ESRF	**Experiment title:** The interplay between magnetism and superconductivity in Gd/La superlattices	**Experiment number:** HE1557
Beamline: ID12	**Date of experiment:** from: 6 March 2004 to: 9 March 2004	**Date of report:** 20-09-2004
Shifts: 9	**Local contact(s):** F.Wilhelm, A.Rogalev	*Received at ESRF:*

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Report:

Gd/La superlattices display the interplay between ferromagnetism and BCS superconducting order. It was shown by SQUID magnetometry and neutron scattering techniques that a unique interplay between these antagonistic phenomena exists in thin film superlattices grown by molecular beam epitaxy (MBE). Single crystal superlattices were grown by MBE with a nominal composition $[Gd_{30}La_{10}]_{60}$. The values denote the number of atomic layers in the Gd and La blocks and the number of bilayer repeats respectively. SQUID magnetometry revealed that zero-field cooling to 2 K from the paramagnetic phase resulted in a large diamagnetic signal superimposed in magnetic order. Field cooling in a small applied field, 50 Oe, results in the suppression of the superconducting order. Neutron scattering revealed that the ferromagnetic Gd blocks align with short range antiferromagnetic order in the ZFC phase[1]. This order exists before superconducting order emerges and is not affect by the onset of superconductivity. Furthermore, analysis of magnetisation lineshapes via Ginzburg-Landau theory, revealed that the superconducting order was 3 dimensional. The superconducting order propagates across the ferromagnetic blocks. In contrast, the magnetic order in the field cool phase is a simple ferromagnetic exchange between the Gd blocks [2].

The aim of the work on ID12 was to probe Gd and La magnetic order individually in both the FC and ZFC phases using the element specificity of X-ray Magnetic Circular Dichroism. XMCD was performed in fluorescence yield mode with detection in backscattering mode. The XMCD asymmetry ratios were obtained both by helicity reversal and by reversing the polarisation of the applied field. The sample was cooled in a large applied field, 4 Tesla. At base temperature, T $\sim$ 5 K, the XMCD asymmetry ratio was measured around the Gd L_2 and L_3 absorption edges, E = 7.930 and 7.243 keV respectively. To determine anisotropic behaviour XMCD spectra were obtained with the magnetic field applied both parallel and perpendicular to the a/b plane of the superlattice. The XMCD spectra surrounding the La absorption edges, E =5.891 and 5.483 keV, were thereafter measured, again with the magnetic field applied in and out of plane.

The solid lines in Figure 1 (a) and (b) show the XMCD assymetry ratio at absorption edges of Gd, L_3 and L_2 respectively. An interesting high energy shoulder is apparent for the L_2 lineshape, Figure (1)b. This is not typical for elemental Gd and is an indication of disorder on the Gd atomic sites.

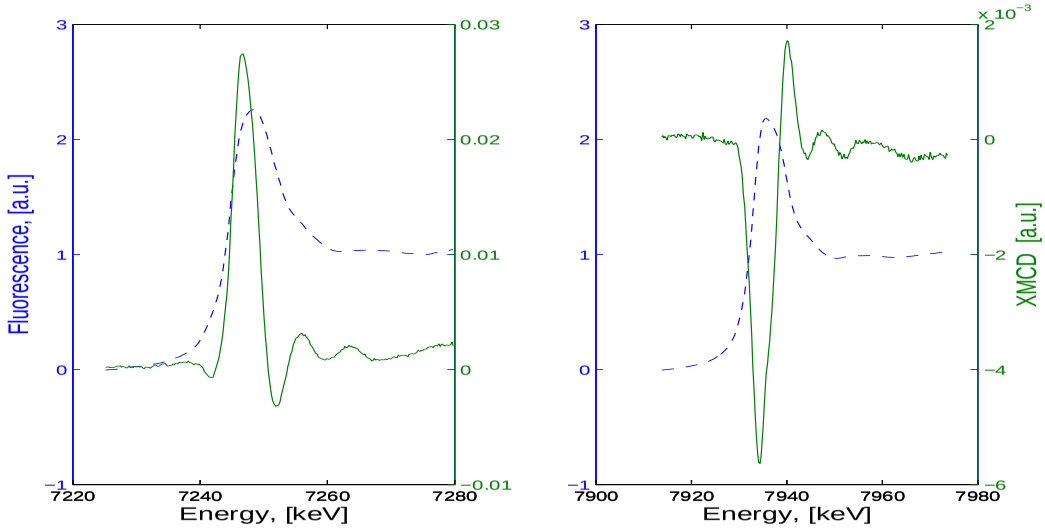

Figure 1 XMCD assymetry ration and Xanes spectra around (a) Gd L_3 with an applied field of 4 T applied perpendicular to the a/b axis.
(b) XMCD assymetry and Xanes spectra around the Gd L_2 absorption edge.

Figure 2 (a) and (b) show the XMCD spectra obtained around the La L_2 and L_3 absorption edges. The magnetic field is applied in the plane of the blocks, along the a/b plane. The intensity is weak but clearly the La blocks are polarised. The XMCD asymmetry ration for the La $L_{2,3}$ edges does not seem to follow the conventional XMCD sum rules where opposite signs are expected for the two absorption edges. Conversely, Gd, as shown in Figure 1, does conform.

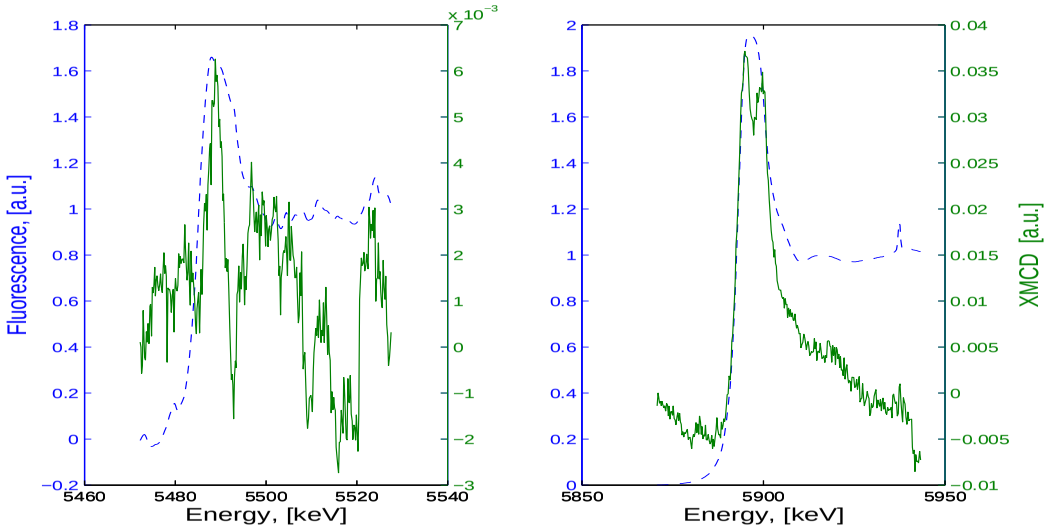

Figure 1 XMCD and Xanes spectra with external field of 4T applied along the a/b axis.
(a) La L_3 absorption edge and (b) around the La L_2 absorption edge

The La spectra obtained around the L_3 absorption edge out of the plane was very weak with poor statistics. Data analysis will therefore only give orbital and spin moment information on the in-plane lineshapes. Data analysis is in process and will shed further light on the extend of the polarisation of the Gd blocks moments on the La blocks. Further work is anticipated. The time allocated permitted the FC phase to be probed but was insufficient to measure the ZFC phase. A complete data set has therefore not yet been gathered. It is hoped that the ZFC phase can be probed at a later date. It is possible that the magnetic order in Gd/La superlattices is propagated via long-range dipole exchange interactions [3]. This would explain why the magnetic order is not perturbed as superconducting order emerges. It would be of interest to verify this hypothesis.

[1]P.Deen . *et al.* J.Magn.Magn.Mater. **240**, 592, 2002.
[2]P.Deen . *et al.* Submitted to Phys.Rev.B.
[3]J.P.Goff . *et al.* .Magn.Magn.Mater.**199**, 309, 1999.