

**Experiment title:**

Intra- and inter atomic contributions in rare earth magnetism; Understanding the RE edges

**Experiment number:**

HE120

HE120

**Beamline:**

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*ESRF***Report:**

Our previous work led to the development of a model for the RE  $L_{23}$  XMCD in terms of the intra-atomic  $4f$ - $5d$  exchange interaction (treated in an atomic model, i.e. including the orbital part of the interaction) and the spin-dependence of the radius of the  $5d$  orbital\*\*.

The role of the exchange interaction is to shift the spin-down spectrum by an amount  $X$  to higher energies. However, because this shift is much smaller than the line width  $W$ , this gives rise to derivative-like XMCD spectra. The spin-dependence of the  $5d$  orbital radial extend also derives from the  $4f$ - $5d$  exchange and pushes out the  $5d^{\downarrow}$  states from the region occupied by the  $4f^{\uparrow}$  orbital. The reduced overlap between the  $5d^{\downarrow}$  states leads to a reduction of the  $2p \rightarrow 5d^{\downarrow}$  matrix element by a factor  $A$ . The line shapes obtained in this XWA model are plotted in figure 1.

To obtain further proof for this model we performed measurements on the Gd  $L_{23}$  edge of the  $Gd_xNi_y$  series of intermetallic compounds. Figure 2 shows the peak-normalized XMCD spectra for both edges, together with the spectrum of Gd metal. The series show a clear trend from a more or less dispersive peak in Gd to a single peak in the dilute Gd case of  $Gd_2Ni_{17}$ . Especially in the  $L_2$  spectra the second lobe of the spectrum is seen to decrease in intensity and to shift to higher energy, as does the zero crossing. This is completely consistent with the XWA model, and implies that on dilution Gd in Ni the Gd ion can increasingly push out spin down states.

Apart from explaining the XMCD line shape this offers direct insight in the magnetism of these materials. The standard picture of these materials has it that they are ferrimagnetic in the Ni-rich part of the series and ferromagnets with zero Ni moment in the Ni-poor part<sup>3</sup>. However, as is shown in the report on our in-house research work on the Ni L edges, Ni always shows dichroism, and in fact the whole series is ferrimagnetically ordered. We can understand this structure now as being completely driven by the intra-atomic  $4f-5d$  exchange that pushes out the  $5d^{\downarrow}$  states to the Ni ions. These can easily accommodate these states by ordering antiparallel to the Gd moment. This is an alternative qualitative way of explaining the magnetic ordering than the more complicated RKKY mechanism that is usually invoked but whose oscillatory character does not show up in R-Ni compounds.

1. M. van Veenendaal, J.B. Goedkoop and B.T. Thole, Phys. Rev. Lett. 78 1162 (1997).
2. **J.B. Goedkoop**, A. Rogalev, M. Rogaleva, C. Neumann, J. Goulon, M. van Veenendaal and B.T. Thole, J. Phys. *IV* France **7 C2-397** (1997) and **ESRF Exp. Rep. CH46**
3. H. Kichmayr et al., Handbook of the Physics and Chemistry of Rare Earth Vol2., p. 138

