

## PSD Mini Symposium

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### Magnetism and spectromicroscopy

Tuesday, May 14, 2019

10:00 to 11:45, WBGB 019

**10:00 LiY1-xHoxF4: a candidate material for solid-state qubits**

*Adrian Beckert, M. Grimm, G. Matmon, S. Gerber, H. Sigg and G. Aeppli*

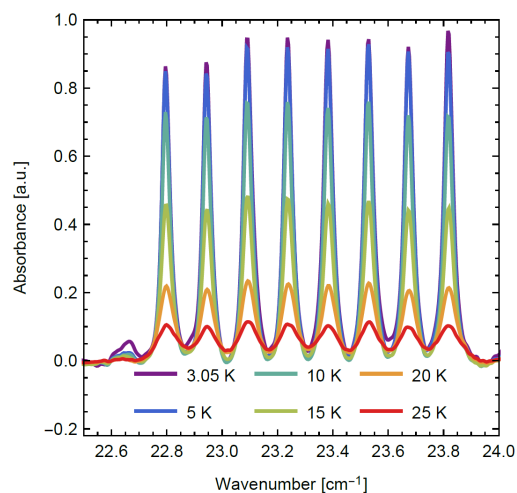
**10:30 Development of a New Soft X-Ray Ptychography Spectro-Microscope at the Swiss Light Source (SLS)**

*Manuel Langer, P. Üresin, S. Chiriotti, D. Bracher, M. Odstrcil, S. Wintz, S. Finizio, M. Guizar-Sicairos, A. Bergamaschi, C. A. F. Vaz, A. Kleibert and J. Raabe*

**11:00 Coffee break**

**11:15 Magnetic characterization of individual cobalt oxide nanooctahedra**

*David Bracher, T. M. Savchenko, M. Testa Anta, V. Salgueiriño, F. Nolting, M. Poggio, A. Kleibert*



# LiY<sub>1-x</sub>Ho<sub>x</sub>F<sub>4</sub>: a candidate material for solid-state qubits

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Rare-earth (RE) doped crystals are promising candidates for quantum technology applications due to their long coherence times, up to hours [1-3], and large magnetic moments which are suitable for fast quantum operations and communication [4]. LiY<sub>1-x</sub>Ho<sub>x</sub>F<sub>4</sub> is a RE model magnet, long known for hosting a plethora of quantum phenomena [5-8]. In the Quantum Technologies Group we focus our attention on LiY<sub>1-x</sub>Ho<sub>x</sub>F<sub>4</sub> as a possible platform for quantum computation. We currently study it by means of ultra-high resolution Fourier transform infrared (FTIR) spectroscopy in combination with high brilliance, high-collimated far-infrared (FIR) synchrotron radiation at the X01DC infrared beamline. This unique combination of ultra-high resolution and FIR synchrotron radiation allows us to determine line shape and width of the Ho<sup>3+</sup> hyperfine-split crystal field levels for low doping concentrations  $x$  and liquid Helium temperatures in the FIR regime, as shown in figure 1. We extract lifetimes and the nature of the decoherence mechanisms. For the low concentration regime, we find the homogeneous line-width contributions associated with the intrinsic lifetime to be below our measurement accuracy, inferring long intrinsic lifetimes. Our next step in this project is the coherent manipulation of two selected electro-nuclear states.

[1] Manjin Zhong et al., Optically addressable nuclear spins in a solid with a six-hour coherence time, *Nature* 517, 177 (2015)

[2] Milos Rancic et al., Coherence time of over a second in a telecom-compatible quantum memory storage-material, *Nature Physics* 14, 50 (2017).

[3] Antonio Ortu et al., Simultaneous coherence enhancement of optical and microwave transitions in solid-state electronic spins, *Nature Materials* 17, 671{675 (2018).

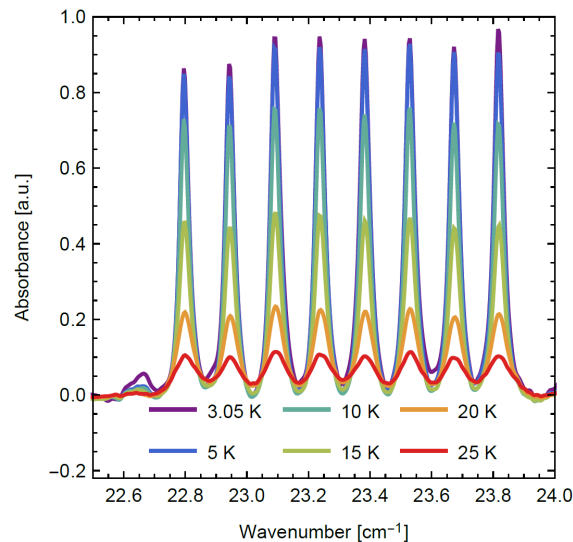
[4] Christoph Simon, Towards a global quantum network, *Nature Photonics* 11, 678{680 (2017).

[5] J. Brooke et al., Quantum Annealing of a Disordered Magnet, *Science* 284, 779{781 (1999).

[6] S. Ghosh et al., Coherent Spin Oscillations in a Disordered Magnet, *Science* 296, 2195{2198 (2002).

[7] S. Ghosh et al., Entangled quantum state of magnetic dipoles, *Nature* 425, 48 (2003).

[8] M. A. Schmidt et al., Using thermal boundary conditions to engineer the quantum state of a



**Figure 1.** FIR absorbance spectrum of the 3rd eightfold-hyperfine-split crystal field state in LiY<sub>1-x</sub>Ho<sub>x</sub>F<sub>4</sub>. For  $x=1\%$  for different temperatures.

## Development of a New Soft X-Ray Ptychography Spectro-Microscope at the Swiss Light Source (SLS)

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Ptychography is a diffractive imaging technique offering the advantages of phase- and amplitude sensitive imaging as well as the overcoming of the resolution of conventional X-ray microscopes towards the limit given by the wavelength of the X-ray light. For the investigation of nanoscaled magnetic systems, the soft X-ray energy range (500 – 2000 eV) is highly relevant, due to the presence of the L2 and L3 edges of 3d transition metals in this energy range and their characteristic high-contrast X-ray magnetic circular dichroism (XMCD).

We are currently developing a new soft X-ray microscope [1] based on ptychography at the SIM beamline at the Swiss Light Source with the goal to provide wavelength-limited spatially-resolved maps of the spectroscopic and magnetic response of a broad variety of materials. For a successful image reconstruction, this technique relies on the acquisition of high-quality diffraction patterns, which are detected in transmission under overlapping illumination. Here, we benefit from the collaboration with the PSI detectors group providing us the *Mönch* detector [2], a low-noise charge integrating hybrid pixel detector, which is incorporated into our setup, offering a high dynamic range with the detection sensitivity on the single-photon level.

We demonstrate the imaging and spectroscopy capabilities of this new ptychography setup on a ferrimagnetic FeGd sample with out-of-plane magnetic domains using the Fe L2 (720 eV) and L3 (707 eV) absorption edges as well as the Gd M5 (1190 eV) edge. Furthermore, we present ptychographic studies of different ensembles of nanoparticles, such as CoO core-shell nanoparticles and BFeO<sub>3</sub> nanoplatelets. Besides, reconstructions of other interesting magnetic structures will be discussed, such as a 50 nm small magnetic vortex core—a magnetic singularity. In addition, we present first data of our recent efforts to realize ptychographic microscopy in reflection geometry.

This setup will be the basis for a dedicated user-friendly end-station that will take full advantage of the upcoming upgrade of the SLS to a diffraction-limited light source. [3]

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[1] Langer, M, *et al.*; *Development of a New Soft X-ray Ptychography Spectro-Microscope at the Swiss Light Source (SLS)*. *Microscopy and Microanalysis* 24(S2), 54-55 (2018);

<https://doi.org/10.1017/S1431927618012709>

[2] Ramilli, M, *et al.*; *Measurements with MÖNCH, a 25 µm pixel pitch hybrid pixel detector*. *Journal of Instrumentation* 12, C01071 (2017);

<https://doi.org/10.1088/1748-0221/12/01/C01071>

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# Magnetic characterization of individual cobalt oxide nanooctahedra

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Antiferromagnetic (AFM) materials become increasingly important for modern spintronics devices such as spin valves, magnetic random access memories, and for the development of novel ultra-hard magnetic materials.[1,2] Antiferromagnetic materials do not exhibit a stray field, which makes their investigation at the nanoscale very challenging. Therefore, important properties of nano-sized antiferromagnets such as their preferred spin axes and their thermal stability are largely unexplored. Here, we use x-ray magnetic linear (XMLD) and circular (XMCD) dichroism spectromicroscopy to investigate the chemical and magnetic properties of individual CoO/Co<sub>3</sub>O<sub>4</sub> core-shell nanoparticles with a diameter of about 100 nm.[3] Complementary high resolution scanning electron microscopy is used to correlate the morphology and the magnetic properties of the very same nanoparticles. Temperature-dependent XMLD spectra of single cobalt oxide nanoparticles indicate a reversible magnetic phase transition of the CoO core close to the Néel temperature of bulk CoO. In addition, we observe a pronounced orientation dependent XMLD signal of the individual nanoparticles, which can be used to determine their spin axis. In addition, by means of XMCD measurements we find uncompensated moments in these nanoparticles exhibiting thermally induced fluctuations at temperatures as low as 100 K, which could indicate respective fluctuations of the antiferromagnetic spin system, which cannot be detected by XMLD alone. Additional measurements will be needed to study the coupling the uncompensated spins and the antiferromagnetic spin lattice.

- [1] V. Baltz, A. Manchon, M. Tsoi, T. Moriyama, T. Ono, and Y. Tserkovnyak, *Reviews of Modern Physics* **90**, 015005 (2018).
- [2] T. Kosub *et al.*, *Nature Communications* **8**, 13985 (2017).
- [3] N. Fontaíña-Troitiño, S. Liébana-Viñas, B. Rodríguez-González, Z.-A. Li, M. Spasova, M. Farle, and V. Salgueiriño, *Nano Letters* **14**, 640 (2014).