Magnetic fluctuations in a thin holmium film measured with soft x-ray photon correlation spectroscopy

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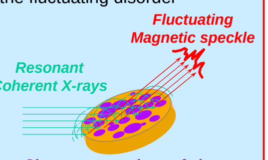
Introduction

If coherent light is scattered from a disordered sample it will produce a random diffraction pattern (**speckle pattern**) which is related to the exact instantaneous structure of the sample. When this structure changes also the speckle pattern will change making it possible to detect fluctuations of the fluctuating disorder (**intensity fluctuation spectroscopy**).

Motivation

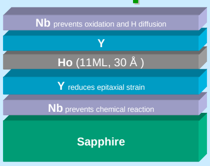
Study ***magnetic fluctuations*** with resonant coherent x-rays.

Proof of principle study to show the feasibility of measuring the low-frequency dynamics in magnetic systems

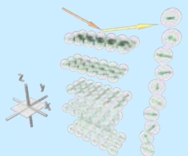


Short range regions of short-lived magnetically ordered spins in a sea of disordered (paramagnetic) spins

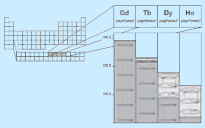
Sample: ultrathin holmium film



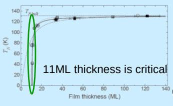
Grown by **molecular beam epitaxy** in the group of H. Zabel, Ruhr-Universität Bochum



Holmium has a **helical antiferromagnetic structure**
This helix of magnetic moments gives rise to a **magnetic satellite peak**

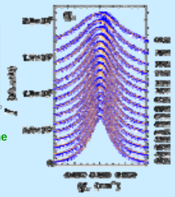


Magnetic phase diagrams of some bulk lanthanide metals.
In **2D systems** (thin films) the ordering temperatures are reduced

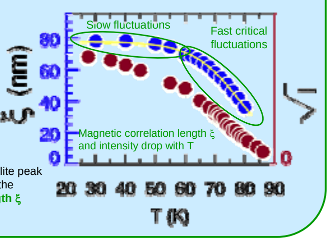


Thickness dependence of the ordering temperature

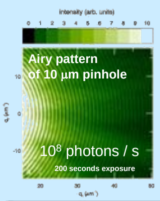
When thickness is reduced, critical fluctuations become increasingly important.

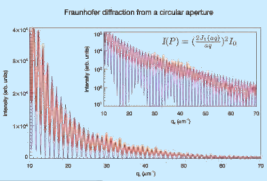


Width of the magnetic satellite peak is inversely proportional to the **magnetic correlation length ξ**



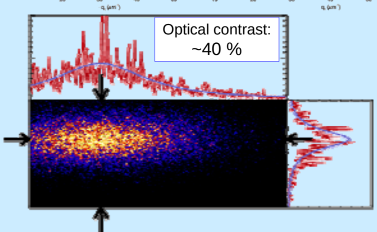
Coherence



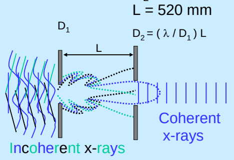


Transverse coherence is obtained by Spatial filtering with two pinholes

λ= 9.2 Å
E=1.35 keV
D_1 = 70 μm
D_2 = 10 μm
L = 520 mm



Magnetic speckle pattern
the peak arises from the helical magnetic structure of Ho



Spatial filtering comes with the cost of huge loss of photons (factor $10^3 – 10^4$)

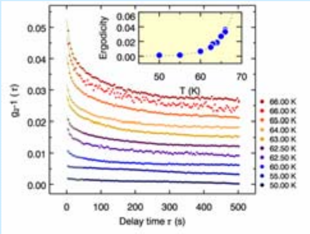
Acknowledgement
This work is performed with the help of the U49/2PGM1 and UE46 PGM beamline staff and financial support from the foundation for fundamental research on Matter (FOM).

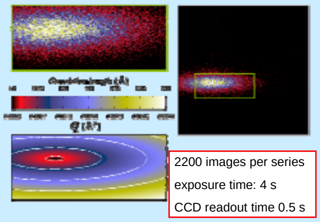
Soft x-ray photon correlation spectroscopy

Slow magnetic fluctuations could be measured by imaging the **speckle patterns**.

The magnetic structure is initially static but becomes increasingly dynamic at higher temperatures at the onset of where critical dynamic fluctuations are to be expected.

The initial drop in the correlation plot shows the critical magnetic fluctuations. The amplitude of the drop increases with temperature which is a measure for the fluctuating part of the sample quantified by the ergodicity parameter



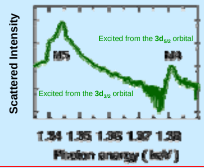


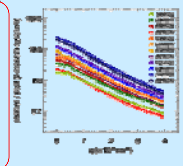
2200 images per series
exposure time: 4 s
CCD readout time 0.5 s

Resonant X-rays

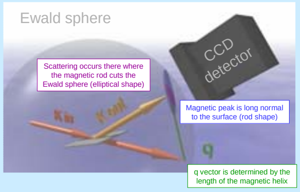
When the photon energy is tuned to the M_V absorption edge of holmium a huge increase in the magnetic cross section occurs.

A 3d electron is excited in a 4f unoccupied state by the x-ray photon and decays by emission of a scattered photon of the same energy.





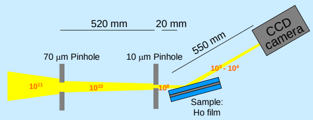
Experimental setup



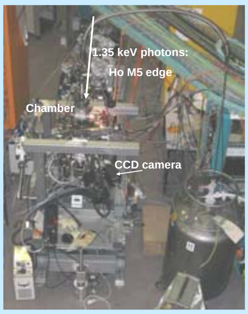
Slow magnetic dynamics (> 1 s):
CCD pixel camera limited by read out time (0.5 sec)
Princeton Instruments, backside illuminated chip
2048x2048 pixels
13.5x13.5 μm pixel size
Quantum efficiency: 55% @ 1.35 keV

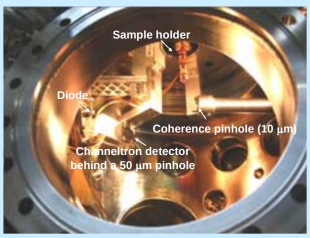
Fast *critical* magnetic dynamics (> 1 μs)
Possibly doable with future XFEL sources by using a single point detector and digital autocorrelator

Experiments were performed at beamlines **U49/2 PGM1** and **UE46 PGM** of the Berlin Synchrotron facility **BESSY**



Flux (photons/sec): E=1.35 keV
Channeltron detector behind a 50 μm pinhole





Conclusions

It is possible to measure slow ***magnetic*** fluctuations (>1 sec) with ***resonant*** coherent soft x-rays by imaging dynamic speckle

This opens up a wide number of experiments on magnetic systems that can be measured with x-ray photon correlation spectroscopy