed and steady sources was the subject of the lectures presented by Daniele Colognesi (CNR-ISC) and Enrico Perelli Cippo (University of Milano Bicocca). Roberto Senesi (University of Rome Tor Vergata) introduced the students to the exciting opportunities provided by the new spectroscopic techniques using eV neutrons. Yuri Gerelli (ILL) and Francesca Natali (ILL) provided extremely clear introductions to SANS & Neutron & X-ray reflectometry and QENS, respectively, with interesting results from water-air interface, peptide inclusion, lipid bilayer and proteins. Tardocchi (CNR-IFP) introduced the state-of-art of neutron and gamma detectors and Giuseppe Gorini (University of Milano Bicocca)
gave a fascinating lectures on i.e. the latest developments of CHIPIR and IMAT instruments under construction at the ISIS TS-2, discussing the dangers of fast neutrons to advanced electronics (how alien invaders can change governments). Gabriele Salvato (CNR-IPCF) and Dario Tresoldi (CNR-IPCF) initiated the students on the complexity of time of flight neutron imaging, with theory and tutorials. Luigi Paolasini (ESRF, CNR-ISM) gave a brilliant lecture on magnetic neutron scattering, while Luis Hennet (CNRS-CEMHTI) and Giuseppe Zaccai (ILL) fascinated the students with the unusual but extremely interesting topics of containerless techniques, for the study of liquid state, and the ecology of protein dynamics.

Margarita Russina (Helmholtz Zentrum Berlin) addressed the dynamical functionality of novel materials robed by time of flight spectroscopy while Feri Mezei (ESS) addressed the evolution of neutron beam sources and introduced the students to the ESS project. Miguel Gonzalez (ILL) gave a beautiful lecture on the computer simulation and neutron scattering tools in biophysics.

One particularly valuable contribution from the Lecturers was a full set of lecture notes (available on the School web site http://www.sonsfpricci.org).

In addition to hard work, the School was also good fun. The unquestionable charm of the School venue helped us to lure the very best lecturers and tutors on each topic from around the world, and this, in turn, attracted a group of highly competent and motivated Italian, European and International students. The scenic setting of Taormina was an almost irresistible distraction for the students and lectures who enjoyed unforgettable lunches and dinners together at Rosso Peperoncino and La Piazzetta restaurants, where after-dinner sessions were accompanied by good dose of Sicilian wines, granite, and sweets.
NMI3: support for education

J. Savin
NMI3 Information manager

NMI3, the Integrated Infrastructure Initiative for Neutron Scattering and Muon Spectroscopy, was created in 2003 to facilitate the integration of neutron and muon facilities, support the community of users and foster innovation in neutron and muon research and instrumentation.

NMI3, like all I3s, dedicates a part of its efforts to Networking activities. These activities include dissemination and outreach. The NMI3 website* for example, which was recently relaunched at www.nmi3.eu falls into this category, as does Inside NMI3, the new biannual newsletter for neutron and muon users and members of the scientific community wishing to know more about the N and M in NMI3’s name.

For NMI3 and the neutron and muon community, Networking also means training and teaching.

Since its inception in 2003, NMI3 has supported the training of future generations of neutron and muon users, as part of its Education Activities. Until July 2011, European institutions could apply for NMI3 funding for a school through calls for proposals. The school proposals were then evaluated by a scientific committee and selected on the basis of their international impact and openness. Twenty-five individual schools, 36 schools in total were supported through calls in the first half of FP7.

As of 2012, NMI3 is supporting neutron and muon schools differently. In order to

Students at PSI Summer school in 2011. Picture courtesy of the organisers.

Students at the ISIS Muon school in 2012. Picture Stephen Kill, ISIS.
coordinate and make the various schools available to European scientists more coherent, NMI3 has decided to focus its efforts on a group of selected schools, occurring annually or every two years. Through the creation of this umbrella called the European Neutron and Muon School, NMI3 aims to improve the planning and scheduling of the European neutron and muon schools and to share resources and information between them. NMI3 has earmarked 415,000 euros for the next four years for the funding of the schools, which are well distributed over the year and over the European regions and will provide training to students with a variety of training needs and scientific interests.

To complement the schools, NMI3 is developing an e-learning resource, the Virtual Neutrons for Teaching platform, in close collaboration with researchers and students from the University of Copenhagen. The Virtual Neutrons for Teaching e-learning platform is aimed at university students and their teachers as well as scientists from other fields. The platform will be accessible from the NMI3 website (www.nmi3.eu). It will offer lesson material compiled by experienced neutron scientists, exercises, live neutron instrument simulations and virtual experiments. In addition, students will receive support and feedback on their work through forums for questions and discussion. The platform will also provide access to teaching material produced for the schools supported by NMI3.

**Introduction to neutron and muon research**
NM13 supports schools offering an introduction to neutron and muon experimental techniques. In these schools, students are given an overview of the relevant theoretical aspects of the techniques, as well as an opportunity to perform real experiments on state-of-the-art instruments from European neutron and muon facilities. These schools are important to introduce neutrons and muons and their many facets to PhD students and post-doctoral scientists embarking on a research program using neutrons and/or muons. Many of the students of past neutron schools supported by NMI3 are now eminent and internationally recognized neutron and muon users. The Jülich Laboratory Course Neutron Scattering, the Oxford Summer school on Neutron Scattering, the Berlin School on Neutron Scattering, the Central European Training School, Fan du LLB, HERCULES, the Italian Society for Neutron Spectroscopy school, the Baltic school (University of Latvia), the HZG Summer School (Helmholtz Zentrum Geesthacht) and the ISIS muon school fall into this category.

**Thematic neutron schools**
Neutron schools focusing on a specific neutron technique, analysis tool or scientific discipline are necessary to attend scientists looking for a more specific type of training. The FullProf school, the Paul Scherrer Institute Summer school on condensed matter, the Bombannes Summer School, and the Jaca School (University of Zaragoza) fall into this category. They complement the introductory schools and address topical subjects, which are updated regularly.

**Communication**
More information on upcoming schools as well as registration and contact details can be found in the Education section of NMI3’s website*. School reports will regularly be published in the News and Media section of the website and pictures of each school will be uploaded in its picture gallery. In addition, NMI3 will soon be distributing a brochure presenting the European Neutron and Muon School in institutions and universities across Europe.

* If you have not already done so, please register on the NMI3 website in order to receive regular information on schools and other matters.
# Neutron Sources


<table>
<thead>
<tr>
<th>Date</th>
<th>Source</th>
<th>Website Address</th>
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<tbody>
<tr>
<td>March 1 and September 1, annually</td>
<td>BER II – Helmholtz-Zentrum Berlin</td>
<td><a href="http://www.helmholtz-berlin.de/user/neutrons/user-info/call-for-proposals_en.html#c63361">http://www.helmholtz-berlin.de/user/neutrons/user-info/call-for-proposals_en.html#c63361</a></td>
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<tr>
<td>September 5, 2012</td>
<td>HFIR – Oak Ridge National Laboratory</td>
<td><a href="http://neutrons.ornl.gov/">http://neutrons.ornl.gov/</a></td>
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<tr>
<td>September 17, 2012</td>
<td>ILL - Institut Laue-Langevin</td>
<td><a href="http://www.ill.eu/users/important-dates/">http://www.ill.eu/users/important-dates/</a></td>
</tr>
<tr>
<td>To be announced</td>
<td>ISIS – Rutherford Appleton Laboratory</td>
<td><a href="http://www.isis.stfc.ac.uk/apply-for-beamtime/apply-for-beamtime2117.html">http://www.isis.stfc.ac.uk/apply-for-beamtime/apply-for-beamtime2117.html</a></td>
</tr>
<tr>
<td>Twice a year, to be announced</td>
<td>LANSCE – Los Alamos National Laboratory</td>
<td><a href="http://lansce.lanl.gov/resources/proposals.shtml">http://lansce.lanl.gov/resources/proposals.shtml</a></td>
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<tr>
<td>May 1 and November 1, annually</td>
<td>LLB - Laboratoire Léon Brillouin</td>
<td><a href="http://www-llb.cea.fr/en/Web/avr2000_e.php">http://www-llb.cea.fr/en/Web/avr2000_e.php</a></td>
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<tr>
<td>Any time</td>
<td>NRC-Canadian Neutron Beam Centre</td>
<td><a href="http://www.nrc-cnrc.gc.ca/eng/ibp/cnbc/about/index.html">http://www.nrc-cnrc.gc.ca/eng/ibp/cnbc/about/index.html</a></td>
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<tr>
<td>To be announced</td>
<td>RID - Reactor Institute Delft</td>
<td><a href="http://tnw.tudelft.nl/index.php?id=331955L=1">http://tnw.tudelft.nl/index.php?id=331955L=1</a></td>
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<tr>
<td>September 5, 2012</td>
<td>SNS – Oak Ridge National Laboratory</td>
<td><a href="http://neutrons.ornl.gov/">http://neutrons.ornl.gov/</a></td>
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Synchrotron Radiation Sources
www.lightsources.org

**Call for proposal**

**ALS - Advanced Light Source**
http://www-als.lbl.gov/index.php/component/content/article/58.html

**ANKA - Institute for Synchrotron Radiation**
http://ankaweb.fzk.de/website.php?page=userinfo_guide&id=1#subpart2

**APS - Advanced Photon Source**

**AS - Australian Synchrotron**

**BESSY II – Helmholtz-Zentrum Berlin**
http://www.helmholtz-berlin.de/user/neutrons/user-info/call-for-proposals_en.html#c63361

**BSRF - Beijing Synchrotron Radiation Facility**
http://www.ihep.ac.cn/bsrf/english/userinfo/beamtime.htm

**CFN - Center for Functional Nanomaterials**

**CHESS - Cornell High Energy Synchrotron Source**
http://www.chess.cornell.edu/proposals/index.htm

**CLS - Canadian Light Source**
http://www.lightsource.ca/uso/call_proposals.php

**CNM - Center for Nanoscale Materials**
http://nano.anl.gov/users/call_for_proposals.html

**Diamond - Diamond Light Source**
http://duo.diamond.ac.uk/propman/duo/main/home?execution=e1s1

**ELETTRA**
http://vuo.elettra.trieste.it/pls/vuo/guest.startup

**ESRF - European Synchrotron Radiation Facility**

**July 15, 2012**
(Structural Biology Beamlines for the period between September–October 2012)

**September 15, 2012**
(Structural Biology Beamlines for the period between November–December 2012)

**November 15, 2012**
(Structural Biology Beamlines for the period between January–February 2013)

**July 15, 2012**
(All other Beamlines for the period between January–June 2013)

**June 30 and January 15, annually**
(For the scheduling periods October–March and April–September, respectively)

**July 13, 2012**
(2012-3: for the period between October and December 2012)

**October 26, 2012**
(2013-1: for the period between January and April 2013)

**June 6, 2012**
(For the period between September and December 2012)

**March 1 and September 1, annually**

**Proposals are evaluated twice a year**

**September 30, 2012**
(For the period between January and April 2013)

**Proposals are accepted at any time**

**September 5, 2012**
(For the period between January and June 2013)

**July 13, 2012**
(For the period between October and December, 2012)

**October 1, 2012**
(For the period between April and September 2012)

**September 17, 2012**
(For the period between January and June 2013)

**September 1, 2012**
(for beam time between March and July 2013)
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<tr>
<th>Synchrotron Radiation Sources</th>
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| **FELIX - Free Electron Laser for Infrared experiments** |
| [http://www.rijnhuizen.nl/felix/beamtime/](http://www.rijnhuizen.nl/felix/beamtime/) |

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<tr>
<th><strong>JULY 15, 2012</strong></th>
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| **FOUNDRY - The Molecular Foundry** |
| [https://sswprod.lbl.gov/TMF/login.aspx](https://sswprod.lbl.gov/TMF/login.aspx) |

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| **HASYLAB – Hamburger Synchrotronstrahlungslabor at DESY** |
| [http://hasylab.desy.de/user_info/write_a_proposal/2_deadlines/index_eng.html](http://hasylab.desy.de/user_info/write_a_proposal/2_deadlines/index_eng.html) |

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| **ISA - Institute for Storage Ring Facilities** |
| [http://www.isa.au.dk/user/access/proposals.asp](http://www.isa.au.dk/user/access/proposals.asp) |

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| **LCLS - Linac Coherent Light Source** |

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| **LNLS - Laboratório Nacional de Luz Síncrotron** |
| [http://www.lnls.br/blog/category/news/](http://www.lnls.br/blog/category/news/) |

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| **MAX-lab** |
| [http://www.maxlab.lu.se/user-info/proposal.html](http://www.maxlab.lu.se/user-info/proposal.html) |

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<th><strong>PROPOSAL SUBMISSION SYSTEM HAS BEEN NEWLY LAUNCHED</strong></th>
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| **LCLS - Swiss Light Source** |
| [http://www.psi.ch/lsis/calls](http://www.psi.ch/lsis/calls) |

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| **SOLEIL** |

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| **SPring-8** |

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| **SRC - Synchrotron Radiation Center** |
| [http://www.src.wisc.edu/users/proposalforms.htm](http://www.src.wisc.edu/users/proposalforms.htm) |

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| **SSRL - Stanford Synchrotron Radiation Lightsource** |

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<td>(Crystallography Proposals for Beamtime March 2013-2015)</td>
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Due to the relocation of the FELIX facility to the Radboud University of Nijmegen there is no call for proposals in 2012.

**July 15, 2012**

To be announced

**July 10, 2012**

(LCLS proposals for beam time January-May 2013)

**November 13, 2012**

(LCLS proposals for beam time Fall 2013)

**September 30, 2012**

(for the period between January and April 2013)

Proposal submission system has been newly launched

**October 15, 2012**

(PX Beamlines III for the period between January and April 2013)

**September 15, 2012**

(Non PX Beamlines II for the period between January and June 2013)

**September 15, 2012**

(for standard proposal for the period between January and June 2013)

**September 1, 2012**

(For Beamtime starting on January 1, 2013)

**July 1, 2012**

(Crystallography Proposals for Beamtime November 2012-2014)
### Calendar

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<th>Event Description</th>
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<tr>
<td>June 7 – 14, 2012</td>
<td>Carcans Maubuisson, France</td>
<td>Bombannes Summer school</td>
<td><a href="http://www.ill.eu/bombannes">http://www.ill.eu/bombannes</a></td>
</tr>
<tr>
<td>August 11 – 19, 2012</td>
<td>Villigen – Switzerland</td>
<td>PSI summer school</td>
<td><a href="http://indico.psi.ch/conferenceDisplay.py?confId=1386">http://indico.psi.ch/conferenceDisplay.py?confId=1386</a></td>
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<tr>
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<tr>
<td>September 3 – 14, 2012</td>
<td>Garching, Germany</td>
<td>16th JCNS Laboratory Course Neutron Scattering</td>
<td><a href="http://www.fz-juelich.de/jcns/EN/Leistungen/ConferencesAndWorkshops/LabCourse/LabCourse2012/_node.html">http://www.fz-juelich.de/jcns/EN/Leistungen/ConferencesAndWorkshops/LabCourse/LabCourse2012/_node.html</a></td>
</tr>
<tr>
<td>October 10 – 12, 2012</td>
<td>Grenoble, France</td>
<td>40 Years D11 – Status and Perspectives of SANS at ILL</td>
<td><a href="http://www.ill.eu/40-years-d11">http://www.ill.eu/40-years-d11</a></td>
</tr>
</tbody>
</table>
Facilities

Neutron Scattering

WWW SERVERS IN THE WORLD
http://nmi3.eu/neutron-research/where.html

ANSTO
Australian Nuclear Science and Technology Organization
Phone: + 61 2 9717 3111
Fax: + 61 2 9543 5097
HTTP://WWW.ansto.gov.au/home

FLNP
Frank Laboratory of Neutron Physics
Phone: (7-49621) 65-657
Fax: (7-49621) 65-085
Email: belushk@nf,jinr.ru
HTTP://FLNP.JINR.RU/25/

BER II
Helmholtz Zentrum Berlin
Type: Swimming pool reactor, 10 MW
Phone: +49-30 / 80 62 - 42778
Fax: +49-30 / 80 62 – 42523
Email: neutrons@helmholtz-berlin.de
HTTP://WWW.helmholtz-berlin.de/user/neutrons/

FRM II
Forschungs-Neutronenquelle Heinz Maier-Leibnitz
Type: Compact 20 MW reactor
Phone: +49 (0) 89 289 10794
Fax: +49 (0) 89 289 10799
Email: userinfo@frm2.tum.de
HTTP://WWW.FRMA2.TUM.DE/EN/USER-OFFICE

BNC - Budapest Research reactor
Type: Swimming pool reactor, 10MW
Phone: +36 1 392 2222
Fax: +36 1 395 9162
Email: tozser@sunserv.kfki.hu
HTTP://WWW.KFKI.HU/BRR/INDEXEN.HTML

GEMS
German Engineering Materials Science Centre
Helmholtz Zentrum Geesthacht
Phone: +49 4152 871254
Fax: +49 4152 871338
Email: klaus.pranzas@hzg.de
HTTP://WWW.HZG.DE/CENTRAL_DEPARTMENTS/GEMS/INDEX.HTML.DE

CAB - Centro Atómico Bariloche
Phone: +54 2944 44 5100,
Fax: +54 2944 44 5299
Email: info@cab.cnea.gov.ar
HTTP://WWW.CAB.CNEA.GOV.AR

HANARO
Center for Applications of Radioisotopes and Radiation
Korea Atomic Energy Research Institute
Phone: +82 42 866-8120
Fax: +82 42 866-8448
HTTP://HANARO.KAERI.RE.KR/ENGLISH/INDEX.HTML

Centre for Energy Research, Hungarian Academy of Sciences
Phone: +36-1-392-2539
Fax: +36-1-392-2533
Email: tamas.BELGYA@energia.mta.hu
HTTP://WWW.ENERGIA.MTA.HU.

CSNS
Phone: 86 10 68597289
Fax: 86 10 68512458
Email: cas_eng@stimes.cn
HTTP://ENGLISH.CAS.AC.CN/

ESS AB
European Spallation Source
Phone: +46 46 888 30 94
Mobile: +46 72 179 20 94
Email: sindra.petersson@esss.se
HTTP://WWW.ESSS.SE/

HFIR
ORNl, Oak Ridge, USA
Phone: 865-576-0214
Fax: 865-574-096
Email: burnettse@ornl.gov
HTTP://NEUTRONS.ORNl.GOV/FAcILITIES/HFIR/EXPERIMENT.SHTML

IBR-2
Frank Laboratory of Neutron Physics
Phone: (7-49621) 65-657
Fax: (7-49621) 65-085
Email: belushk@nf,jinr.ru
HTTP://FLNP.JINR.RU/474/
ILL  
**Type:** 58MW High Flux Reactor.  
**Phone:** +33 (0)4 76 20 71 11  
**Fax:** +33 (0)4 76 48 39 06  
**Phone:** +33 4 7620 7179  
**Fax:** +33 4 76483906  
**Email:** cicogill.fr and sco@ill.fr  
**http://www.ill.eu**

IPEN – Peruvian Institute of Nuclear Research  
**Phone:** 226-0030, 226-003226  
**Email:** ceid@ipen.gob.pe  
**http://www.ipen.gob.pe/site/index/index.htm**

IPNS - Intense Pulsed Neutron at Argonne  
**Phone:** 630/252-7820  
**Fax:** 630/252-7722  
**Email:** cepetersganl.gov mail (for proposal submission)  
**http://www.pns.anl.gov/**

ISIS Didcot  
**Type:** Pulsed Spallation Source.  
**Phone:** +44 (0) 1235 445592  
**Fax:** +44 (0) 1235 445103  
**Email:** uls@isis.rl.ac.uk  
**http://www.isis.rl.ac.uk**

JCNS  
Juelich Centre for Neutron Science  
Forschungszentrum Jülich  
**Phone:** +49 2461 614750  
**Fax:** +49 2461 612610  
**Email:** neutrons@gfz-juelich.de  
  d.richter@gfz-juelich.de (for JCNS-1)  
  t.brueckel@gfz-juelich.de (for JCNS-2)  
**http://www.fz-juelich.de/jcns/EN/Home/home_node.html**

J-PARC  
Japan Proton Accelerator Research Complex  
**Phone:** +81-29-284-3398  
**Fax:** +81-29-284-3286  
**Email:** j-uo@j-parc.jp  
**http://j-parc.jp/index-e.html**

JRR-3M  
**Fax:** +81 292 82 59227  
**Phone:** JAERI425966  
**Email:** www-admin@www.jaea.go.jp  
**http://www.jaea.go.jp/jaeri/english/index.html**

JEEP-II Reactor  
**Type:** D2O moderated 3.5% enriched UO2 fuel.  
**Phone:** +47 63 806000, 806275  
**Fax:** +47 63 816356  
**Email:** kjjl.bendiksen@iehe.no  

KENS  
Institute of Materials Structure Science  
High Energy Accelerator Research Organization  
1-1 Oho, Tsukuba-shi, Ibaraki-ken,305-0801, JAPAN  
**Email:** kens-pac@nml.kek.jp  
**http://neutron-www.kek.jp/index_e.html**

KUR  
Kyoto University Research Reactor Institute  
Kumatori-cho Sennan-gun, Osaka 590-0494, Japan  
**Phone:** +81-72-451-2300  
**Fax:** +81-72-451-2600  
**http://www.rri.kyoto-u.ac.jp/en/**

LANSCE  
**Phone:** 505-665-1010  
**Fax:** 505-667-8830  
**Email:** lansce_users@lanl.gov  
**Email:** tichavez@lanl.gov  
**http://www.lansce.lanl.gov/**

LENS  
Low Energy Neutron Source  
**Phone:** +1 (812) 8561458  
**Email:** pesokol@indiana.edu  
**http://www.indiana.edu/~lens/index.html**

LLB  
**Type:** Reactor  
**Flux:** 3.0 x 1014 n/cm2/s  
**Secrétariat Europe :**  
**Phone:** 0169085417  
**Fax:** 0169088261  
**Email:** experience@llb.cea.fr  
**http://www-llb.cea.fr**

McMASTER NUCLEAR REACTOR  
**Phone:** 905-525-9140  
**http://mnr.mcmaster.ca/**

MIT – Nuclear reactor Laboratory  
**Email:** nrl-rrs@mit.edu  
**http://web.mit.edu/afs/athena.mit.edu/og/n/nrl/www/
**SINQ**

**Center for Neutron Research**

**Type:** Steady spallation source

**Phone:** +41 56 310 4666

**Fax:** +41 56 3103294

**Email:** sing@psi.ch

**Http://** sinq.web.psi.ch

---

**MURR**

**Phone:** 1.573.882.4211

**Email:** MURRCustomerService@missouri.edu

**Http://** www.murr.missouri.edu/

---

**NIST**

**Center for Neutron Research**

**Phone:** (301) 975-6210

**Fax:** (301) 869-4770

**Email:** Robert.dimeo@nist.gov

**Http://** www.ncnr.nist.gov/

---

**NPL – NRI**

**Type:** 10 MW research reactor

**Phone:** +420 2 20941177 / 66173428

**Fax:** +420 2 20941155

**Email:** krz@ujv.cz and brv@nri.cz

**Http://** neutron.ujf.cas.cz/

---

**NPRE**

**Phone:** 217/333-2295

**Fax:** 217/333-2906

**Http://** npre.illinois.edu/

---

**NRU - Chalk River Laboratories**

**Phone:** 613-584-8293

**Fax:** 613-584-4040

**Http://** neutron.nrc-cnrc.gc.ca/home_e.html

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**PIK - Petersburg Nuclear Physics Institute**

**Phone:** +7(813-71) 46025, +7(813-71) 46047

**Fax:** +7(813-71) 36025, +7(813-71) 31347

**Http://** www.pnpi.spb.ru/

---

**RIC**

**Reactor Infrastructure Centre**

**Phone:** +386 1 588 5450

**Fax:** +386 1 561 2335

**Http://** rcp.ijs.si/ric/index-a.htm

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**RID**

**Reactor Institute Delft (NL)**

**Type:** 2MW light water swimming pool.

**Phone:** +31 (0)15 278 5052

**Fax:** +31 (0)15 278 6422

**Email:** secretary-rid@tudelft.nl

**Http://** www.rid.tudelft.nl/en/cooperation/facilities/reactor-instituut-delft/

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**RISØ DTU**

**Phone:** +45 4677 4677

**Fax:** +45 4677 5688

**Email:** risoe@risoe.dtu.dk

**Http://** www.risoe.dtu.dk/
Synchrotron Radiation Sources
WWW SERVERS IN THE WORLD
www.lightsources.org/cms/?pid=1000098

ALBA
Synchrotron Light Facility
Phone: +34 93 592 43 00
Fax: +34 93 592 43 01
Http://www.cells.es/

ALS
Advanced Light Source
Phone: 510.486.7745
Fax: 510.486.4773
Email: alsuser@lbl.gov
Http://www.lbl.gov/als

ANKA
Phone: +49 (0)7247 / 82-6188
Fax: +49 (0)7247 / 82-8677
Email: info@fzk.de
Http://ankaweb.fzk.de/

APS
Advanced Photon Source
Phone: (630) 252-2000
Fax: +1 708 252 3222
Email: fenner@aps.anl.gov
Http://www.aps.anl.gov/

AS - Australian Synchrotron
Phone: +61 3 8540 4100
Fax: +61 3 8540 4200
Email: info@synchrotron.org.au
Http://www.synchrotron.org.au/

BESSY II - Helmholtz Zentrum Berlin
Phone: +49 30 80620
Fax: +49 30 8062 42181
Email: info@helmholtz-berlin.de
Http://www.helmholtz-berlin.de/

BSRF - Beijing Synchrotron Radiation Facility
Phone: +86-10-68235125
Fax: 86-10-68186229
Email: houbz@mail.ihep.ac.cn
Http://www.ihep.ac.cn/bsrf/english/main/main.html

CAMD
Center Advanced Microstructures & Devices
Phone: +1 (225) 578-8887
Fax: +1 (225) 578-6954
Email: leeann@lsu.edu
Http://www.camd.lsu.edu/

CANDLE
Center for the Advancement of Natural Discoveries using Light Emission
Phone/Fax: +(37 4-10) 629806
Email: baghiryan@asls.candle.am
Http://www.candle.am/index.html

CESLAB
Central European Synchrotron Laboratory
Phone: +420-541517500
Email: kozubek@ibp.cz
Http://www.xray.cz/

CFN - Center for Functional Nanomaterials
Phone: +1 (631) 344-6266
Fax: +1 (631) 344-3093
Email: cfnuser@bnl.gov
Http://www.bnl.gov/cfn/

CHESS
Cornell High Energy Synchrotron Source
Phone: 607-255-7163
Fax: 607-255-9001
Http://www.chess.cornell.edu/

CLIO
Centre Laser Infrarouge d’Orsay
Email: accueil-clio@clcp.u-psud.fr
Http://clio.lcp.u-psud.fr/clio_eng/clio_eng.htm

CLS
Canadian Light Source
Phone: (306) 657-3500
Fax: (306) 657-3535
Email: clsuo@lightsources.ca
Http://www.lightsources.ca/

CNM
Center for Nanoscale Materials
Phone: 630.252.6952
Fax: 630.252.5739
Email: Carrieclark@anl.gov
Http://nano.anl.gov/facilities/index.html

CTST
UCSB Center for Terahertz Science and Technology
University of California, Santa Barbara (UCSB), USA
Email: ramian@sbfel3.ucsb.edu
Http://sbfel3.ucsb.edu/
DAFNE Light
INFN-LNF
Phone: +39 06 94031
Fax: +39 06 9403 2582
http://www.lnf.infn.it/acceleratori/btf/

DELSY
Dubna Electron SYnchrotron
Phone: +7 09621 65 059
Fax: +7 09621 65 891
Email: post@jinr.ru
http://wwwinfo.jinr.ru/delsy/variant-2june.htm

DELTA
Dortmund Electron Test Accelerator
FELICITA I (FEL)
Phone: +49-(0)231-755-5383
http://usys.delta.uni-dortmund.de/

DFELL
Duke Free Electron Laser Laboratory
Phone: 919-660-2681
Fax: 919-660-2671
Email: beamtime@fel.duke.edu
http://www.fel.duke.edu/

Diamond Light Source
Phone: +44 (0)1235 778000
Fax: +44 (0)1235 778499
Email: useroffice@diamond.ac.uk
http://www.diamond.ac.uk/default.htm

ELETTRA - Synchrotron Light Laboratory
Phone: +39 40 37581
Fax: +39 (040) 938-0902
http://www.elettra.trieste.it/

ELSA - Electron Stretcher Accelerator
Phone: +49-228-735926
Fax: +49-228-733620
Email: roy@physik.uni-bonn.de
http://www-elsa.physik.uni-bonn.de/elsa-facility_en.html

ESRF - European Synchrotron Radiation Lab.
Phone: +33 (0)4 7688 2000
Fax: +33 (0)4 7688 2020
Email: useroff@esrf.fr
http://www.esrf.eu/

FELIX
Free Electron Laser for Infrared experiments
Phone: +31-30-6096999
Fax: +31-30-6031204
Email: B.Redlich@rijnh.nl
http://www.rijnh.nl/felix/

FOUNDRY
The Molecular Foundry
1 Cyclotron Road, Berkeley CA 94720, USA
Phone: +1 - 510.486.4088
Email: rjkelly@lbl.gov
http://foundry.lbl.gov/index.html

HASYLAB
Hamburger Synchrotronstrahlungsabor
DORIS III, PETRA II / III, FLASH
Phone: +49 40 / 8998-2304
Fax: +49 40 / 8998-2020
Email: HASYLAB@DESY.de
http://hasylab.desy.de/

HSRC
Hiroshima Synchrotron Radiation Center HiSOR
Phone: +81 82 424 6293
Fax: +81 82 424 6294
http://www.hsrcc.hiroshima-u.ac.jp/english/index-e.htm

Ifel
Phone: +81-(0)72-897-6410
http://www.fel.eng.osaka-u.ac.jp/english/index_e.html

INDUS -1 / INDUS -2
Phone: +91-731-248-8003
Fax: +91-731-248-8000
Email: vfn@cat.ernet.in
http://www.cat.ernet.in/technology/accel/atdhome.htm

IR FEL Research Center
FEL-SUT
Phone: +81 47-721-4290
Fax: +81 47-721-4298
Email: felsut@rs.suda.sut.ac.jp
http://www.rs.suda.sut.ac.jp/~felsut/english/index.html

ISA
Institute for Storage Ring Facilities - ASTRID-1
Phone: +45 8942 3778
Fax: +45 8612 0740
Email: fyssp@phys.au.dk
http://www.isa.au.dk/
Synchrotron Radiation Sources

ISI-800
Institute of Metal Physics - Ukraine
Phone: +38 (057) 335-35-30
Fax: +38 (057) 335-16-88
Email: metall@imp.kiev.ua
HTTP://www.imp.kiev.ua/ (Russian)

Jlab - Jefferson Lab FEL
Phone: (757) 269-7100
Fax: (757) 269-7848
HTTP://www.jlab.org/FEL

Kharkov Institute of Physics and Technology
Pulse Stretcher/Synchrotron Radiation
Phone: +38 (057) 319-3191
Fax: +38 (057) 926-3600
Email: knotts@ssrl.slac.stanford.edu
HTTP://www-ssrl.slac.stanford.edu/lcls/

KSR - Nuclear Science Research Facility
Accelerator Laboratory
Fax: +81-774-38-3289
HTTP://wwwal.kuicr.kyoto-u.ac.jp/www/index-e.html

KSRS - Kurchatov Synchrotron Radiation Source
Siberia-1 / Siberia-2
Phone: 8-499-196-96-45
HTTP://www.lightsources.org/cms/?pid=1000152
HTTP://www.kiae.ru/ (Russian)

LCLS - Linac Coherent Light Source
Phone: +1 (650) 926-3191
Fax: +1 (650) 926-3600
Email: knotts@ssrl.slac.stanford.edu
HTTP://www-ssrl.slac.stanford.edu/lcls/

LNLS - Laboratorio Nacional de Luz Sincrotron
Phone: +55 (0) 19 3512-1010
Fax: +55 (0) 19 3512-1004
Email: sau@lnls.br
HTTP://www.lnls.br/site/home.aspx

MAX-Lab
Phone: +46-222 9872
Fax: +46-222 4710
HTTP://WWW.MAXLAB.LU.SE/

Medical Synchrotron Radiation Facility
Phone: +81-(0)43-251-2111
HTTP://WWW.NIRS.GO.JP/ENG/index.html

MLS - Metrology Light Source
Physikalisch-Technische Bundesanstalt
Phone: +49 30 3481 7312
Fax: +49 30 3481 7550
Email: Gerhard.Ulmgptb.de
HTTP://WWW.PTB.DE/MLS/
HTTP://WWW.PTB.DE/MLS/

NSLS
National Synchrotron Light Source
Phone: +1 (631) 344-7976
Fax: +1 (631) 344-7206
Email: nslsuser@bnl.gov
HTTP://WWW.NSLS.BNL.GOV/

NSRL
National Synchrotron Radiation Laboratory
Phone: +86-551-3601989
Fax: +86-551-5141078
Email: zdh@ustc.edu.cn
HTTP://WWW.NSRL.USTC.EDU.CN/EN/

NSRRC
National Synchrotron Radiation Research Center
Phone: +886-3-578-0281
Fax: +886-3-578-9816
Email: user@nsrrc.org.tw
HTTP://WWW.NSRRC.ORG.TW/

NSSR
Nagoya University Small Synchrotron Radiation Facility
Phone: +81-(0)43-251-2111
HTTP://WWW.NAGOA-U.AC.JP/EN/

PAL - Pohang Accelerator Laboratory
San-31 Hyoja-dong Pohang Kyungbuk 790-784, Korea
Email: ilguya@postech.ac.kr
HTTP://PAL.POSTECH.AC.KR/ENG/index.html

PF - Photon Factory
Phone: +81 (0)-29-879-6009
Fax: +81 (0)-29-864-4402
Email: users.office2@post.kek.jp
HTTP://PFWWW.KEK.JP/

PSLS - Polish Synchrotron Light Source
Phone: +48 (12) 663 58 20
Email: mail@synchrotron.pl
HTTP://WWW.IF.UJ.EDU.PL/SYNCHRO/

RitS Ritsumeikan University SR Center
Phone: +81 (0)77 561-2806
Fax: +81 (0)77 561-2859
Email: d11-www-adm@se.ritsumei.ac.jp
HTTP://WWW.RITSUMEIKAN.AC.JP/SE/RE/SLLS/Newpage13.htm

SAGA-LS - Saga Light Source
Phone: +81-942-83-5017
Fax: +81-942-83-5196
HTTP://WWW.SAGA-LS.JP/?PAGE=173
SESAME
Synchrotron-light for Experimental Science and Applications in the Middle East
EMAIL: hhelal.mailer.eun.eg
HTTP://www.sesame.org.jo/index.aspx

SLS - Swiss Light Source
PHONE: +41 56 310 4666
FAX: +41 56 310 3294
EMAIL: slsuo@psi.ch
HTTP://sls.web.psi.ch/view.php/about/index.html

SOLEIL
PHONE: +33 1 6935 9652
FAX: +33 1 6935 9456
EMAIL: frederique.fraissard@synchrotron-soleil.fr
HTTP://www.synchrotron-soleil.fr/portal/page/portal/Accueil

SPL
Siam Photon Laboratory
PHONE: +66-44-21-7047, +66-44-21-7040 ext 211
HTTP://www.slri.or.th/new_eng/

SPring-8
PHONE: +81-(0) 791-58-0961
FAX: +81-(0) 791-58-0965
EMAIL: sp8jasri@spring8.or.jp
HTTP://www.spring8.or.jp/en/

SRC
Synchrotron Radiation Center
PHONE: +1 (608) 877-2000
FAX: +1 (608) 877-2001
HTTP://www.src.wisc.edu/

SSLS
Singapore Synchrotron Light Source - Helios II
PHONE: (65) 6874-6568
FAX: (65) 6773-6734
HTTP://sslsl.nus.edu.sg/index.html

SSRC
Siberian Synchrotron Research Centre
VEPP3/VEPP4
PHONE: +7(3832)39-44-98
FAX: +7(3832)34-21-63
EMAIL: G.N.Kulipanov@inp.nsk.su
HTTP://ssrc.inp.nsk.su/english/load.pl?right=general.html

SSRF
Shanghai Synchrotron Radiation Facility
HTTP://ssrf.sinap.ac.cn/english/

SSRL
Stanford Synchrotron Radiation Laboratory
PHONE: +1 650-926-3191
FAX: +1 650-926-3600
EMAIL: knotts@ssrl.slac.stanford.edu
HTTP://www-ssrl.slac.stanford.edu/index.html

SuperSOR
SuperSOR Synchrotron Radiation Facility
PHONE: +81 (0471) 36-3405
FAX: +81(0471) 34-6041
EMAIL: kakizaki@issp.u-tokyo.ac.jp
HTTP://www.issp.u-tokyo.ac.jp/labs/sor/project/MENU.html

SURF
Synchrotron Ultraviolet Radiation Facility
PHONE: +1 (301) 975-4200

TNK - F.V. Lukin Institute
PHONE: +7(095) 531-1306 / +7(095) 531-1603
FAX: +7(095) 531-4656
EMAIL: admin@niifp.ru
HTTP://www.niifp.ru/index_e.html

TSRF
Tohoku Synchrotron Radiation Facility
Laboratory of Nuclear Science
PHONE: +81 (022)-743-3400
FAX: +81 (022)-743-3401
EMAIL: koho@LNS.tohoku.ac.jp
HTTP://www.lns.tohoku.ac.jp/index.php

UVSOR
Ultraviolet Synchrotron Orbital Radiation Facility
PHONE: +81-564-55-7418 (Receptionist’s office)
FAX: +81-564-54-2254
EMAIL: webmaster@ims.ac.jp
HTTP://www.uvsor.ims.ac.jp/defaultE.html

Information
ON Conference Announcements and Advertising
For Europe and US, rates and inserts can be found at:
WWW.CNR.IT/NEUTRONIELUCEDISINCRONTORENA
Anna Minella
NNLS@ROMA2INFN.IT
It is a great sadness but also a great honour to pay tribute to Roberto Triolo, Full Professor of Physical Chemistry at University of Palermo. Roberto passed away on 21st January 2012 in Palermo, Italy.

We admired Roberto’s character, modest, cooperative and unselfish, his infectious sense of humor, his excellent teaching and research skills, and his ability to arouse students’ enthusiasm.

Roberto obtained the Laurea in Chemistry from the University of Palermo in 1964 and the Libera Docenza in Electrochemistry from the University of Rome La Sapienza in 1969. Since 1965 he taught at the University of Palermo where he remained until the end. Most of his research has been carried out in the US at ORNL’s National Center for Small Angle Scattering Research (NCSASR) at BNL’s High Flux Beam Reactor, in UK at RAL’s ISIS Pulsed Neutron Source, in Germany at the Hahn–Meitner Institut, Berlin, at Forschungszentrum Jülich (Germany), and in Sweden at the Kungliga Tekniska högskolan (KTH) Royal Institute of Technology, where he performed Neutron and X-ray Scattering. From 1976 to 1981, he worked for the US Department of Energy and since 1982 spent at least three months a year cooperating with the Neutron Scattering Group of the NCSASR. During that period, Roberto contributed to the design and construction of the Ultra Small Angle Neutron Scattering (USANS) instrument. He was an unforgettable lecturer in many International Neutron Schools, and a member of the School of Neutron Scattering “Francesco Paolo Ricci”. Since 1988 he has been a member of the Italian National Research Council President’s Executive Committee for Neutron Policy and in March 1996, a member of the Working Group on Large Scale Structures Instrumentation of the European Spallation Source (ESS), and has contributed to the planning of SANS Instruments on future European pulsed neutron sources. He was a wonderful teacher and mentor, with a deep love of experimental physics.

As a university lecturer and director of studies for many years at University of Palermo Roberto also oversaw the education of many generations of undergraduates in chemistry in Palermo. Roberto’s enthusiasm for the study of artifacts using neutrons led him to perform numerous experiments at the Berlin Reactor. Those experiments led to many published articles and to his becoming a regular guest speaker at neutron summer schools and meetings. There, a wider audience was able to enjoy his skill in the use of neutron techniques for these fascinating studies.

As a very active user of the imaging facility at Helmholtz-Zentrum Berlin Roberto Triolo worked energetically in the field of cultural heritage research using neutron and x-ray techniques. His creativity and enthusiasm for organizing and carrying out studies on ancient marbles, submerged artifacts, and wood conservation was remarkable. Roberto was impressed by the combination of x-ray and neutron imaging for the study of treated wood samples and worked with Nikolay Kardilov’s group on implementing complementary methods for cultural heritage research. He dreamed of performing experiments where imaging and scattering methods overlap. One of his last scientific discussions was about validating USANS measurements by high-resolution neutron tomography. He always joked about his capability for using every available neutron for his experiments, from which his nickname at Oak Ridge was “Neutron Scrounger”. Sometimes he worked on two instruments, simultaneously collecting and analyzing data, while at the same time he found energy to laugh and make jokes. Roberto was an incredible combination of the charming person and the excellent scientist. It was always a pleasure to work with him – even during intensive measuring programs he charged us with his enthusiasm and optimism. Being a scientist was not a profession for him – he was born with the scientific spirit. He never stopped working and thinking about scientific problems … until the final end.

We regret intensely the unexpected passing of our colleague, Roberto Triolo. We remember him for his sunny disposition, and for his radiant smile that always filled his surroundings. He was a friend to all, whom we always treasured. And we admire him for his scientific contributions especially in the use of small- and ultra-small-angle neutron scattering for studies of rocks and antiquities. We will miss him.

Roberto’s wife Irene and a daughter, Marida and a son, Fabio, survive him.

Ciao Roberto!

Carla Andreani, University of Rome Tor Vergata
John M. (Jack) Carpenter, Argonne National Laboratory
Nikolay Kardjilov, Helmholtz-Zentrum Berlin
Margarita Russina, Helmholtz-Zentrum Berlin
Editorial News
ESRF Upgrade Programme Reaches Halfway Mark

Scientific Reviews
Building a road map for tailoring multilayer polyelectrolyte films
J. Ankner, A. Baroel, S. Sukhishvili

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A. Baroel, V. Lauter, G. Szulczewski

Magnetism in solid oxygen under pressure by neutron diffraction
S. Klotz, Th. Hansen, Th. Strässle

Research Infrastructures
Instrument Design at the European Spallation Source
K.H. Andersen

Muon & Neutron & Synchrotron Radiation News
The rise of X-ray Free-Electron Lasers: Outstanding characteristics and new opportunities
M. Altarelli, B. Ebeling

School and Meeting Reports
SoNS Neutron School visited Taormina
C. Andreani, S. Magazù

NMI3’s Education and training activities
J. Savin