ESRF	**Experiment title:** Anomalous x-ray scattering on buried InGaAs quantum dots	**Experiment number**: HS-2033
Beamline: ID10B	**Date of experiment**: from: 16.04.2003 to: 22.04.2003	**Date of report**: 26.09.2003
Shifts: 15	**Local contact(s)**: Dr. Bernd Struth, Dr. Oleg Konovalov	*Received at ESRF:*

Names and affiliations of applicants (* indicates experimentalists):

Michael Hanke* (+)
Daniil Grigoriev*
Peter Schäfer*
Rolf Köhler

Address:
Humboldt-Universität zu Berlin
Institut für Physik
Newtonstrasse 15
D-10117 Berlin, Germany

(+) Present address:
Martin-Luther-Universität Halle-Wittenberg
Fachbereich Physik
Hoher Weg 8
D-06120 Halle(Saale), Germany

Report:

We will give preliminary results of an experiment at self-organized InGaAs/GaAs quantum dot (QD) superlattices (SLs) recently done at ID10B beamline. A sequence of samples were grown by MOCVD consisting of typically 5 layers of $In_{0.6}Ga_{0.4}As$ QDs embedded in GaAs spacer layers exhibiting different thicknesses. The strain field of the buried QDs leads to a narrow size distribution and remarkable vertical correlation between subsequent QD layers. Also samples consisting of a single layer of InGaAs QDs have been investigated.

In the present work we have applied high resolution grazing incidence diffraction (GID) taking advantage of anomalous scattering effects. The combined use of a Si (111) analyser crystal and a linear position sensitive detector (PSD) makes full three dimensional mapping in recioprocal space at sufficiently high resolution feasible. The diffusely scattered intensity has been recorded in the vicinity of different reciprocal lattice points at different angles of incidence and at different energies.

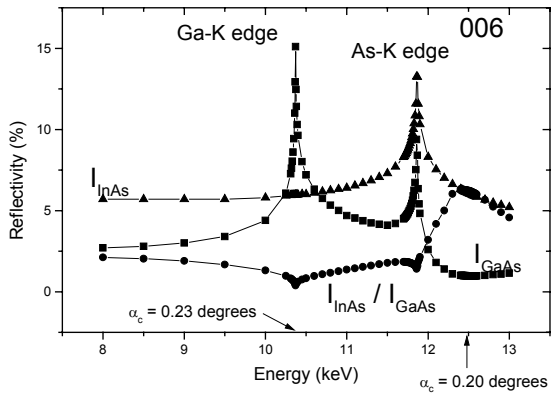

figure 1: calculated reflectivity as a function of x-ray energy for pure InAs, GaAs and the ratio of both of them.

Fig.1 plots the calculated reflectivities for the 006 reciprocal lattice point. Since the scattering from pure GaAs is expected to be comparatively strong at the Ga-K edge (10.367 keV) and As-K edge (11.867 keV), respectively, pure InAs will show an enhanced scattering at the As-K edge only. Consequently, the ratio of scattering form pure GaAs and pure InAs shows a significant minimum at 11.367 keV, and, moreover a maximum at 12.470 keV. Since the (006) reflection is of quasi-forbidden nature in *zink blende* structure the GaAs

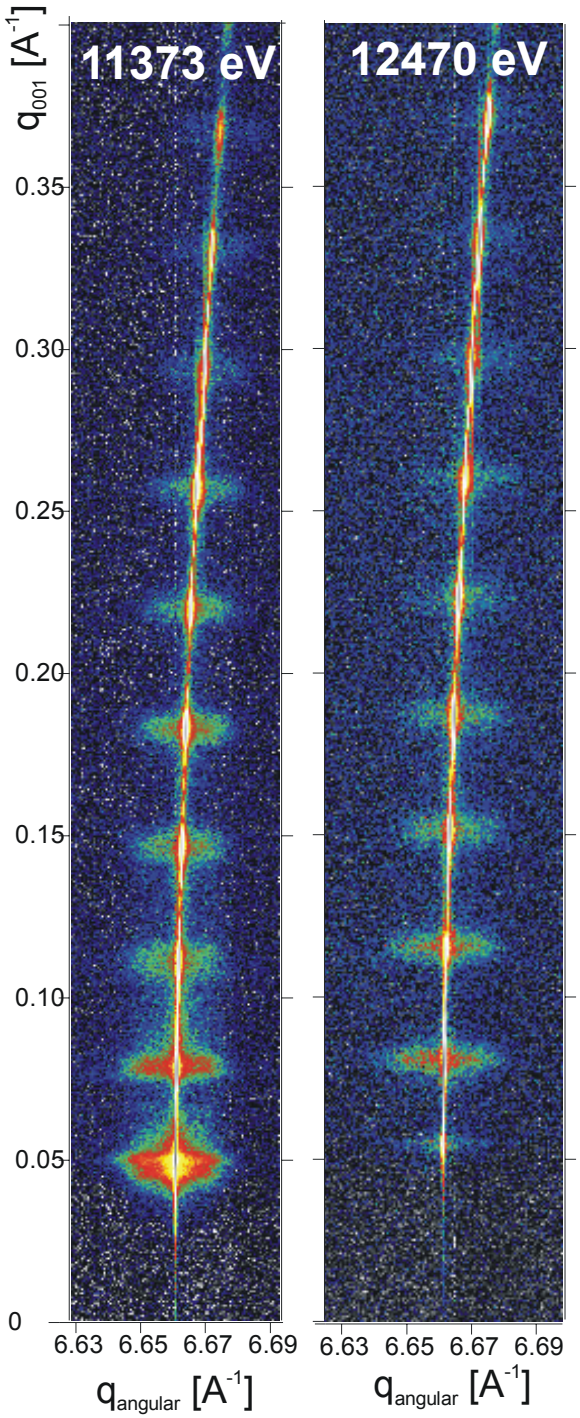

figure 2: Diffusely scattered intensity around 006 reciprocal lattice point at two different energies.

signal is already diminished because only the difference in structure factors of Ga and As enters the scattering signal. Moreover, at this energy we can observe a strongly increased signal of the InGaAs QDs by damping the respective GaAs matrix signal. We have to emphasize that a detailed analysis has not been yet performed and we are presenting preliminary results.

We have systematically studied a variety of quasi-forbidden reflections (200, 460, 280, 680 and 10 00) at different energies. Figure 2 plots as an example the out-of-plane scattering in the (q_{radial} − q_{001}) plane around the 600 reciprocal lattice point at 11.373 keV and 12.470 keV, respectively. Incidence angle has been kept constant at 0.20° for both energies. The pronounced vertical ordering of QDs causes vertical SL peaks with a period of 0.0327 $Å^{-1}$, which corresponds in real space with vertical SL period of 192 Å. Recently, we have reported [1] about investigations done in a previous (exp. number HS-1582) beamtime. The intensity of the mentioned oscillations at strong reflections, as e.g. 400 or 220, will be superimposed by the highly intense diffuse scattering originating from the GaAs matrix material.

In order to suppress further the GaAs matrix signal (beyond damping due to quasi-forbidden reflections) we have tuned the energy to a value, where the intensity ratio of scattering by InAs and GaAs becomes a maximum. This will have a particular influence at regions around the substrate position, which can be clearly seen at q_{001}=0.05 $Å^{-1}$ in both distributions. On the other hand at this energy the signal is dominated by the strained parts within the QDs. However, in order to evaluate quantitatively the measured distributions we are preparing dynamical scattering simulations on the base of finite element calculations for the strain field within the structure, which shows a significant impact of QD's shape and size *and* the particular chemical composition. See e.g. our publication [2] concerning the mentioned evaluation procedure developed for freestanding SiGe islands. Respective measurement were done at ID10B (exp. number HS-1735).

References:

[1] M.Hanke, D.Grigoriev, M.Schmidbauer, P.Schäfer, R.Köhler, U.W.Pohl, R.L.Sellin, D.Bimberg: *Diffuse X-Ray Scattering of InGaAs/GaAs Quantum Dots,* to be published in Physica E (accepted)

[2] D.Grigoriev, M.Hanke, M.Schmidbauer, P.Schäfer, O.Konovalov and R.Köhler, *Grazing Incidence X-Ray Diffraction at Free-Standing Nanoscale Islands: Fine Structure of Diffuse Scattering,* J. Phys. D **36**, A225 (2003)