Magnetic Excitations and Time Resolved Measurements of the Magnetic Response

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The most remarkable feature of materials based on nanoparticles is the ability to change the mesoscopic and macroscopic behavior over a wide range, so that new materials can be tailored for specific applications. Within these groups of materials the magnetic nanoparticles take a distinguished position. On the one hand their versatility opens potential applications in a wide range of areas, such as magnetic recording, cancer therapy or drug-optimization, on the other hand the understanding of their magnetic behavior is only possible by the description of their dynamical characteristics.

Why time dependent?

It is well known that the macroscopic magnetic behavior of a particle is not only determined by the microscopic coupling but also by the dynamic behavior of magnetic domains and their pinning. Particularly, in the case of particles with a size smaller than the typical domain size or even smaller than the domain wall size the dynamic behavior results in new macroscopic effects like the super paramagnetism. Initial experimental and theoretical studies have shown that the behavior is determined by collective excitations which are called eigenmodes of the system. In contrast to time dependent magnetic optical Kerr effect measurements (MOKE), which are presently used to characterize the eigenmodes, time dependent x-ray magnetic circular dichroism (XMCD) measurements will element selectively probe the magnetic behavior. This allows us to study the influence of the substrate, the anisotropy in multi-element alloys and the behavior of multi-layered systems. Furthermore, the large penetration depth of the hard X-rays ensures that the behavior of the total particle inclusive buried particles will be characterized and not only that of the surface.

Why theory-experiment

We want to emphasize that a successful time dependent XMCD experiment is strongly connected to a theoretical description of the eigenmodes. These models will be based on the inter and intra atomic coupling and will describe the orientation of the individual magnetic moments during a collective excitation. The resonance frequencies of the system will be derived, depending on particle size, temperature, or similar parameters and probed by the time dependent XMCD. By comparing the observed and derived resonance frequencies the model will be refined. Beyond the data analyze the theoretical description helps to define experimental conditions that results in relaxation constants matching the experimental time resolution.

The XMCD-signal

The XMCD-effect is a standard tool to determine the element specific magnetization of a macroscopic sample. Focusing on the hard X-ray range the penetration depth of the X-rays ensures that the entire particle will be probed, even if it is buried. Because the XMCD effect is linearly dependent on the magnetization of the sample projected to the

photon propagation vector, an angular dependent measurement will independently test the in-plane and out-of-plane magnetization components.
To ensure an effective use of the available beamtime we propose the combination of measurements with and without spatial resolution (microscope with resolution ~100nm or better). The measurements of the integral magnetization should probe the three components of the magnetization and will provide a first base for the theoretical model. One complete measurement will take about 1 hour so that a huge throughput can be done. The theoretical model will be tested by determining the spatial and temporal response. This microscopic experiment will focus on the out-of-plane component of the magnetization.