XMCD going ultra-cold: Experiments at 100 mK and 7 T

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Synopsis First experiments along with the general capabilities of the TTXMCD endstation at P04, PETRA III, DESY are presented. The TTXMCD endstation allows measuring the magnetic properties of solids, thin films, molecules or atomic adsorbates at ultra-cold temperatures in an element specific way. At such temperatures, electron-electron interaction phenomena are studied, such as the Kondo effect for Co on Cu(100).

The investigation of magnetic properties by means of the X-Ray Magnetic Circular Dichroism (XMCD) has proven to be a valuable tool especially when it comes down to site specific effects. A wide range of samples that need high magnetic fields and ultra-cold temperatures, such as molecular magnets, clusters and other dilute magnetic species are difficult to study directly in the gas phase. The new TTXMCD endstation [1] therefore aims at a solid state sample environment with a well-defined temperature and magnetic field control.

Cobalt adatoms on crystalline copper surfaces have already been studied locally with STM. The Kondo transition temperatures are determined to be ~ 50 K for Cu(111) [2] and ~ 80 K for Cu(100) [3]. Our measurements show, that even below the Kondo transition temperature the electron screening is strongly affected by the exact temperature. The XMCD also allows distinguishing between the spin and orbital d-band magnetic momenta, which are inaccessible with STM based experiments.

The Kondo effect affects both: spin and orbital momenta, which are screened by roughly one order of magnitude on copper surfaces in respect to the atomic value and to similar experiments of adatoms on metallic surfaces. We also found that the spin and orbital momenta behave significantly different for (100) and (111) surfaces. Furthermore, the spin screening strength is increased at ultra-cold temperatures. This is given by the μ_l / μ_s ratio, which rises from ~0.3 at 30 K to ~1.3 at 100 mK for Co/Cu(100). The presented experiments represent a great benchmark for electronic structure calculations in the field of strongly interacting electrons.

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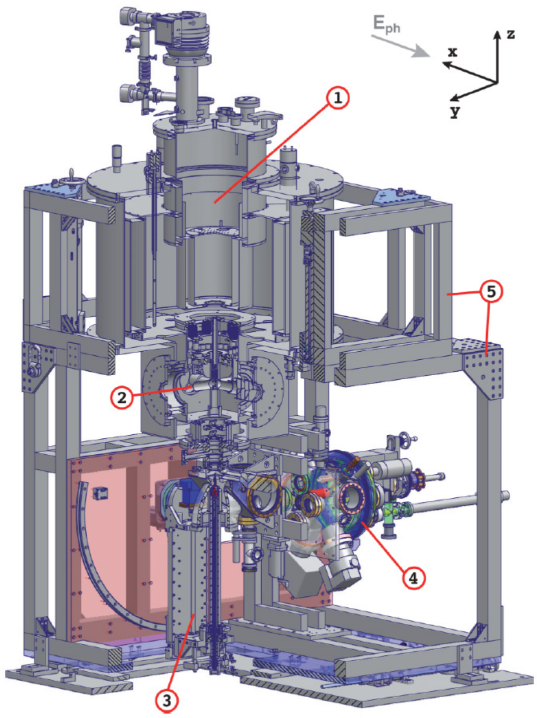

Figure 1. CAD drawing of the TTXMCD endstation from [1]: It contains a dilution refrigerator ①, a preparation chamber ④ and a vector magnet ②.

Additionally, experiments on metal free organic molecules (derivatives of the Blatter radical) are performed at 100 mK. A radical carries a magnetic momentum in terms of an unpaired electron. Our experiments show the feasibility of K-shell related magnetism studies via XMCD. This opens up experimental possibilities for a huge class of important molecules.

This work is funded by the DFG via the collaboration research center SFB 668.

References

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