Magnetism, Correlated Systems and X-rays

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Abstracts

Nanomagnetism in the X-Ray Spotlight at MAXYMUS

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X-ray microscopy allows the application of powerful spectroscopic techniques in length scales far smaller than possible with optical microcopy. Near Edge X-ray Absorption Fine Structure (NEXAFS) allows element and chemically sensitive imaging, while X-ray Circular Magnetic Dichroism (XMCD) allows direct, highly sensitive detection of sample magnetization.

These contrast mechanisms at spatial resolutions of below 15 nm [1], and even better using emergent techniques like ptychography [2], combined with the possibility of using the time structure of synchrotron light for pump- and- probe imaging with time resolutions of <50 ps make X-ray microscopy a powerful tool.

This combination of lateral and temporal resolution and magnetic contrast is especially useful for the investigation of magnetic phenomena on the nanoscale [3-5]. One example is the investigation of skyrmions and their motion [3, 4]. Another example is magnonics, *i.e.* the manipulation of spin waves, which has gained significant scientific interest in the past years [5]. These nanostructures have great potential for technological applications in data processing and storage, and spintronics [3-5]. By use of advanced X-ray microscopy with XMCD contrast, emergent magnetic phenomena can be directly imaged and observed in real space on a scale that goes beyond the capabilities of any other technique.

[1] W. Chao *et al.*: Nature 435 (2005) 1210.
[2] D. A. Shapiro *et al.*: Nature Photonics 8 (2014) 765.
[3] S. Woo *et al.*: Nature Materials 15 (2016) 501.
[4] K. Litzius *et al.*: Nature Physics 13 (2017) 170.
[5] S. Wintz *et al.*: Nature Nanotechnology 11 (2016) 948.

Coherent X-ray Scattering on magnetic material: Insight into spatial and temporal correlations

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Advanced Light Source, Berkeley

With the advent of diffraction limited light sources, coherent X-rays will play an important role in understanding and characterizing nanoscale magnetic surfaces and interfaces with unique and novel spin textures. Diffuse scattering due to coherent X-rays give rise to speckle pattern due to interference of scattered wave fronts that are randomly phase shifted by the morphology of the sample. In this talk I will show various examples to demonstrate how speckle pattern enable us to

undertake studies that provide insight into spatial and temporal correlation of magnetic and electronic features in a quantum material. We have used X-ray Photon Correlation Spectroscopy (XPCS) to study temporal fluctuation of domain walls in an artificial square lattice and determined the nature of the motion. I will discuss our use of coherent X-ray scattering in the stripe and skyrmion phase to obtain speckle patterns that can be used to determine domain cascades and avalanches. Using existing framework of statistical mechanics we were able to extract scaling laws for the avalanches in the stripe and skyrmion phases. Finally, I will briefly show our recent studies on generating soft X-ray orbital angular momentum beams that has the potential to unravel new information about quantum properties in materials.

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Soft X ray magnetic microscopy and tomography

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Soft X ray transmission microscopy with circularly polarized photons tuned at specific resonant energies allows to image magnetic textures by exploiting the dichroic absorption contrast which depends on the angle of the magnetization and X-ray beam. Changing their relative orientations allows determining the orientation of the magnetization of the sample [1]. Using this method, we investigated dynamical aspects of the inversion of the magnetization in thin ferromagnetic films with stripe domains. In addition, a recently developed 3D magnetic tomography technique [2], allowing to reconstruct the magnetization at ~ 30 nm resolution and to localize magnetic singularities in thin films (thickness up to ~300 nm) will be described.

[1] C. Blanco-Roldan, et al.,Nat Comm. (2015) - DOI: 10.1038/ncomms9196
[2] A. Hierro-Rodriguez, J. Synchrotron Rad.(2018) 24, 1144

Some highlights on scientific cases, instrument developments and challenges at ALBA beamline for soft x-ray absorption spectroscopy and scattering

Manuel Valvidares,
BOREAS beamline ALBA, Barcelona

This talk will provide an overview of BOREAS beamline at ALBA, very briefly highlighting some experiments using spectroscopic or scattering approaches. At BOREAS, experiments use either the beamline XMCD vector cryomagnet or a multipurpose UHV reflectometer in combination with x-ray photons of energy on the range of 100 eV to 4000 eV (VLS-grating monochromator) and full-polarization control (Apple II EPU). Examples of studies range from in-situ investigation of the magnetism of isolated atoms or single molecules, to the properties of oxide materials in thin-film or bulk crystal form, topological insulators, or hybrid ferromagnetic -2D materials such as Graphene. A brief account on main experiment topics, statistics and productivity will be provided. The second part of the talk will have an emphasis on scattering, and will present details on the instrument developed, remarking challenges addressed or remaining. Present limitations and directions for on-going or future development will be briefly discussed.

Magnetism and x-rays

Olle Eriksson,
Uppsala University, Uppsala

In this talk I will provide a brief description of the current status of electronic structure theory, and how one can gradually tune the level of sophistication and accuracy of the calculation to a desired precision. I particular I will make a brief overview of how dynamical mean field theory can be used for correlated electronic structures, and I will give examples among complex oxides and f-electron systems. The possibility of extracting spin-resolved information will be discussed and comparisons between theory and experiment of spin-projected energy dispersion of transition metal systems will be given. Finally, the possibility of extending the theoretical concepts to provide a theoretical tool appropriate for XAS, XPS and RIXS will be given and the potential of using these probes to investigate spin-dependent phenomena will be discussed.

Materials informatics for X-ray spectroscopy

R. Matthias Geilhufe[1], Stanislav Borysov[2], Bart Olsthoorn[1], Roberto Díaz Pérez[1], *Johan Hellsvik*[1*], Martin Månsson[3], Alexander V. Balatsky[1]

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The Organic Materials Database (OMDB) [1] is an open database at Nordita that is hosting about 25,000 electronic band structures, density of states and other properties for synthesized 3-dimensional organic crystals. The web interface of the OMDB, https://mathub.io/, offers search tools for the identification of novel functional materials such as band structure pattern matching and density of states similarity search, enabling the prediction of novel functional organic materials [2]. Here we explore mechanisms of protection and formation of electronic band structure Dirac nodes and semimetallicity, properties that can be investigated with X-ray Spin-ARPES. Currently we are implementing a new functionality of the OMDB to include search and prediction of magnetic excitations. New search tool connects OMDB to inelastic scattering experiments such as resonant inelastic X-ray scattering (RIXS) and inelastic neutron scattering (INS). In this talk I will introduce a new dataset containing atomic magnetic moments and Heisenberg exchange parameters for which we calculate the spin wave spectra $\omega(Q)$ and dynamic structure factor $S(Q,\omega)$ with linear spin wave theory and atomistic spin dynamics.

[1] S. S. Borysov, R. M. Geilhufe, & A. V. Balatsky, PloS one 12.2 (2017): e0171501.
[2] S. S. Borysov, et al., Npj Computational Materials 4.1 (2018): 46.
[3] R. M. Geilhufe, et al., Scientific reports 7.1 (2017): 7298.
[4] R. M. Geilhufe, B. Commeau, & G. W. Fernando, physica status solidi (RRL)–Rapid Research Letters (2018)

Pushing frontiers: probe and sample length scales

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Lund University, Lund

As the performance of synchrotrons increases it becomes possible to look at scattering from ever smaller units. In the biological world, the push this has been pushed down to individual virus level. In the magnetic world, smaller lengthscales appear in nanoparticles most explicitly, but also in short-range-ordered features. In this talk, I will look at the prospects for investigating both of these cases, and the different challenges that apply. I will also discuss the experimental opportunities arising from a significant partially coherent beam.

X-ray Resonant Scattering Exploits: Diffraction, Spectroscopy and Imaging

Danny Mannix
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3rd Generation synchrotron sources commenced a quarter of a century ago with the ESRF in Grenoble France. These light sources offered a significant enhancement in photon flux, that allowed the development of new advanced tools for the systematic investigation of magnetic and electronic phenomena with X-ray scattering. This impressive suite of techniques currently extends to, X-ray Magnetic Diffraction with polarization analysis, X-ray resonant surface magnetic scattering, Soft X-ray Resonant Magnetic Scattering, Resonant Inelastic X-ray Scattering, Time-Resolved X-ray Resonant scattering, X-ray Photon Correlation Spectroscopy and Coherent X-ray Diffraction Imaging methods applied magnetic materials. The new 4th generation synchrotrons sources, starting with MAX-IV, with their enhanced coherent and nanobeam X-ray flux, will offer new opportunities to further develop state of the art probes of magnetic and correlated electron materials. In this talk, I will discuss X-ray Resonant Scattering methods applied to the study of magnetic nanomaterials, with Diffraction and RIXS studies of strongly correlated electron phenomena in iridate compounds and Coherent Diffraction Imaging methods exploited to reveal Skyrmion type topological magnetic states.