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UC7: Ultrafast / Magnetic x-ray scattering

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Understanding ultrafast structural and magnetic dynamics in materials is essential for advancing fields such as spintronics, quantum materials, and laser-driven phase transitions. Time-resolved X-ray scattering techniques at free-electron lasers (XFELs) provide a powerful tool to investigate femtosecond-scale structural and spin-related phenomena in thin films and nanostructures. In particular, the combination of ultrashort infrared (IR) laser pulses as the pump and X-ray free-electron laser (FEL) pulses as the probe enables the direct observation of transient changes in magnetic order and lattice structure on timescales shorter than 100 fs.

In a typical pump-probe experiment, an intense IR laser pulse excites the sample, inducing electronic and structural dynamics, while a delayed FEL pulse probes the resulting changes via X-ray diffraction or resonant magnetic scattering. By systematically varying the time delay between the pump and probe, it is possible to capture the evolution of magnetization, spin textures, and lattice distortions with femtosecond temporal resolution. This approach has been instrumental in revealing light-induced phase transitions, demagnetization dynamics, and the coupling between electronic, magnetic, and structural degrees of freedom.

Our investigation utilizes the European XFEL (Hamburg) and FERMI@ELETTRA (Italy) for time-resolved X-ray scattering experiments to study ultrafast dynamics. Elettra's current Data Policy based on the FAIR principles, which the experimental data and metadata of peer-reviewed experiments are stored in an online catalogue, accessible to registered users after a three-year embargo period. For the detailed analysis, we consider experimental data collected by several scientific groups over several years. Collecting all data in the same format for comparison is a critical step in our research.

To enhance data processing and workflow efficiency, we are also working on Data And Metadata iNspection Interactive Thing (DAMNIT) for the HED beamline at EuXFEL. DAMNIT aims to provide an automated pipeline designed to streamline data organization, processing, and metadata handling for ultrafast X-ray experiments, ensuring robust data handling, metadata extraction, and rapid feedback for experiment optimization. Special consideration is given to the specific requirements of pump-probe experiments, where data acquisition must be synchronized with the optical laser and collected when the shutter is open. Therefore, the system is optimized to address these needs effectively. By integrating DAMNIT with our workflows, we aim to improve data accessibility, reproducibility, and compliance with FAIR principles within DAPHNE4NFDI.

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