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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.

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

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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

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.

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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:** Anomalous x-ray scattering from laterally modulated short period InAs/AlAs superlattices	**Experiment number**: SI-763
Beamline: ID01	**Date of experiment**: from: June 12, 2002 to: June 17, 2002	**Date of report**: August 21, 2002
Shifts: 15	**Local contact(s)**: Dr. Till Hartmut Metzger	*Received at ESRF:*

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Report:

A lateral composition modulation (LCM) in short period semiconductor superlattices (SPS) has generated considerable interest because of its potential applications in high efficiency lasers, polarized light emitters and detectors, and high efficiency solar cells. The exact origin of this composition modulation in these semiconductor alloy films is currently a subject of considerable investigation [1]. It has been shown recently that the LCM can be manipulated by growing SPSs containing two nearly strain balanced sublayers only a couple of monolayers (ML) in thickness, such as $(InAs)_n/(AlAs)_m$ on InP (001) (n and m denote the number of monolayers in the superlattice period).

Much effort has been made to characterize these LCM structures in a qualitative or semiquantitative way by both transmission electron microscopy (TEM), atomic force microscopy (AFM) and x-ray diffraction. Since the total thickness of the SPS is far below 1 μm, a surface-sensitive x-ray scattering technique (grazing-incidence x-ray diffraction – GID) can yield much better experimental data that the conventional coplanar scattering arrangement. In our previous studies [2] we have used coplanar diffraction and GID for the structure analysis of the LCM in a $(InAs)_2/(AlAs)_2$ on InP(001) with various values of the surface miscut.

The analysis of the measured data was based on the distorted-wave Born approximation (DWBA). The measured distribution of the scattered intensity in reciprocal space depends both on the modulation of the chemical composition of the superlattice period (due to the periodic modulation of the thicknesses of the individual layers), and on the strain modulation caused by the lattice mismatch between both constituents. Since we have measured the intensity distribution around the zero-order vertical intensity satellite, the vertical superlattice structure played no role in the measured data and the experimental intensity distribution in reciprocal space could be simulated using a simple model of a vertically *homogeneous* layer with a lateral modulation of its chemical composition. This lateral modulation caused a laterallymodulated lattice mismatch and consequently a laterally modulated deformation field. However, the scattered intensty was influenced not only by this elastic field but also by a lateral modulation of the chemical composition itself (i.e. by the lateral modulation of the scattering factor). Therefore, the analysis of the measured data was not straightforward and it suffered from several *ad-hoc* assumptions concerning the elasticity properties of the investigated SPS.

In order to overcome this difficulty, in the experiment Si-763 we have performed the anomalous x-ray diffraction from the InAs/AlAs SPS in the GID geometry, using the wavelength of about 3.36 Å. In this wavelength, the structure factors of unstrained InAs and AlAs are *same*, as shown in figure 1.

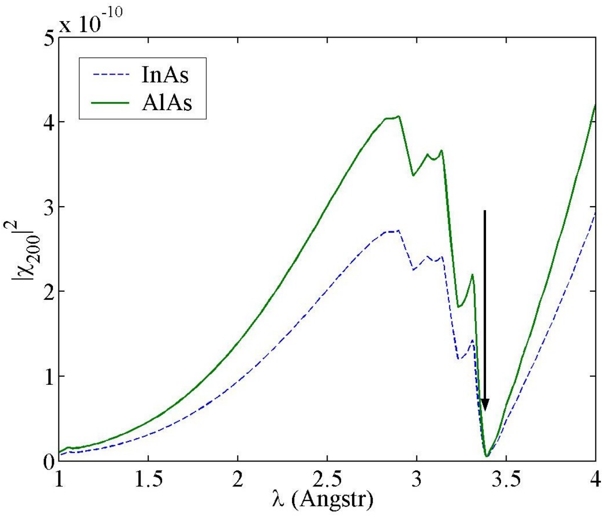

Figure 1. The wavelength dependence of the square of the polarizability χ of InAs and AlAs for diffraction 200. The intensity of diffraction is proportional to $|\chi|^2$. Both polarizabilities are equal for the wavelength denoted by the arrow.

Since the lateral modulation in our samples was along [100], we have performed GID measurements in the in-plane diffractions 200 and 020. The scattereded intensity was measured by a position-sensitive detector (PSD) perpendicular to the sample surface. From a series of the PSD spectra taken for various in-plane scattering angles we constructed the radial Q_rQ_z intensity map parallel to the diffraction vector, from the PSD spectra taken for constant in-plane scattering angle and various azimuthal angle of the primary beam we obtain the angular Q_aQ_z map perpendicular to the diffraction vector.
The radial map in 200 and the angular map in 020 diffractions exhibited lateral intesity satellites caused by the

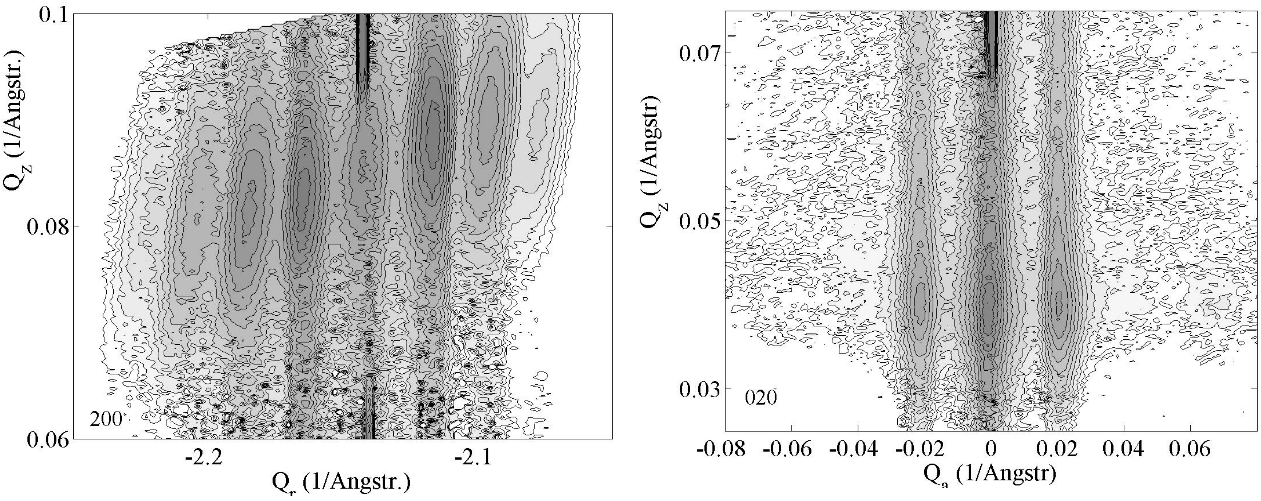

Figure 2. The GID radial (left) and angular (right) maps of a laterally modulated SPS, measured at λ = 3.36 Å.

lateral modulation. The envelope curve of these maxima is asymmetric due to the strain distribution and shifted also in vertical direction due to the miscut. In the angular map, only the $\pm 1^{st}$ lateral maxima can be seen. In this arrangement, the diffraction vector is perpendicular to the modulation direction, thus the scalar product **h**.**u**(**r**) of the diffraction vector with the displacement field is identically zero. The presence of the lateral satellites in this map can be caused either by a weak chemical contrast, if the polarizabilities of InAs and AlAs are not exactly the same, or by the elastic anisotropy causing a non-zero elastic deformation also in the direction perpendicular to the LCM direction.
From these two maps, the strain field distribution in the SPS will be reconstructed and, in combination with previous measurements at λ = 1.54 Å, the modulation of the chemical composition will be determined independently. The results will contribute to the analysis of possible mechanism the generation of spontaneous lateral modulation in short period superlattices.

[1] B.J. Spencer et al., Appl. Phys. Lett. **76**, 3022 (2000).
[2] J. H. Li et al., Appl. Phys. Lett. **78**, 219 (2001); J. H. Li et al., Phys. Rev. B, in press (2002).