TUT 3: Tutorial: Into the Third (and Fourth) Dimension: Imaging Methods for 3D Nanomagnetism (joint session MA/TUT)

Nanostructured magnetic materials have found several applications in everyday objects, such as data storage devices, sensors, and biomedical devices. When one brings these materials to the third dimension, a variety of new physics, and opportunities for applications appear. However, until recently, the vast majority of experimental investigations have primarily been focused on 2D planar geometries, as 3D systems provide a set of experimental challenges that still needs to be overcome. This tutorial seeks to provide a comprehensive overview for both experts and non-experts in the field of 3D imaging to gain a deeper understanding of the recent advances and experimental challenges connected to the investigation of 3D magnetic systems.

Organized by Claire Donnelly (MPI-CPFS, Dresden, Germany) and Simone Finizio (Paul Scherrer Institut, Villigen, Switzerland).

Time: Sunday 16:00–18:15 Location: H4

Tutorial TUT 3.1 Sun 16:00 H4

3D Magnetic Imaging: Utilizing Synchrotron X-Ray Coherence for Nanometric Resolution in Thick Samples — •Marisel Di Pietro Martinez — Max Planck Institute for Chemical Physics of Solids, 01187 Dresden, Germany — International Institute for Sustainability with Knotted Chiral Meta Matter (WPI-SKCM2)

In recent years, there has been a growing interest from the magnetism community in expanding to three-dimensional magnetic systems - from exploring new geometries to revealing complex magnetic textures arising in micrometer-thick samples. 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. This technique can achieve nanometric spatial resolution in micrometer-thick samples by leveraging the penetration depth and coherence of synchrotron X-rays. Furthermore, 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. In this tutorial, I will introduce how to exploit these advantages using coherence-based techniques, such as Fourier transform holography and ptychography, to perform 3D magnetic imaging. Visualizing the magnetization vector field with nanometer spatial resolution in micrometer thick 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.

Tutorial TUT 3.2 Sun 16:45 H4

Nanoscale Mapping of Magnetic Textures in 3D Using Vector Field Electron Tomography — •Axel Lubk[1,2] and Daniel Wolf[1] — [1]Leibniz Institute for Solid State and Materials Research, Dresden, Germany — [2]Institute of Solid State and Materials Physics, TU Dresden, Germany

Vector field Electron Tomography (VFET) combines Electron Holography and Electron Tomography in the Transmission Electron Microscope (TEM) to reconstruct magnetic induction vector fields in 3D down to several nanometer resolution. In this tutorial we discuss the foundations of the technique, the practical workflow including pitfalls, and application to topical examples in nanomagnetism including domain walls in nanowires and skyrmion strings.

Tutorial TUT 3.3 Sun 17:30 H4

3D magnetic imaging: an experimental window to study 3D magnetization at the nanoscale — •Aurelio Hierro-Rodriguez — Department of Physics, University of Oviedo,33007, Oviedo, Spain — CINN (CSIC-University of Oviedo) , 33940, El Entrego, Spain

The synergetic confluence of technological and scientific developments in nanofabrication and characterization techniques is paving the way towards the advance in Three-Dimensional Nanomagnetism, fuelled by the richness of phenomena and technological potential of the exploitation of the magnetization vector field in their natural dimensionality: three dimensions. In this lecture, a broad picture of the importance of the topic, in the framework of the novel physics that can be explored and exploited will be given, with a brief description of the methods that allow to fabricate almost any 3D magnetic geometry with nanometer resolution. The core of the lecture will deal with the advanced magnetic imaging techniques, which are opening a window towards the characterization of the full three-dimensional magnetization vector. Specifically, X-ray based magnetic vector tomography will be described and exemplified, showing the capabilities of the technique to volume resolve the magnetization vector field in arbitrary systems with nanometer resolution. These developments in vector magnetic imaging are making possible a change in the actual paradigm on how magnetization is characterized and studied at the nanoscale, by bringing a direct experimental probe to realize experimental micromagnetism.