ESRF	**Experiment title:** Induced magnetic order in Nd/Pr superlattices	**Experiment number:** HE-108
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Report:

Bulk Nd orders below $T_N \sim$ 19.9 K and, as the temperature is reduced further, passes through a series of multi-q magnetic structures. In contrast, bulk Pr has a singlet ground state and does not exhibit long-range magnetic order until it is induced by the hyperfine coupling at $T_N \sim$ 0.05 K. Neutron diffraction studies of Nd/Pr superlattices have revealed that the Nd magnetic order propagates coherently through the intermediate layers, and suggest that localised order is induced in the Pr in some cases. Synchrotron x-rays are ideally suited to study these phenomena further, since by tuning the energy to the Nd and Pr edges the ordering of the moments in the two components of the superlattice may be investigated separately. Furthermore, unlike the heavy rare earths, there is an in-plane component to the magnetic modulation vector, and this moves the magnetic scattering away from the direction of the surface normal where the structural background is high.

A single-crystal superlattice of composition $[Nd_{20}Pr_{20}]_{80}$ has been studied using ID20. Polarization analysis ($\pi -$ a) was employed to distinguish between magnetic and charge scattering. Magnetic resonances were observed at the L_{II} edges of both the Nd (6.722 keV) and Pr (6.440 keV). This proves that the $5d$ bands are magnetically polarized in both elements, and the magnitude of the signal at the Pr edge suggests that the induced order is also localised.

The high resolution of wave-vector transfer, Q, obtained with x-rays enables the magnetic structures to be studied much more closely than before. Figure 1 shows a scan of Q in the c* direction through a magnetic peak at the Nd L_{II} edge. The observation of narrow superlattice peaks implies that the Nd magnetic order is coherent over many bilayer repeats. The magnetic correlation length is found to be about 2000 $\AA$ at all temperatures studied, and this is considerably larger than the values obtained for other rare-earth superlattices. Figure 2 shows a scan of Q in the $\boldsymbol{a}^*$ direction at the Pr L_{II} edge, and the splitting of the peak into two components at T = 2 K is the first direct observation of a multi-q magnetic structure in Pr. The temperature dependence of the integrated intensities and the positions of the magnetic modulation vectors are found to be identical at the two edges, and the superlattice therefore exhibits a uniform magnetic structure.

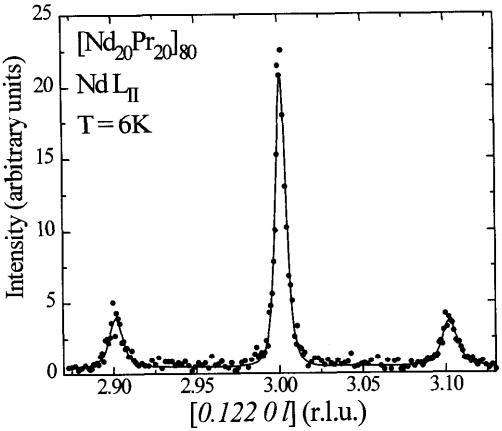

Fig. 1. Reciprocal space scan showing that the magnetic order in the Nd blocks couples across the intermediate Pr layers. Superlattice peaks are observed offset from the magnetic Bragg reflection by $\Delta Q = \pm 2\pi/\Lambda$, where A is the bilayer repeat.

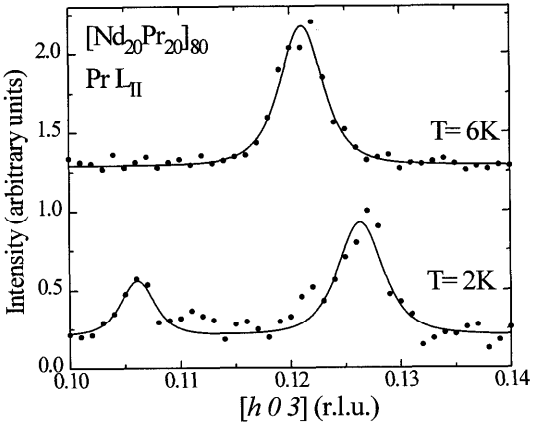

Fig. 2. Reciprocal space scans showing changes in the magnetic structure of the Pr at different temperatures. At T = 6 K a single modulation vector is observed, but separate peaks are detected at T = 2 K from two domains of a multi-q magnetic structure.

We plan to perform further measurements to investigate the magnetic structures as a function of superlattice composition, and we intend to use the polarization and energy dependence of the cross section to distinguish between polarization of the $5d$ bands and an ordered $4f$ moment on the Pr sites.