

## 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 report should be submitted electronically to the User Office using the **Electronic Report Submission Application:**

*<http://193.49.43.2:8080/smis/servlet/UserUtils?start>*

### ***Reports supporting requests for additional beam time***

Reports can now be submitted independently of new proposals – it is necessary simply to indicate the number of the report(s) supporting a new proposal on the proposal form.

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.



	<b>Experiment title:</b> <b>Magnetic behaviour of europium epitaxial thin films and of europium based superlattices</b>	<b>Experiment number:</b> HS-1624
<b>Beamline:</b> BM28	<b>Date of experiment:</b> from: 14.11.01 to: 20.11.01	<b>Date of report:</b> 28/02/02
<b>Shifts:</b>	<b>Local contact(s):</b> David Paul	<i>Received at ESRF:</i>

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**Report:**

The purpose of the project was the study of the magnetic behaviour of europium epitaxial thin films and of europium based superlattices. It is known that europium exhibits a bcc structure above  $T_N = 90$  K, where a magnetic helical order takes place. The magnetic transition is accompanied by a tiny tetragonal lattice distortion with an expansion along the wave vector of the helices which propagates close to the  $\langle 100 \rangle$  directions. The aim of the study was to know in which extend the magnetisation of europium in thin films and in superlattices was affected by the shape of the sample, the epitaxial strains and the superperiodicity of the material.

The Eu(110) thin films have been epitaxially grown on Nb(110) buffer layers (with  $[001]_{\text{Eu}} // [001]_{\text{Nb}}$ ) previously obtained by deposition on a  $\alpha\text{-Al}_2\text{O}_3$  (11-20) sapphire (with  $[-111]_{\text{Nb}} // [0001]_{\alpha\text{-Al}_2\text{O}_3}$ ).

Previous measurements performed during experiment n°HE-937 (February 2001) provided encouraging results. Indeed for the first time, we had observed the diffraction magnetic satellites associated with the magnetic helical order of Eu by using the resonant X-ray magnetic scattering at the  $L_2$  and  $L_3$  edges of this element. Up to now, these satellites had only been observed by neutron diffraction. The values of the order temperature as well as the helix periodicity in our film were found to be similar to the bulk ones. However, at 10K we observed two differences with the bulk sample. First, we noted the absence of magnetic diffraction peaks corresponding to the helix propagating along the cubic axis located in the plane of the sample ( $[001]$  axis, figure 1). Secondly, we observed that the wave vectors of the helix was not exactly along the other cubic axis but presented a slight tilt of  $4^\circ$  (figure 1). However the sample we used during these first experiments presented three crystallographic domains which seriously complicated any quantitative analysis in order to elucidate the origin of these differences.

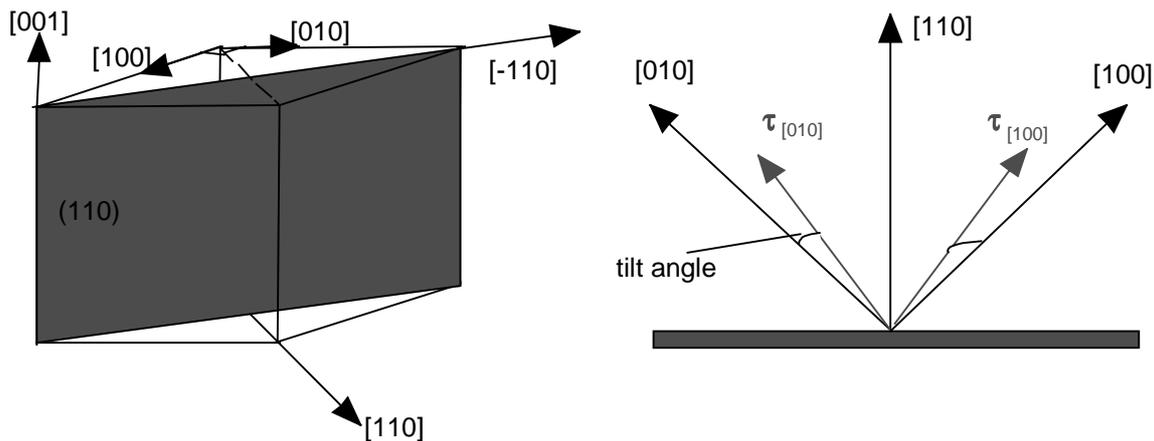
For the November experiment, owing to an improvement of the growth process, we disposed of a single domain crystal. We systematically measured the magnetic satellites from the transition temperature  $T_N = 90.4$  K down to the lowest available temperature 10K. This study revealed that three helices appear simultaneously at  $T_N$ . They correspond to three magnetic domain and their wave vectors are close to the three equivalent  $\langle 100 \rangle$ . However we observed that the intensity of the magnetic satellites related to the  $[001]$  helix (propagating in the plane of the sample) decreased below 60 K at the benefit of the satellites related to the  $[100]$  and  $[010]$  directions and reached 0 near 40K (figure 2). There is clearly a change of population between the three magnetic domains. On the other hand, we observed an hysteresis effect because, while increasing the temperature from the lowest temperature, the  $[001]$  axis satellites reappeared only around 70K (figure 2).

The experiment confirmed there was a tilt angle  $\alpha$  between the cubic directions  $[100]$  and  $[010]$  and the wave vectors of the related helices. The thermal dependence of the tilt angle has been measured and is shown in figure 3. It increases when the temperature decreases, which means the helix wave vectors become closer to the perpendicular axis of the sample. The thermal dependence of the helix wave vector is shown in the same figure.

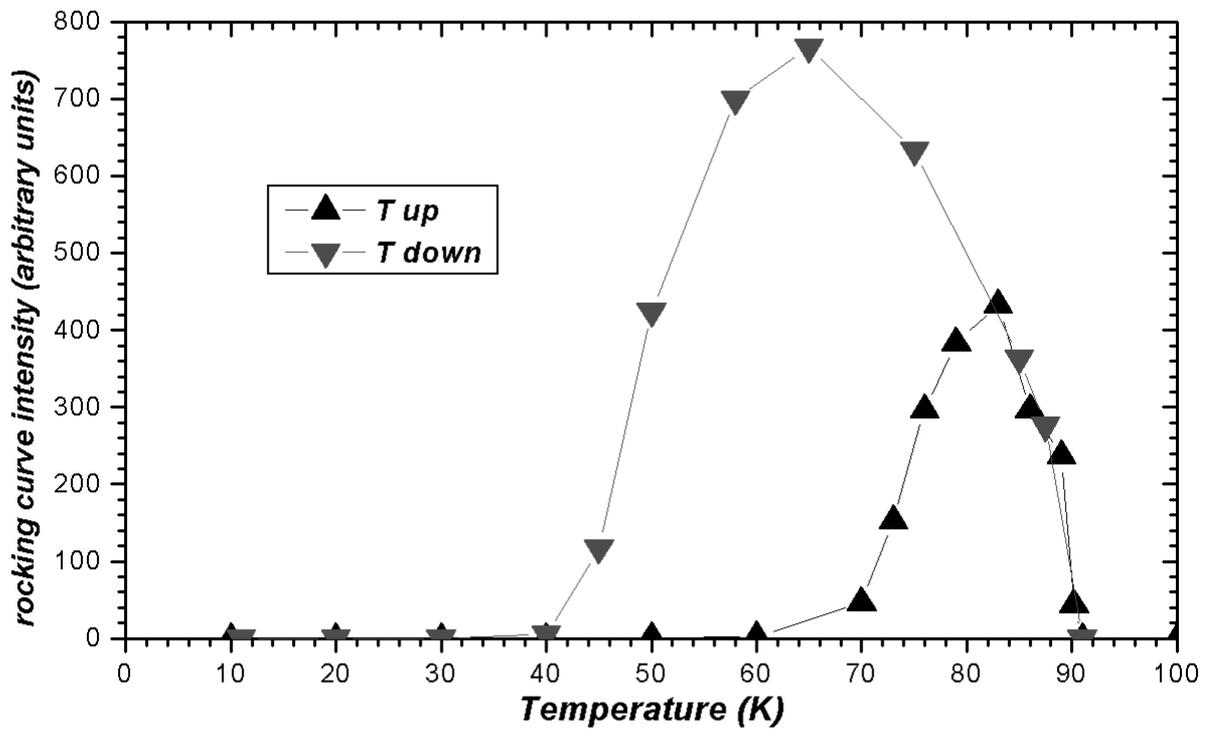
Along with the intensities of the magnetic satellites, we measured the position and the width of some charge peaks in order to determine quantitatively the deformations occurring in the sample. We observed deformations partly due to epitaxial strains and partly due to the spontaneous distortion related to the magnetic ordering. First data analysis data lead to the conclusions that :

- the epitaxial strains are responsible of the thermal dependance of the domain populations
- the tilt angle is probably an intrinsic property of europium.
- the tilt angle do not split the domains into subdomains as it should occur in a bulk sample, which is probably an epitaxial strain effect.

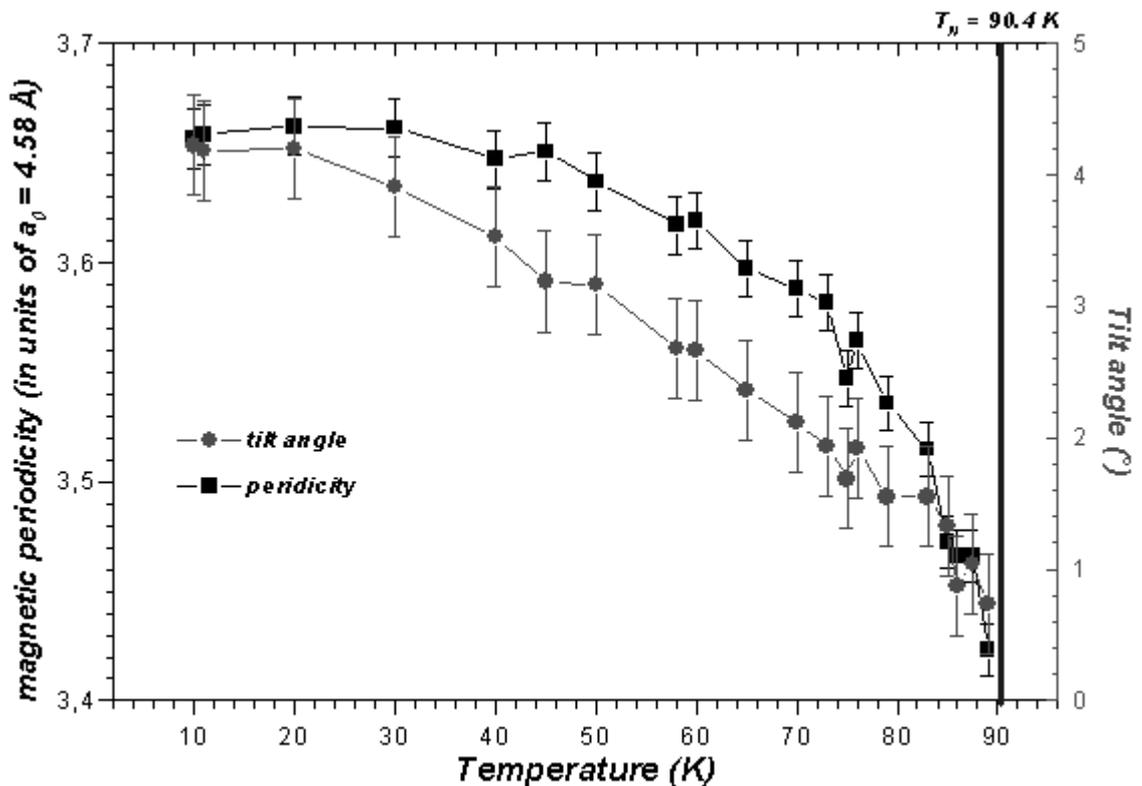
We finally tried to determine the magnetic structure of an  $(\text{Eu}_{80}/\text{Yb}_{20})_{63}$ . Superlattice. Unfortunately, we did not find magnetic satellites, maybe because the quality of the superlattice was too poor. We have to improve the quality of the samples and makes first measurement from superlattices with a higher periodicity.



**Fig 1** sample geometry. 3D view and 2D view in the (a, b) plane



**Fig.1** : rocking curve intensity of the  $(2,2,\tau)$  magnetic satellite along the  $c$  axis as a function of the temperature



**Fig.2** : Magnetic periodicity and tilt angle as a function of the temperature. The tilt angle is the angle between the helix propagation vector and the  $a$  (or  $b$ ) axis of the cubic lattice