ESRF	Experiment title: Anomalous magnetic order in dhcp Ho:Ce alloys	Experiment number: HE-480
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Names and affiliations of applicants (* indicates experimentalists):

* Jon Goff, Oxford University
* Roberto Sarthour, Oxford University
* Des McMorrow, Risø National Laboratory
* Assunta Vigliante, Max-Planck-Institut Stuttgart

Report:

In the standard model of rare earth magnetism localised *4f* moments interact with the crystalline electric field and with each other via the conduction electrons. However, hybridisation effects in cerium systems lead to unusual magnetic properties such as intermediate-valence and metallic *4f* behaviour. Neutron diffraction studies of Ho_xCe_{1-x} alloys have revealed a rich magnetic phase diagram with anomalous short-range magnetic order over the composition range $0.35 < x < 0.5$. The aim of this x-ray magnetic resonant scattering study of Ho_xCe_{1-x} alloys was to understand the influence of the electronic state of Ce on this complex magnetic phase diagram. A sample of composition $x \sim 0.3$ was chosen since it is close to the region of interest and its long-range antiferromagnetic magnetic order makes it suitable for a magnetic x-ray diffraction experiment. By measuring the resonant magnetic scattering we are able to separate the magnetic response of the Ce and Ho, and to obtain spectroscopic information on the magnetically ordered species.

A single-crystal $Ho_{0.3}Ce_{0.7}$ alloy with the dhcp structure was grown using molecular beam epitaxy. The sample was mounted in a variable-temperature cryostat with a base temperature $T \sim 1.7$ K on the four-circle diffractometer ID20. Polarisation analysis was employed to remove the background charge scattering (π-π) from the magnetic scattering measured in the π-σ channel. Magnetic resonances were detected at the Ce L_{II}, Ce L_{III} and Ho L_{III} edges below $T_N \sim 7$ K, and in each case the magnetic diffraction was measured as a

function of wave-vector transfer.

Figure 1(a) shows the elastic magnetic scattering at fixed $\boldsymbol{Q}$ = (0.5,0,7) as the x-ray energy varies in the vicinity of the Ho L_{III} edge. The magnetic cross section is dominated by a transition from a *2p* core state to the *5d* band, and a single peak is observed. The magnetic resonances at the Ce edges are more complicated and at least three components can be resolved. A typical energy scan obtained at $\boldsymbol{Q}$ = (0.5,0,7) at the Ce L_{II} edge is shown in figure 1(b). The $\boldsymbol{Q}$-dependence of peaks B and C are identical, while that of peak A is different. A magnetic structure with a longitudinal modulation vector [0.5,0,0] has been derived which is consistent with these data provided that B and C are dipolar and A is a quadrupolar transition. We note that this has the same modulation vector as the transverse magnetic structure in β-Ce.

The energies of the resonances at the Ce L_{III} edge are identical to those identified in x-ray absorption studies of Ce systems. Peak B is very close to the absorption edge and is the usual dipolar *(2p-5d)* transition observed at the rare-earth L edge. The quadrupolar peak A is about 7 eV below this energy, and is attributed to a transition from a core state to the *4f* level. The dipolar peak approximately 10 eV above the edge has been observed in highly delocalised Ce systems, and is associated with hybridisation of the Ce *4f* electron with the conduction band. We are able to estimate a `spectroscopic valence' from the ratio of intensities C/B, and the value obtained corresponds to that of delocalised α-Ce. These results therefore suggest that hybridisation of the Ce *4f* electron is responsible for the anomalous magnetic behaviour of Ho_xCe_{1-x} alloys.

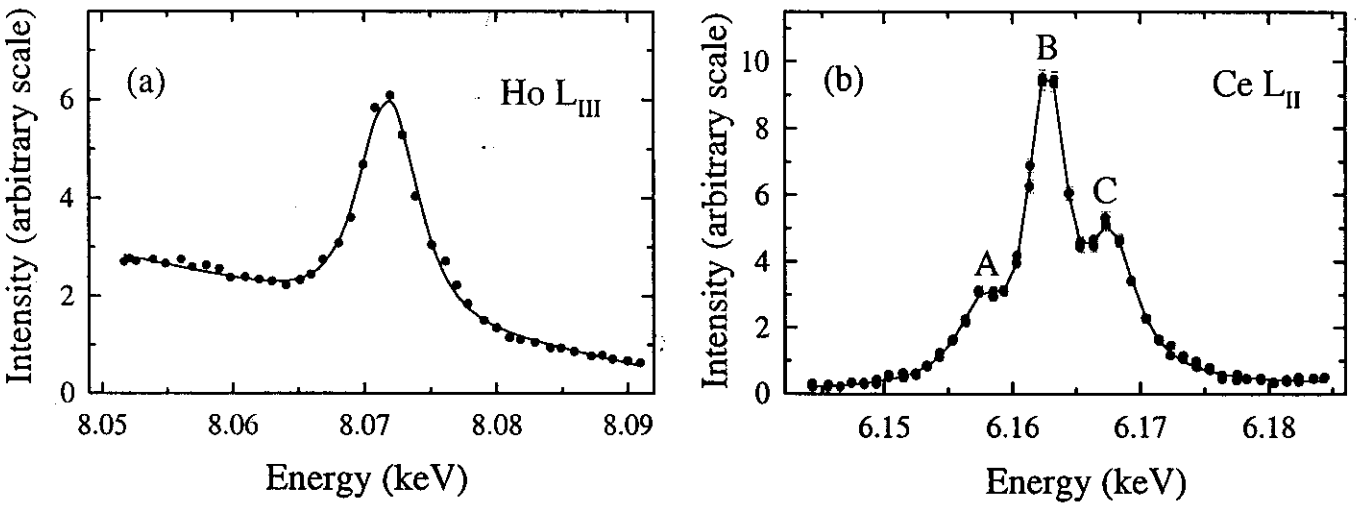

Figure 1. Scans of x-ray energy in the π–σ channel with $\boldsymbol{Q}$ fixed at (0.5,0,7) and at T ~ 1.7 K (a) at the Ho L_{III} and (b) at the Ce L_{II} edges.