N°26

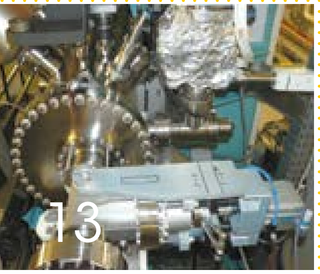
LE RAYON DE SOLEIL

THE SYNCHROTRON MAGAZINE

2- and 3-dimensional imaging

SOLEIL SYNCHROTRON

CONTENTS



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EDITORIAL

Jean Daillant
Director General

2016 was a year of anniversaries. SOLEIL celebrated 10 years of its first beams: to begin with, electron beams, since the first electrons turned in the storage ring in May 2006. Then the DIFFABS beamline was the first to «see the light» on September 13, 2006, soon followed by TEMPO, ODE, SAMBA and DESIRS that same year.
In ten years, so many achievements! On September 26, 2016, X beam reached the first experimental hutch of the ANATOMIX beamline. When it is the turn of PUMA, in early 2017, the 29 SOLEIL beamlines will have received photons. In addition, the first ultra-short X pulses were produced by slicing on TEMPO on December 6, 2016, almost 10 years to the day after the SOLEIL inauguration.

We chose to place the imaging techniques at the heart of this "Rayon de SOLEIL" issue. Since 2016, a second microscope is available to users on the HERMES beamline: after the XPEEM, a STXM station can now benefit from the high coherence of the synchrotron beam for imaging samples in various environments, up to a 20 nm resolution. Each SOLEIL beamline having its specificities, the «range of experimental possibilities» is very broad: imaging in 2D or in volume; from infrared to hard X-rays; spatial resolution from the micrometer to the tens of nanometers, and a temporal resolution lower than the picosecond; Techniques of absorption, fluorescence, photoemission, diffraction, phase contrast which, moreover, can be coupled...
The increase in the number of beamlines and techniques available goes hand in hand with an increase in the volumes of data to be analyzed. SOLEIL adapts, with several projects allowing data treatment in real time.

This year, 2017, will be, a year of reflection around an upgrade of SOLEIL. This iterative process between the beamlines and the accelerators teams will take into account the specificities and advantages of our synchrotron. This upgrade is part of our approach to meeting the needs and expectations of our scientific communities, in terms of the characteristics and properties of the synchrotron beam, while preserving SOLEIL's wide range of wavelengths and experimental techniques.
We will give you more details in the next edition of the Rayon de SOLEIL.
Until then, I wish you an excellent year 2017.

KEY FACTS ABOUT SOLEIL

MEDICINE

Easier biopsy analyses, thanks to "Diagotron"

Several SOLEIL beamlines are already strongly involved in research in medical diagnosis (graft quality control, identification of renal pathologies, cancer prognostic) but the Diagotron project aims to go further. This is, in order to combine speed and regularity of access, to allow a weekly beamtime slot for the medical samples, and to complete the existing SOLEIL infrastructures to optimize their processing: safety, preservation, preparation and anonymization.
Furthermore, specific protocols and analysis equipments developed at SOLEIL in this context can be exported to medical facilities; in 2013, the "centre hépatobiliaire" (Hepatobiliary Center, CHB) of Villejuif had already benefited from such a technology transfer (IR microscope for liver graft analysis).
The project, approved by the SOLEIL Board, is already supported by more than a dozen hospitals in Ile de France region and province. Diagotron would initially be a virtual institute using the SOLEIL resources, and could ultimately «materialize» in dedicated premises.

PARTNERSHIP

MAX IV

The last steering meeting between SOLEIL and MAX IV, the future Swedish synchrotron, took place at SOLEIL on 24 and 25 October 2016. The results of this collaboration over the past 4 years have strengthened the partnership between the two synchrotrons through 6 projects including know-how transfer and instrumental development. MAX IV and SOLEIL are planning to continue their collaboration for years to come.

IN BRIEF

LES ATELIERS SCIENTIFIQUES

SCIENTIFIC WORKSHOP "SKIN-PRODUCT INTERACTIONS"

SOLEIL was a partner of the first edition of the Cosmetic Valley's scientific workshops, which took place on September 21, 2016 at Cergy-Pontoise University, in front of more than a hundred players of the cosmetics industry. SOLEIL intervened at every stage of that day: scientific conference, speech for the inauguration of the Shared Innovation Platform (PFMI) Cosmetomics in the premises of the University and presentation of the SOLEIL equipment and skills in the technical workshop.

INRA-SOLEIL: ALREADY 10 YEARS!

The strong partnership between INRA and SOLEIL initiated in 2006 is still fruitful. In January 2017 a new document, following an earlier edition published in 2012, presents a selection of scientific results obtained at SOLEIL by several INRA teams.

CASSIOPEE

Spintronics harnesses
the exotic electrons of topological insulators

This study led jointly by researchers of the unité mixte de physique CNRS – Thales and CEA INAC in collaboration with the team of the CASSIOPEE beamline led to the observation of a high level of spin – charge conversion at ambient temperatures achieved because of the particular electronic structure of the topological insulator α-Sn. Angle-resolved photoemission (ARPES) and spin pumping by ferromagnetic resonance measurements have provided evidence of this phenomenon promising for spintronics applications.

The functioning of the majority of existing spintronic devices is based on the manipulation of spin currents that do not carry electrical charges. These currents can be described as equal fluxes of electrons of opposite spin moving in opposite directions.

The essential processes used in spintronics are the creation of such spin currents from charge currents or their detection by transforming them into charge currents. Both cases involve conversion phenomena between charge currents and spin currents. Normally these conversions are made using magnetic materials but now it appears that the spin-orbit interaction phenomenon can likewise be used. Typical examples of spin-orbit coupling effect are the spin Hall effect in heavy metals through which a charge current can be converted into a transverse spin current and the inverse spin Hall effect which enables the inverse conversion. This spin current generation effect based on the spin-orbit interaction can also be exploited for the switching of the magnetisation in magnetic memories. One of the advantages, compared to conventional tunnel junctions, is that the spin current is orthogonal to the charge current, which consequently need not cross the tunnel junction at the risk of its degradation.

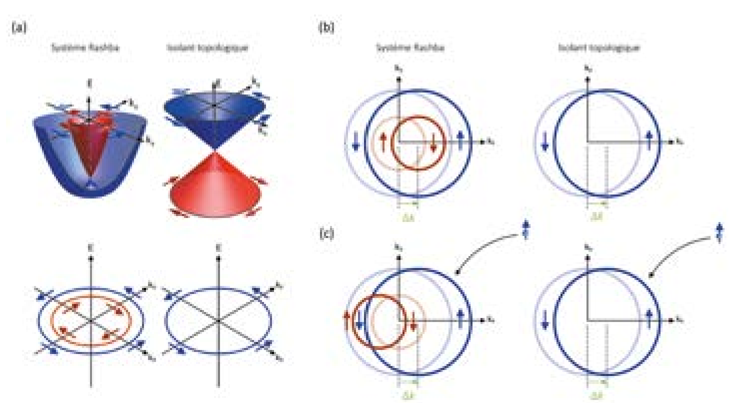

Fig. 1 (a) Distributions *E(k)* of the two-dimensional states of the surface or interface in a Rashba system and in a topological insulator. Rashba systems exhibit circular Fermi contours (set of values of k_x and k_y corresponding to the Fermi energy, i.e. the level of filling of the conduction band in the present case) with tangential spin polarisations in opposite directions for each of the contours (red and blue in the figure). Topological insulators have a single Fermi contour with a tangential spin polarisation. (b) Edelstein effect in a Rashba system and in a topological insulator. An electrical current along k_x corresponds to a surplus in the wavevector Δk for the Fermi level electronic states, that is a shift Δ*k* of the Fermi contours. This shift leads to a increase in spin up along k_y (partially compensated in the case of the Rashba system) and hence in the appearance of a net spin polarisation along y. (c) Inverse Edelstein effect in a Rashba system and in a topological insulator. An spin up polarised current, for example along y, is injected into spin up states of the two-dimensional electron gas, that is in the k_x positive direction. The accumulation of spin up electrons therefore leads to a shift Δ*k* of the Fermi contours which corresponds to an electrical current along k_x.

It appears now that a more efficient conversion could be obtained by exploiting the spin polarisation properties of the two-dimensional electron gas which exists at the surface of certain materials. This spin polarisation may result from the spin-orbit interaction generated by the high potential gradient due to the symmetry breaking caused by the surface (Rashba effect) or from the particular electronic structure existing in a class of materials referred to as topological insulators. A spin texture exists in these two material categories that results from the relationship existing between the direction of the spins and the wavevector *k* of the electronic states which are perpendicular. Thus the contours of constant energy are circular and the spin polarisation is tangential to these circles (Fig. 1a).

The particular geometry of these spin textures implies that an electrical current in this type of two-dimensional electron gas is automatically accompanied by the appearance of a spin polarisation, that is of an accumulation of spin in the direction perpendicular to the current. This is the Edelstein effect (Fig. 1b) which can be understood as a charge – spin conversion phenomenon.

The inverse Edelstein effect also exists and corresponds to the inverse spin – charge conversion (Fig. 1c). In this case, the injection of a current having a vertical spin polarisation leads to the appearance of an electric current in the two-dimensional electron gas.

The aim of this work [1] was to study the existence of an inverse Edelstein effect in α-Sn(001) whose topological insulator properties have recently been highlighted [2] and for which a spin – charge conversion efficiency higher than any other attained thus far has been observed. To be able to observe this effect, it is necessary to inject spin polarised electrons into the topological insulator. At a practical level this requires the growth of a thin ferromagnetic film on the topological insulator. To integrate these surfaces states in spintronics devices, it is therefore interesting to observe the change in these states when they are covered by a material. We therefore prepared thin films of 30 atomic layers of α-Sn(001) deposited on InSb(001) which represented the start topological insulator. These thin films were then characterised by angle-resolved photoemission (ARPES) and they were further covered by different thickness films of Fe and Ag. The results obtained are shown in Figure 2. The Dirac cones observed on the bare surfaces of α-Sn(001) are characteristic of a topological surface state. The Dirac point (which corresponds to the intersecting vertexes of the lower and upper cones) is located at approximately 30 meV below the Fermi level. It is noted that this topological state disappears as soon as the α-Sn(001) surface is covered by a fraction of Fe atomic layer, while it remains when the surface is covered by a film of silver, even for a thickness up to 12 Å. Therefore the Ag film does not destroy the topological state that exists at the interface but rather shifts the Dirac point towards a higher binding energy (about 75 meV below the Fermi level).

Measurements of spin pumping by ferromagnetic resonance intended to measure a possible spin – charge conversion were then performed on the different stacks: InSb(001)/Fe/Au (for reference measurements on a film of Fe), InSb(001)/α-Sn(001)/Fe/Au and InSb(001)/α-Sn(001)/Ag/Fe/Au. The principle of these measurements is to apply a static magnetic field in the plane of the thin films so that macroscopic magnetisation is created in the Fe layer, then to apply, in the perpendicular direction, but still in the plane of the films, a radio frequency field of varying frequency which causes the magnetisation to precess. At the frequency of resonance, a spin current is injected into the non-magnetic layers and a possible charge current can be detected by the appearance of a voltage between the ends of the sample (Fig. 3a). Figure 3b shows the results of the ferromagnetic resonance (top) and the charge current signal

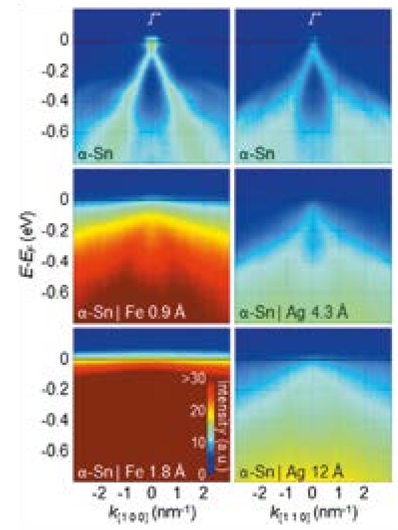

Fig. 2 Surface state of α-Sn measured by ARPES for bare surfaces (top) then covered by Fe (left) and Ag (right) films of different thicknesses.

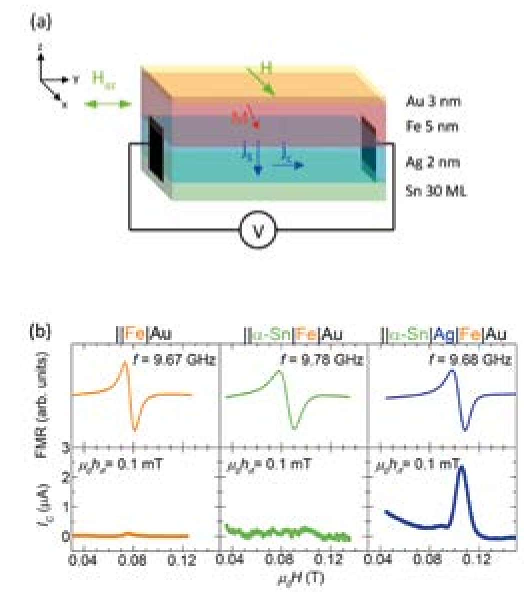

Fig. 3 (a) Schematic diagram of the experimental set-up enabling spin pumping experiments. The magnetic field H applied along the x direction aligns the macroscopic magnetisation *M* of the Fe which precesses under the effect of the radio frequency field H_{RF} applied along the y direction. This precession causes the injection into the non-magnetic layers along the z direction of a spin current j_s which is ultimately converted into a charge current j_c along the y direction and which is detected here by the potential difference present between the ends of the sample. (b) Results of the ferromagnetic resonance (top) and charge current measurements for the 3 investigated stacks (bottom).

for the 3 stacks (bottom). It is noted that only the sample where an Ag film is inserted between the Fe ferromagnetic layer and the topological insulator α-Sn(001) (that is when the Dirac cone is observed by ARPES) presents a clear charge current signal resulting from a spin – charge conversion phenomenon. The efficiency of this conversion can be quantified by the coefficient λ_{IEE} which is the ratio of the injected spin current to the charge current generated. A value of λ_{IEE} = 2.1 nm is found for this system which is much greater than the values obtained up until now, for example at the interface Bi/Ag or with other Rashba systems.

These results draws a promising avenue for room temperature spintronic devices even though the theoretical picture of α-Sn properties is not completely clear yet, opening the road to further experiments and better understanding of this new topological insulator.

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Spintronics

Spintronics, or spin electronics, is a new electronics, which in addition to the electron's charge, makes use of its spin. The basic idea is to integrate ferromagnetic materials into devices and then to exploit the influence of the spin of the electrons on their mobility. For example, it is possible to design non-volatile magnetic random access memory (MRAM) the basic building blocks of which are magnetic tunnel junctions in which the bit of information 0 or 1 corresponds to the parallel or anti-parallel orientation of the magnetisations of two thin ferromagnetic layers separated by an insulating barrier. Reading of information is by means of the tunnel magnetoresistance effect (the electrical resistance depends on the relative orientation of the two magnetisations) while writing of information takes place by injecting spin currents capable of switching a magnetisation given a sufficiently high current density.

Topological insulators

Amongst its many other properties, a material can be either a conductor or an insulator. The fundamental difference at the origin of one or other of these states is the band structure, that is the way in which the electron binding energies are distributed. In a conductor there are both occupied and unoccupied states at the Fermi level and the electrons can acquire a small amount of surplus energy to be set in motion to create an electrical current. In an insulator there is a forbidden band of energy (the energy gap) between the occupied and unoccupied states and the electrons cannot easily be promoted into unoccupied states because the energy difference is too great. Therefore an electric current cannot be established.
In 2005 and 2007, a new type of insulator was theoretically predicted before being observed experimentally for the first time in 2007. In these materials, a property of the band structure (its topology) combined with the spin-orbit interaction causes the existence of electronic states in the gap, but solely at the surface of a 3D material (or at the edges of a 2D material). These surface states exist in the form of Dirac cones and simultaneously possess occupied and unoccupied states at the Fermi level, the condition for being a conductor. Therefore a topological insulator is a material that behaves as an insulator within its volume but as a conductor at its surface.
Moreover the particular topology of the electronic states of these materials ensures that the conducting surface states cannot be destroyed by faults or non magnetic impurities, in contrast to conventional surface states.

SWING

Insight into membrane proteins' structure

A hybrid modeling based on SAXS data

Membrane proteins play crucial roles in transport and signaling, and are often key targets for efficient drugs. Their specific localization and their amphiphilic properties are an obstacle to structural studies. On SWING beamline, a strategy has been developed to tackle with those refractory proteins.

Membrane proteins are proteins which are functional within the lipidic membranes surrounding biological cells or cellular compartments. Being simultaneously in contact with both the interior and the exterior of the cell compartment, they play crucial roles in transport and signaling, and are often key targets for efficient drugs. All membrane proteins specifically share a structural intermediate domain whose surface is hydrophobic, allowing their insertion into the membrane interior, itself constituted by hydrophobic lipidic tails. For this reason mainly, they are notoriously difficult to tackle. Despite a continuous increase, the number of known structures of membrane proteins (monitored at http://blanco.biomol.uci.edu/Membrane_Proteins_xtal.html) remains less than 2% of the total number of known protein structures, while their occurrence in the genome is about 30%.

Small Angle X-Ray Scattering (SAXS) is a mature and powerful technique able to precisely distinguish different protein structural models in solution, and therefore is a strong complementary support to all structural studies, in particular those from protein crystallography. However, studying membrane proteins with SAXS is not either a simple task, as for other techniques. Not only are these proteins difficult to overexpress, extract and purify, but because they must be maintained in an amphiphilic environment, they can never be studied in isolation. To be maintained folded in solution, membrane proteins have to be associated with amphiphilic molecules (most often detergents, but more recently lipidic surroundings are increasingly used), whose hydrophobic tails cover the hydrophobic transmembrane surface of the protein, thus hiding it from the (aqueous) solvent. However, when their concentration is raised to values needed to dissolve membrane proteins (i.e. higher than their critical micellar concentration, cmc), detergent molecules themselves spontaneously associate into micelles, with X-ray scattering power comparable to those of the proteins. The resulting coexistence of different particles in the sample then requires a specific strategy to analyze the protein structure, as the one designed on the SWING beamline [1].

Online Size exclusion chromatography

Size exclusion chromatography (SEC)-SAXS must be used as the basis of this strategy. The membrane protein solution (concentrated using a protocol that most of the time also concentrates the detergent micelles), is eluted through a column pre-equilibrated with a buffer containing the detergent. The SEC process then ensures both that the level of free micelles around the protein is the same as in the buffer, and that the surplus of free micelles elutes with a different retention volume, usually higher, than the protein-detergent complex. The SAXS data collected under the protein peak can then be reduced afterwards in the same way as for a soluble protein, i.e. by experimental subtraction of the detergent buffer data collected before the column void volume.

Producing a detergent/protein hybrid model with Memprot

The first step in the strategy requires modeling the detergent moiety around a known construct of the protein, e.g. using the program Memprot developed on SWING that models a detergent corona shaped as an elliptical torus using a coarsed grain approach [Fig.1 up]. The program was built on experimental data collected on the SWING beamline from Aquaporin-0 solubilized in DoDecylMaltoside (DDM), a transmembrane protein of known crystal-

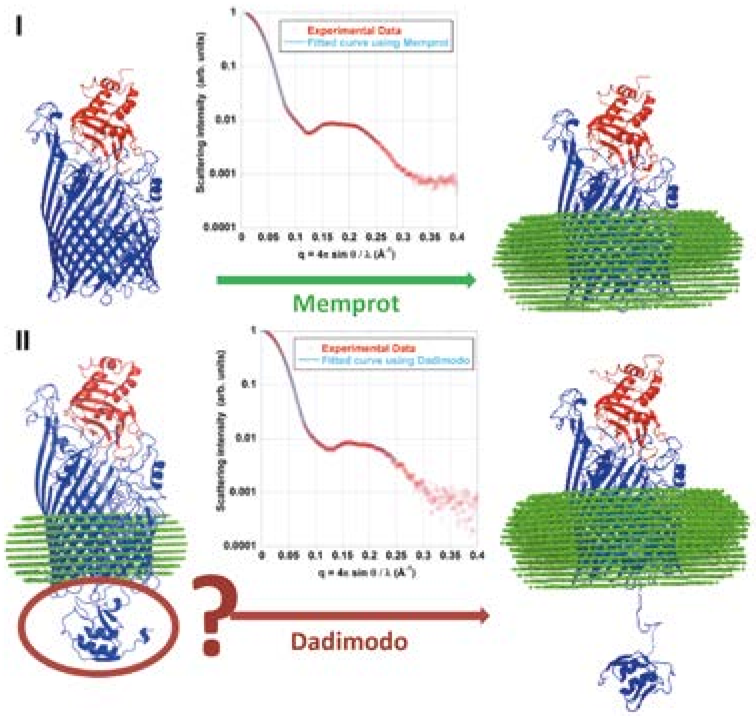

Figure 1. Two-steps strategy to model the conformation of a transmembrane protein based on partial high-resolution structural information and SEC-SAXS data.

lographic structure. It was shown that there is an optimal set of the parameters for which the experimental curve was perfectly fitted, suggesting that the hybrid structure (coarse grain / atomic structure) can be considered as a reliable modeling basis [2].

Interactions study, with Dadimodo

The second step consists in putting to good use the known hybrid structure to analyze its (unknown) interactions with soluble protein partners, whether these are additional domains within the same chain than the known construct or separate chains that make a complex with the membrane protein (Fig. 1 down). An example of such a study was recently published by Wojtowicz *et al* (3). In this study, the interactions between the periplasmic signaling domain of the transmembrane heme transporter HasR and its transmembrane domain could be directly investigated in the presence or not of the outer hemophore HasA. Given that HasR has no symmetry, the design of the detergent corona was improved to mimic the shape of the protein in the transmembrane plane, without increasing the number of parameters. The optimization of the signaling domain position was performed using a specifically modified version of the docking program Dadimodo, also developed at SOLEIL, which should be shortly open to users via a web access. The output of the study points to a position of the signaling domain closer to the main body when the latter is associated to HasA.

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2- J. Pérez & A. Koutsioubas, Acta Cryst. (2015), D71, 86.
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On SOLEIL beamlines and support laboratories, equipment keeps on evoluting, according to the needs and expectations of the scientists. This new section aims at briefly introducing the latest setups, with a particular focus on two of them. For this first edition we look to DEIMOS and HERMES.

A new X-ray microscope at SOLEIL

Exploring the matter at a nanoscale

HERMES is a beamline dedicated to soft X-ray microscopy. The originality of HERMES is to combine two different approaches (STXM & XPEEM) on the same beamline with the goal to reach spatial resolution bellow 20nm.

While the XPEEM is already operational and open to the users since several years, the STXM microscope is a newly developed setup that has been recently delivered and installed at HERMES beamline.

The STXM microscope (Scanning Transmission X-ray Microscopy) takes advantage of the high coherence of the synchrotron beam to extremely focus the photon beam down to few tenths of nanometers using a dedicated diffractive optics. The beam is scanned across the sample and the transmitted photons are collected to form a magnified image of the scanned area.

STXM is probably among the most suitable methods to respond to the growing demand to explore heterogeneous matter. Besides taking advantage of the unique properties of synchrotron X-ray, it allows to suitably combine spectroscopic and microscopic methods. Finally, the STXM allows to operate with a versatile sample environment: liquid samples, high magnetic and electrical field, cryo... which allow in turn to cover a very broad field of applications: Magnetism, soft matter, environmental & biological science... The STXM microscope has been fully commissioned and all the targeted specifications have been demonstrated in terms of spatial and energy resolution, flux, stability...

The microscope is now fully operational and open to the users.

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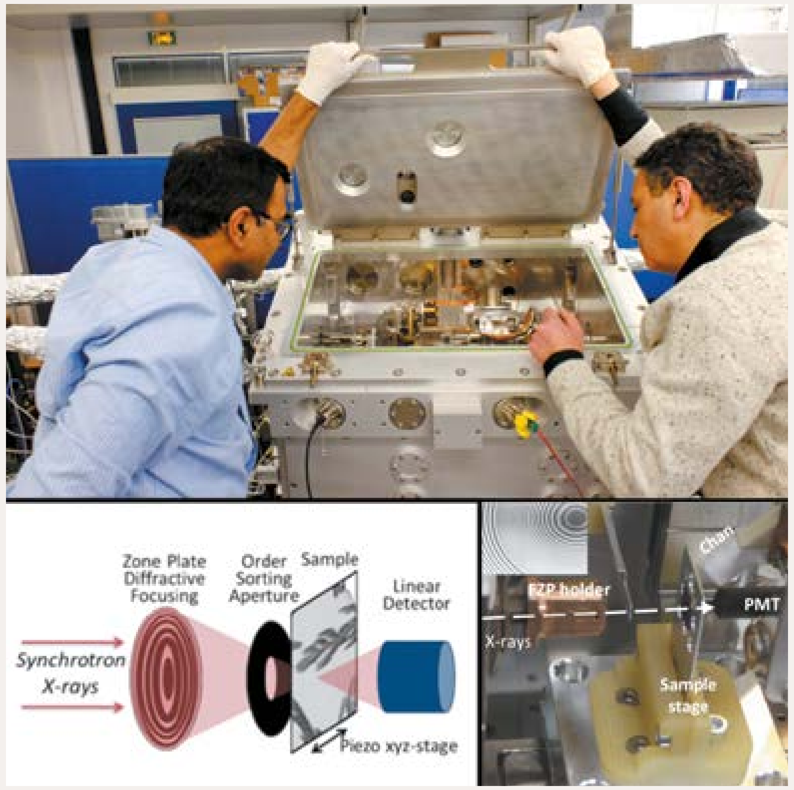

Figure 1. Up: The STXM microscope installed at the HERMES beamline. Down, left: Schematic scanning transmission X-ray microscope (STXM) A Fresnel Zone Plate (FZP) is used to focus the x-rays in the sample plane. To generate an image, the sample is raster-scanned under interferometer and computer control. The transmitted X-rays are collected using a PMT placed behind the sample plane. Down, right: View of the internal scanning stages of the STXM microscope.

A new
Ultra Low Temperature device on DEIMOS

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**IMPMC : Institut de Minéralogie, de Physique des Matériaux et de Cosmologie (Paris).

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The magnetic properties of matter depend essentially on two parameters, namely the temperature (T) and the magnetic field (H). The higher the H/T ratio, the more the ground state system will be accessible. From an experimental point of view, increase of this ratio by increasing H is quickly bounded within the limits of static fields (around 15 teslas), on the contrary decrease T by a factor of 20 is technically feasible. Industrial companies propose cryostats with few dozen of mK for set-up but without of course the constrains of Synchrotron Radiation (SR) environments. In the SR centers, on an X ray magnetic circular dichroism (XMCD) beamline, one can generally get a H/T ratio of about 1. The current DEIMOS CroMag is characterized by a ratio of 5 and the Dichro50 project aims a target ratio of about 100, by developing a cryogenic insert able to perform magnetic dichroic measurements at T=50 mK (- 273,05 °C).

The peculiarities of XMCD devices at Ultra Low Temperature (ULT)

The use of ^{3}He-^{4}He dilution refrigerator [1] to produce ULT is quite widespread for standard measurements, but the XMCD set-up requires superconducting split coils (high magnetic fields), electrical insulation of the sample, optical access, adaptations to ultra-high vacuum and in situ sample transfers, making the XMCD device developments at ULT more difficult.
History - Through associations initiated 20 years ago, at the time of LURE -before SOLEIL was built- with researchers and engineers of IPCMS* and IMPMC**, ULT devices dedicated to magnetic dichroism have been designed and implemented. They still hold the world record of low temperature (T limit=300mK) for XAS experiments, thanks to the SOLEIL-TBT device installed since 2006 on the SIM beamline at SLS (Switzerland), dedicated mainly to molecular magnetism studies.

The originality of the new DEIMOS device

For X-ray absorption experiments at low energy and ULT, the sample must be both electrically isolated and in contact with the cold source. The scientists have invented and validated the use of a sapphire ring which separates the mixing chamber in two parts; that allows filling the electrical insulation criterion without adding thermal impedance: the sample holder is in direct contact with the He bath (^{3}He-^{4}He mixing). It was shown, through the observation of expected physical phenomena [2], that the temperature of the sample was indeed that of the helium bath, and then that measured by the thermometer. This is the key strength of the new DEIMOS device and a promise of success.
After a period of feasibility studies (2015), designing and building of the insert have begun in June 2016. The commissioning under X-ray beam is scheduled for early 2017.

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Dichro50 project

The project involves the construction of a device with an expected temperature limit of about 50 mK on the end station of DEIMOS, thanks to technology and know-how of Synchrotron SOLEIL transfer to the French CryoConcept company. In the framework of knowledge transfer, this project was selected for a SATT Paris-Saclay investment as well as others prestigious programs (LabEx, PALM, ASTRE). Moreover, the project got the supports from ten European laboratories inside the DILUX consortium.

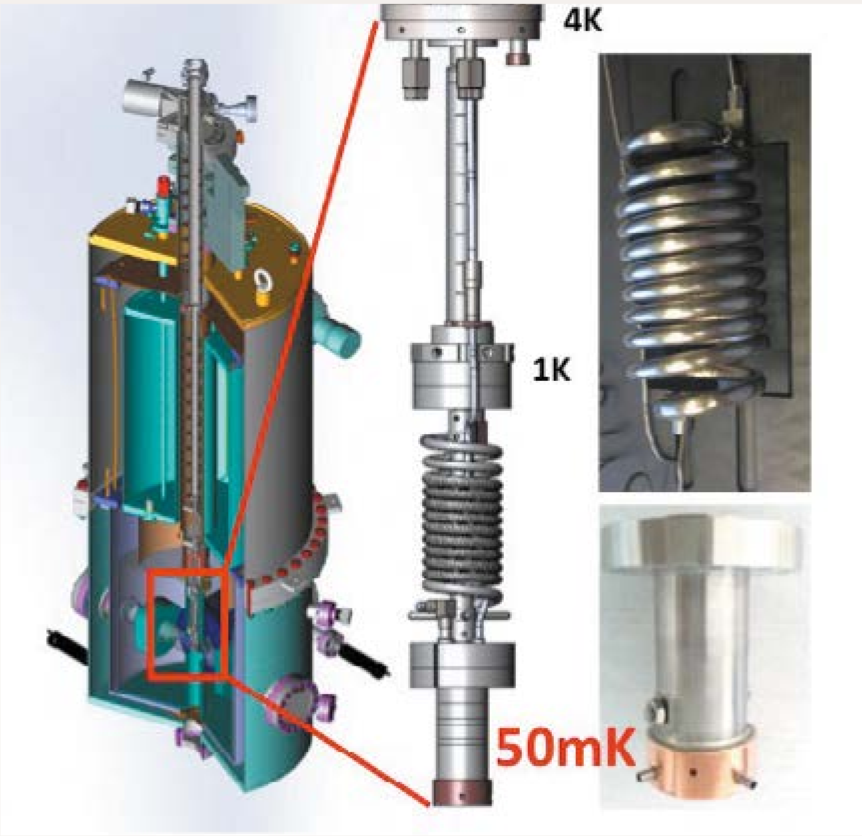

Figure 1 - 3D projection of DEIMOS cryomagnet, details of the low temperature stages of the device; right: pictures of the components before assembly (courtesy of Cryoconcept)

Scientific cases

Magnetic studies of molecular magnets (Rayon de SOLEIL #25 (2015), page 4), strongly correlated systems, isolated paramagnetic ions, super-paramagnetism clusters, magnetic ordering in organic radicals or superconductor gaps are at the heart of the scientific community concerns which require Ultra Low Temperature (ULT) devices. These scientific topics take advantage of the specificities of the magnetic dichroism, the main tool of the DEIMOS beamline.

Dispersive CD on DISCO

The DISCO beamline consists of 3 experimental hutches, including one for synchrotron radiation circular dichroism (SRCD). Until now, the technique used was «classic» CD: absorption by the sample of circularly polarized light, first anti-clockwise, then clockwise, measured wavelength by wavelength. It takes about five minutes, using this method, to create a complete spectrum.
By using the naturally circularly polarized properties of synchrotron radiation, circulating clockwise above the orbit of the electrons and anti-clockwise below, it is possible to record in one go the clockwise and anti-clockwise components of the absorption by spectography .The only limit to the measurement speed relates then to the detection chain, i.e. of the order of one microsecond per complete spectrum. This technique, known as dispersive CD, is in the process of being installed: the intensifier and the camera are in place, the spectrograph is working and polarimetric measurements have been carried out. From the beginning of 2017, this device will make it possible, for example, to follow the «live» folding of an entire protein in solution.

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Continuous scans in reciprocal space on SIXS

SIXS is dedicated to studying the structure of surfaces, interfaces or nano-objects, using X-ray scattering / diffraction techniques. This beamline makes it possible to study samples prepared under vacuum or in different environments (reaction chamber, electrochemical cells, Langmuir trough, etc.). Measurements can be taken in situ, in operando and in real time. SIXS has a two-dimensional hybrid detector coupled to a system of automatic attenuators, which allow data to be recorded over a very large range, with the detection response remaining linear throughout. Data acquisition is carried out using the «FLYSCAN» protocol (see Rayon de SOLEIL 22, page 9), which opens up the possibility of acquiring data in reciprocal space at unprecedented speeds. This type of scan allows you to exploit the accuracy of the diffractometer encoders by ensuring very high resolution measurements. In addition, these very fast scanning protocols can be used to measure evolving systems over very short time intervals. This new acquisition method will be available to users in 2017.

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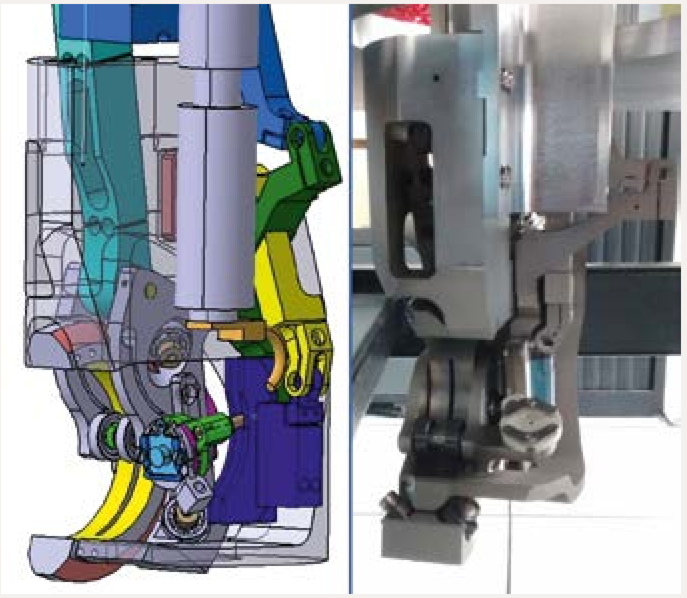

Left: 3D view of the new CASSIOPEE manipulator.
Right: photo of the device taken in December 2016.

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Manipulator on CASSIOPEE

One of the two branches of the CASSIOPEE beamline, dedicated to photoelectron spectroscopy, is equipped with a high-resolution angle-resolved photoemission setup. The measurements consist then in collecting electrons as a function of their emission angle. To do this, the sample is attached to a manipulator which allows to orient it with respect to the (fixed) electron analyzer as well as to control the temperature of the sample. The present manipulator rotates the sample only about a vertical axis, and can cool it down to about 5 K. To increase performance and to make measurements easier, a new manipulator is being installed, developed in the framework of the collaboration between SOLEIL and MAX IV. It will provide three rotations: about the vertical axis, about a horizontal axis contained in the surface of the sample, and about the normal to the sample surface. The minimum temperature will be 9-10K. First tests are planned for January 2017.

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NanoIR on SMIS

The nanoIR2s microscope technology is based on the coupling of an atomic force microscope (AFM) with an infrared (IR) source, with the aim of carrying out nanoscale spectroscopy and imaging. The main advantage of this approach is to push the limits of resolution which, for conventional IR microscopes, means a few microns. The nanoIR2s microscope includes two different physical approaches to obtain absorption measurements, one photothermal (developed by the A. Dazzi group, Paris-Sud) and the other using optics. In both cases, the idea is to probe the surface of a sample with an AFM tip (with a 10 nm radius of curvature) and to measure its local absorption when irradiated with IR radiation. In the first approach, known as AFM-IR, the AFM tip records the dilation of the sample when the sample heats up by absorbing the incident wave. The repetition frequency of the IR source is tuned to the resonant frequency of the AFM tip, enhancing the sensitivity by several orders of magnitude and allowing the measurement of objects only a few nm thick. In the second approach, scanning near-field optical microscopy, or SNOM, uses the tip as an antenna to concentrate the incident electromagnetic field and backscatter a carrier wave of chemical information. This technology has already proved its worth and it is now possible to analyze objects as small as protein assemblies (amyloid fibrils) or even to detect nanoparticles inside macrophages.
The possibility of obtaining a vibrational (IR) spectrum on a nanometric scale opens the door to an incredible number of applications, and in all fields of science (biology, materials science, agronomy, chemistry, photonics, etc.). The commercial system generally works with a tunable laser that does not cover the full IR range and is often very unstable energy-wise. The SMIS project is to couple the nanoIR2s microscope to the synchrotron radiation source, in order to measure IR spectra over a range that no laser based source can provide and thus gain access to more detailed analysis of matter at the nanometric scale.

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Protein purification in the biology laboratory

To purify macromolecules in solution prior to their analysis on beamlines, the Biology Laboratory has an HPLC system from Agilent Technologies with a size exclusion column (size-separation): HPLC-SEC. This technique is calibrated with globular proteins. For non-globular, rod-like or, on the contrary, more compact molecules, the retention time cannot be straightly used to evaluate their molecular weight. Recently, a multi-angle laser light scattering detector (MALLS) and an index refractometer (RI), were coupled to the HPLC-SEC. These make it possible to evaluate the molar mass of each eluted molecule, independently of the retention time on the column and of the «theoretical» molar extinction coefficient (calculated for a protein from its amino acid sequence). This combined instrument-environment has already shown its effectiveness, notably on a protein for which the elution profile more corresponded to a dimer, but was actually found to be a monomer. This can therefore provide essential structural information, complementary to that given by SAXS or SRCD. For molecules that are modified (glycosylation), ramified proteins (with aliphatic chain) or membrane protein, their interpretation may be more complex; this expertise is being acquired.

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FOCUS ON

A storage ring
fit to operate two long beamlines simultaneously

It required the work of more than a dozen SOLEIL groups to enable the respective undulators of ANATOMIX and NANOSCOPIUM to provide a beam simultaneously to both of these long beamlines.

Each long SOLEIL beamline, ANATOMIX and NANOSCOPIUM, takes a photon beam from an in-vacuum undulator with a minimum gap width of ± 2.5 mm, installed in a long straight section of the storage ring. The linear optics of the machine have been specially optimized to ensure a minimum vertical size at the center of each insertion device; this has been made possible by the introduction of a focusing quadrupole triplet at the center of the section and also a magnetic chicane. By November 2011, the first beam tests had been carried out, while simultaneously closing both undulators at their minimal gap. Unfortunately, vertical instabilities and strong out-gazing were quickly observed upstream of the second undulator. After removing the downstream undulator during the technical shutdown in January 2012, the reason for this instability was investigated and clearly identified: the photon beam from the upstream undulator had overheated the copper and nickel (Cu/Ni) protective sheet covering the undulator magnets, deforming it and eventually piercing it several times. A project group was created to analyze the reasons for this incident and find a perennial solution for simultaneously closing both undulators at their minimal gap values.

The solution: a beam absorber and finer local monitoring of the electron beam

It became clear that the characteristics unique to SOLEIL (lever arm linked at a large distance between the two undulators, magnetic gaps of 5.5 mm) significantly increased the risk of damaging the undulator for any large enough accidental vertical displacement of the incident beam. The solution was to insert a dedicated absorber at the entrance of the downstream undulator, as well as introducing finer monitoring of the position and angle of the electron beam going through the upstream undulator.
Optimizing the altimetry of the magnets inserted downstream, and therefore the Cu/Ni sheet covering them, was another major factor to minimize any local defects in the surface. Any "bump" would concentrate the power deposited locally, which would then be multiplied by a factor of 40. This complex project took into account the constraints of operating or constructing ANATOMIX and NANOSCOPIUM beamlines, but also the ability to intervene only during sufficiently long shutdown period.
By June 2015, an interim solution without the absorber had been introduced (a gap of 8 mm instead of 5.5 mm for upstream insertion) to allow the two long beamlines to function simultaneously. This was also accompanied by increased position monitoring by adding, for the first time, control of the vertical angle of the electron beam within the upstream undulator. The system is fast as it interrupts the beam in 2 milliseconds when there is a faulty angle.
The final solution consisted of a new type of local high-speed interlock system (position and angle in both transverse planes) as well as a dedicated photon absorber. This absorber's main purpose was to prevent photons from reaching the upper or lower jaws of the downstream undulator, but also to protect the double XBPM* installed downstream on the beamline front end during technical shutdown in January 2016. The setting up of the absorber and machine interlocks, as well as checking the absence of deleterious effects on the beam, were followed by a series of radioprotection tests that were completed in late May 2016.
This multidisciplinary project involved many groups: magnetism and insertion devices, accelerator physics, electronics and data acquisition, control, mechanical engineering, machine operation, diagnostics and synchronization, alignment and metrology, ultra-vacuum, security, building and infrastructure, as well as the personnel of the ANATOMIX and NANOSCOPIUM beamlines.

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Figure 1: Dedicated absorber, installed just before the downstream insertion in section 13.

* XBPM: X beam position monitor

EXPERT PORTRAIT

Laurent Barthe,
beamline Assistant Engineer

Laurent Barthe in the ROCK experimental hutch.

What is your background?

I obtained a BTS in Fluid Energy and Environment in Montpellier, where I first learned about the techniques of industrial and commercial refrigeration. Then I chose to specialize in vacuum technology and cryogenics with a two-year scientific and technical degree from University Paul Sabatier in Toulouse. This training, which has been given the name «Professional Certificate» since then, helped students become aware of the opportunities offered by large scientific facilities. I applied to positions in several of them after my graduation in 2002, and was hired at the European Synchrotron Radiation Facility (ESRF) for a fixed-term contract in a group called «Sample Environment Service». This group meets the demands of teams working on the beamlines in terms of sample environment design in five areas: cryogenics, high temperatures, high pressures, (ultra) high vacuum, and magnetism. I participated in the assembly of "customized" environments designed by the engineers of the group, especially in cryogenics and high temperatures—areas for which I received great training during these two years. The group is also responsible for supporting beamline users, which is why I was also involved in providing technical support to teams working on the beamlines during the installation and implementation of trade instruments and of those developed by the group.
After this first contract, I applied for an Assistant Engineer (AE) position at SOLEIL, on SAMBA beamline. My open-ended contract started in January 2005.

What is your job exactly?

After two years working at a synchrotron in operation, I arrived at SOLEIL, where the Phase 1 beamlines were in their pre-construction phase. This is a very different experience: I have had to deal with new projects and master various trades, including in optics. It has required versatility and adaptability.
Once the SAMBA beamline construction was completed, I worked on the sample environments for the beamline. For both the maintenance and operation of existing sample environments, and soon on the design of new ones. This means starting from the specifications, designing and drawing the mechanical components, ordering their production, assembling them, and, finally, testing them.
Following a project from the beginning to the end and seeing that the final design is effective is highly rewarding. I quickly realized that, due to the characteristics of the beamline, this position gave me the opportunity to develop a wide range of systems, with much room left to technical imagination. This is what really makes me love my job.
Yet, even though combining mechanics and thermal science (high temperatures) remains my strongest interest, I also design more traditional mechanical assemblies; for example, for the motorization of detectors: a commercial instrument must be moved as close to the sample as possible along several axes, with a set of combined crossed movements.
For the thermal side only, since 2005, I have been entrusted with three significant projects: the first, completed in 2009, is a furnace for catalysis experiments on SAMBA. The sample can be heated to 600° C and the furnace allows the coupling of analysis techniques (X-ray transmission, X-ray fluorescence, Raman). The challenge with this type of furnace is reaching high temperatures despite multiple openings necessary to install the measuring instruments. The mechanical parts were also produced at SOLEIL using turn/mill machines of the mechanical workshop, which makes maintenance easier and ensures a great result. More than 7 years after its commissioning, this equipment is still widely used, which I find gratifying, especially since it has been frequently used on several beamlines, such as ROCK, SAMBA, ODE, and GALAXIES.
In 2012 and 2013, I had to design a furnace for SAMBA beamline, for experiments in grazing angle (RELEXAFS) dedicated to the measurement of X-ray absorption in fluorescence mode. It allows for temperatures as high as 900° C at the sample position, under high vacuum. The mechanical production of parts has once again been carried out at SOLEIL's mechanical workshop, which shows that the collaboration with our colleagues specialized in mechanics is a real success! After an implementation phase on the beamline for various experiments, we worked with Guillaume Alizon (current AE on SAMBA) to improve its ultimate vacuum value.
Finally, the most recent project was made possible through funding from a collaboration with the Swedish synchrotron MAX IV. I recently completed a first prototype that is in the qualifying phase. It is the coupling of two separate systems to go from very high temperatures (up to 1,000° C) to cryogenic temperatures (cryo-cooled gaseous nitrogen), for catalysis experiments on samples inserted in quartz capillaries. These studies will also be possible by coupling techniques (e.g., transmission, fluorescence, Raman), and will be used on ROCK and SAMBA at first. Once the prototype is validated, a prototype will be build for MAX IV.
The furnace part is removable to make room for the second, cryogenic sample environment. The constraint is also in the size of each piece of equipment, which has to be minimized. It has to be small and effective! Each new project brings new challenges, but that is what makes them interesting.
In addition to «instrumentation design,» my duties include the maintenance of the beamline, which means ensuring the daily functioning of the equipment (vacuum, motorization, automation, etc.) and providing support and technical advice to users.

So you now work on beamline ROCK?

SAMBA is an X-ray absorption spectroscopy (XAS) beamline on which a novel Quick-EXAFS monochromator designed at SOLEIL (Marc Ribbens) was installed during its first years of operation. The beamline was already in high demand, and with this new addition, the number of applications for beamtime, increased significantly. The SAMBA supervisor at the time, Valérie Briois, then managed to obtain funding from the French National Research Agency (ARN) as part of the «Investissements d'avenir» projects (Equipex 2010) to build ROCK, a second quick-EXAFS beamline for X-ray absorption spectroscopy (time-resolved studies). Valérie then asked me if I would be interested in joining her on this adventure with a new beamline. After a short time of reflection, I accepted her offer, as the prospect of using my seven-year experience acquired on SAMBA in the context of ROCK was a big source of motivation, especially as ROCK offers the same opportunities for sample environment development as SAMBA.
For 18 months I alternated duties on two beamlines, then Guillaume Alizon took over on SAMBA. I have been working full-time on ROCK since September 2013, and it's even more enjoyable now that I have more experience. It has given me a clearer vision of my tasks and I am now able to make decisions and take the initiative more easily.
The first users started working on the beamline in March 2015.
I feel very lucky to have been involved in the construction and implementation of not just one but two beamlines, both being a real success. The friendly and positive working atmosphere between teams from both SAMBA and ROCK has played a significant part in this achievement.

You are also a Cluster Delegate. What is it exactly that you do?

A study was conducted by the upper management at SOLEIL to optimize the organization's structure in order to keep up with its development 10 years after the beginning of its construction. Today this translates in the Experiment Division by bringing together the support labs and beamlines within six «clusters» based on the analysis techniques implemented on the beamlines.
The delegate then acts as the middleman between the teams working on the beamlines (or support labs) of a cluster, the Scientific Direction, and the Accelerator and Engineering Direction. I was part of the working group that participated in the background study on the organization of SOLEIL, and upon the solicitation of colleagues in my cluster, I agreed to become a delegate. This cluster has a strong focus on X-ray spectroscopy—but not only—and gathers six beamlines, including two that I am very familiar with: ROCK and SAMBA. This new work organization is at its very beginning, and I have just started my tenure as a delegate.

Looking back on these almost 12 years at SOLEIL, how do you feel?

Time has gone by so fast that I didn't even realize it. This really shows that there never was a dull day here for me. And you have to keep in mind that something really strange occurs at SOLEIL: Ph.D. students come and go, but they are always the same age; so how can you expect me to realize that so many years have gone by?!

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SPOTLIGHT ON

SOS beamlines:

the hall coordinators are on hand…

There are six of them, and during beamtime operations when the beamlines are functioning, they work in eight-hour shifts, twenty-four hours a day, six days a week. Their mission is to help beamline personnel and users with problems that they may encounter with their experiments at SOLEIL. Make a note of their phone number: 9797!

The team of six hall coordinators, from left to right: Didier Trévarin, Julien Pinon, Bruno Cortès, Rodney Redman, Philippe Maugan and Michel Dot with their manager in the centre, Pascale Prigent.

Analysis, diagnosis and then decision-making: repairs, if possible, or a request for help from the «local contact» scientist for the experiment or one of the SOLEIL support groups, as required. When the technical issue is beyond their skills, the hall coordinators set up a link between the user and the appropriate resource(s)-person(s) – they are ¨signalmen¨ who know how to deal effectively with requests. This involves a global view of the workings of the equipment inside the beamlines, and a wide and varied technical knowledge including but not limited to mechanics, electronics, instrument techniques, vacuums, cryogenics, infrastructure, robotics, the use of I.T. tools. It would be hard to find more varied fields than those concerned by the hall coordinators' work. So curiosity and a thirst for knowledge are necessities, as there will always be something new to discover and learn no matter what the educational background. The coordinators have several years' training or experience in the different specialities linked to the range of instruments used on the lines – that is why each of them has their own strengths depending on their past experience or the training received at Soleil in the techniques they are less familiar with. This ensures versatility in problem-solving. They also have extensive experience in maintenance and in installing equipment onsite in France or abroad.
Versatility is required: all the team must be able to intervene irrespective of why a call is made, when they are on duty. That is to say, in the morning (6.30 a.m. to 3.00 p.m.), the afternoon (2.30 to 11.00 p.m.) or at night (10.30 p.m. to 7.00 a.m.), during the week or on weekends. So there is always a half-hour tie-in period for passing on information from the finished shift to their replacement.
Making the timetable for the team is a real puzzle, which Philippe resolves for each beamtime session, which is called a run. For the six coordinators the right balance must be struck between the 11 hours minimum recovery time between shifts, without going over 40 hours on average per week, while alternating on-duty shifts during the week (nights/mornings, etc.). This is a complex exercise, and the success of which is based on each individual's flexibility and adaptability. It is very important to be able to count on one's colleagues, in the event of personal constraints, in particular, to «fix» the timetable. In other words: here, probably even more than elsewhere, a good understanding within the group is primordial.

Technique and psychology…

The hall coordinators must act fast in the event of a problem, but without rushing: they need to have the necessary distance to assess the situation correctly, even when faced with scientists whom might be overwhelmed by stress due to a halted experiment. That is to say that a sense of contact and service, together with (almost) boundless calm are indispensible advantages in this job. Setting up procedures for some equipment, alongside the line teams and the support groups, helps simplify and speed up the coordinators' work. The 29 beamlines are shared out between them, and each of them knows the lines – this facilitataes where they can or cannot intervene and how, what their «weak points» are, where a breakdown is likely to occur, etc. From the robots transferring crystals on the PROXIMA lines to the helium compressor to cooling down the DEIMOS magnet, via the laser used on the FemtoSlicing facility, they have been trained to know how to react in the event of an incident. And it was logical that the coordinators should put forward ideas about computer monitoring of the lines («Global Screen»): even if they must and can adapt themselves, it is obviously easier and quicker for them to identify a problem if the monitoring systems are standardised and do not vary from one beamline to another.
All this information and knowledge, as well as reports on their interventions, are of course transmitted to the colleagues in the group, in particular via dedicated e-log and a wiki programs.

To these multiple technical interventions is added a safety role. When the beamtime is attributed, all experiments are assessed by the SOLEIL Safety group according to their danger level (green/yellow/red rating) and, for each experiment, a document, called the Safety Approval Shift (SAS), is placed on the corresponding line on the first day of the experiment to warn scientists of potential risks. For the past few years, the coordinators distribute the green, yellow and red SAS rating, while the Safety group takes charge of all the explanations linked to to the red and yellow SAS rating. Since they are often the first ones to intervene when a problem is signalled on a line, it is particularly important for the coordinators to be informed beforehand about the potential risks in the various ongoing experiments. They have also all taken an official workplace first-aid course. In fact, the users are now so used to contacting the coordinators in the event of an incident that they sometimes call them for problems that are the responsibility of the Safety group.

Transversal knowledge

The coordinators make sure they maintain wide-ranging and continually updated information about the «health» of the lines; their interventions are a good way to update it, but prevention is better than cure. This is why they regularly share information with a number of SOLEIL support groups during meetings that need to be scheduled, despite the complexity of their timetables and possible interruptions because of calls for help.
Information is also pooled at the cluster meetings, the laboratories and beamlines support groups that have given structure to the Experiments Division since the groups were reorganised to adapt to the development of SOLEIL (*cf.* portrait of L. Barthe, page 15). The coordinators make sure that there is a coordinator present at the meetings of the six clusters. It's a chance to learn if technical developments or new instruments are planned and maybe even to foresee shared work with the engineering assistants on these projects.
Another of their tasks is to take charge of the mechanics workshop, located in the synchrotron, where repairs, adjustments or minor mechanical work often needs to be carried out on the lines, but which is not under the responsibility of the mechanical engineering department. The equipment available (vertical milling machine with horizontal milling table, lathe, and drill press) can only be used by trained and authorised staff – including three coordinators. In a second workshop with an electronics section they can carry out minor electronics repairs with equipment that is independent of the tools used by the Electronic Control and Acquisition group – a highly useful laboratory when work needs to take place, for example, on the FemtoSlicing laser system or on repairs to the lines.
Lastly, they manage the stocks of certain specific spare parts that are not supplied by the other support groups: XPS diffractometer cards, monochromator coders, computer cables of varying lengths, special connectors, power supplies for monitors on the beamlines, cryogenic heater modules, cryo keypads, exhaust pipe fittings, inlet hoses, electronic fuses, etc.

Victims of their success

So being a hall coordinator is a demanding job, in terms of work rhythm and technical awareness: their versatility must go hand in hand with curiosity and a desire to always learn new things. As a result, users are often positively surprised by the level of skill of the group's six members, who can be contacted evenings, nights and weekends. So much so that some things needed to be made clear: no, they can't take a look at your experiment once it's been launched, even though there's no reason to do so, nor repair your shower if you are staying at the SOLEIL guest house!

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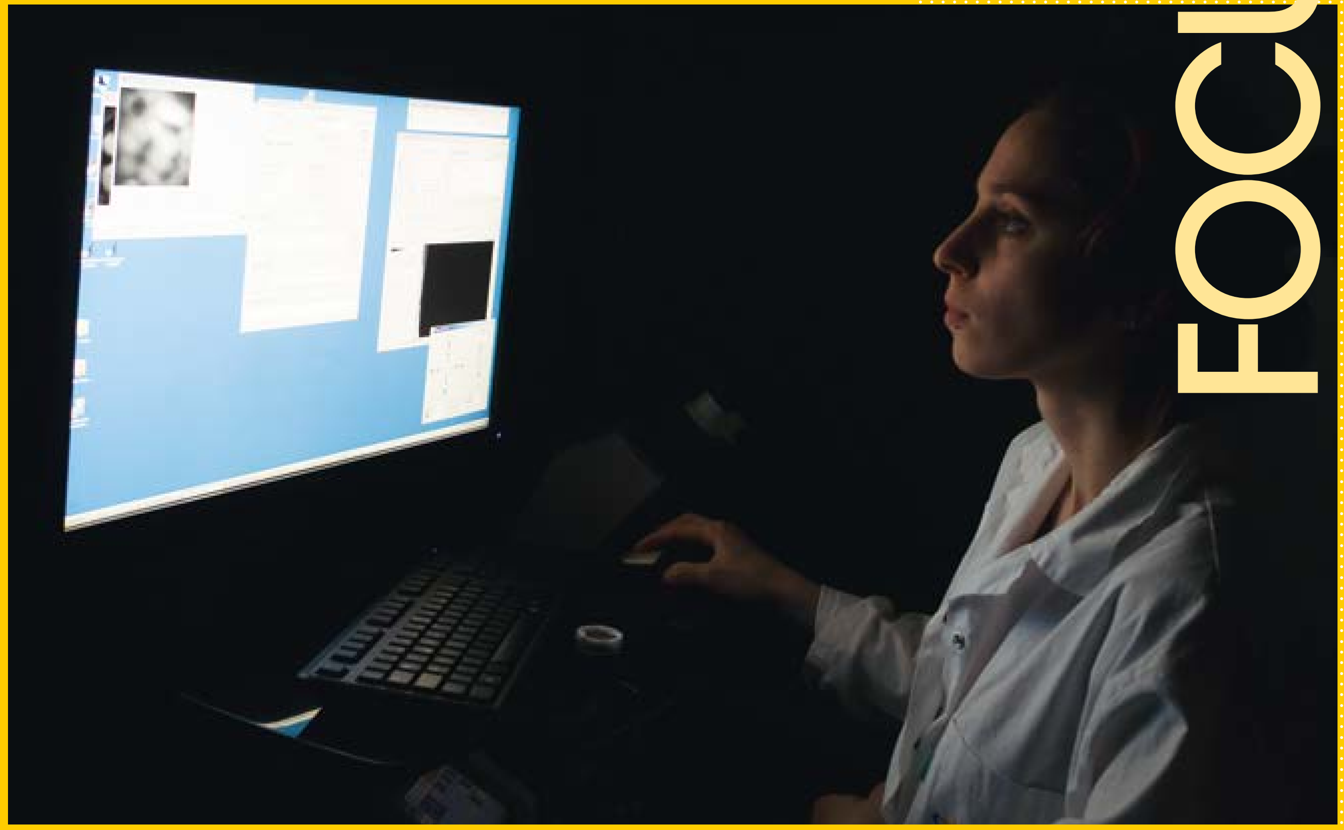
2- and 3-dimensional imaging



Very early on, Man felt the need to access what his eyes could not see. Diving into the infinitely small—from the first lenses and magnifying glasses, followed by the very first microscopes by the end of XVIth century and finally today's transmission electron microscopes—over time, the resolution of the images obtained has gained many orders of magnitude. With resolutions now reaching a few hundred picometers (10^{-12} m), scientists are able to detect details as small as two separate carbon atoms in a diamond.
At SOLEIL, imaging techniques are available on about half of the 29 beamlines, and this proportion is set to increase in the years to come.

HERMES

Weaving 3D magnetic memories using nanowires

There is a tremendous need for high data storage capabilities, which continues to increase exponentially these last years. Requirements other than the amount of storage also include, depending on the application: access speed, endurance, volatility, energy for writing / reading a bit and the cost per bit. Within the framework of an EU project (M3D), several European laboratories are involved to address materials for non-volatile mass storage, where the density and cost per bit are the key issues. The original approach of the project is to envision 3D magnetic memories using magnetic nanowires: series of bits would be shifted along vertical magnetic wires densely packed in arrays, requiring only one single read/write element per wire.

Understanding the magnetic properties in a single magnetic nanowire and nanotube is a first and mandatory step toward the full design of such devices. We have recently carried out XMCD-PEEM observation of such nanotubes at HERMES beamline. To the best of our knowledge this is the first direct observation of a clear domain pattern in magnetic nanotubes. However, contrary to the predictions, we evidence in these tubes orthoradial magnetization with multiple well-defined domains. Such tubes with orthoradial magnetization are appealing for a 3D race-track memory as their domain walls give rise to a very small dipolar field, unlike the case of nanowires, which warrants absence of cross-talk (magnetic interaction between the nanotubes) despite the dense matrix.

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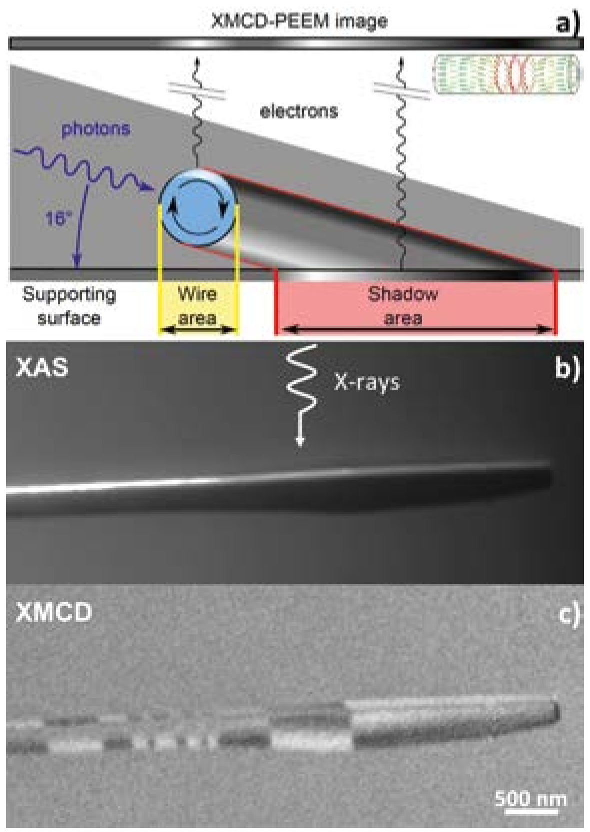

Figure 1 : High resolution XPEEM image of a CoNi tube. a) Schematic of the geometry of XMCD-PEEM used in a combined surface/transmission mode. The nanotube is lying on a supporting surface, which gives rise to a shadow of the tube from the 16° grazing-incidence beam. The analysis of the helicity-dependent intensity in the shadow provides information on the magnetization distribution in the bulk of the object. b) XAS-XPEEM image recorded at the Ni edge. The bright region corresponds to the tube while the dark one is the shadow of the tube. c) XMCD-XPEEM image at the Ni edge evidencing the surface (top) and the bulk (bottom) magnetic domain structure.

The microscopy techniques that the scientists use to achieve the highest resolutions[1] do not rely on visible light, as is the case with optical microscopes. Instead, they use other ranges of electromagnetic radiation, or even electrons. In addition, the images no longer form directly in the eye of the experimenter: they must be «reconstructed» in order to be interpreted. The reconstruction methods include one or more stages, from the signals recorded by detectors that are no longer our eyes. Several imaging techniques exist depending on the type of radiation employed and the interaction between the radiation and the investigated object: absorption, emission, diffraction, to name a few.
Although for the time being, electron microscopy remains unbeatable in terms of image resolution, the synchrotron techniques are making great progress by achieving resolutions of a few tens of nanometers, while providing additional data revealed by the interaction of radiation with matter. Moreover, in the case of imaging techniques based on electromagnetic radiation, a synchrotron naturally offers the largest variety of techniques as a result of the wide spectrum of photons and diversity of analytical devices currently available.
SOLEIL makes it possible to explore the various scales of matter, from the micron to the nanometer, and to collect information that come as a complement to the "topographic" data recorded by a microscope, such as the magnetic or electronic properties of a material, or its chemical composition.

[1] Resolution: The minimum distance between two contiguous points so that they are correctly distinguished by an observation or measurement system..

Continued on page 22...

NANOSCOPIUM

MMX-I: a software for multi-modal X-ray imaging

Scanning hard X-ray imaging allows simultaneous acquisition of multimodal information, i.e. of images in which each pixel contains several types of data. The output is, for instance, a map of the sample in absorption, phase and dark-field contrasts and X-ray fluorescence, providing with a single scan both structural and chemical details.

Combining this scanning technique with the FLYSCAN infrastructure developed for fast data acquisition at Synchrotron SOLEIL [1] permits to perform multimodal tomographic imaging and tomographic reconstruction during routine user experiments at the NANOSCOPIUM 155m long beamline [2]. A computerized analysis reconstructs the 3D inner structure of the observed object from these tomographic data, which are a large set of images of the sample in different orientations.

A main challenge of such imaging techniques is the online processing and analysis of the important amount of generated multimodal data. This is particularly important for the wide user community working at the user oriented NANOSCOPIUM beamline (e.g. biology, life sciences, geology, geo-biology), having sometimes no experience in such data-handling.

MMX-I is a new and unique multi-platform open-source freeware for the processing and reconstruction of scanning multi-technique X-ray imaging and tomography datasets [3]. The MMX-I project aims to offer both expert users and beginners the possibility of processing and analyzing raw data, either on-site or off-site. Therefore we have developed a multi-platform (Mac, Windows and Linux 64 bit) data processing tool, which is easy to install, comprehensive, intuitive, extendable and user-friendly. A dedicated data-input stream copes with the input and management of large datasets (several hundred of Giga Bytes) collected during a typical multi-technique fast scanning and this even on a standard PC. The data of each scanning imaging technique (included into the software) or any of their combinations can be treated by MMX-I. Experienced users can use this program as a library for their existing software or develop new functions, which are then released for other users. MMX-I is now routinely used by the NANOSCOPIUM users community either on-site or off-site and has demonstrated its effectiveness in dealing with big data.

MMX-I is available online at the following address: https://bitbucket.org/antoinebergamaschi/mmx-i

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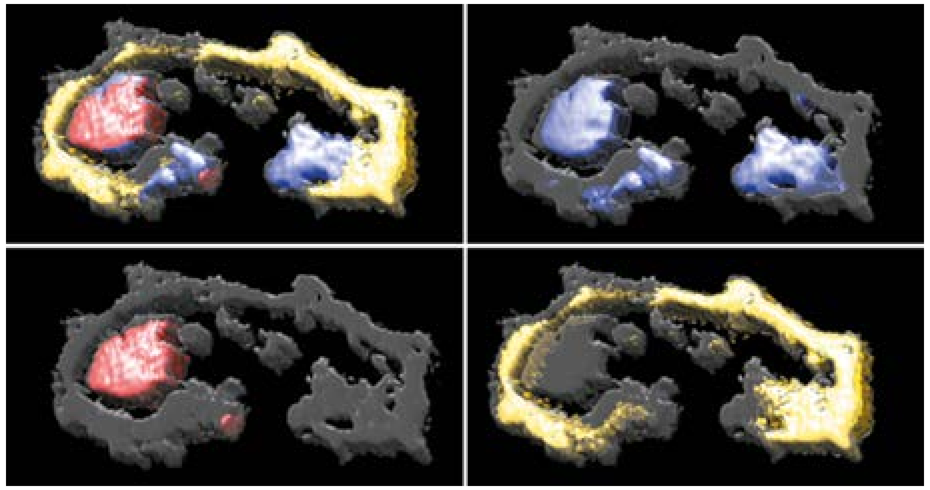

Figure 1: 3D volume rendering of the multimodal tomogram of a fossil single-cell foraminifera. Scanning multi-technique tomography provides simultaneous structural and elemental information for the study of heavy metal incorporation mechanisms during bio-mineralization processes. The different contrast modalities were reconstructed by the MMX-I data-processing software developed at the NANOSCOPIUM beamline. The reconstructed phase is shown in grey, the dark field is in blue, the iron distribution is in red and the calcium distribution is marked in yellow in the figures.

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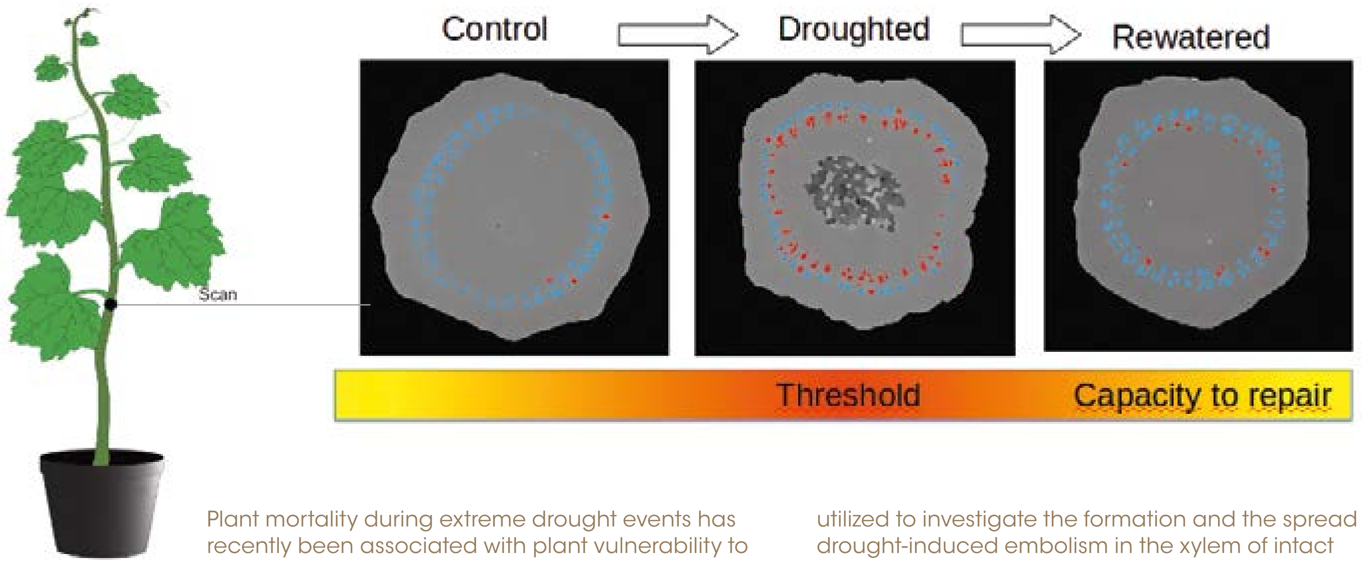
PSICHE

Plant embolism and drought resistance



Plant mortality during extreme drought events has recently been associated with plant vulnerability to xylem cavitation, a phenomenon corresponding to the disruption of water transport in embolized vessels. Despite the recent advances in the field of plant hydraulics, there is still debate as to whether plants routinely face embolism and recover easily from it or are highly resistant to embolism. Some studies have suggested that plants are highly vulnerable to embolism but recover from it on a daily basis. In both branches and leaves, this recovery would involve the refilling of vessels, via transpiration during the daytime or through root pressure. However, this process has been observed only in species with long vessels, such as laurel, poplar and grapevine, possibly reflecting methodological issues that bias conventional measurements in species with long xylem pipes. Synchrotron based micro tomography has been utilized to investigate the formation and the spread of drought-induced embolism in the xylem of intact plants and test whether plants are thus routinely exposed to high levels of embolism even when well-watered.

During their first SOLEIL campaign in 2015 [1], scientists from BIOGECO (INRA – Bordeaux University) first demonstrated how high resolution computed tomography (HRCT) - a non-invasive method, which allows the direct observation of air and sap-filled xylem conducting elements in the wood of intact plants - can provide non biased assessment of plants adaptation to drought. Their direct observations of vessel have evidenced the remarkable ability of long vessels such as oak to resist embolism. Second, in 2016, they evidenced xylem refilling and an increase in the number of functional vessels after the plant was re-watered (Figure 1). Refilling of xylem vessels was not observed as long as the pressure remained negative. However, as soon as positive pressure was measured, xylem refilling could be seen. They also demonstrated that the most living cells remained alive (Figure 2) 10 days after scanning.
Part of the activity of the PSICHE beamline is tomography and imaging for a wide range of applications, including the example shown. The synchrotron source provides very high x-ray flux, much brighter than a laboratory or medical tomograph. This can be used to make very fast measurements to study time resolved phenomena such as cracking or deformation in engineering materials. Alternatively, a monochromator can be used to select just one wavelength from the beam in order to study delicate living samples, such as these living plants, which would be damaged by the higher flux. Measurements are nonetheless much faster than in a laboratory, taking just 90 seconds for a complete 3D measurement. This allows the researchers to study large numbers of samples in the course of a week of beamtime.

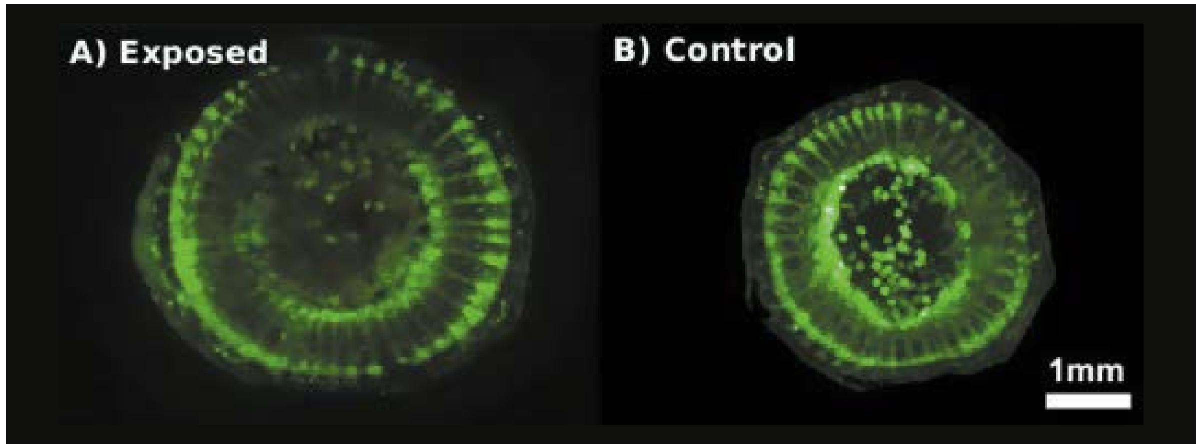


Figure 2. Cross section of the upper stem part of a grapevine plant that was scanned with HRCT 10 days before treatment with fluorescein-diacetate. The fluorescent, green colored cells represent living cells, which were slightly more pronounced in the control image (B) compared to the area that was exposed to x-ray beam (A). White bar = 1mm scale [2].

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References:
1-B. Choat et al. Plant Physiology (2016) 170, 273.
2- G. Charrier et al. Plant Physiology (2016) 172, 1657.

... Continued from page 20

As early as SOLEIL's first years of operation

Since 2007, DIFFABS has made it possible to combine analyses in high-energy diffraction and absorption on the same area of the sample and under identical physicochemical conditions, with the possibility of using an X-ray microbeam (10 x 10 µm²). In the case of complex materials, the obtained mappings with moderated resolution reveal the inhomogeneity of the sample—for ancient materials, for example, but also in the medical field. The measurements can also be carried out under stress to study the mechanical behavior of the sample under extreme conditions of temperature—the field of excellence of this beamline—and pressure.
The beamline LUCIA, on the other hand, offers a more focused microbeam (2.5 x 2.5 µm²) for absorption and X-ray fluorescence mappings at energies lower than DIFFABS, hence the complementarity between these two beamlines for the chemical mapping of heterogeneous objects.
The first time-resolved magnetic imaging results at SOLEIL were obtained by electron photoemission spectroscopy and soft X-ray absorption spectroscopy on TEMPO, another beamline that was commissioned as early as 2007. This work was carried out in collaboration with Institut Néel in Grenoble.
With the installation of new microscopes, the beamline TEMPO has shifted its focus towards a better consideration of the time variable of the measurements. Making it possible to determine the reaction kinetics along a surface or at interfaces, and to measure the magnetization dynamics in magnetic materials, for example. Photoemission imaging results were also obtained on the second branch of TEMPO, using the microscope of CEA laboratories IRAMIS and LETI.

[2] Reflets de la Physique (2013), 34-35, p38-42.

In the low-energy range

At SOLEIL, every possible wavelength range is covered by at least one beamline for imaging studies. In the infrared (IR), the beamline SMIS combines absorption spectroscopy and Fourier Transform Infrared spectroscopy (FTIR). For nearly 10 years, this beamline has made it possible to create chemical mappings of various compounds with a few micrometer resolution: polymer films, mineral inclusions, materials of biological, biomedical, or archaeological interest, and more. SMIS was recently equipped with a station called «nanoIR» for the chemical analysis of the samples with spatial resolution up to a few tens of nanometers—a leap of three orders of magnitude compared to traditional IR microspectroscopy. The IR beam illuminates the sample from the top. Two analysis techniques called AFMIR and SNOM can then be provided. See page 12 for more information.
Although NanoIR currently operates with a pulsed IR laser source, coupling with a wide-band laser source (access to the range of C-H, O-H and N-H stretching vibrations) and with the synchrotron source (access to the entire mid-infrared region) will be available shortly.

Continued on 24...

SMIS

Infra-red imaging and spectro-tomography

For a number of years the team of the SMIS beamline has developed a worthwhile collaboration with researchers of the IAS (Institut d'Astrophysique Spatiale d'Orsay) in respect of the analysis of small extra-terrestrial dust systems originating from primitive objects (asteroids, comets, see Rayon de SOLEIL, no. 18 p. 4) using micro-IR and micro-Raman spectroscopy. This helps to improve our understanding of the start of the Solar System and the evolution of these materials in different astrophysical environments ranging from primitive solar nebula, through to the accretion process and incorporation in planetesimals up to changes in the surface of asteroids and comets and the addition of volatile materials to the terrestrial planets.

A new FTIR microscope-imager equipped with a matrix detector of focal plane array type of 128x128 pixels has recently been installed on SMIS, which makes it possible to simultaneously obtain a very large number of spectra over surfaces extending from several centimetres down to a few microns. The speed of this type of detector also allows development of a new analysis method: three-dimensional microtomography. This technique was developed in 2013 at the Synchrotron Radiation Center at Madison (USA) by M. C. Martin and his team and is now in course of implementation on the SMIS beamline. The first analyses were performed on grains of the "Paris" carbonaceous meteorite, mounted at FIB points.

The results show the 3D distribution of different phases of these grains, which have a very heterogeneous composition. Complementary analyses have been performed using X-ray tomography on the PSICHE beamline. The coupling of these two techniques makes it possible to determine at a small scale, the relationships between organic materials and minerals that is fundamental in understanding the origin and evolution of organic material in the different development phases of our planetary system. These analyses constitute the initial phase of a measurement protocol, extending from the least destructive to the most destructive analytical techniques, aimed at characterising all of the properties of samples, with an eye to the next space missions that will bring back samples (Hayabusa 2, JAXA, and OSIRIS-REx NASA).

The objective is to develop and exploit a wide range of analyses using FTIR three-dimensional microtomography for use on various materials of extra-terrestrial origin by the researchers of the IAS and for other samples (biological, medical, heritage, physics of materials, etc.) for scientists and other users of the SMIS beamline. This analytical method represents a major technological breakthrough that will permit non-destructive characterisation of the composition of these materials at a scale that has never yet been achieved.

The instrument will likewise be available for large surface area 2D IR spectroscopy. Coupling with the synchrotron source is in progress and it is expected that the instrument will be available for calls for projects in the second half of 2017.

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... Continued from page 23

As for the range of energy of the ultraviolet: one of the three branches of beamline DISCO is a UV fluorescence imaging station for studies in biology (living cells) and materials science. New possibilities of sample excitation and detection (autofluorescence, used to avoid probe-based labeling) have proved particularly promising for applications in biomedical diagnosis [3] or treatment: for example therapies targetting tumors that usually cannot be reached by photochemotherapy [4], or the improvement of radiotherapies using nanoparticles [5].

Electronic and magnetic properties of advanced materials at the nanometer scale

To make the best use of the remarkable properties of nano-objects, scientists must carry out an exhaustive study of their electronic structure through the detection of core levels, and the analysis of the structure of the delocalized valence bands, which are directly responsible for chemical bonds, electrical transport and thermal and mechanical properties. Angle-resolved photoelectron spectroscopy (ARPES) is the appropriate technique in this case, allowing for precise measurements of the dispersion of the strip structure of materials in the reciprocal space. Since 2011, the beamline ANTARES has offered a Nano-ARPES microscope capable of performing, with a spatial resolution of a few tens of nanometers, the imaging of the electronic properties of systems close to the devices used for applications in tomorrow's electronics as well as quantum engineering.

[3] - D. Bazin *et al.*, Comptes Rendus Chimie (2016) 19, 1439.
[4] - S. Kaščáková *et al.*, Nano Research (2015) 8, 2373.
[5] - L. Štefančíková *et al.*, Cancer Nanotechnology (2014), 5, art.n° 1.

A little higher up in the energy range is HERMES, another spectromicroscopy beamline that is the combination of two types of equipment: one for photoemitted electron microscopy (PEEM), a technique which, unlike ARPES, preserves the spatial provenance of the photoelectrons, and one for scanning transmission X-ray microscopy (STXM). One of the many applications made possible by spatial resolutions of a few tens of nanometers consists in physically imaging the magnetic domains. It then becomes possible to manipulate magnetic bits within a magnetic structure.

SOLEIL also offers another technique of magnetic imaging available on beamline SEXTANTS: Fourier transform holography, with a spatial resolution of a few nanometers—limited by the wavelength of the X-rays. The team of the beamline showed that linearly polarized X-rays can be used to image the magnetic domains in thin layers, usually studied using circular polarization. This technique makes full use of the characteristics of X synchrotron radiation, i.e. high intensity and short pulses (for time resolution), energy and polarization tunability (for chemical selectivity and magnetic sensitivity) and high degree of coherence (for a large field of view).

The CRISTAL beamline is dedicated to the X-ray diffraction study of powders and non-biological (single)crystals. The beamline gives access to the atomic structure of crystals by measuring the intensity of the diffraction peaks (Bragg reflections). Users can also take advantage of the coherence of the X-ray beam: the modification of the shape of the Bragg peaks is related to the shape of the diffracting crystal and to its internal deformations due to the constraints imposed by its environment (coherent diffraction, Bragg ptychography). And just like TEMPO, CRISTAL provides users with the additional asset of the time dimension thanks to time-resolved diffraction, as shown by the first pump (IR)-probe (RX) experiments that started in September 2016 using the slicing mode for a temporal resolution of the order of 200 fs (10^{-15} s).

And the volume, too

Four beamlines provide (or will soon provide) tomography and/or imaging systems with coherent diffraction scanning (ptychography), in addition to two-dimensional analyzes.

In tomography, similar to a medical scanner except with much better space resolution, the sample, placed on a rotation stage, is illuminated by X-rays and a projected image (X-ray) is formed on a detector positioned downstream. During the rotation of the object across 180°, it is radiographed from all angles. The 3D structure of the object is reconstructed from all the projected images through calculations. This non-destructive technique allows for visualization of the inside of the sample thanks to X-rays and without having to cut through, while making it possible to study sample evolution over time, for example under stress.

The high brilliance and partial spatial coherence of synchrotron radiation make it possible to use the technique known as phase contrast imaging, which is more sensitive than the absorption technique traditionally used in radiography. After traveling through the sample, the electromagnetic waves dephase, thus creating an interference phenomenon observable by the detector when placed at a distance optimizing this contrast. Small variations in the density of the sample can thus be revealed, and this makes it possible to thoroughly study micro or even nanometric objects, depending on the beamline.

Finally, in ptychography, 3D reconstruction is the result of the «compilation» of hundreds of thousands of diffraction images of the sample: for each orientation of the sample, several hundred diagrams are recorded, allowing to reconstruct the 2D image of each projection (orientations of the sample). All the 2D images collected are then used in the final 3D reconstruction—a procedure that requires the implementation of especially powerful algorithms. Beamline PSICHE offers these 3 techniques when it operates in non-focused, monochromatic X-ray mode. This beamline is optimized for experiments in materials science: composite or structured materials, batteries, studies on corrosion, fatigue or deformation, and more.

In 2017, the beamline PUMA, for studies of ancient materials, will include a hard X-ray spectromicroscopy station (2D imaging and point microanalyses) and an X-ray hard microtomography station—both aimed at resolutions of the order of one micrometer. PUMA is one of the three long beamlines available at SOLEIL. Its length was defined to ensure sufficient X-ray beam coherence (long distance between the X-ray source point and X-ray/sample interaction point), as well as to create a large field of view for full-field measurements on large samples.

This distance is even more important for beamlines ANATOMIX and NANOSCOPIUM (160 m) to achieve appropriate coherence and size (30-100 nm) of the X-ray beam expected at the sample. Dedicated to full-field radiography and tomography in absorption and phase contrast, beamline ANATOMIX will cover a large range of space resolutions: between 30 nm and 10 µm. NANOSCOPIUM allows to perform 2D/3D qualitative, chemical and structural analyses (ptychography) in various fields such as microelectronics and materials, biomedical, geo-biological and environmental sciences, with the aim of achieving the highest resolution: 30 nm.

Processing data and constructing images

The different techniques listed, and especially those allowing for the 3D reconstruction of the samples, require the processing and analysis of enormous amounts of data. On beamline NANOSCOPIUM, for example, scanning hard X-ray microscopy allows for the acquisition of multimodal data, meaning that it acquires images in which each pixel contains several types of data. For example, the same sample can be mapped using absorption, phase, dark field and X-ray fluorescence contrasts through a single scan, as made possible by the FLYSCAN infrastructure for rapid acquisition.

A free and open-source software for the processing and reconstruction of multimodal X-ray imaging and tomography data was developed at SOLEIL to support scientists in their work. Known as «Multi-Modal X-ray Imaging» or MMX-I, this software allows users to process their raw data either directly on beamline NANOSCOPIUM, or on their personal computer. The most experienced programmers can also integrate MMX-I as a computing library into an existing software, or develop new functionalities that will benefit the rest of the community.

Another project called «Défi imag'in» is underway, involving scientists from DESY, KIT and SOLEIL. With support from the CNRS mission for interdisciplinarity (MI), its objective is to develop the tools (computing platform, graphical interface) necessary for the processing of rapid imaging measurements by X-ray diffraction over the course of the experiment, or even in real time. This is quite the challenge since the increase in brilliance of the X-ray sources and the detectors' improved efficiency and dynamics have led to an increase in collection speeds by several orders of magnitude over the last two decades.

So users can rest assured: there is no doubt that the terabytes of data collected over shorter and shorter times across SOLEIL's different beamlines will be processed and converted into superb 2 or 3D high-resolution images.

LBS³:
a winning³ partnership in the conception of innovative medicines for the future

Bringing together the companies and the synchrotron facility in an efficient and sustainable way: this has been the stated ambition of SOLEIL since its start of operation in January 2008. The last decisive advance in this approach was embodied by the inauguration of the Laboratoire de Biologie Structurale (Structural Biology Laboratory) SERVIER at SOLEIL (LBS³) on the 23 June 2016.

LBS³ is the result of a partnership between 3 main players in French research and development in the medical field:

1. Servier Group, the first independent French pharmaceutical laboratory, which undertakes industrial research in 5 major therapeutic areas (cardiology, oncology, metabolic disorders, neuropsychiatry and rheumatology),

2. The SME NovAlix (90 staff), a company undertaking contract research on behalf of the pharmaceutical sector, having a high level of expertise in chemistry and biophysics,

3. Synchrotron SOLEIL, a French Very Large Scale Research Infrastructure, centre for research and services for research and industry for studies into live matter and advanced materials.

This partnership, effective since April 2015, has a renewable duration of 5 years and relates to the siting of a commercial laboratory in the synchrotron building of SOLEIL, as close as possible to its two bio-crystallography beamlines.

Servier is the first commercial group to benefit from facilities made available by a French synchrotron radiation centre, as part of a unique integrated technology platform which supplements the open platforms already available at SOLEIL, both by sector (agriculture-food, cosmetics, cultural heritage) or region (administrative Grand Est region of France).

With a surface area of 170m², the LBS³ is a laboratory intended expressly for structural and functional studies of therapeutic target molecules (proteins). These studies are led by a team of 5 researchers from the NovAlix company, who likewise benefit from the offices made available by SOLEIL in the synchrotron building; at the heart of LBS³, these researchers perform the various steps of production, purification and crystallisation of proteins, before the possible transfer of the crystals to the bio-crystallography beamlines PROXIMA-1 and PROXIMA-2A of SOLEIL for the 3D determination of the structure of these proteins.

The three partners were already involved in bilateral collaboration programmes. Servier and NovAlix have been working together for twelve years, the two companies having been independently using the bio-crystallography beamlines of SOLEIL, since 2008 and 2011 respectively, while SOLEIL and Servier have been collaborating scientifically since 2011. The strengthened tripartite partnership embodies the scientific and technological complementarity between the three players and their shared willingness to advance medical research and reinforce the position of France in international competition.

Visit of the PROXIMA-2A beamline, during the inauguration of the LBS³, on the 23 June 2016. Standing, in the foreground, from left to right: Michel Bournat, Vice-President of the Conseil Départemental of Essonne and President of the Plateau de Saclay urban community, Olivier Laureau, President of Servier, Maud Olivier, Member of Parliament for Essonne, Stephan Jenn, President of NovAliX, and Christophe Gegout, Assistant Managing Director of CEA, following the explanations given, on his computer screen, by the PROXIMA-2A manager, William Shepard (seated, back to camera). Also present, in the background: Jean Daillant, Stéphanie Hustache, Andrew Thompson, respectively Director General, Head of the Communications and Life Sciences Director of SOLEIL, and Gabriel Chardin, President of the Very Large Scale Research Infrastructures comity at CNRS.

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IN BRIEF

AN INDUSTRIAL CONSULTANCY COMMITTEE AT SOLEIL

The Comité d'Orientations Stratégiques pour l'Industrie à SOLEIL (Strategic Industrial Consultancy Committee at SOLEIL [COSIS]) will start operations at the end of 2016. A consultative structure advising the Director General of SOLEIL, COSIS brings together personalities from companies representative of the main SOLEIL application markets (pharmaceuticals, petrochemicals, aerospace, materials). Its main purpose is to express the requirements and expectations of industry in the short and medium terms in respect of the provided synchrotron research services.

µPPI AND NANOSATELLITES

SOLEIL is involved in the µPPI project aimed at miniaturising the electronic thrusters for a low mass class of satellites. This project, undertaken by an engineer of the University of Versailles Saint-Quentin-en-Yvelines, is also the responsibility of two other technical partners, CNRS and Ecole Polytechnique, and has a financial backer, SATT Paris-Saclay, which selected the project at the end of 2015 within the framework of its call for incubator projects.

Machine shutdown: objective tunnel

On 3 and 4 May 2016, the staff at SOLEIL took advantage of a machine shutdown to (re) explore the tunnels in the various accelerators of the synchrotron.
An enjoyable moment to be shared by all, especially since the visit-guides were the operators themselves. The operators had the chance to share their daily work with the rest of the
SOLEIL staff. In all, almost 100 staff members took part in these special visits, including a host of anecdotes about the machine. The success of the visits led to the idea of organising new initiatives of the same kind, with the aim of highlighting the value of each person's work, and familiarising staff with this unusual workplace, the SOLEIL synchrotron.

Muriel Martin-Vacherot, Travel Manager in the Travel Office.

" I organise "made-to-measure" business trips for the staff, users, and scientific guests at SOLEIL. As well as reservations, keeping track of spending, and managing expenses, I also have to be a good listener, reactive and friendly! "

Youtubers at SOLEIL

This year, the Fête de la Science festival also took place on the internet for the SOLEIL synchrotron as part of the «Youtubers under Infras» initiative, launched by the French Ministry of Education and Research, with the aim of forging links between Very Big Research Infrastructures (TGIR in French) and Youtubers. SOLEIL was selected by the channel «LaboCube». Two video-makers, Maxime Labat and Maxime Devige, set up a rap battle between SOLEIL and e-ReColNat, a digital platform for the environment and society. In the end, there was no winner between the two «rappers», Elliot from SOLEIL and Patrick from e-ReColNat, but rather an off-the-wall and original presentation of the two organisations. The video was put online on the Ministry website, providing even greater diversity as a possible introduction to the SOLEIL synchrotron. In just two and a half months, the video has been seen over 4000 times.
https://www.youtube.com/watch?v=U_XDzzOhnx0

SOLEIL at the Paris International Agricultural Show

As part of its partnership with the Institut National de la Recherche en Agronomie (INRA), which celebrated its 70th anniversary in 2016, SOLEIL took part in the Paris International Agricultural Show from 27 February to 6 March 2016. Together with synchrotron users from INRA, our scientists had an opportunity to meet members of the public and discuss the nature of a light source such as SOLEIL, and the possibilities it offers in the fields of agriculture and the food industry. This successful experience underlines the excellent relations that have existed for several years between SOLEIL and INRA.

KEY FIGURE

+38%

of followers on the SOLEIL's Twitter account in 2016. This evolution, similar to the one on our LinkedIn page, rewards the work which has been done for 1 year to develop a real digital communication strategy on Twitter, LinkedIn, Facebook and YouTube.

COHERENCE2016

The International Workshop on Phase Retrieval and Coherent Scattering, COHERENCE2016, is a biennal conference, which takes place traditionally in a waterside location. The 2006 edition was held in the beautiful congress center "Le Grand Large", from 7-10 June 2016 in Saint-Malo. The local organizing committee, chaired by Virginie Chamard from Institut Fresnel Marseille, Sylvain Ravy, from LPS Orsay and Olivier Thomas, from IM2NP Marseille, represented almost all the French coherence community, and had gathered around the synchrotron-SOLEIL and its organizational know-how for this 2016 edition.

The conference was attended by 131 participants working on four broad areas, separated in 12 sessions: Coherent Diffraction Imaging (CXI), dynamics (XPCS), theorical and computational methods and progress in new sources. Let us note for this edition the confirmation of the importance of ptychography, a scanning imaging technique discussed in two sessions, and the rapid rise of X-ray Free Electron Lasers (XFEL) studies also present in two sessions.

The conference has confirmed the dynamism of the community, which will see in a few years the arrival of new facilities, either synchrotron-based sources emitting light more than ten times brilliant and coherent than current sources, or a couple of XFELs in Europe and Asia. Besides imaging and dynamical techniques that current facilities strive to make available to non-experts, emergent techniques are arising, which use progress in pixel detectors, nanometric source size and ultrashort pulses.

Despite a rather foggy weather, a "rayon de soleil" has joined the Celtic banquet as well as the group photograph, taken in front of the "Fort National" designed by Vauban, remembering the prestigious past of the corsair city.

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TAILOR-2016: TAILored surfaces in Operando conditions: structure and Reactivity

Extensive efforts are currently made in order to achieve a rational design of high-performance catalysts, which in turn will lead to substantial savings of costs, as well as to sustainable use of resources. Advancement has been achieved in the field during the last years. However, it still remains an enormous need for fundamental research into understanding the mechanisms underlying the catalytic processes.

In this context and with the goal of promoting fruitful scientific exchanges, the third edition of the international workshop on"TAILored surfaces in Operando conditions: structure and Reactivity"was held at Fontainebleau, France, from March 29th to April 1st, 2016. The workshop was organized jointly by Synchrotron SOLEIL and several researchers from INSP, Néel Institut, ESRF, IRCELYON, LITEN (CEA), ENS Lyon, LEPMI, ICB and MAX Lab.

This 3-days workshop showcased the main scientific advances on operando and in situ studies of reactivity at surfaces, both from experimental and theoretical points of view. A large range of experimental techniques were covered during the sessions and keynotes, including spectroscopy, microscopy, x-ray scattering, scanning probes, new developments of instrumentation, all of them applied to different catalytic tailored materials, including model surfaces, oxide-supported nanoparticles and electrochemical systems. Complementing the experimental studies, there was a number of presentations on state-of-the-art modeling of surfaces and model catalysts.

The workshop was a definite success with the participants of TAILOR 2016 looking forward to the next edition, which will be held in Lund, Sweden in 2018. It is important to underline that the fourth installment of the workshop, will be held for the first time in a country other than France. This is a testament on the success of the TAILOR series and to the relevance of the field in today's materials science and in engineering.

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Workshop "Low Emittance Ring 2016"

1 – Participants of the LER 2016 workshop.

The 6th Low Emittance Ring workshop, LER2016, was held during 26-28 October 2016 at SOLEIL as the last workshop of the series, under the auspice of EuCARD2, a network for coordinated Research and Development on Particle Accelerators, co-funded by the European Commission under the FP7 Capacities Programme. It integrates the work package "Low Emittance Rings (LOW-ε-RING)", within the frame of which the present workshop was organized. A local organizing committee was formed at SOLEIL involving the accelerator physics group and the three assistants of the Accelerators and Engineering Division (DAI). Despite held during the period with a number of conflicting workshops elsewhere, as many as 66 delegates participated from all around the world, from a total of 28 laboratories and universities, in which 14 were from Europe, 7 from US, Canada and Brazil, and 6 from Asia including Australia (Photo 1).
The scope of the LOW-ε-RING workshops is to gather the experts from the communities of the damping rings for high energy physics and the synchrotron light source rings, as they share today many of the physics and technological challenges in common. With today's rapidly increasing interest of constructing DLSRs (Diffraction Limited Storage Rings) in the light source community, there was a clear dominance of the latter in both the number of participants and contributions. There were as many as 49 talks over the three days of the workshop. Talks were grouped into three sessions; those related to the project progress reporting and single beam dynamics, those on beam collective effects, and on the low emittance ring technology.
SOLEIL also presented possible scenarios for its future machine upgrade, contributed by Amor Nadji, the DAI Director. A special session was held on the second day, honouring Prof. Dieter Einfeld, for his major involvement in the construction of numerous light source rings around the world and for his pioneering studies of MBA (Multi Bend Achromat), which turned out to be the key to the success of DLSRs today (Photo 2). In the summary session, the work package coordinator introduced the successful transition of LOW-ε-RING to RULE (Ring with Ultra Low Emittance) under ARIES (Accelerator Research and Innovation for European Science and Society) that replaces EuCARD2. The workshop LER2016 site is found at: **www.synchrotron-soleil.fr/Workshops/2016/LER2016.**

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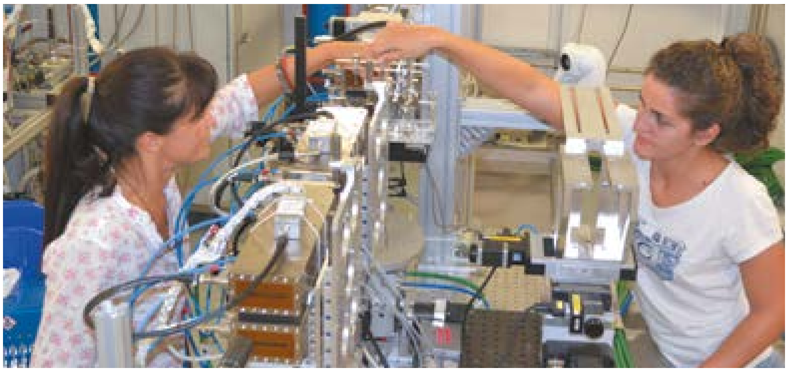
2 – Professor Dieter Einfeld (centre) receiving an award for his career achievement.

ENERGY

Towards the electrochemical storage of energy, a new generation

Global warming and the finite nature of fossil fuels mean that renewable energy is a French and European priority. Within this context, the aim of RS2E*, initiated in 2011, is to develop new methods for the low cost, large-scale, electrochemical storage of energy whilst adhering to sustainability principles.

* Research network on electrochemical energy storage



Stéphanie Belin (left), ROCK beamline scientist, and Antonella Iadecola, CNRS/RS2E research engineer, positioning electrochemical cells in the multiple sample carrier of the ROCK experimental cabin.

It is a French research and technology transfer network, dedicated to various electrochemical energy storage devices: rechargeable batteries, supercapacitors and alternative technologies for electric cars, portable electronics or the storage of electricity generated from renewable sources. Noteworthy amongst medium-term objectives are: assembly of batteries in a single step using 3D printing; design of systems comprised of abundant materials, at low cost and produced using low-temperature processes; the emergence of lithium-free technologies; development of devices that simultaneously combine energy storage and conversion capabilities, etc.

RS2E is a partner in the ROCK "équipement d'excellence", notably including the SOLEIL beamline of the same name, the construction of which was financed by the French National Research Agency (ANR) within the scope of the "Plan Investissements d'Avenir" (Investing in the Future Programme). The ROCK beamline is dedicated to the study of fast kinetic processes on nanomaterials used mainly in the fields of catalysis and batteries, using X-ray absorption spectroscopy.
Via a specific CNRS/RS2E/SOLEIL collaboration, a research engineer is working on ROCK, under the co-responsibility of the beamline and the network, tasked with developing innovative experiments using the synchrotron for research into the electrochemical storage of energy. This engineer is likewise responsible for assisting RS2E scientists as users of ROCK.

SOLEIL beamlines offering analysis techniques complementary to those available on ROCK can also be called upon within the scope of this network: a range of light radiation wavelengths available for research into the storage of energy.

→ **To find out more:**
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Project in 3 points

1 CNRS (French national centre for scientific research) Research network created with the support of the French Ministry of Higher Education and Research, the RS2E brings together 17 public research laboratories, 3 public research and technology transfer establishments (CEA, IFP, INERIS) and 15 industrial partners.

2 RS2E was created to prevent domination of the latest energy storage technologies by Asian economies,as was the case in the 1990s when, in spite of highly active western research, Li-ion battery technology was dominated by them.

3 Since the start of operation of ROCK in March 2015, studies on the mode of operation of a range of electrode materials have been performed thanks to developments of dedicated equipment, and powerful chemometric tools are now available, making possible the exploitation of thousands of energy spectra recorded during the experiments.

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