Report for ID08 experiment 23653

August 25 – 28, 2010

Magnetic linear Dichroism of $YbInNi_4$: determining the crystal-field ground state

We have successfully performed a soft-x ray absorption spectroscopy experiment with the objective to determine the crystal-field ground state wave function of a cubic Yb^{3+} compound. $YbInNi_4$ is a low T_K (Kondo temperature) Heavy Fermion compound which orders ferromagneticaly below 3 K. It has become prominent as a stable valence reference compound to $YbInCu_4$, which undergoes a first order valence transition as function of temperature, similar to the γ->α valence transition of cerium. In the field of concentrated Kondo, Heavy Fermion and intermediate valence materials, knowing the ground state wave function is crucial for the modelling of the thermodynamic, transport, and magnetic properties and there is a long, outstanding debate concerning the nature of the ground state in $YbInNi_4$. (see different crystal-field schemes in Figure 1) The present *Magnetic Linear Dichroism* (MLD) experiment at the Yb M_5 edge is able to settle this issue*.

We have shown that linear dichroism in the soft-XAS at the $M_{4,5}$ edges of tetragonal cerium compounds is a powerful technique to determine the ground state wave function of the crystal-field split Hund's rule ground state [5-7] due to its sensitivity to the initial state symmetry. In a cubic environment this linear dichroic effect vanishes, yet, using an external magnetic field perpendicular to the Poynting vector, it can be made to appear as *magnetic linear dichroism* (MLD). Whether or not a MLD signal is indeed generated depends very much on the wave function of the ground state: the Zeeman splitting for a doublet ground state will *not* give rise to MLD while it will do so for a quartet ground state. This is the effect which will allow us to determine unambiguously the ground state symmetry of $YbInNi_4$.

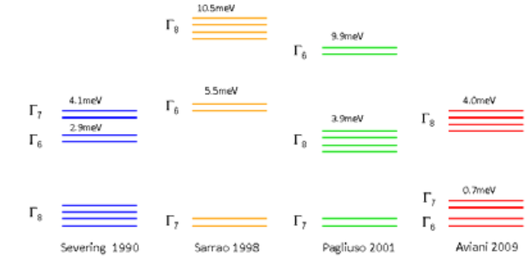

Figure 1: different crystal field scenarios of $YbInNi_4$ [1-4]

$YbInNi_4$ is peculiar in the sense that the crystal-field splittings are very small and therefore can be quite comparable to the Zeemann splittings for strong magnetic fields. In such a case, the applied field causes an appreciable additional intermixing of the J_z states so that none of the crystal-field states resembles a cubic wave function, with the result all the states exhibit MLD, some stronger than the other. We have simulated the MLD effect for the different ground state scenarios using the full multiplet calculations for temperatures of 5-7 K as function of the magnetic field. Figure 2 shows clearly that the size of the MLD for a given magnetic field and temperature depends very strongly on which scenario is used. In other words, the experimental determination of the magnitude of the MLD effect will directly pin point which scenario is the correct one for $YbInNi_4$. The MLD effect is very sensitive to temperature so that it is essential to reach 5-7 K and to have temperature stability at the sample surface.

The High Field End Station on ID08 provides low temperatures and a magnetic field which can be turned perpendicular to the Poynting vector. When measuring, the magnetic field was actually about 5° off the 90° position in order to avoid the Lorenz force hindering the electrons to escape the sample. A lot of care had been taken by the beam line scientists to guarantee stable low temperatures: a base temperature of 5.39 K was measured with a calibrated Lake Shore Cernot thermoelement on the sample holder just above the sample position so that a base temperature of 6.5+/-0.5 K on the sample surface could be reliably reached. This way we were able to determine the MLD signal with an accuracy of ±0.5% for a 10% MLD signal - which is sufficient to distinguish between the different scenarios discussed in the literature. The single crystalline sample was aligned as in Figure 3.

Figure 4 shows the absorption spectra of $YbInNi_4$ for B = 5 T and T = 6.5K for light parallel and perpendicular to the applied magnetic field. The resulting *relative magnetic linear dichroism* $(M_{\perp}-M_{\parallel})/(2M_{\perp}+M_{\parallel})$ is about 10.5%. The black dots in figure 2 are the measured relative dichroism at 6.5 K for various field strengths. The size of the dots resembles the error bars accuracy with which the relative MLD can be determined.

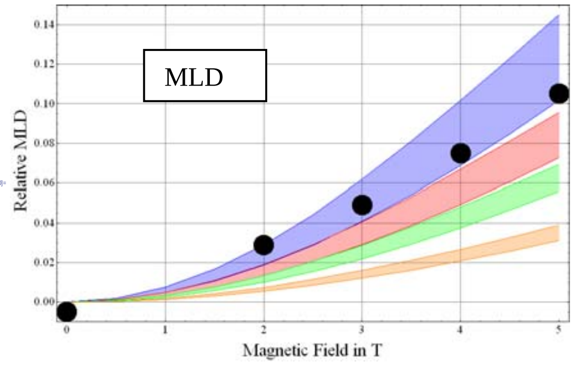

Fig. 2: MLD (vertical) versus magnetic field [T] for the crystal-field scenarios of Fig. 1. The curves cover the temperature range from 5-7K (the lower the temperature the larger the MLD). The black dots are the measured MLD

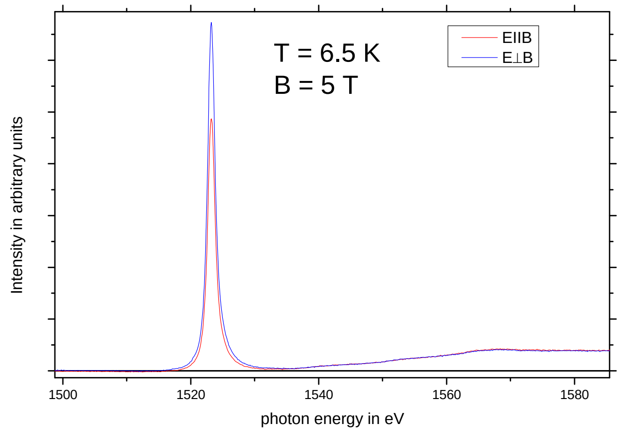

Fig. 4: Measured M_5 edge of $YbInNi_4$ at B = 5 T and 6.5 K for light parallel and perpendicular to the applied magnetic field B.

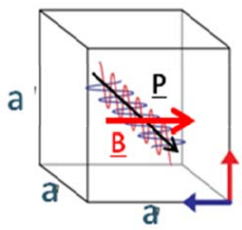

Fig. 3: sample alignement with respect to the field and Poynting vector

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***Remark:** XMCD has different selection rules and calculations show that it cannot provide the information uniquely whereas MLD can.