# 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.

| ESRF | **Experiment title:** Investigation of an ordered EuSe quantum dots using magnetic scattering and XMCD at the Eu $M_{IV}/M_V$ -edges | **Experiment number**: HE 1086 |
| --- | --- | --- |
| **Beamline**: ID08 | **Date of experiment**: from: 30.01.2002 to: 05.02.2002 | **Date of report**: 12.11.2002 |
| **Shifts:** 18 | **Local contact(s)**: P. Bencok*[1], S. Dhesi*[1] | *Received at ESRF:* |


**Names and affiliations of applicants** (* indicates experimentalists):

T. U. Schülli*[1,2], R. T. Lechner*[2], J. Stangl*[2], G. Bauer[2], P. Bencok*[1], S. Dhesi*[1]

[1]*European Synchrotron Radiation Facility, BP 220, F-38043 Grenoble Cedex, France*
[2]*Johannes Kepler Universität Linz, Institut fürHalbleiterphysik, A-4040 Linz, Austria*


In order to study the influence of strain and finite size on their magnetice behaviour, EuSe was deposited on the surface of a template of highly ordered PbTe/PbSe dots ([1-2]). This induced the formation of a quantum dot monolayer of Euse islands, aligned in a hexagonal in-plane lattice. To prevent the sample from oxidation, the dots where covered with a 100 nm thick Se layer that was evapourized after introduction in the UHV chamber at id08. The completion of the removal of this layer was verified with the absorption spectra measured via the absorption spectrum at the Eu $M_{IV}/M_V$-edges (Fig. 1(a)).
Oxidation had to be avoided, as e.g. the formation of EuO could not be excluded. As EuO is known to be ferromagnetic it could have prevented the study of the subtle changes in the magnetic behaviour. A comparison of the absorbtion spectra in the vicinity of the Eu $M_V$-edge of the previously Se-capped samples with [3] showed an $f^7$-like spectrum. It could be shown, that even after exposure to air after the cap removal, that no EuO was formed, as the absorption spectra where $f^6$-like, being an indicator for $Eu_2O_3$. Furthermore, the existence of $Eu_2O_3$ was confirmed in the measurement of the dichroic behavior. As $Eu_2O_3$ is nonmagnetic, the dichroism of these samples was extremely week compared to the nonoxidized ones (see Fig 1(b)-(c)). Due to the extremely small escape depth of the photoelectrons, the dichroic signal of the EuSe islands covered by a $Eu_2O_3$ layer remains very weak, but shows the same $f^7$-like line-shape. Therfore oxidation is expected to have indeed little influence on the magnetic properties of these islands. As EuSe becomes ferrimagnetic or, dependent on the strain also ferromagnetic at low temperatures [4], we intended to investigate the influence of a small variation in the island size on the magnetic behaviour on the mesoscale such as superparamagnetism or antiferromagnetic coupling between the islands (the latter has been observed already in multilayered structures). As there exists no other technique than XMCD to investigate these samples, there was little knowledge about the estimated phase transformation temperature. From SQUID measurements on 2D multilayers, the temperature range for the expected ferrimagnetic ordering could be estimated to be 5-10 K. By the time our experiment was performed, the minimum temperature achievable at id08 was 8 K. The hysterisis loops where measured at the lowest achievable temperature for two samples of average island sizes of 60 nm and 80 nm. As shown in Fig. 2 one observes a slightly different behaviour concerning the spin moment. The phase tarnsformation temperature was not reached in both samples but the larger sized islands show already a coupling of the Eu-spins. The resulting spin moment from the brioullin

function fitted to the magnetisation curves results to be 3.5 for the smaller islands (corresponding to the spin of a single Eu $f^7$ atom) whereas it tends to lie 3 times higher for the larger islands.

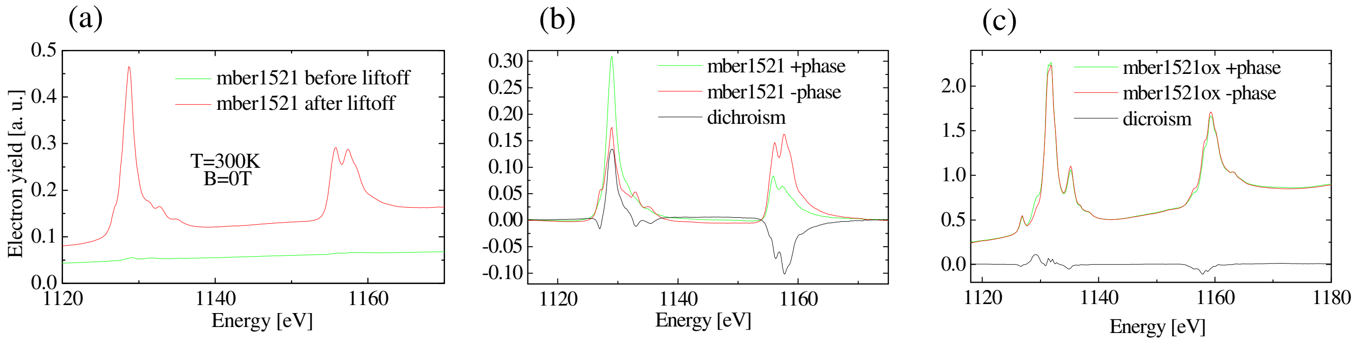


*Fig. 2 (a): Absorption spectrum in the vicinity of the Eu $M_{IV}/M_V$ –edges, for a EuSe-island sample covered by a 100 nm thick Se layer(green line) and after the evapourizition of this layer (red line). (b): absorbtion spectrum and dichroicsm at 9 K in 7 T magnetic field. (c) The same as in (b) after exposure to air: the $f_6$ multiplett structure and the non-magnetic behaviour are a footprint of the formation of $Eu_2O_3$ rather then ferromagnetic EuO.*

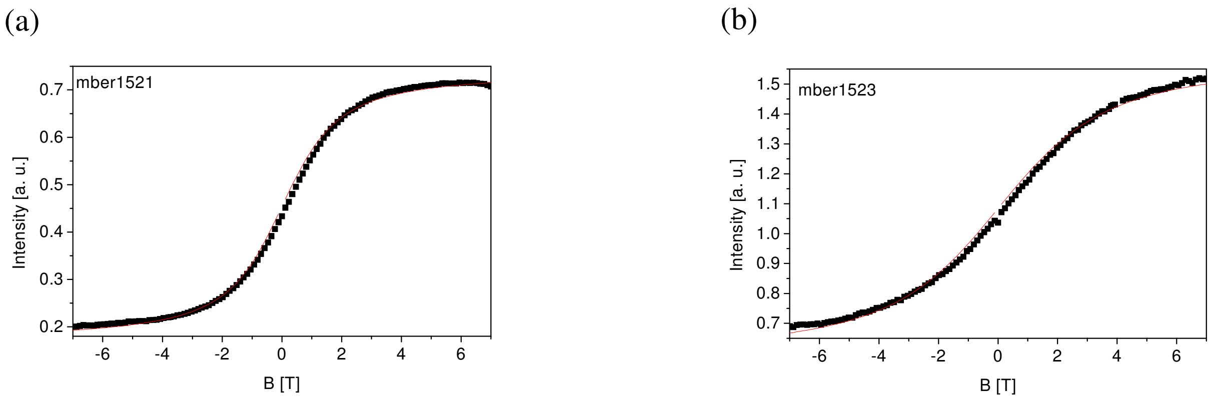


*Fig. 2: Magnetisation loops at 9 K for samples of different dot sizes on different templates. (a) Fit with Brioullin function returns spin moment of ~8.5. (b) Fit with Brioullin function returns spin moment of ~3.5 (magnetic moment of one Eu atom).*

## References

[1] G. Springholz, V. Holy, M. Pinczolits, G. Bauer, Science **282**, 734 (1998).

[2] G. Springholz, J. Stangl, M. Pinczolits, V. Holy, P. Mikulik, P. Mayer, K. Wiesauer, G. Bauer, D. Smilgies, H.H. Kang, L. Salamaca-Riba, Physica E **7**, 870 (2000).

[3] B.T. Thole, G. van der Laan, J.C. Fuggle, G.A. Sawatzky, R.C. Karnatak, J.M. Esteva, Phys. Rev. B **32** (1985).

[4] I.N. Goncharenko and I. Mirebeau, Phys. Rev. Lett. **80**, 1082 (1998).

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