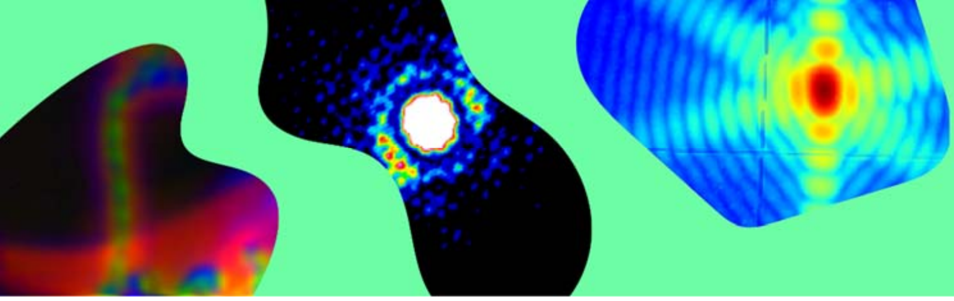
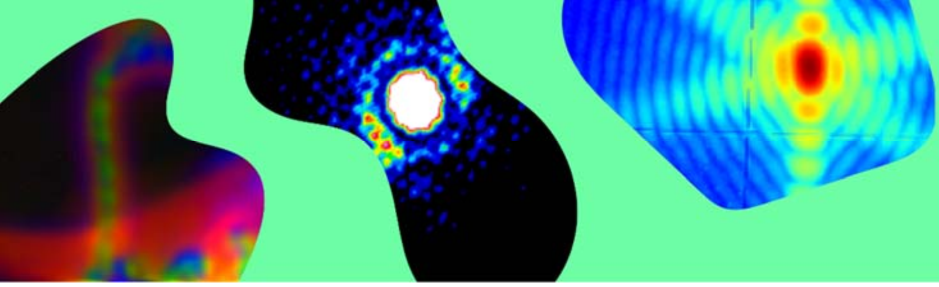


Summary



Welcome!

The **GDR CohereX Workshop** (Science with coherent X-rays at 3^{rd} and 4^{th} generation synchrotron sources) takes place from **the 7^{th} to the 9^{th} of October 2025, at SOLEIL.**

It aims to bring together the French community using coherent X-rays, covering a wide range of research fields from **biological systems** to **magnetic and electronic structures** over **functional materials** and **cultural heritage materials** up to the **dynamics of matter**.

The goal of the General Meeting of the GDR CohereX is:

- To **present the latest research results** using coherent X-ray techniques and to **share the know-how**.
- To **promote** particularly **the development of innovative studies and data analysis approaches** with respect to the unique opportunities offered at upgraded extremely brilliant synchrotron sources.

Bienvenue!

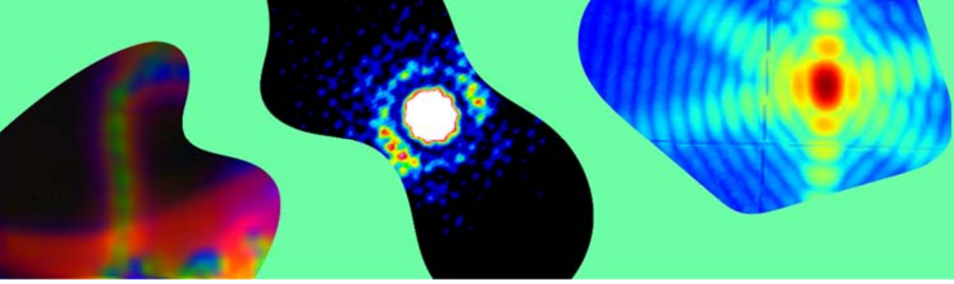
Le workshop **GDR CohereX** (Science with coherent X-rays at 3^{rd} and 4^{th} generation synchrotron sources) a lieu **du 7 au 9 octobre 2025 à SOLEIL.**

Le **GDR CohereX** vise à rassembler la communauté française utilisant le rayonnement X cohérent, couvrant des domaines de recherche variés allant des **systèmes biologiques** aux **structures magnétiques et électroniques**, en passant par les **matériaux fonctionnels** et ceux du **patrimoine culturel** et jusqu'à la **dynamique de la matière**.

Les journées du GDR CohereX ont pour but de **présenter les derniers résultats scientifiques obtenus** et de **partager les savoir-faire**.

Ces journées ont également pour objectif de :

- **De promouvoir le développement de nouvelles études innovantes** et
- **De partager les nouvelles approches d'analyse de données**, en lien en particulier avec les opportunités uniques offertes par les mises à jour des sources synchrotrons extrêmement brillantes.



Programme

Tuesday, October 7th, 2025

12 :30 – 14 :00	*Welcome coffee*
14 :00 – 14 :30	Opening/Welcome
14 :30 – 15 :15	How coherent X-rays help to understand the dynamics of glassy water ***Katrin Amman-Winkel*** *- Max-Planck Institute for Polymer Research, Mainz, Germany*
15 :15 – 15 :45	Probing particle dynamics in a fully opaque porous network using X-ray differential dynamic radiography (XDDR) ***Pierre Levitz*** *- Phenix Laboratory Sorbonne université, Paris, France*
15 :45 – 16 :15	*Coffee Break*
16 :15 – 17 :00	From Bragg CDI to Bragg ptychography: Recent developments and future directions ***Clément Atlan*** *- ESRF, Grenoble, France*
17 :00 – 17 :30	Crystallisation in biomineral mollusc shell studied by 3D Bragg ptychography ***Virginie Chamard*** *- Institut Fresnel, Marseille, France*
17 :30 – 18 :00	Multi technique approach for catalysis: Ammonia oxidation as case study ***Andrea Resta*** *– Synchrotron SOLEIL, St Aubin, France*
18 :00 – 20 :30	Poster session – *Cocktail dinner*

Wednesday, October 8th, 2025

09 :00 – 09 :45	X-ray imaging at SOLEIL and the SOLEIL II upgrade ***Andrew King*** *– Synchrotron SOLEIL, St Aubin, France*
09 :45 – 10 :15	Unraveling hydrogen-induced phase transitions in palladium nanoparticles via In Situ BCDI ***Petra Khater*** *- Université Grenoble Alpes, CEA, France*
10 :15 – 10 :45	*Coffee Break*
10 :45 – 11 :30	Probing the thermally activated magnetisation dynamics in patterned arrays ***Thomas Hase*** *- University of Warwick, UK*

11 :30 – 12 :00 Fourier transform holography of magnetic textures employing soft X-rays with orbital angular momentum
Pietro Carrara *- INSP-CNRS, Montrouge, France*

12 :00 – 13 :30 *Lunch*

13 :30 – 15 :00 Round Table

15 :00 – 15 :30 *Coffee Break*

15 :30 – 16 :15 *In situ* Bragg coherent diffraction imaging from energy materials
Marie-Ingrid Richard *- CEA Grenoble, France*

16 :15 – 16 :45 HoToPy: A toolbox for X-ray holo-tomography in Python
Jens Lucht *- Georg-August-Universität Göttingen, Gemany*

16 :45 – 17 :30 Tomoptychographies des éléments constitutifs d'un composite à matrice organique utilisé dans l'aéronautique
Mathieu Ducousso *– Safran, Magny les Hameaux, France*

19 :30 – 22 :00 *Conference Dinner at La Table D'Ivin*

Thursday, October 9th, 2025

09 :00 – 09 :45 Imaging the magnetic vector field in thick samples using coherent scattering
Marisel di Pietro Martinez - *Max-Planck Institute for Chemical Physics of Solids, Dresden, Germany*

09 :45 – 10 :15 Nanosecond XPCS with two-dimensional X-ray detector
Yuriy Chushkin *– ESRF, Grenoble, France*

10 :15 – 10 :45 *Coffee Break*

10 :45 – 11 :30 Reaching the yield point of glasses with X-ray irradiation
Alessandro Martinelli *- Laboratoire Charles Coulomb, Université de Montpellier, France*

11 :30 – 12 :00 Multi Bragg coherent X-ray diffraction imaging of strain and defect dynamics in unconventionally oriented catalytic nanoparticles
Mouad Bouita *- CEA-Grenoble, France*

12 :00 – 13 :30 *Lunch*

ABSTRACTS

Tuesday, October 7th, 2025

GDR-CohereX 2025

Tuesday, October 7th

IT-01	How coherent X-rays help to understand the dynamics of glassy water ***Katrin Amman-Winkel***
OC-01	Probing particle dynamics in a fully opaque porous network using X-ray differential dynamic radiography (XDDR) ***Pierre Levitz***
IT-02	From Bragg CDI to Bragg ptychography: Recent developments and future directions ***Clément Atlan***
OC-02	Crystallisation in biomineral mollusc shell studied by 3D Bragg ptychography ***Virginie Chamard***
OC-03	Multi technique approach for catalysis: Ammonia oxidation as case study ***Andrea Resta***

How Coherent X-rays Help to Understand the Dynamics of Glassy Water

K. Amann-Winkel

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ABSTRACT

Water is ubiquitous and the most important liquid for life on earth. Although the water molecule is seemingly simple, various macroscopic properties of water are most anomalous. It was suggested that the anomalous behaviour of ambient and supercooled water can be explained by a two-state model of water. An important role in this ongoing debate plays the amorphous forms of water. Since the discovery of two distinct amorphous states of ice with different density (high- and low-density amorphous ice, HDA and LDA) it has been discussed whether and how this phenomenon of polyamorphism at high pressures is connected to the occurrence of two distinct liquid phases (HDL and LDL). The glass-to-liquid transition of the two states is still not fully understood (1). While experimental determination of the glass transition at elevated pressure and cold temperatures is technically difficult to implement, measurements on water and amorphous ices are even more challenging, as the glass transition is interrupted by crystallization. In my talk I will give an overview about recent XFEL experiments (2) as well as X-ray photon correlation spectroscopy (XPCS) on amorphous ices. The experiments are done at ambient pressure conditions (3) as well as elevated pressure using a diamond anvil cell(4).

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4. Aigerim Karina et al., “XPCS at elevated pressure and cryogenic temperatures: Multicomponent dynamics in amorphous ice”, Communications.Chemistry (2025) 8:82

Probing Particle Dynamics in a Fully Opaque Porous Network Using X-ray Differential Dynamic Radiography (XDDR)

P. Levitz[a], L. Michot[a], N. Malikova[a], M. Scheel[b] and T. Weitkamp[b].

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ABSTRACT

Being able to follow in real-time the motion of particles of various nature, shape and size in porous media clearly represents a major research and societal issue. Currently, the leading technique used for tracing particle dynamics in porous media is based on optical microscopy. However, such methods require working with partially transparent samples, which is not the case of many naturally occurring porous media. The latter can indeed be fully opaque, with soil being the most salient example. We propose an alternative method based on recording the time evolution of X-ray radiographs in pure absorption mode. We show that a specific analysis of such a dataset can provide a quantitative determination of the intermediate scattering function (ISF) of these particles in various opaque porous media. The potential of our approach, named X-ray Differential Dynamic Radiography (XDDR), was first checked by simulating random walk dynamics of light colloids inside a porous SiO_2 random close packing network saturated with water. Potential perturbation induced by Fresnel diffraction is analyzed. Finally, two experiments are performed on the beamline ANATOMIX at the SOLEIL synchrotron, demonstrating the possibility to probe mm SiO_2 particle sedimentation either in bulk water or inside a RCP of Poly (Methyl Methacrylate) (PMMA) spheres. XDDR appears to fill a relevant “niche" between DDM (differential dynamics microscopy) and XPCS (X-ray photon correlation spectroscopy), allowing to cover a time scale from 0.2 ms to several minutes and a q-range from 0.1 mm^{-1} to 5 mm^{-1}.

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From Bragg CDI to Bragg Ptychography: Recent Developments and Future Directions

C. Atlan[1], J. Garriga-Ferrer[2], J. Zhao[1], F. Maillard[3], M.-I. Richard[4], S. Leake[1], M. Allain[2], V. Chamard[2], V. Favre-Nicolin[1]

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[2]*Aix-Marseille Univ, CNRS, Centrale Med, Institut Fresnel, Marseille, France*
[3]*Univ. Grenoble Alpes, Univ. Savoie Mont Blanc, CNRS, Grenoble INP, LEPMI, Grenoble 38402, France*
[4]*Univ. Grenoble Alpes, CEA Grenoble, IRIG, MEM, NRX, Grenoble 38000, France*

ABSTRACT

Coherent Diffraction Imaging (CDI) techniques1 under Bragg conditions are powerful tools for probing the structure of crystalline materials at the nanoscale. Traditional Bragg CDI allows for the investigation of finite crystals and enables the retrieval of structural properties under realistic environments, such as gas-phase conditions2 or electrochemical setups3,4. Bragg Ptychography (BP)5-8, by combining the principles of ptychography and Bragg CDI, leverages overlapping coherent diffraction patterns acquired at multiple scanning positions to image extended and possibly highly strained crystalline structures. While X-ray ptychography is now a well-established method at many synchrotron facilities, Bragg Ptychography poses additional experimental and computational challenges. This talk will explore approaches to address these challenges, along with recent advances in Bragg Ptychography—including Python-based reconstruction tools, data analysis pipelines, experimental methods, and applications in materials science.

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Crystallisation in Biomineral Mollusc Shell Studied by 3D Bragg Ptychography

V. Chamard

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ABSTRACT

Biomineralisation integrates complex biologically assisted physico-chemical processes leading to an extraordinary diversity of calcareous biomineral crystalline architectures, in intriguing contrast with the consistent presence of a submicrometric granular structure. While the repeated observation of amorphous calcium carbonate is interpreted as a precursor to the crystalline phase, the crystalline transition mechanisms are poorly understood. Access to the crystalline architecture at the mesoscale, *i.e.*, over a few granules, is key to building realistic crystallisation models. Here we exploit 3D X-ray Bragg ptychography microscopy to provide a series of nanoscale maps of the crystalline structure within the “single-crystalline” prism of the prismatic layer of a *Pinctada margaritifera* shell. The mesocrystalline organization exhibits several micrometer-sized iso-oriented/iso-strained crystalline domains, the detailed studies of which reveal the presence of crystalline coherence domains ranging from 130 to 550 nm in size. The further increase in the lattice parameter with the size of the coherence domain likely results from the crystallisation mechanism, pointing towards a maturation process occurring after the initial amorphous-to-crystalline transition [1].

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Multi Technique Approach for Catalysis: Ammonia Oxidation as Case Study

A. Resta[1], D. Simonne[1], A. Vlad[1], Y. Garreau[1,3], C. Chatelier[2], M-I. Richard[2], A. Coati[1]

[1)] Synchrotron-soleil
[2)] CEA Grenoble
[3)]Université Paris Cité

ABSTRACT

The main objective of this work is to study heterogeneous catalysts *in situ* and *operando* for ammonia oxidation under conditions approaching industrial settings, with the aim of linking morphology and surface structure to chemical selectivity. Currently, the macroscopic structural changes associated with this industrial process are partially known, but their role in selectivity remains unclear. The proposed approach is based on three different platinum model catalysts: large single crystals, submicron single crystals, and assemblies of iso-oriented submicron single crystals.

Three techniques were primarily used: Bragg coherent diffraction imaging *(BCDI) and* surface X-ray diffraction *(SXRD) at the SixS beamline of SOLEIL synchrotron*, and X-ray photoelectron spectroscopy *(XPS) at the B07-C beamline of DIAMOND synchrotron*. The catalytic activity was monitored in parallel with each technique for each sample, temperature and gas compositions by tracking the partial pressures of the three oxidation products: nitrogen (N_2), nitric oxide (NO), and nitrous oxide (N_2O).

BCDI enables the retrieval of detailed information on single particles, such as shape, facets, surface and interface tension, compression, and the nature of some defects. The average particle behavior was analyzed using SXRD on epitaxial nanoparticles. Additionally, SXRD was employed to study the behavior of individual facets namely, {111} and {100} on large single crystals. XPS was performed on single crystals to determine the major surface species associated with each condition. The parameter space explored involved a few selected temperatures ranging from 300°C to 600°C for a chosen set of ammonia-to-oxygen ratios in the mbar regime.

The study revealed the existence of two distinct families of particles, potentially exhibiting different behaviors during the reaction, as well as the alternative responses of individual facets to the gas environment.

ABSTRACTS

Wednesday, October 8th, 2025

GDR-CohereX 2025

Wednesday, October 8th

IT-03	X-ray imaging at SOLEIL and the SOLEIL II upgrade ***Andrew King***
OC-04	Unraveling hydrogen-induced phase transitions in palladium nanoparticles via In Situ BCDI ***Petra Khater***
IT-04	Probing the thermally activated magnetisation dynamics in patterned arrays ***Thomas Hase***
OC-05	Fourier transform holography of magnetic textures employing soft X-rays with orbital angular momentum ***Pietro Carrara***
IT-05	*In situ* Bragg coherent diffraction imaging from energy materials ***Marie-Ingrid Richard***
OC-06	HoToPy: A toolbox for X-ray holo-tomography in Python ***Jens Lucht***
IT-06	Tomoptychographies des éléments constitutifs d'un composite à matrice organique utilisé dans l'aéronautique ***Mathieu Ducousso***

X-ray Imaging at SOLEIL and the SOLEIL II Upgrade

A. King

Synchrotron SOLEIL, Saint-Aubin, France

ABSTRACT

Imaging experiments are performed across many SOLEIL beamlines using many different techniques and for many applications. This talk will give an overview of some current results, and developments in progress. It will discuss the SOLEIL II upgrade program, and its expected impact on imaging experiments. In particular we will look at how the improved coherence in the X-ray domain can be used to enable new science at SOLEIL.

Unraveling Hydrogen-Induced Phase Transitions in Palladium Nanoparticles via In Situ BCDI

Petra Khater[1,2], Ewen Bellec[1,2], Kyle Olson[1,2], Michael Grimes[1,2], Clement Atlan[2], Frederic Maillard[3] and Marie-Ingrid Richard[1,2]

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[3]Univ.Grenoble Alpes, CNRS, Grenoble INP, Université Savoie Mont Blanc, LEPMI, Grenoble, France

The advent of 4th-generation x-ray light sources offers transformative opportunities for conducting *in situ*/*operando* studies on the structural evolution of nanoparticles in reactive liquid or gas environments. In this study, we demonstrate how Bragg Coherent x-ray Diffraction Imaging (BCDI) [1–3] enables direct probing of the strain fields, lattice deformations, and defect dynamics within palladium (Pd) nanocrystals under gas-phase hydrogenation reactions.

Palladium's unique hydrogen absorption properties underpin its widespread applications in water electrolysis, catalysis, hydrogen storage, and hydrogen sensing technologies [4]. However, key questions remain about the fundamental mechanisms governing hydrogen uptake, hydride nucleation, and the nanoscale dynamics of the hydrogen-poor (α) to the hydrogen-rich (β) phase transition in Pd crystals.

We systematically investigate the interplay between hydrogen partial pressure and lattice response at room temperature, using *in situ* BCDI, resolving strain and lattice parameter distributions with nanometer precision. The measurements have been performed at the ID01 beamline of the ESRF synchrotron. By tracking the kinetics of individual Pd nanoparticles during the α-to-β phase transition, we investigated how the particle responds structurally to varying hydrogen partial pressures. Our results reveal how lattice strain, defects, and phase nucleation evolve locally across the particle during the α–β transition, providing insights into hydrogen absorption dynamics at the nanoscale as shown in Figure 1. Our analysis addresses open questions regarding hydride nucleation mechanisms whether they initiate preferentially at defect or strained sites or uniformly across the nanoparticle surface and elucidates whether the α/β phase transformation occurs through sharp transitions or two-phase coexistence.

This work demonstrates the capability of BCDI to visualize structural dynamics in reactive environments, advancing our understanding of phase transformations in Pd systems and laying the foundation for optimizing Pd-based materials for energy conversion and storage applications. These insights also contribute to broader efforts in nanomaterials science to correlate nanoscale structure and functionality under operating conditions.

This research was supported by the European Research Council (ERC) under the Horizon 2020 research and innovation programme, grant agreement CARINE No. 818823.

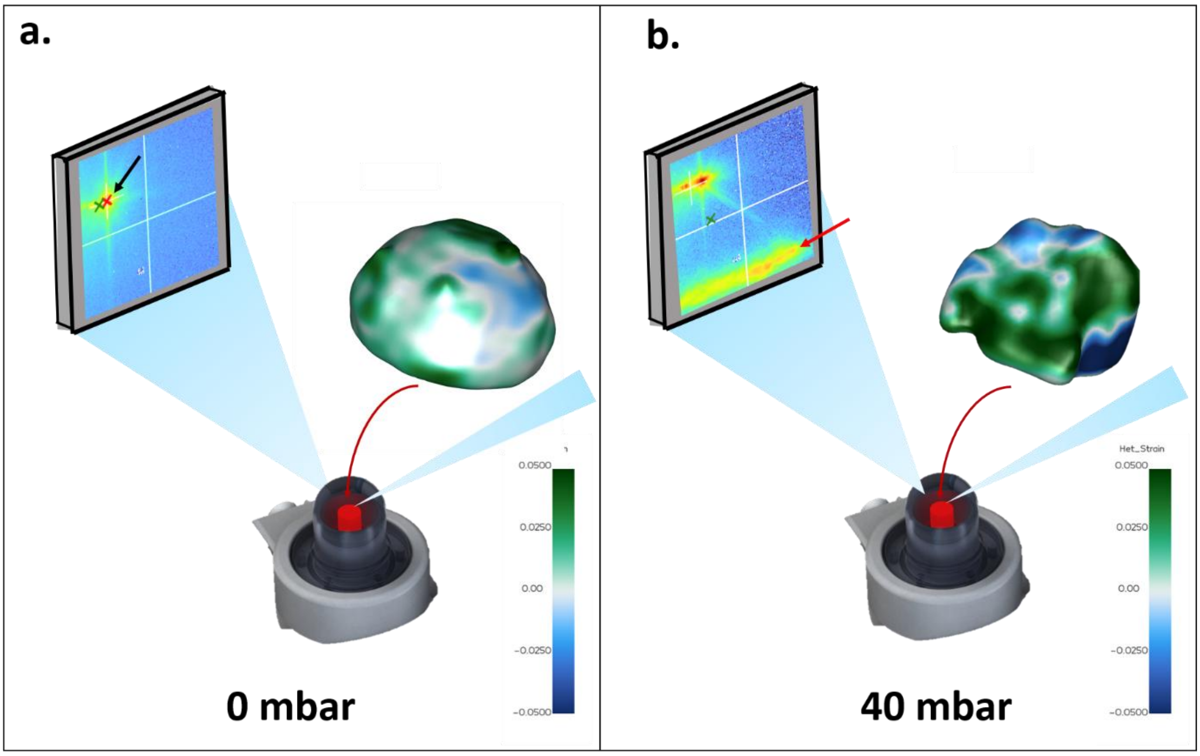

Figure 1: Scheme of the furnace and BCDI technique, along with reconstructed particles under different applied hydrogen partial pressures. (a) Particle at 0 mbar, where only the α phase (indicated by the black arrow on the left detector) is present. (b) Same particle at 40 mbar, showing the coexistence of both alpha and β phase (red arrow on the right detector) simultaneously.

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Probing the Thermally Activated Magnetisation Dynamics in Patterned Arrays

T.P.A. Hase[1], N. Strandqvist[2], A. Stamatelatos[1], C. Vantaraki[2], V. Kapaklis[2] and O. Bikondoa[1,3]

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ABSTRACT

Arrays of nanoscale magnetic elements, each acting as a single mesospin, are the building blocks of artificial spin systems in which the mesospin and lattice geometry can be used to design emergent mesoscale magnetic order. The geometry of the mesospins coupled with their spacing determine their magnetic dimensionality and temperature dependent interactions which define the global ordering and thermally driven dynamics of the array [1].

Here, we focus on Ising chains of elliptical islands as well as square artificial spin ice (SASI) structures. The different mesospin gaps generate varying coupling strengths at the vertices which compete with the thermally active Fe/Pd base material to drive the collective array behaviour. As a function of increasing temperature, the rate of island reversals or flips increases, introducing defects into the arrays and reducing the magnetic correlations over characteristic timescales. Direct imaging using PEEM is limited for fluctuating systems, so here we use a different approach and combine coherent magnetic scattering with x-ray photon correlation spectroscopy (XPCS) to probe the spatial and temporal variations of the magnetic super-structure. We present the dynamic evolution of Ising chains and SASI arrays at different length scales using coherent scattering and record the speckles produced from the dynamic array configurations. In the SASI, the ground state is ordered with a magnetic configuration comprising two mesospins pointing in and two mesospins pointing away from a vertex. This configuration results in a doubling of the charge unit cell and magnetic scattering being found in-between the diffraction peaks from the long-range order of the islands. Island reversals drive the system away from an ordered ground state with excited vertex states giving scattering around the structural Bragg peaks. The intensity and spatial extent of the magnetic scattering is measured across the temperature window between blocking temperature (fixed by the Zeeman and shape anisotropy) of the mesospin and the Curie temperature of the Fe/Pd. In this temperature window, thermodynamically metastable phases occur [2-5], which include both intra- and inter-Island magnetic excitations. This ongoing study yields new insights into the dynamics of magnetic excitations in these arrays, with both high spatial and temporal resolution.

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Fourier Transform Holography of Magnetic Textures Employing Soft X-rays with Orbital Angular Momentum

P. Carrara,[1,2] H. Popescu,[3] F. Fortuna,[4] M. Pancaldi,[5,6] R. Delaunay,[7] B. Roesner,[8] J. Vila-Comamala, [8] I. Bykova, [8] C. David, [8] N. Jaouen[3] and M. Sacchi[1,3]

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ABSTRACT

Besides circular polarization, which encodes a Spin Angular Momentum (SAM), Laguerre-Gaussian beams also carry Orbital Angular Momentum (OAM), amounting to $\ell\hbar$ per photon, due to an azimuthal dependence in the electric-field phase of the form $\exp(i\ell\varphi)$ [1]. As the OAM index ℓ defines a set of orthogonal modes, OAM beams found application in high-bandwidth optical data transfer [2]; their ability to exert mechanical torque has been employed in optical spanners for manipulation of micro-particles [3], and their radial intensity dependence led to improved resolution and contrast in microscopy and imaging [4-5]. Analogous to Magnetic Circular Dichroism, the intrinsic handedness of OAM beams also found spectroscopic applications, *e.g.* with chiral molecules [6] and magnetic materials [7-8], benefiting from extension into EUV and soft x-ray range thanks to core-level electronic resonances, sharper focusing capabilities, and the availability of intense and ultra-short OAM pulses at large-scale facilities [9] and lab-based sources [10].

I will present some recent results on the employment of OAM light beams applied to magnetic material: resonant soft x-ray Fourier Transform Holography in transmission from thin magnetic films possibly reveals enhanced contrast arising from the light structuration in intensity and in phase. I will also present a second experiment, to be performed the next future, which explores the employ of an optical Transient-Grating setup to gate the synchrotron pulses and to generate short 10-ps soft x-ray pulses with on-demand OAM charge.

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In Situ Bragg Coherent Diffraction Imaging From Energy Materials

M-I. Richard[1,2], E. Bellec[2], C. Atlan[2], C. Chatelier[1,2], M. Grimes[1,2], M. Bouita[1,2], P. Khater[1,2], T. Sarrazin[1,2], M. Levi[3], E. Rabkin[3], S. Leake[2], T. Schülli[2], S. Labat[4]

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ABSTRACT

The emergence of 4th generation x-ray light sources offers an unparalleled opportunity for conducting ***in situ*** and ***operando*** studies of nanoparticle structures in complex environments, especially in the field of energy materials. Gaining insights into the dynamic strain behavior of catalysts is critical for developing cost-effective, efficient, and long-lasting catalytic systems. In this talk, I will demonstrate how **Bragg coherent x-ray imaging (BCDI)** [1] enables three-dimensional (3D) nanoscale imaging of strain, defect dynamics, and re-faceting processes within nanoparticles during catalytic reactions.

For instance, we successfully mapped the 3D lattice displacements and strain distribution of a platinum (Pt) nanoparticle under electrochemical conditions [2] and during CO oxidation [3,4]. More recently, we achieved sub-second time resolution during ***operando*** chemical reactions, detecting oscillatory strain changes with a 6.4-second periodicity, directly associated with site-specific CO adsorption during oxidation [5], with a benchmark resolution of 0.25 seconds.

Additionally, I will present our latest findings on the core-shell transition in NiFe catalysts during annealing [6], discuss the potential of measuring particles as small as 20 nm [7], demonstrate high-energy imaging of embedded materials [8] using BCDI and show how charge-integrating detectors can improve the spatial and temporal resolutions of BCDI [9].

We acknowledge funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme under grant agreement CARINE No. 818823.

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HoToPy: A Toolbox for X-ray Holo-tomography in Python

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ABSTRACT

The ability of X-ray radiation to penetrate matter is key to its use as a non-destructive probe for the inner structure of objects, materials and tissues, by ways of computed tomography. For samples with vanishing absorption contrast, lens-less X-ray phase contrast imaging (XPCI) is an unique tool, that is adopted on a growing number of beamlines. Recent cutting edge examples are as diverse as nanoimaging of neuronal tissue for connectomics [3,4], morphological transitions of nanoparticles [5,6], or ultrafast imaging of hydrodynamics at X-ray free electron lasers (XFELs) for cavitation [7]. Rapidly evolving X-ray imaging capabilities by advances on instrumental side (photon counting detectors, fourth-generation sources) as well as on the analysis and reconstruction side (e.g. automated segmentation with machine learning), demand specialized software for efficient and high-quality phase retrieval in XPCI, in particular in the high resolution full-field variant of holographic tomography (holo-tomography).

To this end, we present *HoToPy* [1], a Python-based toolbox for X-ray holo-tomography. It features a state-of-the-art phase retrieval algorithms for the deeply holographic and direct contrast imaging regimes, including nonlinear approaches and extended choices of regularization and constraint sets [2]. By using recent optimization methods, automatic differentiation, popularized by machine learning, and fully differentiable forward operators, we enable straightforward extensions and modifications to the problem of phase retrieval. Examples are the addition of a (smoothed) total variation regularization or structured illumination, while still being able to apply (non-smooth) objects constraints, such as a compact support or range constraints. Furthermore, HoToPy features auxiliary functions for iterative tomographic alignment, image processing, and simulation of imaging experiments.

We demonstrate HoToPy's capabilities and discuss current developments and challenges in phase retrieval on data recorded with the 'GINIX' instrument of the P10 beamline at the PETRA III storage ring (DESY, Hamburg).

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Tomoptychographies des Eléments Constitutifs d'un Composite à Matrice Organique Utilisé dans l'Aéronautique

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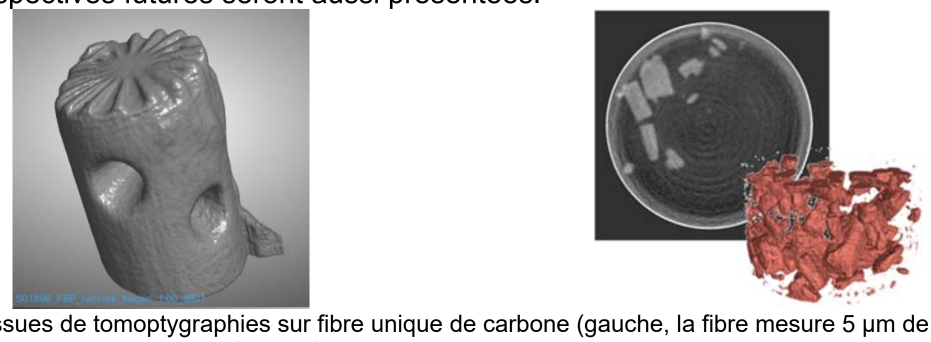
Les matériaux composites à matrice organique, majoritairement faits de fibre de carbone et d'une matrice polymère, sont un des matériaux clefs pour réduire le poids des aéronefs et contribuer à la réduction des émissions carbonées dans l'industrie aéronautique. Une meilleure utilisation de ces matériaux passe par une meilleure connaissance de leur éléments constitutif (fibre de carbone pour le renfort et polymère pour la matrice).

On présente ici des expertises de ceux-ci, réalisées par tomoptychographie obtenues sur synchrotron (Soleil, ligne SWING, 8 keV).

Sur fibre de carbone, des valeurs absolues locales de densité électronique ont été obtenues de même qu'une analyse de la morphologie de fibre (forme globale et texture de surface). [1] Des travaux des texturation de la fibre de carbone par FIB ont également été réalisés pour améliorer les résolutions (meilleures performances autour de 45 nm) et valider expérimentalement leur calcul, numériquement obtenu par Fourier Shell Correlation.

Sur matrice polymère, la présence d'éléments durcisseurs dans de l'epoxy 'liquide' est observée. Les mesures sont réalisées pour différents niveaux d'avancement de dissolution. La séparation des différents éléments pour réaliser ensuite les mesures physico-chimiques est faite en utilisant des algorithmes d'intelligence artificielle. La fraction volumique en fonction du taux d'avancement est finalement évaluée. D'autres analyses sont en cours.

Les perspectives futures seront aussi présentées.



Images issues de tomoptygraphies sur fibre unique de carbone (gauche, la fibre mesure 5 µm de diamètre) et sur mélange biphasique durcisseur/epoxy (droite, image globale des deux phases et visualisation volumique de la phase durcisseur uniquement) utilisés dans la conception de matériaux composites pour l'aéronautique.

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ABSTRACTS

Thursday, October 9th, 2025

GDR-CohereX 2025

Thursday, October 9th

IT-07	Imaging the magnetic vector field in thick samples using coherent scattering ***Marisel di Pietro Martinez***
OC-07	Nanosecond XPCS with two-dimensional X-ray detector ***Yuriy Chushkin***
IT-08	Reaching the yield point of glasses with X-ray irradiation ***Alessandro Martinelli***
OC-08	Multi Bragg coherent X-ray diffraction imaging of strain and defect dynamics in unconventionally oriented catalytic nanoparticles ***Mouad Bouita***

Imaging the Magnetic Vector Field in Thick Samples using Coherent Scattering

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ABSTRACT

In recent years, there has been a growing interest from the magnetism community in expanding to three-dimensional magnetic systems [1,2] – from exploring new geometries to revealing complex magnetic textures arising in extended samples [3-5]. A key aspect of this exploration is the ability to visualize the magnetization vector field at the nanoscale throughout the entire sample, made possible by the development of 3D magnetic imaging [6]. This technique can achieve nanometric spatial resolution in micrometer-thick samples by leveraging the penetration depth and coherence of synchrotron X-rays [7,8,9]. Indeed, the coherence of the X-ray beam provides magnetic contrast not only in the absorption of the transmitted wave, but also in the phase. This phase contrast enables the investigation of micron-sizes magnets, even with soft X-rays, while minimizing the sample damage [7]. Here, we present a new tomographic technique [9] based on Fourier transform holography, a lensless imaging technique that uses a known reference in the sample to retrieve the object of interest from its diffraction pattern in one single step of calculation. We obtain a 3D vectorial image of an 850nm-thick extended Fe/Gd multilayer in a 5μm-diameter field of view with a resolution of 80 nm. Visualizing the magnetization vector field with nanometer spatial resolution in extended samples opens the door to studying magnetic textures in higher dimensions, offering insights into fundamental physical phenomena as well as promising new applications in information storage and processing.

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Nanosecond XPCS with Two-dimensional X-ray Detector

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ABSTRACT

The fastest pixel array X-ray detectors can record images with nanosecond resolution. This is accomplished by storing only a few images in in-pixel memory cells. In this study, we demonstrate the nanosecond resolution over a large number of images by operating a prototype detector TEMPUS in an event driven mode (1). The performance of this mode is tested by measuring the Brownian dynamics of colloidal nanoparticles. We can achieve sub-100 ns time resolution and overcome the pixel dead time by applying a cross-correlation analysis of the neighboring pixels (2). The detector and the approach used in this work are not only suitable for fast XPCS measurements with ESRS-EBS (3) but can also be extended to study time-resolved fast processes with diffraction, scattering, or imaging techniques.

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Reaching the Yield Point of Glasses with X-ray Irradiation

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ABSTRACT

A solid loaded beyond the yield stress loses its elastic properties and becomes plastic. From a microscopic point of view, this corresponds to the condition where plastic regions become so densely packed to give rise to system-spanning structures [1]. This limit for glasses is abrupt, which makes experimental investigations challenging: Brittle glasses exhibit mechanical failure at yield and the transition is strongly dependent on the glass history and preparation protocol [2].

In this talk I present recent experimental results on atomic glasses, combining X-ray Photon Correlation Spectroscopy [3,4] with Fast Scanning Calorimetry [5]. I show that absorbed X-rays create point defects that behave as plastic regions, with their number directly controlled by the irradiation dose.

By following the atomic length-scale dynamics as a function of the exchanged momentum, it is possible to distinguish different regimes: at low defect densities, the defects behave as isolated plastic zones that induce displacements typical of an elastic solid (i.e., ballistic-like dynamics). As defect density increases, the mechanical response of the glass shifts gradually from elastic to more and more plastic behavior, characterized by non-diffusive atomic motion. Eventually, the system approaches a limit where the dynamical properties resemble the ones of a flowing system, marking the reaching of the yield point.

Fast Scanning Calorimetry evidences concurrent shift in thermodynamic properties: the yielded glasses exhibit higher enthalpy than annealed ones, with their state closely matching that of glasses instantaneously quenched from a temperature ~20% above the glass transition.

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Multi Bragg Coherent X-ray Diffraction Imaging of Strain and Defect Dynamics in Unconventionally Oriented Catalytic Nanoparticles

M. Bouita[1,2], P. Khater[1,2], T. Sarrazin[1,2], E. Bellec[2], M. Levi[3], E. Rabkin[3], S. Leake[2], S. Labat[4] and M-I. Richard[1,2]

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ABSTRACT

Mass particle compression is a synthetic approach that can lead to the formation of either oligocrystals or nanoparticles exhibiting unconventional crystallographic orientations, which are different from the typical [111] direction observed in platinum. This process sometimes results in the emergence of vicinal surfaces (Figure 1a). In addition, some particles may contain lattice dislocations (Figure 1b). These structural features are known to enhance catalytic activity by introducing strain fields and generating active sites at the nanoscale. In this study, we use multi-reflection Bragg coherent diffraction imaging (m-BCDI) [1–4] to fully characterize the internal structure of platinum (Pt) particles, focusing particularly on those displaying vicinal surfaces or lattice dislocations. By measuring several Bragg reflections on the same crystal (Figure 1), we reconstructed the complete three-dimensional strain, rotation and stress tensors within individual particles. The experiments were performed at the ID01 beamline of the European Synchrotron Radiation Facility (ESRF), leveraging the capabilities of the fourth-generation synchrotron source, which offers enhanced brightness and coherence. These features allowed us to monitor the structural evolution of platinum nanoparticles in real time under catalytic conditions. We followed the development of strain, lattice deformation, and defect dynamics during both thermal treatment and *operando* CO oxidation. These findings provide critical insights into the structure–reactivity relationships in nanostructured catalysts and underscore the capabilities of multi-BCDI for probing functional materials at the nanoscale.
This research was supported by the European Research Council (ERC) under the Horizon 2020 research and innovation program, grant agreement CARINE N0. 818823.

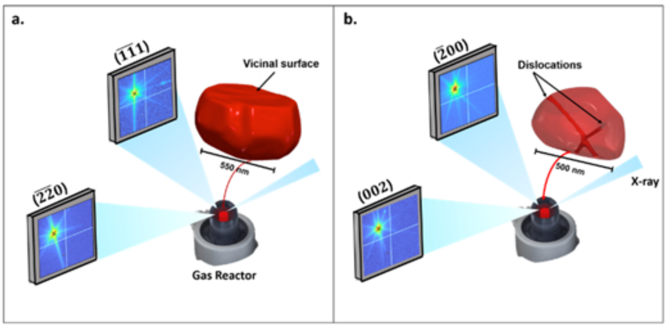

Figure1: Reconstructed platinum particles with a- vicinal surface and b- dislocations, using multi-BCDI (only the amplitude is displayed).

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POSTERS SESSION

List of Posters

PO-01 Coherent diffraction imaging at the CRISTAL beamline

Pierre Fertey *- Synchrotron SOLEIL, Saint-Aubin, France*

PO-02 Advancing coherent X-ray science with high-speed detection and seamless data processing

Sascha Grimm *- DECTRIS, Baden, Switzerland*

PO-03 Pushing the limits of EELS with the new Iliad EELS spectrometer

Arno Meingast *- Thermo Fisher Scientific, Eindhoven, The Netherlands*

PO-04 Soft X-ray (coherent) scattering for magnetic studies

Horia Popescu *- Synchrotron SOLEIL, Saint Aubin, France*

PO-05 Synchrotron-based studies of self-assembled biogenic photonic crystals

Vinodkumar Saranathan *- IRBI, Université de Tours, France*

PO-06 Implementation of ptychography workflow at the HERMES beamline

Stefan Stanescu *- Synchrotron SOLEIL, Saint Aubin, France*

Coherent Diffraction Imaging at the CRISTAL beamline

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ABSTRACT

CRISTAL is a hard X-ray diffraction beamline dedicated to the study of the structural properties of matter at different length scales, ranging from sub angstromic to millimetric lengthes, possibly in non-ambient conditions.

Coherent Diffraction Imaging in Bragg conditions (BCDI) is one of the techniques proposed to the users among a large panel. A dedicated setup displayed on Figure 1 is used, based on a piezo-goniometer installed in front a Fresnel Zone Plates focusing optics. The setup is optimized to work at 7 keV, 8.5 keV and 10 keV. The goniometer has 2 rotation degrees of freedom and allows mapping of the sample over a volume of about 1 cm3. Due to the maximum loading weight compatible with the piezo-goniometer (150 g), a limited number of sample environments are accessible. In particular, a specially designed reactor for heterogeneous catalysis at atmospheric pressure can be mounted on the piezo goniometer [1].

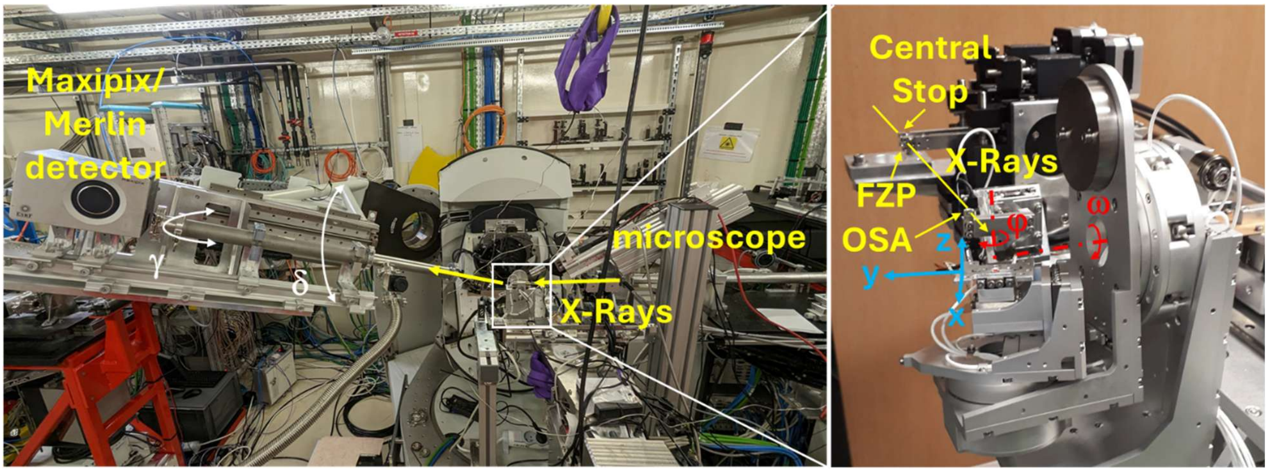

Figure 1: BCDI setup at the CRISTAL beamline

Several examples [2,3] illustrating the possibilities and performances of the BCDI setup at CRISTAL will be presented.

In the context of the upgrade of the SOLEIL source, perspective of the coherent diffraction imaging activity at the CRISTAL beamline will be detailed.

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Advancing Coherent X-ray Science with High-speed Detection and Seamless Data Processing

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ABSTRACT

The unprecedented coherent flux of 4th-generation synchrotron sources demands equally advanced detection and data analysis tools. DECTRIS addresses this challenge with high-speed, noise-free photon-counting detectors — PILATUS4 [1], EIGER2 [2], and the new SELUN [3]— that combine high dynamic range with kilohertz to 100-kHz frame rates. These capabilities enable efficient data collection for ptychography, coherent diffraction imaging, and time-resolved scattering.

In the R&D pipeline, DECTRIS is pushing photon-counting technology into the low-energy range around 1 keV, expanding coherent X-ray methods into the soft X-ray regime, and developing real-time feedback pipelines for ptychography, allowing users to iteratively optimize experiments during acquisition. In parallel, DECTRIS pursues charge-integrating detection with the JUNGFRAU, designed to handle high instantaneous flux through adaptive gain switching, providing both single-photon sensitivity and large dynamic range. Together, these developments target critical bottlenecks of modern synchrotron science from soft X-ray detection to mitigating radiation damage through faster acquisitions, and managing the massive data volumes generated by upgraded sources. Here we demonstrate these advances with measurements at BESSY II, Diamond Light Source, MAX IV, and the ESRF.

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Pushing the Limits of EELS with the New Iliad EELS Spectrometer

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ABSTRACT

Electron energy-loss spectroscopy (EELS) in a transmission electron microscope (TEM) is an exceptionally versatile technique that goes far beyond its well-known application in elemental analysis. Analogous to X-ray absorption spectroscopy (XAS) at synchrotron facilities, EELS is based on the ionization of core electrons and provides similar information, while offering the significant advantage of superior spatial resolution.

Historically, the performance of EELS has been limited by chromatic aberrations and distortion, which introduce severe artifacts and signal degradation, thereby restricting the usable energy-loss range to approximately 2 keV.

In this work, we introduce the Iliad platform, featuring a newly designed EELS spectrometer that unlocks powerful new capabilities for nanoscale materials characterization. To ensure optimal performance and high-quality EELS data, we have tightly integrated the optics of the TEM and the EELS spectrometer. This integration minimizes chromatic effects and eliminates the artifacts that traditionally compromise data quality.

Our innovations such as Always-in-Focus technology significantly enhance data fidelity across a broad energy-loss range. Additionally, MultiEELS™ extends the accessible energy range. The improved optical design and seamless coupling of the spectrometer to the microscope column have enabled us to develop Extreme EELS (XEELS™) mode, which allows acquisition of EELS data up to 30 keV [1] previously the exclusive domain of XAS.

This extended energy-loss capability enables retrieval of fine structural information equivalent to XANES and EXAFS, as illustrated in Figure 1.

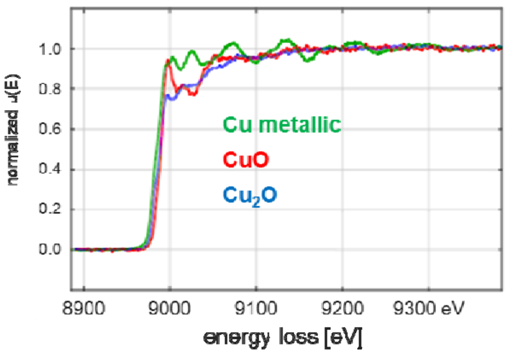

Figure 1. EELS data of metallic Cu, CuO and Cu_2O showing the ELNES (XANES) as well as EXELFS (EXAFS).

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Soft X-ray (coherent) Scattering for Magnetic Studies

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ABSTRACT

Many current forthcoming applications of magnetic materials involve heterostructures or alloys containing magnetic and non-magnetic elements. X-ray Resonant (Coherent) Scattering is the technique of choice to probe such phenomena thanks to its element-selectivity and spatial sensitivity.

In this poster I will introduce the experimental set-up that we developed at SOLEIL and illustrate their capabilities. SEXTANTS [1] is a beamline of the SOLEIL synchrotron, covering the 50-1700eV energy range dedicated to soft x-ray scattering. The resolving power exceeds 10^4 and maximum flux on the sample ranges from 1×10^{14} (100 eV) to 2×10^{13} (1000 eV) ph./s/0.1% bw. The beamline's main objective is the investigation of the electronic and magnetic properties of solids using three scattering techniques: resonant inelastic x-ray scattering (RIXS), x-ray resonant magnetic scattering (XRMS) and coherent x-ray scattering (CXS), the last one including also imaging via Fourier transform holography (FTH) [2].

The coherent scattering is an important aspect at the Sextants beamline and several techniques are now routinely available: coherent imaging using holography and ptychography in transmission and reflectivity, 3D imaging of magnetic domains [3, 4], with 5-10 nm spatial resolution, while keeping the sample under extreme conditions of temperature, magnetic or electric fields, RF or continuous currents. Recent experiments showed the possibility to also create and use OAM beams at the Sextants beamline.

Finaly, the new IR fs laser, 7W, 1 kHz repetition rate, and synchronized with the synchrotron beam, is now available for IR/x-rays pump-probe experiments. Single or custom number of laser pulses is also possible.

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Synchrotron-based Studies of Self-assembled Biogenic Photonic Crystals

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ABSTRACT

Colors in animals can be produced either chemically by pigments or physically by the constructive interference of light scattered by photonic nanostructures and sometimes as a combination. Fade-proof, saturated structural colors have evolved convergently in diverse animal taxa, including birds[1,3], insects and spiders[2,4]. However, given that the underlying nanostructures are overwhelmingly diverse in form and function, their characterization has suffered for over a century. I have pioneered the use of synchrotron Small Angle X-ray Scattering (SAXS) as a high throughput technique to structurally and optically characterize integumentary photonic nanostructures from hundreds of species across diverse animal orders in a comparative fashion[1-4]. This led to the discovery of the first single gyroid crystals in biology within the iridescent green wing scales of certain papilionid and lycaenid butterflies[4], and recently in the feather barbs of the Blue-winged Leafbirds[1]. But broadly, this wealth of structural knowledge has led to the realization that these diverse photonic nanostructures share a unifying theme – they all appear to be self-assembled within cells by lyotropic membrane invagination in insect scales and liquid-liquid phase separation in bird feather barb cells. In this talk, I will broadly summarize how using synchrotron techniques has advanced our current state of knowledge about the structure, function, development and evolution of self-assembled animal structural colors using examples from birds, butterflies, beetles, and bees.

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Implementation of Ptychography Workflow at the HERMES Beamline

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ABSTRACT

Since 2019 HERMES beamline [1] implemented and is continuously optimizing a dedicated setup to perform ptychography experiments and such push the spatial resolution limit beyond the present Fresnel zone plates limitations, i.e. 30 nm. Here we present the mechanical, optical, hardware and software integration of the setup in the STXM instrument, along with the functional workflow from a user perspective. This includes the entire process from setting up the working geometry parameters to the reconstruction process using PyNX [2]. Few examples will be equally presented demonstrating the actual capabilities of the setup.

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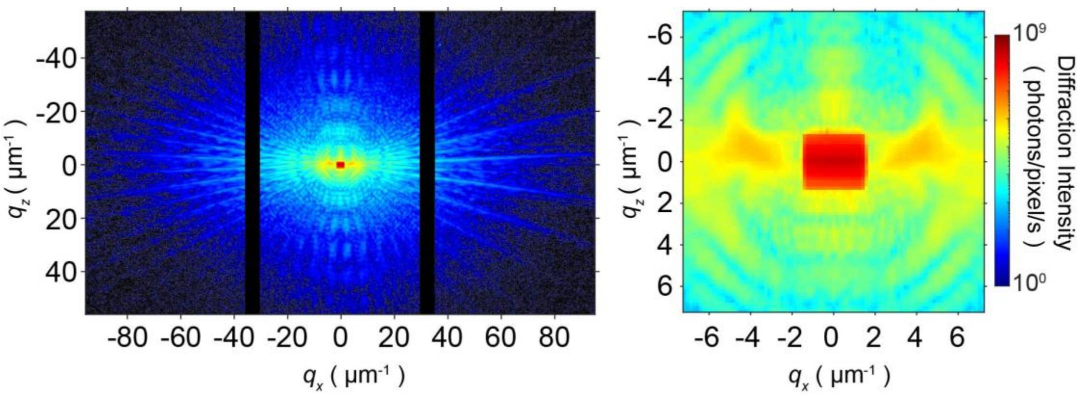

CITIUS used in a ptychography experiment by Takahashi et al. in J. Synchrotron Rad. (2023). 30, 989–994 showing the direct beam alongside lower intensity diffracted X-rays. The maximum intensity was ~250 Mcps pixel^{-1} at 6 keV.

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