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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.

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http://193.49.43.2:8080/smis/servlet/UserUtils?start

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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

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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:** Facet orientation in PbSe/PbTe quantum dot superlattices determined by anomalous X-ray diffraction.	**Experiment number**: Si-812
Beamline: ID01	**Date of experiment**: from: 12.12.2002 to: 18.12.2002	**Date of report**: 25.08.2003
Shifts: 18	**Local contact(s)**: Tobias Schülli	*Received at ESRF:*

Names and affiliations of applicants (* indicates experimentalists):

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Report:

PbSe quantum dot single layers and PbSe/ $Pb_{0.92}Eu_{0.08}Te$ island superlattices, grown in [111] direction, where investigated using anomalous diffraction at the Pb M_V-edge. At these energies, one observes a pronounced minimum in the scattering intensity from the $Pb_{0.92}Eu_{0.08}Te$ (111) superstructure Bragg reflection. This leads to a material selectivity and an increase in the scattering contrast between the two materials. In the case of the PbSe quantum dots that form a 3D trigonal ordering in the $Pb_{0.92}Eu_{0.08}Te$ matrix [1], which leads to a 3D satellite intensity distribution in reciprocal space in the vicinity of a Bragg reflection. The uncapped PbSe pyramidal shaped islands on top of a PbSe/ $Pb_{0.92}Eu_{0.08}Te$ multilayer have three {100} facets, determined by AFM and are hexagonally ordered in the (111) plane. We performed an anomalous diffraction study on a multilayer of 30 PbSe/ $Pb_{0.92}Eu_{0.08}Te$ bilayers, with the aim to get information both on ordering, strain and in particular on the shape of the buried islands.
Anomalous diffraction in the vicinity of the Pb M_V-edge allows for either the suppression of the PbSe-scattering or the$Pb_{0.92}Eu_{0.08}Te$ scattering respectively. The suppression is achieved e.g. at the (111) superstructure Bragg reflection, where the structure factor of the rock salt like lattice of PbSe reads:

$$F_{111}=f_{Pb}-f_{Se} \qquad (1)$$

A similar expression holds for PbTe or $Pb_{0.92}Eu_{0.08}Te$ alloys. Therefore one finds pronounced minima in the scattering amplitude from these compounds at the intersection points of the atomic scattering factors of the elements. As Pb is the dominating scatterer at almost for any energy in the x-ray cristallography regime, this required to exploit the strong M-edge resonance of Pb at 2.5 keV. $q_\perp$-$q_{||}$ reciprocal space maps in the vicinity of the specular (111) Bragg reflection were recorded at an x-ray energy of 2.41 keV, leading to a selective suppression of the scattering from the $Pb_{0.92}Eu_{0.08}Te$ matrix. The *envelope function* of the *intensity* satellites in reciprocal space is therefore attributed to the *shape function of the pyramids*. Having a trigonal symmetry in the (111) plane, one expects now to see the same type of intensity envelopes, whenever the sample is rotated by 120 °. Projected in the (111) plane, the facet normals point along the <11-2> in-plane direction. Any $q_{?}$-$q_{||}$ map cutting the (111) reflection in a <01-1>-plane therefore contains a truncation rod from these facets. Fig. 1 shows maps across the (111) reciprocal lattice point for a symmetrical <112> type azimuth (a) and an asymmetrical <110> type one (b). In (b) the direction of the facet truncation rod is indicated.

The observed angle between the facet normal and the [111] surface normal is 35-40 °. This corresponds to a considerable flattening of the facet orientation of buried islands with respect to the angle of 54.7 ° for the {100} facet orientation for the uncapped ones on the top surface. However, we note that in the trigonal PbSe island lattice, the trigonal angle between the three lattice unit vectors and the [111] direction was observed to be 39° [2,3]. This value of 39° is determined by the surface positions of mimimum elastic energy density above a buried PbSe island, as a consequence of the elastic anisotropy of the PbEuTe matrix [1]. Interestingly enough, the three facets of the buried PbSe islands orient themselves such that their facet normals coincide with these orientations.

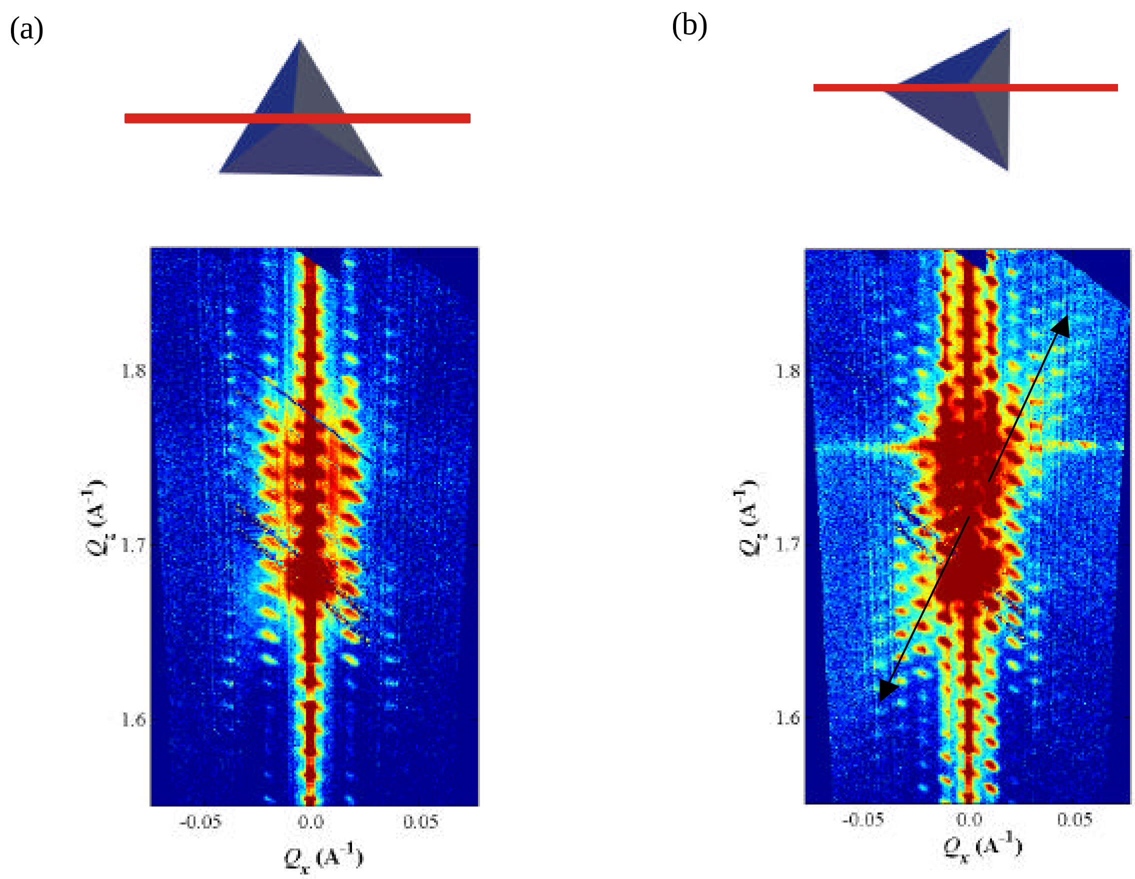

Figure 1 (a): Symmetric $q_{?}$-$q_{||}$ reciprocal space map across the specular (111) reflection frm a PbSe/ $Pb_{0.92}Eu_{0.08}Te$ quantum dot superlattice. No asymmetry due to facet truncation rods can be seen
(b): *Asymmetric $q_{?}$-$q_{||}$ reciprocal space map. The asymmetry in the envelope of the satellite peaks is attributed to the facet truncation rod. The black arrows indicate the observed direction of the facet normal.*

References

[1] G. Springholz, V. Holý, M. Pinczolits, G. Bauer, Science **282**, 734 (1998).
[2] V. Holý, G. Springholz, M. Pinczolits, G. Bauer, Phys. Rev. Lett. **83**, 356 (1999).
[3] G. Springholz, M. Pinczolits, P. Mayer, V. Holý, G. Bauer, H. H. Kang, L. Salamanaca-Riba, Phys. Rev. Lett. **84**, 4669 (2000).