N°25

LE RAYON DE SOLEIL

THE SYNCHROTRON MAGAZINE

Highlighting the challenges of the 21st century

SOLEIL SYNCHROTRON

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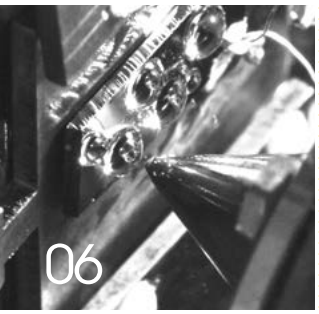
The magazine of the SOLEIL Synchrotron_N°25 December 2015



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EDITORIAL

Jean Daillant
Director General

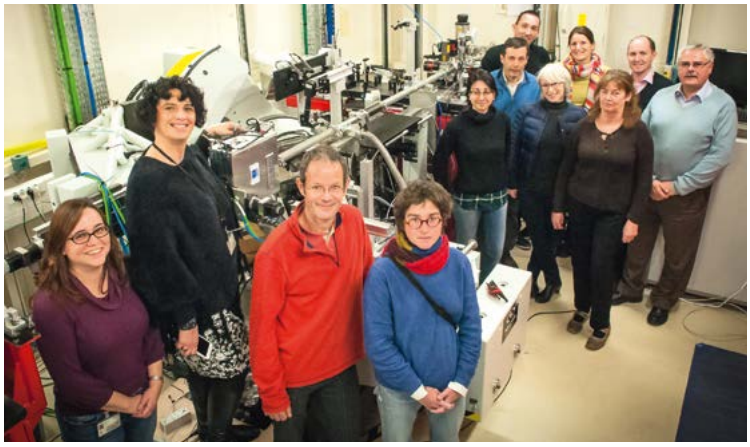
2015 being the International Year of Light, as declared by the UN, this was the perfect occasion for organizing many events where SOLEIL took center stage, for example, the lecture by Sylvain Ravy, "How light became a wave" in June or the Science Festival in October. In partnership with the Rector of the Academy of Versailles, SOLEIL also reached out to primary schools by creating the Primary Lights project to encourage interest in science among the young and teach them the investigative process. Maybe we will meet these youngsters again one day, as users or scientists on our beamlines? Speaking of which, there are even more beamlines this year to host user communities, making 27 in total with the addition of ROCK and NANOSCOPIUM. As for the HERMES beamline, its XPEEM (X-ray Photoemission Electron Microscopy) station opened in the summer and its latest instrument, the Scanning Transmission X-ray Microscope (STXM) has recently welcomed its first users. The performance of this instrument, in particular its spatial resolution, is extremely promising.

The year 2015 was also a decisive one for the climate, as the COP21 was hosted in Paris, and we decided to show you how research at SOLEIL, whether carried out by our visiting users or by our own researchers, helps to provide answers to current social issues. This is the goal of our feature article «Highlighting the challenges of the 21st Century», which gives a brief overview of the techniques and equipment developed at SOLEIL under this heading. This potential will be further developed in 2016 as it will be the turn of the ANATOMIX beamline to welcome its first users, followed by PUMA in 2017.

I wish you a very happy 2016.

FEMTO-SLICING

An additional step taken on CRISTAL



Some of the SOLEIL staff involved in this achievement, gathered in the CRISTAL experimental hutch.

Ultrafast structural dynamics studies at SOLEIL have come one step closer. After the first interaction between a femtosecond laser pulse and one of the electron bunches circulating in the storage ring, observed at the end 2014, the first ultrashort X-ray pulses were detected on the CRISTAL beamline on 5th October 2015.
Unlike other existing femto-slicing facilities in the world, at SOLEIL the device will provide femtosecond X-ray pulses to multiple beamlines, so as to cover the X-ray photon energy range. After CRISTAL it will soon be TEMPO's turn.

Aline Passos, from Araraquara Unesp (Brazil), the first user to inaugurate ROCK, in March 2015.

26, AND 27!

First users on the ROCK and Nanoscopium beamlines

In March 2015, the ROCK beamline (Rocking Optics for Chemical Kinetics), dedicated to the study of fast kinetic processes on nanomaterials used mainly in the field of catalysis and batteries, was the 26th SOLEIL beamline to open its doors to its first outside users. In total, 15 projects were programmed in 2015. Then, it was Nanoscopium's turn in June. Thanks to micro and nanoprobe experiments in the 30 nm to 1 µm range, this beamline offers unique research possibilities, based on 2D/3D quantitative elemental, chemical, and structural analysis. The research fields are multiple: microelectronics and materials, biomedical, geo-biological and environmental sciences.

IN BRIEF

CLIMATE
In this crucial year for the climate, with the COP21 in Paris, SOLEIL encouraged debates on this theme by hosting the 150 participants of the scientific symposium «Objectif Climat» organized on 12th November by Paris-Saclay University. It was an opportunity to display the work at SOLEIL in this area. In the evening, a public debate hosted by Valérie Masson-Delmotte (LSCE, CEA Saclay) helped to publicize the existing interdisciplinary scientific potential around the climate issue.

BOOK
Photoemission techniques are used to study the physico-chemical and electronic properties of surfaces by giving access to the band structure of materials. Antonio Tejeda, an LPS researcher (Orsay) associated with SOLEIL (CASSIOPEE beamline) co-authored with Daniel Malterre (IJL, Lorraine Univ.) the book «Photoémission dans les solides. Concepts et applications» (EDP Sciences), which targets an audience ranging from undergraduates to researchers specialized in these techniques.

DEIMOS

Nanomagnets device integration:

study of the magnetization at the surface

At the nanometer scale, properties of matter start to diverge from those of the bulk, and size dependent effects come into play. Magnetism at the nanoscale is a fast growing area that attracts intense activity in both fundamental and applied research. As the scaling down process continues to advance, particle characterization becomes significantly more challenging or inadequate. At the cutting-edge in this domain the DEIMOS beamline offers magnetic measurement techniques based on polarized x-rays absorption thus allowing such challenging studies to be performed.

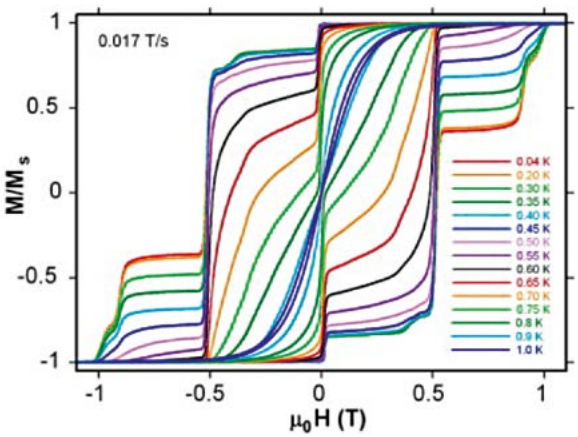


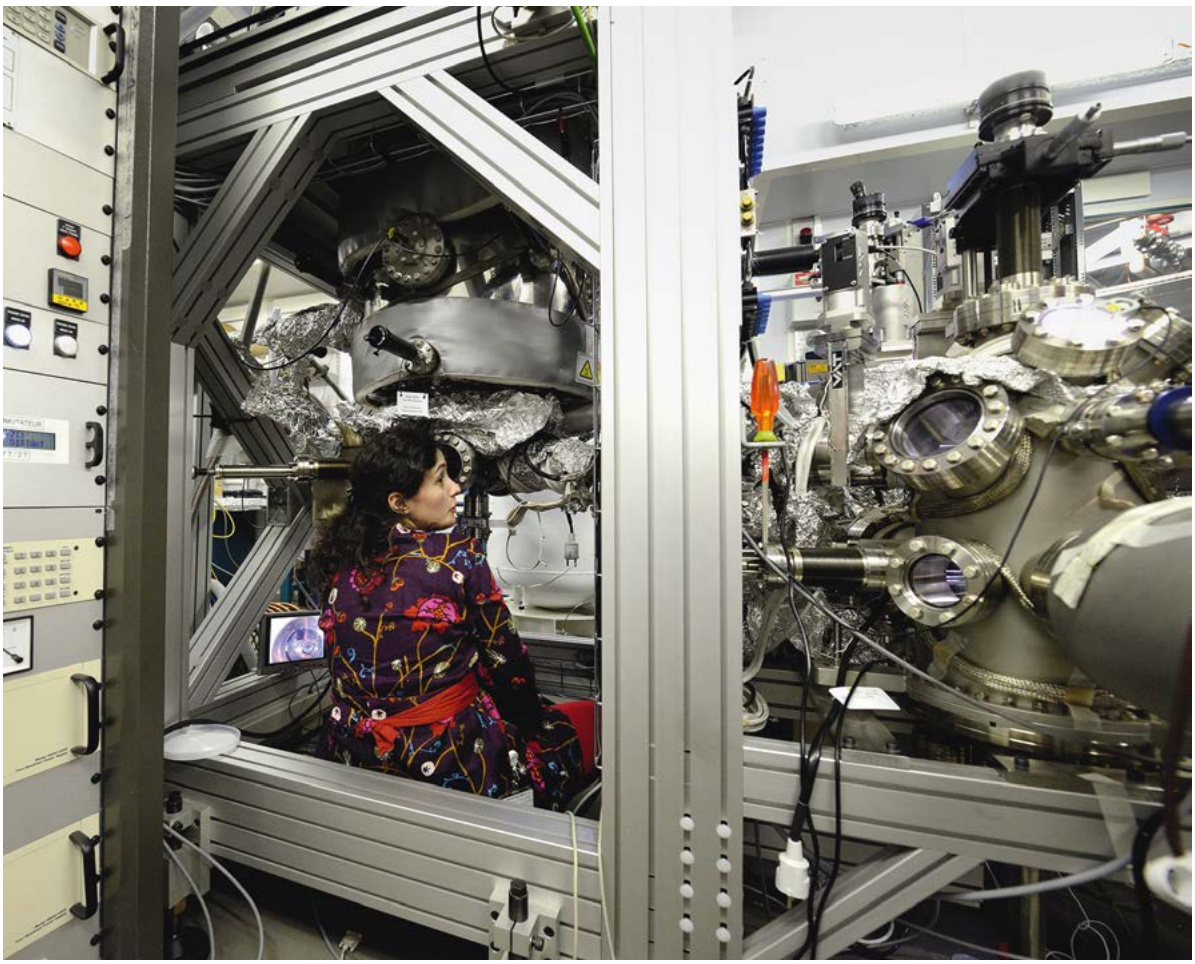
Figure 1. Magnetization curves (i.e. sample magnetization vs. applied magnetic field) of Fe_4 molecule magnet measured on single crystals by microSQUID magnetometry (with a magnetic field sweep rate of 0,017 Tesla/s and at temperatures ≤ 1 Kelvin). The presence of hysteresis curves demonstrates the magnetic bistability of Fe_4 at subKelvin temperatures; sharp steps in the hysteresis loops is a proof that the spin dynamic is dominated by quantum effects [ref.1]

As magnetic properties depend uniquely on both dimensionality and length scales, the exceptional magnetic properties of nanoparticles have put them at the forefront in the quest to develop the next generation of information storage technology, to improve cancer treatment and diagnosis protocols, as well as in environmental applications. However, standard magnetometric techniques only provide macroscopic information on the total magnetization of the objects measured. Moreover, they cannot discern between the contributions from the different elements present in alloys or multilayer systems. Also, the very small amount of materials present in such nano-structures requires a very sensitive measuring method.
Such measurements have become possible using the synchrotron based technique of x-ray absorption spectroscopy (XAS), in which the magnetic sensitivity is obtained by using circularly or linearly polarized x-rays (see insert).

Single Molecular Magnets

Single Molecular Magnets (SMMs) are the smallest existing nanomagnets. Made up of a small number of interacting spin centers (e.g. paramagnetic ions), this new class of fascinating magnetic material provides a unique opportunity to observe the coexistence of classical and quantum properties (see fig.1; ref.1). Indeed, while some possess magnetic ground states, they may also show quantum tunneling of the magnetization which could make them most promising candidates for nanoscale information technology based on the molecular spin state (ref.2). However, to achieve such technological innovation, and while these unprecedented quantum effects have been extensively investigated in bulk powders, they had first to be demonstrated by isolating them on a surface. The SMM community had to wait until 2009 for the first experimental evidence that SMMs isolated on a surface could exhibit so-called "memory effects" (ref.3). This collaborative work between the group of R. Sessoli (Department of Chemistry, University of Firenze, Italy) and Ph. Sainctavit (IMPMC-CNRS, Université Pierre et Marie Curie, France) demonstrated using XMCD (X-ray Magnetic Circular Dichroism, see insert) that a functional molecule (a tetrairon (III) clusters with a propeller-like structure, a.k.a. Fe_4) chemisorbed to form a single monolayer on a gold substrate, could show magnetic memory effects at the single-molecular scale, in addition to quantum effects bellow 1K.

This essential step towards the fabrication of molecular memory arrays was far from trivial and required the use of a linker (a carbon chain) to bind by chemical means the molecule to the gold surface, thus ensuring mono-



Edwige Otero, beamline scientist at DEIMOS, sitting underneath the "CroMag" setup.

layer coverage of the substrate. The challenge was then to measure such a minute amount of material at sub-Kelvin temperatures where quantum effects take place. For these measurements, the unique surface sensitivity of XMCD was pivotal.

In the continuation of this work, XNLD (X-ray Natural Linear Dichroism) was used to correlate the length of the linker with the structural ordering of the molecules chemisorbed on the gold surface. The researchers demonstrated the important discovery that short chains promote the growth of ordered films (ref.4). Also, as expected, the molecules with a higher structural order were also found to display higher magnetic ordering temperatures. This result paves the way towards SMM «device integration», but in this approach an important parameter to consider is the interaction that can arise between the molecule and the surface.

Towards quantum bits and molecular memristance

In order to accomplish this, the unique feature of the element selectivity of XMCD is used to explore simultaneously the magnetic properties and interactions of both the molecule and the substrate. In this continuous effort in engineering device suitable systems, functionalized $TbPc_2$ anchored to a silicon substrate (see fig. 2-a) was investigated at the DEIMOS beamline, and an unexpected enhancement of magnetic stability was observed (see fig. 2-b; ref.5). In these double decker lanthanide complexes (a class of SMM where one lanthanide atom is sandwiched between two phthalocyanine rings), such interplay between the molecule and substrate (gold, copper, nickel, silicon) has been used to tune the magnetic anisotropy.
It is hoped that such examples of fundamental approaches in research, used in order to understand the complex interplay between SMMs and materials (substrates), could ultimately succeed in the realization and fabrication of q-bits.

Another example of important work, with the ambition to realize a nanoscale molecular memory, is the first proto-

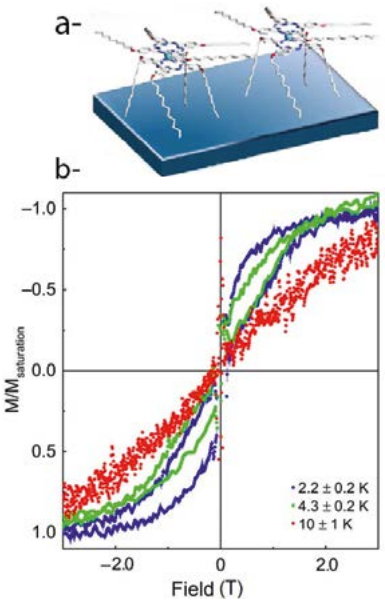


Figure 2.
a-Schematic representation of $TbPc_2(OC_{11}H_{21})_8$ molecules adsorbed on silicon by mean of 11 carbon atoms chains.
b-XMCD magnetization curves of a monolayer of $TbPc_2(OC_{11}H_{21})_8$ molecules assembled on silicon (recorded at M_5 edge and with a sweeping rate of 0,05Tesla/s) [ref.5].

type of memristance at the level of individual molecules demonstrated by Miyamachi and co-workers (ref .6). The authors were able to address individual molecules and to switch them between a combined high-spin/high-conduction state and a low-spin/low-conduction state. Adding such spin functionality to molecular switches is a key concept for realizing molecular spintronic devices.

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X-ray magnetic circular dichroism (XMCD) was first observed in 1986 (one year after its theoretical prediction). It relies on the preferential absorption of left or right circular polarized x-rays by magnetic materials. Because XMCD is related to the spin state of the absorbing atoms, it thus probes the magnetic structure but also, as an energy dependent technique, the electronic configuration for each absorbing atoms present in the nanoparticle (i.e. it is an element selective technique). Moreover, in certain cases, XMCD can identify the different contributions to the magnetization, such as orbital and spin magnetic moments. Today, almost all synchrotron facilities around the world have dedicated beamlines for XMCD; at SOLEIL, the DEIMOS beamline has been optimized to perform XMCD in the soft energy x-ray range from (350eV to 2500eV). By probing only the first few nanometers of matter, soft x-ray XMCD has found its way into the community of magnetic nanomaterials, among them molecular magnets and organometallic complexes.

XMCD spectra are given by the difference between two x-ray absorption spectra (with the circular polarization vector orientated parallel or antiparallel to the external magnetic field). Thus, this technique is very sensitive to the x-ray beam stability (energy, flux and polarization) and reproducibility (the ability to repeat the same XMCD scan without altering the signal) is a key factor for a state-of-the-art XMCD beamline and which DEIMOS excels at. Moreover, at DEIMOS, the sample environment has been designed specifically for nanomagnetism case studies: it offers a magnetic field up to of 7 Tesla, a cryogenic sample stage (down to 1.5 K) and state-of-the-art sample preparation facilities including a glovebox, a MBE (molecular beam epitaxy) chamber and several in situ UHV characterization tools (such as variable temperature STM, a LEED (low energy electron diffraction) and an Auger spectrometer).

TEMPO

Near ambient pressure photoemission and environmental science

Where do the ions go at vapor water interface?

Using an original setup designed on the TEMPO beamline by scientists from Laboratory of Physical Chemistry- Matter and Radiation (UPMC, Paris), it becomes possible to carry out x-ray photemission spectroscopy measurements at pressures that can reach 20 mbars, far from ultra-high vacuum conditions. This bridges the pressure gap with "real-life" conditions, and allows applications in environmental sciences, for instance.

Since the work of Kai Siegbahn (Nobel price 1981) we know that when X-rays impinges on a sample, energy is conserved in the photoemission process. Besides, the measurement of electron energy distribution gives important information not only on which atomic species are observed but also on their chemical bonding. As the inelastic mean free path of electrons in the kinetic energy range 50-1000 eV is short in condensed matter, with a minimum of a few atomic layers at 50 eV, the information extracted with this technique is extremely surface sensitive.

Usually experiments are performed in ultra-high vacuum conditions needed to operate soft X-rays beamlines and electron energy analyzers. To bridge the pressure gap with "real-life" surfaces, for instance those of catalysis or environmental chemistry, new X-ray photoemission spectrometers were designed, capable to reach working pressures of ~20 mbar.

For the pressure to rise up...

The design involves a very short distance between the surface under study and the analyzer (~1mm) to minimize the inelastic scattering of the photoelectrons by the gas phase and a highly efficient pumping of the analyzer lenses. The latter point implies that the photoelectrons are collected through a pinhole of diameter ~0.3 mm drilled in the conical skimmer shown in figure 1.

Because of the small dimension of the X-ray spot (~0.1 mm for Branch n°2 of TEMPO beamline), these geometrical constraints make that the best performances are obtained at synchrotron sources. The high photon flux also balances the signal attenuation by the gas phase.

A unique and specific setup

With respect to other setups installed in the world, one specificity of the Laboratory of Physical Chemistry-Matter and Radiation (LCPMR) installation at SOLEIL is the absence of window to confine the near ambient pressure region under study. Indeed, the soft X-rays photons beam at TEMPO beamline goes through a differential pumping system whose final diameter is 300 microns. In consequence, the incoming photon flux is not damped by the absorption edges of silicon nitride or aluminum windows. Therefore, experiments can be performed at all photon energies between 50 and 1500 eV (the energy range of TEMPO beamline). The specially designed lens system has no negative impact on photoelectron collection, and photoelectrons are measured with high energy and angular resolution as efficiently as in any "regular" UHV setup. Studies of catalytic reactions at partial pressures equivalent to those of real devices are one of the main applications. However, the example presented below is an original application to environmental science.

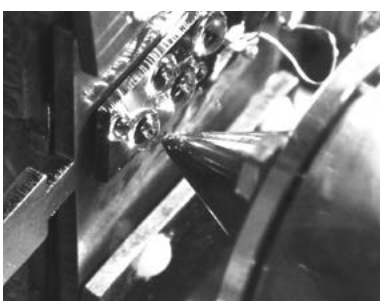

Figure 1: Water droplets on a gold coated silicon surface in the analysis chamber during the acquisition. The soft X-ray beam of TEMPO beamline impinges on the sample from the right. The cone pointing to the droplet is the 300 microns diameter entrance of the electron energy analyzer.

Reproducing marine aerosols on TEMPO

Experiments are performed on liquid water and we can learn about ion distribution at the water surface by using the tunability of the photon energy and hence by changing the probed depth. The sample environment during the experiment is presented in fig. 1. Some salt is deposited on a metallic substrate (gold in our case), and then the sample is cooled down to 8°C. When water vapor is introduced in the experimental station under a pressure of 8 mbar, one assists to the deliquescence of the salt crystals until liquid droplets form. The prepared solution can now be studied.

The conventional view of electrolyte solution surfaces was essentially the one of ion-depleted surfaces, similar to the surface of neat water (the Onsager-Samaras model). However, in the last decade, theory and experiments have shown a very different picture, pointing to the segregation of ions at the water surface. Naturally, this observation is highly relevant to environmental systems: the segregation of halide ions at the surface of marine aerosol has a relevant impact on atmospheric chemistry.

Reference:
Tissot, H. et al. (2015) Journal of Physical Chemistry C, 119 (17), 9253.

http://www.synchrotron-soleil.fr/Recherche/LignesLumiere/TEMPO

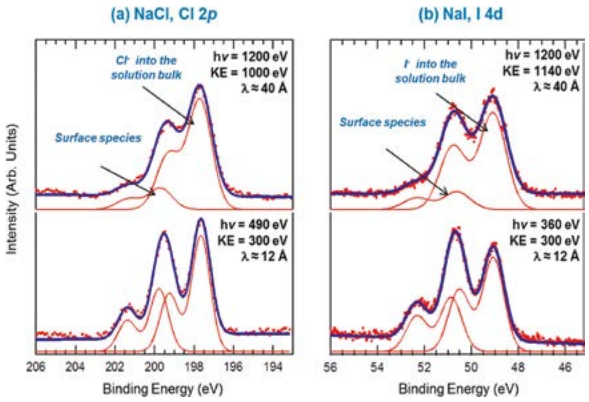

Figure 3: (a) Cl 2p spectra of a saturated NaCl (6M) solution surface and (b) I 4d spectra of a saturated NaI (11M) solution surface measured with two photon energies at RH = 95% (P = 8 mbar, T = 278 K). The BE is referenced with respect to the Fermi level of the gold substrate. Inelastic mean free paths (λ) are theoretically determined for pure liquid water.

The Na 2p/O 2s energy window is shown in fig. 3. We can identify the electrons from sodium atoms and oxygen atoms of water. The same experiment can be repeated changing the photon energy (the electron kinetic energy) and then the probing depth. This procedure that is currently used in surface science to obtain atomic distribution in a solid can be readily applied to solutions. It is observed that the intensity ratio between the Na 2p level and the O 2s changes as the photoelectron kinetic energy increases (i.e. as the probing depth increases). After taking into account photoemission cross section variations, the analysis of the data comes to the conclusion that this change in relative intensity is mainly due to an accumulation of Na^+ close to the surface for the NaI solution. This is also true for the NaBr solution, but this trend is not seen for the NaCl one.

In agreement with molecular dynamics results, when the anion polarizability increases, a cation plane is formed below the anion one near the liquid surface, to recover the electro neutrality of the solution. This is an important result. It is the first time that an experimental measurement proves the existence of an increase of cation concentration below the surface.

Looking in another kinetic energy region, photoelectrons from the salt anions, such as the chlorine atoms of the NaCl solution or iodine atoms of the NaI one, can be observed (see fig. 3). Ions at the surface have different coordination than in the bulk solution, for instance less water molecules around them. This has a sizeable impact on their binding energy.

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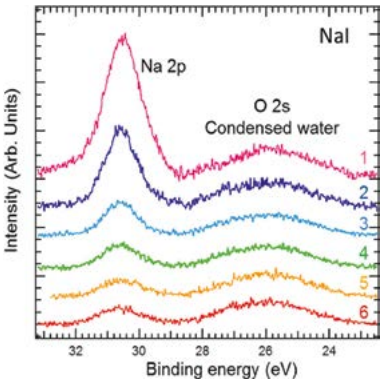

Figure 2: Na 2p and O 2s XPS spectra of a saturated sodium iodide solution surface measured at several photon energies with the gold substrate biased at –40 V at relative humidity (RH) = 95% (P = 8 mbar, T = 278 K). The spectra are normalized to the O 2s peak intensity and a vertical offset is added to make the figure clear. The binding energy (BE) is referenced with respect to the Fermi level measured on the gold substrate. (1) hν = 200 eV, λ ≈ 13 Å; (2) hν = 400 eV, λ ≈ 17 Å; (3) hν = 600 eV, λ ≈ 20 Å; (4) hν = 800 eV, λ ≈ 23 Å; (5) hν = 1000 eV, λ ≈ 33 Å; and (6) hν = 1200 eV, λ ≈ 50 Å are theoretically determined for pure liquid water. The sample was biased to -40 V with respect to the spectrometer to get rid of the O 2s gas phase contribution.

FOCUS ON

The High Pressure Laboratory

Diamonds and know-how available to scientists

Open to users for the last four years, the High Pressure Laboratory (HPL) provides, as its name suggests, the equipment and expertise necessary for conducting studies under extreme pressure conditions. The laboratory specialized in high pressure cells. In these cells, the studied sample is placed between two diamonds with a planar tip of 100 to 400 micron diameter. The experimental chamber positioned between these two points, is delimited by a gasket, in stainless steel or rhenium, depending on the pressure range to be explored, drilled by micro-Electrical Discharge Machining (EDM) with a diameter of 50 to 200 microns. The sample, which can also be subjected to a laser beam to raise the temperature and a ruby sphere (for pressure measurement) is then placed in the hole, together with a pressure transmitting medium. When the ruby fluorescence pressure measurement is no longer suitable for determining the pressure on the sample (values greater than 100 GPa), Raman spectroscopy of the diamond anvil can take over (equipment also provided by the HPL), or X-ray diffraction of a standard (gold, platinum or silver, for example) previously mixed with the sample, for which the volume as a function of pressure is known.

Support and training

Since its inception, many things have changed: the laboratory has moved to be closer to the beamlines that need it most, namely those carrying out X-ray diffraction or absorption, or infrared spectroscopy. The HPL now has among its regular users the ODE, CRISTAL, SMIS, GALAXIES, PSICHE and AILES beamlines. A total of 10 beamlines have already applied to HPL for their in-house research requests, as well as for their users. On average, two high pressure experiments are conducted per week at SOLEIL. Support requests vary depending on the scientists; the beamlines managers are now more autonomous. The quality of the laboratory has been recognized as it was chosen to host the 2014 training session given every two years by the CNRS high pressure network. However, although researchers have become more operational, the HPL remains at their disposal to prepare their experiments, notably the difficult step of loading the «pressure transmitting medium»: this involves introducing neon or helium into the cell at a pressure of 1300 bars. The HPL team can also offer good advice for the equipment's maintenance, and is always ready to detect early signs of a possible problem during the experiment.

Pressure, but also temperature

The HPL also proposes to link these high pressure studies to extreme temperature conditions. Two cryostats are available that can go down to 5K (-268°C) and heating jackets placed around the experimental cells can raise the temperature up to 500°C. For «large volume» samples (a few milliliters), the HPL also has a multi-anvil pressure cell, to reach pressures above 30 GPa and temperatures of 2000°C, i.e. corresponding to the extreme pressures of the Earth's mantle.

The High Pressure Laboratory is now seeking to push experimental boundaries even further through various instrumentation projects. A laser drilling system for the gaskets, to replace the EDM and decrease the size of the experimental cell to less than 50 microns, is currently being developed. This will also be used to cut ever smaller samples. The development of a more powerful vacuum heater for diamond-anvil cells is also under consideration. It should enable the 800°C barrier to be overcome, at which diamonds turn back into graphite.

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Alain Polian (on the left) and Jean-Paul Itié, in charge of the High Pressure Laboratory, checking the correct alignment between the experimental chamber and the two diamonds with a binocular microscope.

EXPERT PORTRAIT

Marie LABAT,
Researcher in the Diagnostics Group

Marie in the Diagnostics laboratory, at SOLEIL.

Whether they are lasers or synchrotrons, light sources are at the heart of Marie's research. And since her thesis, one of these sources has been SOLEIL.

What path led you to SOLEIL?

When I began my engineering studies at the Ecole Centrale, the physics program left me hungry for more. So I decided to follow evening classes for the Master in Fundamental Physics offered by the University of Paris Sud on the Orsay campus. This Master then led to a DEA in large-scale facilities in my final year. In 2005, I started a thesis on free electron lasers (FEL) supervised by Marie-Emmanuelle Couprie, who was at the CEA at that time. The experimental part of my thesis work was taking place both on the UVSOR synchrotron in Japan and on the SPARC FEL project in Italy. Then Marie-Emmanuelle went to work at SOLEIL, where I joined her in 2007 for the final year of my thesis. Since I was based at SOLEIL, I gradually got involved in the Diagnostics Group activities of the Source Division at SOLEIL, essentially by helping in the installation of a streak camera for electron bunch length measurements on the storage ring. At the end of my thesis, the experimental module that I had made for the SPARC project had still not been installed. It was waiting quietly in a crate for the accelerator to be finished: the delay was more than a year for various reasons. To finish what I had started, I went for a one-year post-doc to Frascati, Italy. I then had the chance to get involved in the commissioning of the SPARC FEL. But after the first year, my module was still not installed. In view of the accumulated delays and weary of battle, I decided to leave the project and search for a new post-doc position, preferably in France. As luck would have it, a position came up at SOLEIL in the Diagnostics Group, led at this time by Jean-Claude Denard. I had very little experience in this area, but the Diagnostics Group just happened to be looking for a physicist/engineer to work on new generation light sources: a godsend. So I joined SOLEIL in 2010.

What does your work involve?

The aim of the Diagnostics Group is to characterize the electron beam in the LINAC and storage ring at SOLEIL. The group consists of six people, each with their own specialty. Mine is optical diagnostics, i.e. diagnostics using the radiation produced by electrons to measure their properties, and not the electrons directly, as in the case of electronic diagnostics. It is both the work of an engineer and a researcher, which I particularly like.
I am also involved in the femto-slicing project (see Rayon de SOLEIL No. 24, p 20) the goal of which is to provide femtosecond X-ray pulses to several SOLEIL beamlines, for the study of ultrafast phenomena. I set up the diagnostics for the «machine» part of the project and I am currently participating in its commissionning. Again, I find myself at the interface between physics and engineering.
Furthermore, I am also carrying out more «research» based work focused on the [1]LUNEX5 project, led by M.E. Couprie. This is an original fourth and fifth generation source project. The purpose is to

provide high brilliance sub-picosecond pulses in the soft X-ray region with an FEL powered by a conventional radio frequency accelerator (LINAC), and to set up the first FEL powered by a plasma accelerator. Two years ago, an ERC grant enabled us to launch the COXINEL1 program, which should enable us to create a plasma accelerator based FEL prototype at the Laboratoire d'Optique Appliquée (LOA). Initial experiments are programmed for early 2016. My work for [1]LUNEX5 is essentially carrying out simulations of radiation generation. However, on [2]COXINEL, I am also in charge of setting up photon diagnostics. My colleagues in the group are responsible for setting up electron diagnostics.
This research topic is in some ways an extension of my thesis, the theoretical part encompassing the 4th generation light source project «Arc-en-Ciel», which never saw the light of day. Synchrotrons and FELs are complementary; operational FELs are currently being inundated with requests from users, so it is essential that France acquires such equipment.

At SOLEIL, I thus have the opportunity to immerse myself in the «very theoretical» but also to do something practical by installing equipment that I designed. This is exactly what I look for in my work.

How is your work going on slicing?

The project started in 2012. By 2013 we had installed most of the equipment, and in 2014 the laser has been transported to the interaction point in the storage ring. In September 2014, we obtained the first laser-electron interaction and we are now commissioning the CRISTAL beamline. Also, an important step was taken recently: on October 5th, the first sliced X-ray beam from the laser was recorded by the detector located in the CRISTAL optics hutch, the first SOLEIL beamline to use slicing!
Commissioning has also started gently on the TEMPO beamline, another beamline using slicing, but this one is more complex for the moment. Indeed, on CRISTAL, only the diaphragm had to be modified to capture the radiation emitted by the classical off-axis sliced bunches. In the case of TEMPO, changes are required further upstream, adding magnets in the ring to help sliced bunches to acquire the appropriate axis to enter the front-end. First tests have been carried out, leading to improved diagnostic tools. We will hopefully get the first sliced beams in early 2016.

And what about monitors for the storage ring?

My work focuses on two main types of equipment: XBPMs (X-ray beam position monitors) and pinhole cameras (PHC). The former consist of metal blades sensitive to X-rays, placed right at the beginning of the beamlines (still in the ring tunnel). The blades are used to detect the position of the radiation emitted by the dipoles and undulators at the front-ends. They thus provide additional indirect information on the position and angle of the electron bunches at the source of the storage ring. The ring was already equipped with several XBPMs when I arrived. But I then took over from Jean-Claude Denard, to design and install new XBPMs with Nicolas Hubert. In particular, we have developed a special double XBPM for the Nanoscopium and ANATOMIX beamlines. Because of the existing angle between their respective undulators, the synchrotron radiation is in fact divided into two when it arrives at their common front-end. It was therefore necessary to design a «two-headed» XBPM.
As for pinhole cameras, these give a measure of the transverse dimensions of the beam through constantly measuring the X-rays produced by the electrons. If there are two such devices, it is also possible to measure the dispersion, which is an important parameter of the machine. Up to now only one pinhole camera is in operation; we plan to install a second one at the beginning of 2016.

What highlights will you remember from those years at SOLEIL?

Obtaining the first sliced beams in the ring remains a special moment as we had been waiting for months and for which we had slaved extremely hard for almost two years. The beginning of my maternity leave was fast approaching: it was essential that it work before I left, as I really wanted to be present and not miss that moment! In September 29, 2014, we were all eyeing the screen of the oscilloscope, to scan the signal from the bolometer which would prove to us that there was some interaction between the «slicing» laser and the electron bunch. When the signal finally appeared, a great cry of joy rang out, followed by huge relief. The «bolo» was in the spotlight. So much so that my colleagues jokingly suggested that I should name my future child «Bolo». I have just kept the «o» sound!

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[1]LUNEX5: free electron Laser Using a New accelerator for the Exploitation of X-ray radiation of 5th generation

[2]COXINEL: COherent Xray source INferred from Electrons accelerated by Laser

SPOTLIGHT ON

Library and SOLEIL User Office:
one group, three missions

With five permanent staff, four working full time and helped by two young apprentices, the so-called BBUS (Bibliothèque et Bureau des Utilisateurs de SOLEIL), run by the Experimental Division and directed by Frédérique Fraissard, assures essential missions that follow and punctuate the scientific life of SOLEIL.

The BBUS team. From left to right: Anaïs Humblot, Jean-Marc Lucacchioni, Sylvie Koguc, Sylvie Pavan, Frédérique Fraissard and France Pochard.

Library

As well as managing all operations related to documentation (fifty journals, electronic and / or paper made available by the library), the librarian, Jean-Marc Lucacchioni, is responsible for compiling all 500 or so publications resulting from experiments carried out at SOLEIL each year.

Articles must, of course, be identified and classified according to the beamline and other SOLEIL groups involved. This sometimes involves true «detective work» leading to SOLEIL scientists or users, and includes a painstaking literature search.
Jean-Marc is also involved in publishing the booklets of submitted contributions to various conferences organized by the group. A good example is all the the book of abstracts for the annual SOLEIL Users' Meeting, one of the major events organized by the BBUS, which annually hosts more than 300 participants. But this conference is not the only scientific event managed by the group.

Scientific events

Each year is punctuated by almost a dozen French or international scientific conferences, organized by the Experimental Division via the BBUS.
At the end of an annual call for candidacy, held from mid-September to mid-October, the events to be organized are selected by the Scientific Directors. The choice is based on creating a balance between subjects to be treated, and also the human resources available. The events are then organized into projects that must be planned and distributed among the managers, Sylvie Koguc, Sylvie Pavan and France Pochard. Faced with an increasing number of events to organize, BBUS has had to seek the help of Jacqueline Lassagne, Assistant to the Scientific Directors.
When an event has been accepted, a whole chain of logistics activities, communication and management has to be put into place to ensure that everything runs smoothly. These different steps and their implementation have evolved over the years toward greater standardization and structuring, in order to gain time, efficiency and to

simplify the work of support groups who work with BBUS.
After nearly ten years of operation and very positive feedback from the scientific organizing committees with which BBUS has worked, the latter has been very successful. Applications are now also coming from outside scientists (in collaboration with SOLEIL scientists) wishing to use the expertise of the BBUS Events group. These events can be located at SOLEIL or outside.
Among the recurring scientific events, BBUS (and mainly Sylvie Pavan) therefore organizes one of SOLEIL's unmissable events, the annual SOLEIL Users' Meeting. The 11th meeting will take place on 21st & 22nd January 2016. It provides an occasion to take stock of the past year, to present current and future projects and, in particular, the opportunity for users to interact with beam line scientists and support laboratories, Sources staff and also SOLEIL management. Its program is developed by the Organization of SOLEIL Users (ORGUES), in agreement with the SOLEIL management. The interface is provided by BBUS at 4 annual meetings. Some of these meetings are also used every two years to prepare and validate the renewal of half of the ORGUES members.
As part of its training program, SOLEIL is also involved in the organization of schools or regular courses such as HERCULES (Higher European Research Course for Users of Large Experimental Systems) or Crystallography Training for Large Facilities (organized every two years). Members of BBUS also undertake the organizational side and management of the participants.

Relations with SOLEIL users: the User Office

SOLEIL receives over 4000 annual user visits. With the possibility of the same user coming several times a year, this represents about 2,200 different researchers each year. These users conduct their experiments on the beamlines (26 available in 2015, 29 by 2017), and sometimes also in one of SOLEIL's support laboratories (biology, chemistry, surfaces, high pressures, and ancient materials. Each year, about 680 experiments are performed and over 1,200 projects registered. Proposals are submitted via the «SUN» dedicated internet register (SOLEIL Users Net), using SUN Set : http://sunset.synchrotron-soleil.fr/sun/), which includes a general guide for users. There are two calls for proposals per year, which deadlines are February 15th and September 15th. SUN Set is the central, single entry portal for the management of research projects submitted to SOLEIL. To harmonize as much as possible the procedures in force between synchrotrons and thus simplify the system for users, the initial goal was to start with an existing tool, while integrating the specific needs of SOLEIL.
After a survey of needs and specifications organized by Frédérique Fraissard, SUN Set was developed internally by the Management Systems Integration Group (ISG) of the SOLEIL Computing Division (mainly Angelique Prevost and Idrissou Chado) based on a tool used at SLS, the DUO. Its potential has regularly been upgraded since the opening of SOLEIL to external users in 2008.
At the outset, SUN Set was used only to register research proposals. Since then, this tool is been used to evaluate these projects and the scheduling of experiments, the management of experimental reports and for end of run report, declaration of experiment, requests to use a support laboratory (one of the specificities of SOLEIL) and the linking of scientific articles submitted for publication to the project from which they came.
So this is a constantly evolving tool. Users' expectations are also taken into account and, for this, Frédérique relies on ORGUES members, enlisted to test and validate the «latest features» offered by SUN Set before they become available to other scientists.
Among the new features already planned are the running of experiments, remote-access data processing and sample tracking: each successive addition following the needs identified for the beamlines.
Once deposited in SUN Set, proposals follow an entire process. They are technically assessed by beamline Managers and then allotted according to subject, under the control of SOLEIL management, to the six Peer Review Committees[1] (PRCs) that evaluate them scientifically. Decisions are taken at face-to-face meetings organized by the SOLEIL Users Office and immediately recorded during the session in SUN Set.

The BBUS team mobilized to welcome the participants of the SOLEIL Users' meeting, in January 2015.

It is then up to the safety group to assign a level of risk to each project (from green to black - black preventing the experiment from taking place, at least without modification). These data are also stored in SUN Set.
Frédérique, responsible for the beam time partition time which is then validated by the scientific management, has to take into account multiple factors (commissioning operations and training, with possible periods of 'exotic' filling of the storage ring that are not suitable for all experiments, etc.). A real headache!
The beam time dedicated to the PRCs (at least 65%) is then divided between them according to demand and after consultation with the beamline Managers, in order to match requested beam time and project.
This volume / beam time quota per PRC is communicated to members of the PRCs before the meetings, held in April and November.
SOLEIL management may decide to give its 5% share of beam time to the PRCs prior to evaluation.
The beamtime reserved for paid access is set after consultation with the Industrial Relations and Valorization Group.
After the PRCs have met, the SOLEIL management validates beamtime allocations, which are then published on SUN Set and communicated to users in mid-May and mid-December.
The beamline Managers then program the accepted experiments and notify the main proposers for the accepted proposals. The latter then carry out formalities prior to their arrival at SOLEIL and once the experiment is over, complete a satisfaction questionnaire ('end of run report') and an experimental report. Finally, they must provide references of any publications based on the results of these experiments.

Two managers, Sylvie Pavan and France Pochard, are at the disposal of users to assist them in these different steps, before and after the experiment, as they follow all the proposals. Sylvie and France divide up the management of the proposals between them, based on the beamlines and SOLEIL laboratories for which they are responsible.

Guaranteeing that the rules developed by the management, in collaboration with ORGUES, are respected, the User Office team aims to simplify access and reduce the difficulties for scientists coming to use the synchrotron.

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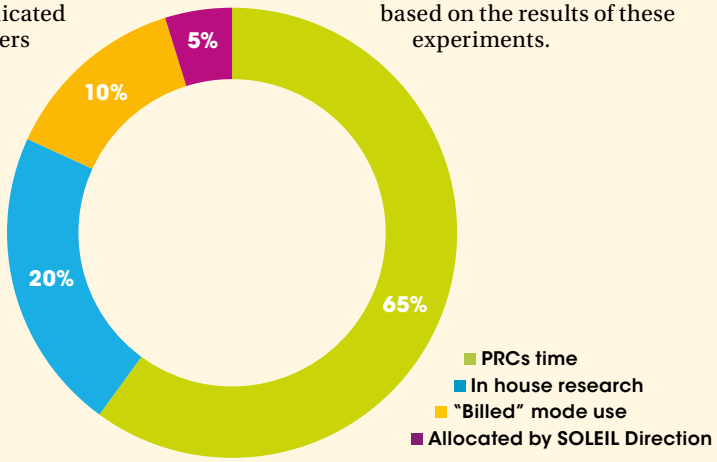


Figure 1: Beam time allocation.

[1]There are 6 Peer Review Committees (PRCs) in total: Diluted material; Electronic and magnetic properties of matter - surfaces and Interfaces; Properties of matter and materials: structure, organization, characterization, development; Chemistry and physical chemistry - reactivity in situ - Soft matter; Biology - health; Ancient materials - earth and environment.
PRC members are appointed by the SOLEIL management for a renewable two-year term. The BUS (User Office) is in charge of organizing the renewal of the members of each PRC. All PRCs are composed of between 9 and 11 members, who between them cover all subfields of the discipline.

Highlighting **the challenges of the 21st century**

Reflection on results obtained on the SMIS beamline.

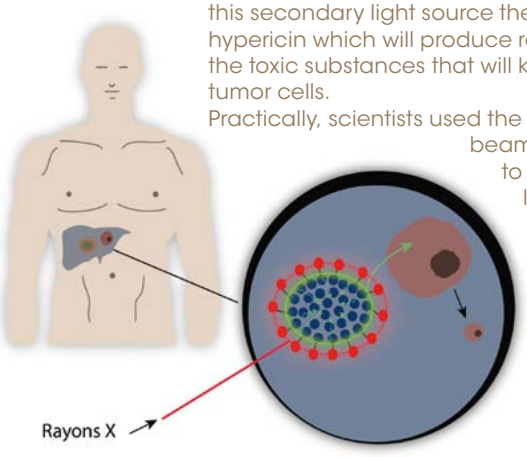
An essential purpose of research is to assist society in identifying the challenges of tomorrow and implementing the necessary solutions. To address the problems we face, it is essential to establish links between the different scientific disciplines and create greater international cooperation. Research at synchrotron SOLEIL also reflects societal concerns.

DISCO-METROLOGY

Medecine - a nanoflash-light to activate drugs in solid tumors

Light has been used in medicine for decades, until now. Photodynamic therapy (PDT) relies on the use of substances which become toxic for their immediate environment when subjected to visible light. The major limitation of the technique: only the reachable zones can be treated (skin, esophagus, lungs…). The whole issue is about vectorising these substances in the tumor before illuminating them to trigger the reaction. Scientists from SOLEIL Synchrotron and the Center of Molecular Biophysics of Orléans had the idea to trigger a chain reaction allowing them to access deeper tumors.

First step, a liponanoparticle micellar structure, with peripheral lanthanides, comes flanking a photosensitizer, the hypericin, which allows vectorising this highly hydrophobic substance until it reaches the zone to be treated. Step 2, the whole area is irradiated by X-rays that initiate the chain reaction. Actually, lanthanides (ex: Gadolinium or Europium) present a long-known luminescence property: when submitted to X-rays, they reemit ultraviolet or visible light. Step 3, this secondary light source then irradiates the central hypericin which will produce reactive oxygen species, the toxic substances that will kill the surrounding tumor cells.
Practically, scientists used the METROLOGY and DISCO beamlines of SOLEIL in order to irradiate liponanoparticles and collect the associated luminescence spectra. They thus showed that the presence of lanthanides did indeed allow emitting a UV-visible radiation which matches the absorption spectrum of hypericin. They then characterized the light energy transfer between those two molecules. They later measured with mass spectrometry the increasing of production of reactive oxygen species, consequence of the light absorption of hypericin. Furthermore, the UV-luminescence properties of the micellar structure allowed the scientists to monitor them inside the cells, and even inside the nuclei.
This system benefits from being extremely versatile: it is indeed possible to enlarge this method to other photosensitizers, or other liponanoparticles already tailored for specific targets. When current photodynamic treatments amount to no more than superficial therapies, the use of the penetrating capacity of X-rays promises to bring new perspectives in the issue of treating deep tumors and also offers perspectives in magnetic resonance imaging.



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Our synchrotron radiation facility is a large-scale research infrastructure (LSRI), which, thanks to its multidisciplinary nature, can address many challenges facing our society, including health, biology, energy, pollution, food production, etc. By programming more than 4,000 research visits each year, SOLEIL is increasingly at the heart of international scientific cooperation, essential to the implementation of global solutions to the problems facing us today. With its 27 beamlines (soon increasing to 29) using different techniques and energy fields, SOLEIL is providing effective tools to meet current research needs and offers a unique platform for study.

As well as the examples presented in this issue of Rayon de SOLEIL, the involvement of our synchrotron in social issues is varied and transversal: all our beamlines are active on these issues, either by their in-house research, or from visiting users. Without being exhaustive, let us scan over some of the research at SOLEIL that covers social issues.

In 2015, with the organization of COP21 (2015 UN Climate Change Conference), France is a central player in the global coordination of measures to control the climate and the environment. SOLEIL has been contributing to this effort for several years. Examples include the study of proxy data, providing natural archives of former or current environmental changes. These climate indicators may

to be continued on page 18…

ROCK - SAMBA

ENERGY - A SOCIETY TURNING TO HYDROGEN

One of the great issues facing our society is to find alternatives to fossil fuels, the reserves of which are dwindling day by day. Clean energy production based on renewable resources is becoming more widespread but this is creating new challenges because of its intermittent nature and its distribution over the country. The use of hydrogen as a clean energy reserve is now being considered for many applications in everyday life, especially to power our cars or our homes. It can be produced from a natural energy source (wind, biomass, solar panels, etc.) but is unfortunately available today only in an intermittent and localized manner. We will be able to talk of the hydrogen age only when we are able to use it without geographical or supply restraints for the conversion of electrical energy into chemical energy and vice versa. We must have enough efficient ways to produce hydrogen cleanly for use in devices such as fuel cells, and the conversion of energy in these batteries must be sufficiently effective to compete with fossil fuels. To solve these two problems, the search is on for low-cost effective catalysts over the long term.

Hydrogen (H_2) of purity compatible with the fuel cell can be produced by converting ethanol from biomass in the presence of alumina-supported cobalt-based catalysts. In collaboration with the Institute of Chemistry of Araraquara (Brazil), researchers on the ROCK beamline undertook to follow on the scale of a few seconds, using time-resolved X-ray absorption measurements, the speciation of cobalt phases when the catalyst is working and losing efficiency. It was shown that the activity of such a catalyst vis-a-vis H_2 production was stable over a long period when metallic cobalt, active in the conversion of ethanol into H_2, coexisted on the alumina surface with a divalent species of cobalt, CoO, used for reoxidizing the coke formed on the catalyst surface. The proportion of the two species must be close to CoO/Co(0) = 1/3. This result was confirmed by studying the regeneration of the activity of the catalyst poisoned by coke formation. If pulses of oxygen are introduced in the medium, the production of H_2 picks up significantly after the coke has been re-oxidized to CO_2 and the CoO/Co(0) ratio is close to 1/3, despite the re-oxidation of the metallic cobalt, inherent with the introduction of oxygen.

In a fuel cell, hydrogen is oxidized to produce electricity directly. These hydrogen oxidation and oxygen reduction reactions are mediated through a proton permeable membrane and an electrical conductor; these reactions are not, therefore, explosive, but controlled. The price to pay is that among the catalysts required for these reactions, the most effective is platinum, which is both very expensive and rare. Fortunately, new low-cost catalysts are emerging. Among these, those based on non-noble metals such as iron, cobalt or molybdenum, or noble but more abundant such as gold, are beginning to compete with platinum on performance. In close collaboration with a research group of the Charles Gerhardt Institute, UMR 5253, CNRS, University of Montpellier, the SAMBA research group were able to clarify one of the most obscure and controversial issues in the study of iron based catalysts in the reduction of oxygen: determining the structure of the active site. Simulating the XANES spectra of Fe obtained on very effective catalysts but with low iron content, they found that the active site consisted of an iron atom linked to four nitrogen atoms, in a structure similar to porphyrin (close to that which coordinates to iron in our blood) and can be located at the edges of a graphene sheet.
This new revelation opens the way for a more rational approach to the study of these systems: one step closer to the hydrogen age.

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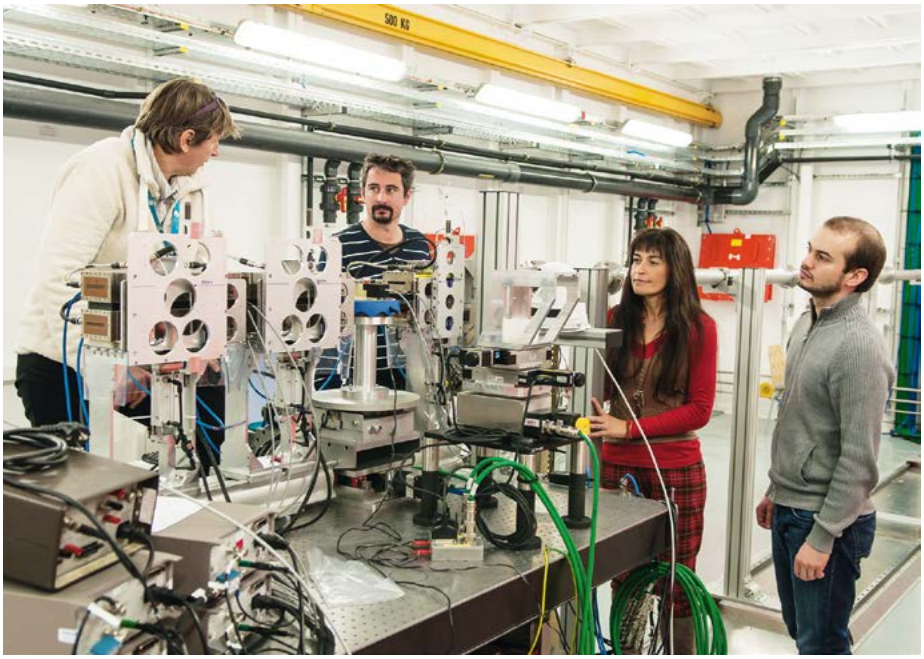

The beamline team working in the ROCK experimental hutch

MARS

Environment – Radionuclides and sea water

From left to right: Christophe Den Auwer, Mélody Maloubier and Maria Rosa Beccia (Nice Sophia Antipolis University) and Pier Lorenzo Solari (MARS beamline).

What happens to natural radionuclides or those resulting from nuclear activity in the environment, particularly in sea water? Take, for example, the Fukushima nuclear accident in 2011, with its nuclear reactor on the coast. Land contamination should also be considered because radionuclides can be transported via waterways to the sea, which appears as the ultimate receptacle. This question is even more crucial given that very few studies have been carried out on this subject.
Establishing a model for understanding how radionuclides are dispersed in seawater and evaluating their impact on man needs to take into account multiple parameters such as current fields, advection and diffusion, exchanges between water and suspended matters, wind and chemical speciation, i.e. the chemical form in which radionuclides exist in the environment. Speciation is often difficult to establish because radionuclide concentrations are extremely low (e.g. 10^{-17} M in the Mediterranean for 239,240-plutonium, thus well below ppb), but it is an essential factor if one wants to properly understand the dispersion of radionuclides after an accident. Moreover, the toxicity and bioavailability of those elements often depends on their speciation, hence this factor is important for its toxicological impact.
A research group from the Nice Chemistry Institute (Nice Sophia Antipolis University/ CNRS), with the CEA-DAM-DIF, have been trying to establish a link (in cooperation with the environment laboratory of the International Agency of Atomic Energy (IAEA), Monaco) between the speciation of actinide radionuclides, more specifically in sea water, and their assimilation by marine organisms, to better understand the biochemical transfer mechanisms involved.
Initially, the researchers studied the speciation of uranium (VI) and neptunium (V) in seawater. Uranium is a specific case because it occurs naturally in the earth's crust but can be locally concentrated by human activity (e.g. mining). Its natural concentration in seawater is extremely low (around 10^{-8}M in the Mediterranean). These are quantities below the detection threshold for many spectroscopic

... Continued from page 16

be in the form of shells and skeletons of marine organisms, biominerals studied by combined X-ray microscopy and spectroscopy on the LUCIA beamline, or by photoemission spectroscopy (XPS) on TEMPO. Fish otoliths are also sensitive witnesses to environmental variations, as shown by X-ray diffraction, absorption and fluorescence on the DIFFABS beamline.

In the context of energy transition, developing the energy of tomorrow is also important. The SAMBA and ROCK beamlines are particularly active and specialized in this field with their research on catalysis and batteries (see p.17). Furthermore, on CRISTAL, our researchers are studying the structure of abundant and low-emission materials (Cu_2ZnSnS_4) that can be used as absorbers in solar cells, with the aim of improving their energy conversion efficiency. The DESIRS beamline, for its part, has already welcomed several researchers whose combustion studies could help improve engine efficiency and thus reduce pollution.

Food production is also a recurrent research theme at SOLEIL, which has a particularly strong partnership with the National Institute for Agricultural Research (INRA), with three of its research engineers working full time on our premises. After a first edition in 2012, we are currently preparing a new book to celebrate 10 years of this fruitful collaboration, which will show all the richness and

techniques used to determine chemical speciation.
To work around this problem while remaining as representative as possible of the natural environment, the group studied natural seawater solutions doped with actinide at 5.10^{-5} M, a concentration above X-ray spectroscopy detection limits, but still lower than that of major ions in seawater.
EXAFS (Extended X-ray Absorption Fine Structure) measurements were made on MARS, the SOLEIL beamline dedicated to the study of radioactive samples. Coupled with time-resolved laser spectroscopy (TRLS), the EXAFS results showed that uranium was linked to three carbonate groups, with the $Ca_2UO_2(CO_3)_3$ complex found not to be bioavailable. By comparing the spectra obtained on MARS beamline with theoretical data from thermodynamic models, the researchers suggested that neptunium (V) was, meanwhile, present in two forms in seawater: NpO_2^+ and $NpO_2CO_3^-$.
These first results validate the interest and relevance of this approach, a compromise between the use of model systems and direct environmental measurements, often inaccessible to spectroscopy.

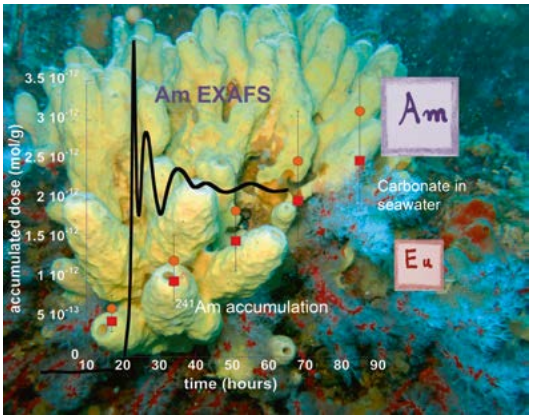

Figure 1: In the background of the photograph of *Aplysina cavernicola*, the accumulation curves of Am-241 over time (two specimens). In black, an example of an Am L_3-edge EXAFS spectrum.

The group then turned to the speciation of 241-americium, a heavy trivalent actinide, and its accumulation in a Mediterranean sponge, *Aplysina cavernicola*. Among living marine organisms, sponges are known for their ability to bind heavy metals, which makes them good sentinel biomonitors candidates.
The methodology used consisted in doping seawater with americium to 5.10^{-5} M and comparing with europium, an element in the lanthanide family, which has stable chemical properties close to those of americium.
The use of TRLS (mentioned above), attenuated total reflectance Fourier transform infrared spectroscopy (ATR-FTIR) (which allows the study of ion coordination methods) and finally scanning electron microscopy (giving morphological information about the complexes formed) complemented the EXAFS data for the seawater set-up, but also for the contaminated sponge *Aplysina cavernicola*.
It appeared that the marine sponge specimens tested accumulated 241-americium linearly over time (Figure 1). *A. cavernicola* thus fixes it under the chemical form it adopts in seawater. But what is that form? The combined results of the 4 techniques cited suggest the form $NaAm(CO_3)_2.nH_2O$ and the equivalent $NaEu(CO_3)_2.nH_2O$.
The next steps in this research will be to determine the biological and chemical transformations of these carbonate complexes after uptake by the marine organisms under consideration.

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diversity of the research. From yeast cell metabolism for applications in green chemistry, as revealed by infrared on SMIS, to the tomography of plants under drought conditions on the PSICHE beamline, via the secrets of gum arabic on SWING and DISCO, many and varied are the topics of interest in nutrition and biotechnology at SOLEIL.

SOLEIL is also deeply involved in solving biological and health problems, with two beamlines, PROXIMA 1 and PROXIMA 2, specialized in the crystallography of macromolecules (see p.20 article on dengue and legionella), as working out their 3D structure is often an essential step in the design of new drugs. Beside structural biology, SOLEIL is also involved in early diagnosis (e.g. of liver or kidney disease) and is focusing on disease development, with the aim of developing more suitable treatments (e.g. graft quality analysis before liver transplant - a protocol developed on SMIS, then exported directly to the hospital). The DISCO beamline is also a major contributor in these issues, in cell biology, for example, where individual cells can now be isolated and studied: the improved localization of glioblastoma tumor cells before radiation therapy, the study of antibiotic-resistant bacteria and the better targeting of antitumor treatment, etc. (see p.16, collaboration with the METROLOGY beamline). SOLEIL is also working with the pharmaceutical industry by hosting a structural biology research lab, built and

To be continued on page 20...

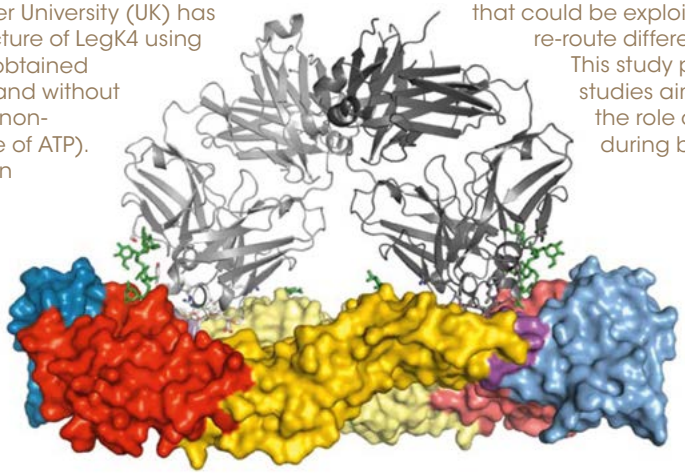
PROXIMA2

Legion fever and dengue: X rays against bacteria and virus

This year, beamline PROXIMA2 has contributed to major findings concerning two pathogens: the bacteria called Legionella pneumophila and virus DENV, respectively responsible for the Legion fever, an aggressive form of pneumonia, and the dengue virus, which can develop into a hemorrhagic, and therefore mortal, fever.

In the case of the study of Legionella, researchers combined biocristallography with the SAXS technique on beamline SWING. The study focuses on LegK4, one of the proteins used by the bacterium to hijack the cellular machinery of the host cell (i.e. an epithelial cell in the lung, or a macrophage) to reproduce rapidly within it. To do so the bacteria targets phosphorylation cascades which often act as switches to control cellular processes. The intervention of LegK4 consists in phosphorylating host cell proteins in the manner of parasites to impact their activity. A group of researchers from IBCP and CIRI in Lyon as well as Leicester University (UK) has solved the crystal structure of LegK4 using X-ray diffraction data obtained from the enzyme with and without substrate (AMP-PNP, a non-hydrolyzable analogue of ATP). The structure reveals an atypical eukaryotic-like kinase domain, which is responsible for phosphorylation, along with several unique features—nucleotide binding does not involve the canonical glycine-rich activation loop, but is instead mediated by unusual amino acids in nearby structural elements. Another remarkable specificity of LegK4 lies in its ability to self-assemble to generate a dimeric interface never observed up to that point in the protein kinase super-family, as confirmed by SAXS. Complementary enzymatic studies demonstrate that LegK4 is a constitutively active enzyme (even without being activated by phosporylation) and the structural data suggests that the dimer assembly stabilizes the active conformation in the absence of phosphorylation.

Sequence comparisons indicate that some of these elements may be found in other members of this protein family. This new structure also points toward specific mechanisms of kinase regulation that could be exploited by the bacteria to re-route different host pathways. This study paves the way for further studies aiming at understanding the role of eukaryotic-like kinases during bacterial infection.



3D structure of the antibody complexes for all four serotypes bound to the dengue virus envelope protein. ©Institut Pasteur.

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operated by an industrial partner, giving it easy access to synchrotron tools.

Finally, technological issues raised by data inundation, or Big Data, that will make profound changes in such areas as health, transport, energy, and electronic component miniaturization, are also the subject of SOLEIL experiments: the study and optimization of materials (graphene or organometallic compounds, for example) for use in spintronics or nanoelectronics on the DEIMOS, HERMES or CASSIOPEE beamlines and ferroelectric thin films on ANTARES are all cutting-edge topics

Another sizeable challenge to society is human evolution, discovering our history, understanding and preserving our heritage, to which some of our researchers devote their studies. Many in-house and visitor research experiments on «ancient materials» are conducted at SOLEIL. One example is the recent results obtained on ANTARES, showing the degradation of the gilded bronze on the «Gates of Paradise», a Ghiberti masterpiece in the Baptistery of Saint John in Florence, thanks to a high resolution photoemission study of artificially corroded gilded bronze replicas. Note that the PUMA beamline, optimized for the study of ancient materials, is under construction

Dengue is the most widespread viral disease in our planet's tropical regions. There are four strains of dengue virus. While a patient produces antibodies specific to one serotype during an initial infection, these do not confer effective protection against subsequent infection by the other serotypes. These specific antibodies may even constitute a risk factor for developing a dengue hemorrhagic fever in the case of a subsequent infection by any of the 3 other forms. This explains the need for a vaccine providing simultaneous and efficient protection against all four virus serotypes.

Although a team from Imperial College London had already identified and isolated antibodies that simultaneously neutralize all four virus serotypes in a cohort of infected patients, the mode of action of these antibodies remained unknown. Researchers from Institut Pasteur and CNRS then carried out a crystallographic analysis to study the antibodies in complex with protein E, which constitutes the virus envelope and on which antibodies are known to bind as part of the immune response. Through X-ray diffraction analyzes performed on beamline PROXIMA2 and at ESRF, the researchers were able to solve the structure of these complexes and to identify the binding site on protein E. The latter is similar for all four virus serotypes, and therefore gives it obvious potential as a vaccine target.

Based on this structure, the researchers also discovered why this antibody binding site is found in all serotypes despite the viral flow that it represents: although a mutation on this site would enable the virus to evade the immune system, it would however highly limit its diffusion, since a protein which is essential to viral replication also binds to this site. The researchers have thus highlighted a true double Achilles' heel for the virus. Introduced in a patient, antigens mimicking this site would potentially be able to trigger an immune response targeting all four dengue serotypes simultaneously, thus constituting a prime vaccine candidate against dengue.

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Discussions on the PROXIMA2 beamline.

and will open to users in 2017. SOLEIL also hosts the IPANEMA platform, a mixed CNRS and Ministry of Culture and Communications Unit, aimed at making it easier for the Ancient Materials community to have access to synchrotron techniques.

In addition to its research, SOLEIL is also introducing various measures, such as the Smart Building project, alongside the Chamber of Commerce and Industry (CCI) of Essonne and the Advancity Sustainable Cities Cluster, in which some of our energy data are recorded and analyzed by SMEs to suggest possible areas for improvement.

Finally, we are continuing our science awareness program for the general public, schools and universities, in order to build lasting relationships between science and society (see e.g. p.24 and back cover).

These are just a few examples of research at SOLEIL dealing with societal challenges. New scientific perspectives are opening up all the time, for example with the NANOSCOPIUM and ANATOMIX beamlines. You will find all this information and much more, on our website.

The professional integration of young graduates in industry :
a strategic challenge for SOLEIL

Beyond the (initial or research) training of young people working temporarily within its research groups, SOLEIL is keen to ensure their employability in three sectors: directly with SOLEIL, in public research institutions or in industry. The latter entry point was the subject of a Research-Industry Forum held on October 8th, 2015 at SOLEIL.

Signature of the "Scientific and industrial collaboration for research infrastructures agreement" between the PIGES association and the 3 institutes. From left to right: J-L. Lancelot, President of the PIGES association and Director of SIGMAPHI; Ch. Herbeaux, acting director of SOLEIL "Technical Services" division; J. Daillant, SOLEIL Director General; M.Faury, Deputy-director of the CEA Saclay, Matter Sciences Direction; A. Nadji, SOLEIL Director of the "Sources and Accelerators" division; J. Martino, IN2P3 Director, CNRS.

This Research-Industry Forum was established at the initiative of the Industrial Partners for Large Scientific Instruments Association (PIGES), grouping 11 French companies operating in the field of scientific and industrial instrumentation, including 2 large companies (Air Liquide and THALES) and 11 SMEs or SME groups, with the support of its three main technology partners in the research community, IRFU within CEA, IN2P3 of the CNRS and SOLEIL.

The strategic objective of this forum was to encourage exchanges between professionals and young people under training in research structures and who have aspirations to start their careers in industry. It was structured around four main aims:

Speech of Sébastien Bousson, engineer at the Nuclear Physics Institute (IN2P3/CNRS, Orsay, France), winner of the CNRS 2015 Crystal Medal.

1. Presentation of areas of activity and expertise of each member company of the PIGES Association, in order to introduce students, trainee engineers and PhD students to industrial activities that have openings for young graduates,

2. Presentation of the employment policy of the three research structures regarding their trainees, apprentices and PhD students,

3. Presentations by young people currently under training of a range of internship topics and theses within the three research structures, in order to enable industrialists of the PIGES Association to discover new talents that could facilitate the uptake of devices and innovative methods in their businesses,

4. Direct discussions between the directors and representatives of these companies and young people being trained in these three research structures.

In the morning, the forum brought together more than 60 participants and programmed about 20 five-minute presentations. Many contacts were also established between business representatives and future graduates. The subjects of internship or theses and CVs of young people who could not participate in the forum, (taking courses, away on projects, etc.) but interested in working in industry were handed in to the secretary of the PIGES association.

This forum is part of a comprehensive approach to encourage the mobility of staff between research organizations and industrial companies. The external mobility of its engineers, researchers and PhD students to industry is one of SOLEIL's three pillars in its research development activities, the other two being research partnerships and the transfer of knowledge (know-how, patents, software, etc.).

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IN BRIEF

↘ DICHRO50 AND SATT

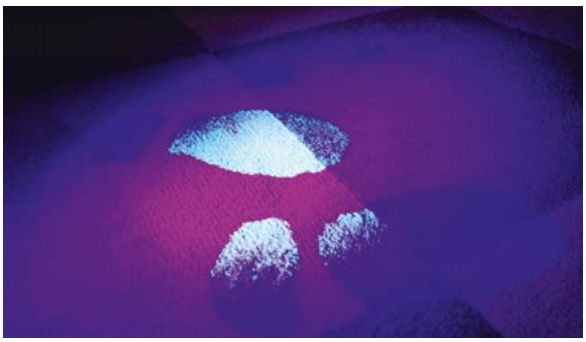
The Dichro50 project of SOLEIL is one of the ten projects selected by Paris-Saclay's Technological Transfer Acceleration Society (TTAS) during its first call for projects, Maturation 2014, which received 33 projects from 14 structures of the Université Paris-Saclay. Dichro50, which propose the valorization of a specimen-holder cryogenic insert, is driven by the DEIMOS beamline of SOLEIL, in partnership with two laboratories from the University of Strasbourg and the Pierre and Marie Curie University and with Cryoconcept, a company based in Essonne.

↘ ONE FOR SIX, AND SIX FOR ONE

The LUCRECE project gathered around SOLEIL two local laboratories – the Laboratory of the Linear Accelerator (LAL, Orsay) and the Institute of Research into the Fundamental Laws of the Universe (IRFU, Saclay) – and three companies, member of the PIGES association (gathering the French industrial partners of the large scientific facilities) – THALES Electron Devices, ALSYOM and SIGMAPHI Electronics.
It aims to develop an elementary radio-frequency kit in continuously run to equip Energy Recovery Linac (ERL) or femtoseconds free electron laser sources.

Another year of **scientific events at SOLEIL**

On the occasion of the International Year of Light, a new science awareness workshop was created at SOLEIL. Based on the 'Escape room' principle, it asks budding investigators to use a light (laser, UV, visible) kit and help professor Lampion find a lost object. Launched in May 2015 at the Paris Culture and Mathematical Games Fair, it then proved very successful during the Science Festival at the Moulon gymnasium in Gif-sur-Yvette. The 2015 edition, organized by the 'Ile de Science' Association on 9th to 11th October, attracted nearly 3,000 people, including 1,000 schoolchildren.



Fluorescent clues in the «Professor Lampion's office".

Like every year, the month of September has been full of exchanges with the general public. As part of European Heritage Days (EHDs), on the 19th and 20th September, SOLEIL combined forces with the ancient materials research platform, IPANEMA, the synchrotron's neighbor and partner, and organized an open weekend for the public at the initiative of the Essonne Departmental Council. Nearly 150 people discovered IPANEMA and the synchrotron, and followed the educational workshop «see the invisible», designed by the ArkéoMédia association, specialized in archeology public awareness.

SOLEIL de Minuit was held, for the 4th consecutive year, as part of the Researchers' Night on 25th September. After being guided through the synchrotron, 450 visitors were able to participate in the «Invisible Light» workshop, a series of scientific and recreational activities offered by the «Atomes Crochus» Association. Pursuing the «Light» theme, an introduction to the laser harp was also offered to everyone, before the highlight of the evening: the concert by artist Sylvain Bezia on this instrument made famous by Jean-Michel Jarre.

SOLEIL in **Japon**

SOLEIL was invited by the EU Delegation to Japan to participate in the 10th edition of «Science Agora», the Science Festival being held in Tokyo from 13 - 15 November and hosting more than 8,000 participants. Ryutaro Nagaoka, Head of the «Accelerator Physics» group at SOLEIL, was able to describe to the public of all ages how a synchrotron works and the research conducted on the beamlines.

Ryutaro Nagaoka in front of the SOLEIL poster.

KEY FIGURE

25

At the end of September, the CuriositAS festival exhibited 25 works in a collaboration between artists and scientists. SOLEIL awarded a prize to the work «$C_{20}H_{10}Na_2O_5$ Effect», voted by the public in the «Light» category.

www.ladiagonale-paris-saclay.fr/curiositas/

Jean Daillant, surrounded by the two winners Fulneau Barbara and Carolyn Mortier, holding the «ballot box» containing the colorful public votes.

“My mission is to ensure that SOLEIL users can operate the system with high-level applications to control their equipment and data acquisition.”

Katy Saintin, Java HMI (Human Machine Interface) engineer, in the «Data Acquisition and Control» group.

CORPES

The international conference CORPES (strong correlation and angle resolved spectroscopy) took place from the 5th to the 10th of July 2015 at the Couvent des Cordeliers (Université Pierre et Marie Curie) in Paris, France. The event, organized by the synchrotron facility SOLEIL and led by Véronique Brouet from the Laboratoire de Physique des Solides (Orsay), gathered more than 150 attendees from all over the world. Around 50 international scientists gave talks about their work in the field of photoemission in condensed matter on correlated systems (superconductors such as cuprates, iron pnictide, Mott insulators, semiconductors, heavy fermions, etc.) or on typological systems (topologic insulator, graphene and 2D materials, Weyl semimetal), with a specific interest on underdeveloped techniques (ultra-speed phenomenon, RIXS, etc.). Oral presentations have then been completed by two poster sessions.

Following the spirit of CORPES, the scientific program was a mix between speeches on both theoretical and experimental researches. A large part was also dedicated to new instrumental developments and discussion between attendees.

A visit of SOLEIL has been organized on the third day. It allowed several groups of speakers to discover the beamlines using photoemission: ANTARES, CASSIOPEE, GALAXIES and TEMPO.

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Synchrotron Radiation Instrumentation (SRI) 2015

The twelfth International Synchrotron Radiation Instrumentation Conference (SRI 2015), organized by the Brookhaven National Laboratory (BNL), was held in New York from 6th -10th July 2015. This triennial event gathered researchers and engineers worldwide from synchrotron radiation and free electron laser light sources.

For all contributors, this conference was a unique opportunity to present the latest instrumental and methodological developments and research associated with these developments, and initiate collaborations and exchanges with their peers, but also to meet a very wide range of instrument suppliers in order to discover the latest devices available on the market.

Prior to the conference, a visit was organized round the new National Synchrotron Light Source II (NSLS II), one of the latest synchrotron radiation facilities located at the Brookhaven National Laboratory in Upton (Long Island). Visitors were able to discover the first seven operational beamlines and new facilities being set up or under development.
The conference attracted nearly 800 participants. During the various plenary and parallel sessions, 189 speakers presented many results and prospects in a variety of fields, such as optical metrology, beam diagnostics, future upgrade plans for storage rings, the acquisition and processing of large volumes of data, microscopy and nanoscopy, as well as biomedical applications. 438 posters were also presented, providing opportunities for rich

ICON² – 2015

The first edition of the international conference on "Novel nanomaterial: engineering and properties" (ICON2) has been organized in SOLEIL last September. The organizing committee was coordinated by Mathieu Silly (SOLEIL), Stéphane Campidelli and Fabien Silly (CEA Saclay). Emblematic researchers have joined the conference to give exciting plenary lectures and invited talks. The event gathered 60 participants from around the world, including Japan, Singapore, United-Kingdom, Saudi Arabia, Germany, Italy and Belgium.

The conference was divided into three sessions. The first session was dedicated to synchrotron time resolved experiments, whereas the second and third sessions focused on the engineering and the characterization of nanomaterials and nanomaterial applications in energy conversion and storage. ICON2 2015 event was a great opportunity to facilitate discussions and scientific interactions on issues related to nanomaterial engineering and characterization as well as their potential applications. It provided a platform for people working in this field to share their respective knowledge and experiences and to develop new ideas to improve nanomaterial technology.

The aim of ICON² was also to promote the exceptional work of promising young scientists. The best PhD oral presentation has been awarded to David Peyrot (CEA) and Géraud Delport (ENS Cachan) for their respective presentations on hybrid nanoarchitectures on metal surface and on supramolecular organization of porphyrin molecules. The best poster prize was awarded to Heejae Lee (Ecole Polytechnique) who presented his work on perovskite solar cells.

ICON² 2015 was organized thanks to the financial support of SOLEIL, CEA-IRAMIS, Campus Paris-Saclay, C'Nano IdF, Dim Nano-K, Labex NanoSaclay, and Scienta-Omicron.

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exchanges between colleagues from around the world.

Besides its participation in the International and Scientific Committees of SRI, SOLEIL was represented by 12 scientists, not only from the beamlines, but also representatives from the Magnetism and Insertion, Instrumentation, Optics and Detectors groups and the Surfaces Laboratory. Many of our most recent developments were exhibited.These included the in-vacuum wiggler on the PSICHE beamline, pixel detectors dedicated to high X-ray energies, multilayer grating monochromators, optical developments for infra-red beamlines and the use of coherent THz radiation on AILES. We also showed the possibilities offered by the SEXTANTS, SIRIUS and LUCIA beamlines, as well as the construction of the ANATOMIX and nano-tomography instruments. Finally, the first results on the detection of laser-electron interactions using the FemtoSlicing technique to generate X-ray pulses of one hundred femtoseconds on the CRISTAL beamline were also presented.

The conference closed with the announcement that the next SRI conference will be organized by the Taiwan Photon Source in May 2018 in Taipei.

EDUCATION

Primary lights

Scientific awareness is one of SOLEIL's missions and for over 10 years it has attempted to share scientific and technical knowledge with the general public. As 2015 was the Year of Light, this was a perfect excuse to develop a new project for 8 to 11-year-old pupils and their teachers.

From 2002, even before its facilities were built, SOLEIL was already going out to meet its young public: educational workshops were being run for secondary school classes in the Ile de France Region. This approach, based on education/research, has continued to grow and, since 2004, more than 3,000 pupils and students (out of the approximately 5,000 annual visitors) have come to the synchrotron to follow interactive presentations aimed at every age and level, to interact with SOLEIL staff and visit the science facilities. This is great opportunity to make science more meaningful for all these youngsters.

Until now the audience for these presentations has been at least 12 years old. The "Primary Lights" project is intended to broaden this approach by specifically addressing 8-11 year-old pupils.

The initial contact takes place through teachers, who are offered training and science awareness exercises. In turn, they can then introduce pupils to several approaches to the investigative process: starting with what children know (or think they know) on the themes of «light, shadow and color» and then encouraging them to start asking questions, with the experimental process itself providing the answers. In other words, getting them to take a scientific approach!

To help teachers, an educational kit is available, containing the equipment needed to design and carry out these experiments with small groups.

And the icing on the cake: at the end of these workshops the children prepare a show in a shadow theater designed specifically for the project, where art meets science.

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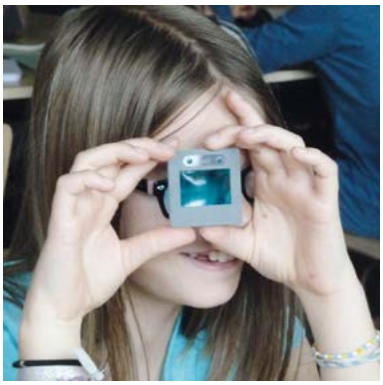

The project in **3 points**

1. Primary Lights was developed through a partnership between the SOLEIL synchrotron and Management of the National Education Services of Yvelines, in collaboration with three Yvelines school teachers and an educational consultant

2. Primary school pupils of the three teachers involved in the project were the first to try out the workshops: the «Shadow» set-up with Poirier-Saint-Martin School (Montigny-le-Bretonneux), «Light» with the Francis Poulenc School (Guyancourt) and «Color» with the Bois de la Garenne School (Voisins-le-Bretonneux).

3. In 2015-2016 the project will be used in 10 classes in Yvelines, before being extanded to other Departments, including Essonne, in the years to come.

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