Experiment Report Form

The double page inside this form is to be filled in by all users or groups of users who have had access to beam time for measurements at the ESRF. Once completed, the original report should be sent, together with 5 reduced (A4) copies, to the User Office.

In addition, please send a copy of your file as an e-mail attachment to reports@esrf.fr**,** using the number of your experiment to name your file. This will enable us to process your report for the ESRF Annual Report.

Reports accompanying requests for additional beam time

If your report is to support **a new proposal**, the orginal report form should be sent with the new proposal form, and a copy of your report should be attached to each copy of your proposal. The Review Committees reserve the right to reject new proposals from groups who have not reported on the use of beam time allocated previously.

Reports on experiments relating to long term projects

Proposers awarded beam time for a long term project are required to submit an interim report at the end of each year, irrespective of the number of shifts of beam time they have used.

Published papers

All users must give proper credit to ESRF staff members and proper mention to ESRF facilities which were essential for the results described in any ensuing publication. Further, they are obliged to send to the Joint ESRF/ ILL library the complete reference and the abstract of all papers appearing in print, and resulting from the use of the ESRF.

Should you wish to make more general comments on the experiment, please note them on the User Evaluation Form, and send both the Report and the Evaluation Form to the User Office.

Deadlines for submission of Experimental Reports

- 1st March for experiments carried out up until June of the previous year;
- 1st September for experiments carried out up until January of the same year.

Instructions for preparing your Report

- fill in a separate form for each project or series of measurements.
- type your report, in English.
- include the reference number of the proposal to which the report refers.
- make sure that the text, tables and figures fit into the space available.
- if your work is published or is in press, you may prefer to paste in the abstract, and add full reference details. If the abstract is in a language other than English, please include an English translation.
- bear in mind that the report will be reduced to 71% of its original size. A type-face such as "Times", 14 points, with a 1.5 line spacing between lines for the text, produces a report which can be read easily.

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ESRF	**Experiment title:** **MAGNETIC X-RAY RESONANT STUDY OF THE MAGNETIC COUPLING IN dhcp Sm/Nd SUPERLATTICES**	**Experiment number**: HE-1046
Beamline: ID20	**Date of experiment**: from: 06/06/01 to: 12/06/01	**Date of report**: 28/08/01
Shifts: 18	**Local contact(s)**: Nolwenn Kernavanois	*Received at ESRF:*

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Report:

Samarium and Neodymium are two light rare earths that exhibit complex modulated magnetic phases. They crystallize in a hexagonal lattice, with a four-plane stacking sequence along the c-axis for Nd (dhcp) and a nine-plane one for Sm.
Previous detailed investigation devoted to pure samarium has shown that Sm films with a dhcp structure could also be obtained by Molecular Beam Epitaxy, under specific elaboration condition [1]. The magnetic phases in this dhcp structure have been determined by resonant X ray magnetic scattering (experiment HE 719) [2-3]. Taking advantage of this elaboration method, we could also grow Sm/Nd superlattices, where both element exhibit the same dhcp stacking sequence and where this dhcp stacking is coherent over many periods (i.e. bilayer thickness) [1].
The study of the magnetic phases and magnetic coupling phenomena in such superlattices, related to crystal structures and stackings, is a suitable way to test magnetic coupling models. Such investigation in these complex heterostructures, where both components are magnetic, requires a powerful technique as RXMS that combines a high sensitivity and the essential chemical selectivity.

The main sample investigated during this experiment was a [Sm(37Å)/Nd(187Å)]x50 superlattice whose growth direction is parallel to the (0001) axis. The Resonant X-ray Magnetic Scattering experiments with polarization analysis have been performed on the ID20 beamline, at both the Sm L_3 edge (6.708 keV) and the Nd L_2 edge (E=6.723 keV), using a crystal Cu(220) as analyzer. The scans have been measured along various directions of the reciprocal space (H and L), in order to determine the magnetic propagation vectors and the coherence length along the growth direction. A cryostat for experiments has been used to carry out a careful thermal analysis down to 2K.

At the samarium L_3 edge, we could measure the magnetic satellites corresponding to the magnetic ordering of the moments located on the cubic sites. As in pure dhcp films, the magnetic propagation vector for cubic sites is (0.25 0 1), it does not evolve with temperature, and the ordering temperature is close to 24K. The scan measured along the L direction exhibits a broad contribution whose full width at half maximum reveals a magnetic coherence length of 23 Å, that is smaller than the samarium individual layer thickness. It was not possible to measure any magnetic contribution from the ordering on the hexagonal sites: The expected positions are superimposed to charge contribution that was still too high, even in the rotated channel.

At the neodymium L_2 edge, the thermal investigation revealed particularly interesting results that are gathered in figures 1 and 2. Figure 1 presents the scans measured along the H-direction at various temperatures, whereas figure 2 presents three scans measured along the L-direction across the various magnetic contributions.

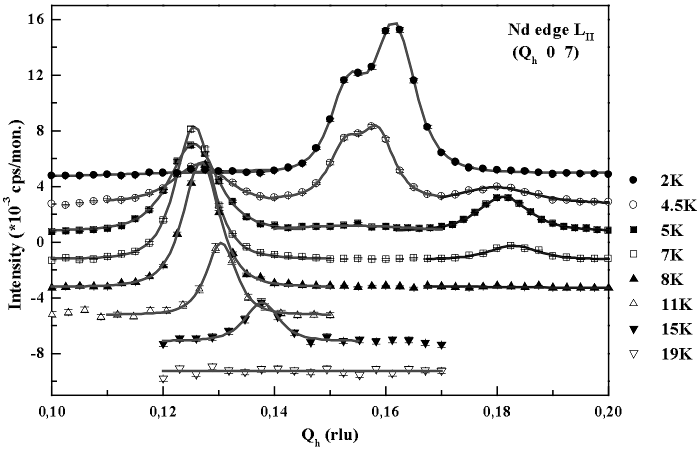

Fig.1: H-scans measured for L=7 in decreasing temperature for the incident photons energy tuned to the Nd L_2 edge

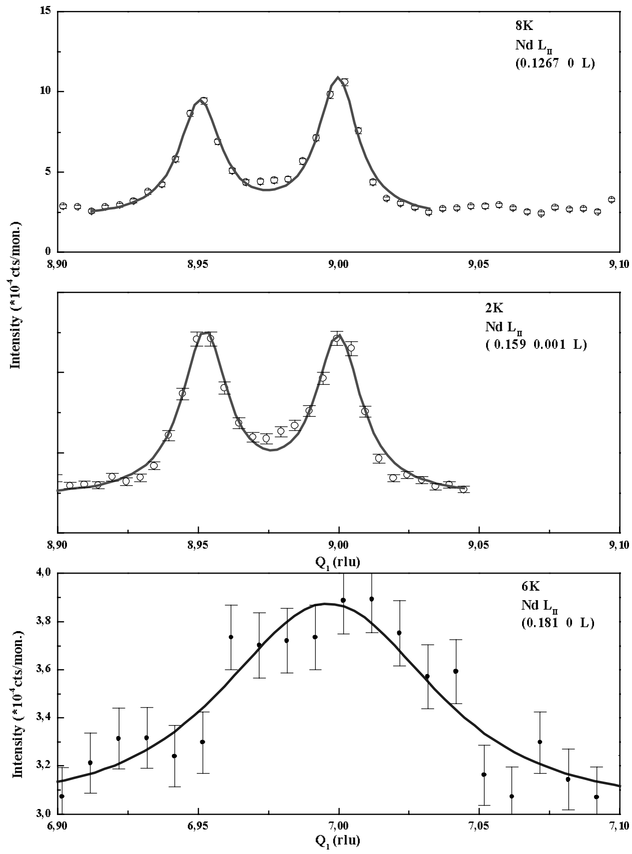

Fig.2: L-scans measured across the three magnetic contribution observed in figure 1, for the incident photons energy tuned to the Nd L_2 edge

Figure 1 reveals that the magnetic phases in Nd between 19K and 5K are close to bulk Nd. The ordering on the hexagonal sites (green contribution between Q_l=0.14 and 0.12 r.l.u.) occurs below 19K, whereas the ordering on the cubic sites (blue contribution around Q_l=0.18r.l.u.) occurs below 8K. The propagation wave vectors are similar to the bulk ones, although no multi-q structure was observed. Figures 2a and 2c show a main difference for these two phases: the magnetic order on the hexagonal sites propagates coherently through magnetic samarium with a coherence length of 244 Å, whereas the coherence length of the cubic order is limited to 73 Å (i.e. smaller than Nd individual layers).
A point of high interest has been observed at lower temperature (T<5K), since the magnetic intensity on the previous satellites (corresponding to hexagonal and cubic sites) decreases to give rise to a new magnetic phase for Nd (red contribution around Q_l=15.5 r.l.u.). In contrast to what is usually observed in Nd or Nd-based systems, the magnetic moments on hexagonal and cubic sites seem to form an almost homogeneous magnetic phase with very close propagation vectors. Moreover, this phase also propagates coherently through magnetic samarium, as evidenced in figure 2b. The coherence length has been calculated to be around 271 Å.

In conclusion, RXMS experiments performed in polarization analysis permitted to determine separately the magnetic phases and the magnetic coherence of Sm and Nd elements in a dhcp Sm/Nd superlattice. In both components, the cubic magnetic orders appear to be confined to individual layers. Nevertheless, the hexagonal magnetic orders that, in Nd, is coherent through magnetic samarium, coexists with these non-coherent phases. Moreover, an amazing magnetic structure, also coherent through Sm, has been discovered at low temperature in Nd. A complementary study has now to be undertaken in order to investigate the Sm magnetic behavior in this low temperature range.
We plan also to perform further experiments to investigate the magnetic structures as a function of the superlattice composition, especially for much thinner Nd layers.

[1] C. Dufour, K. Dumesnil, S. Soriano, D. Pierre, Ch. Senet, Ph. Mangin, accepted for publication in J. of crystal growth
[2] C. Dufour, K. Dumesnil, P.J. Brown, A. Stunault, N. Bernhoeft, P. Mangin, submitted to publication in Phys. Rev. B
[3] K. Dumesnil, C. Dufour, S. Robert, Ph. Mangin, J. M. M. M. 226-230, 1702 (2001)