Experiment title: Strain and Correlation of InGaAs/GaAs quantum dot arrays studied by grazing incidence x-ray diffraction	Experiment number: HS 1582

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Report:

We give a preliminary report on an experiment at self-organized InGaAs/GaAs quantum dot (QD) superlattices very recently performed at ID10 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 (Figure 1). Within this process the intermediate layer undertakes the role of a bandpass filter suppressing deviations from a mean dot size. Furthermore the strain field caused by buried dots propagates through this layer establishing favorable nucleation sites for QDs within the following QD layer. For a detailed understanding of island nucleation process and accompanied decomposition effects within the dots an accurate analysis of strain field is inevitable. Also samples consisting of a single layer of InGaAs only have been investigated.

We have applied high resolution grazing incidence diffraction (GID). The combined use of a Si (111) analyser crystal and a linear position sensitive detector (PSD) enables three dimensional mapping in reciprocal space at high resolution. The diffuse intensity has been recorded in the vicinity of different reciprocal lattice points at different angles of incidence to allow depth resolved investigations.

A detailed analysis has not been yet performed and we are presenting preliminary results which can be summarized as follows:

- The QDs exhibit a high degree of vertical ordering (even at rather high spacer layer thicknesses of 20 nm). Therefore, the scattering patterns are very similar for various angles of incidence α_i. The high degree of vertical ordering is illustrated in Figure 3a and 3b where strong resonant diffuse scattering

(RDS) sheets could be observed in the vicinity of the 200 reciprocal lattice point. The vertical width of the RDS sheets indicates a vertical correlation length which is comparable to the entire thickness of the QD superlattice.

- Despite the large vertical correlation, surprisingly, no lateral ordering of the QDs could be detected. The 220 in-plane reciprocal space map shows a broad intensity distribution of difffuse scattering only (Figure 2) without any intensity modulations that can be assigned to lateral correlation.

- The QDs show no size anisotropy with respect to the [100] and [010] directions. This can be clearly seen in Fig. 3a,b and c. Also the [110] and [1$\bar{1}$0] directions are equivalent (not shown).

- Different strain states can be observed. Both dilatated and compressed areas are visible in the 200 and 020 diffraction pattern (Figure 3). Dilatated areas lead to intensity at the left side of the crystal truncation rod (CTR) whereas compressed areas are loctated at the right side of the CTR. Dilatated and compressed areas can be probably attributed to the QD and the spacer layer, respectively. It is interesting to mention that the centre of mass of the RDS sheets are different for different values of q_z. A detailed understanding of the diffraction pattern requires x-ray simulations. These are currently in preparation.

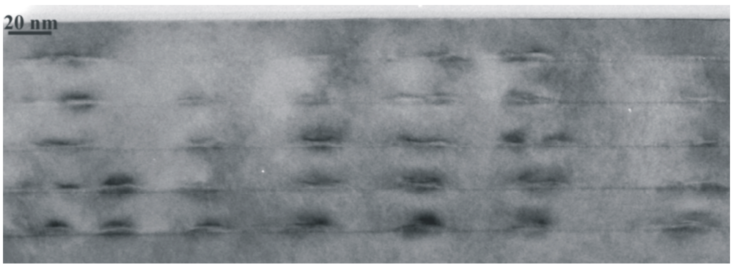

Figure 1: *Transmission electron micrograph (cross section) of an InGaAs/GaAs quantum dot multilayer proving high degree of vertical correlation.*

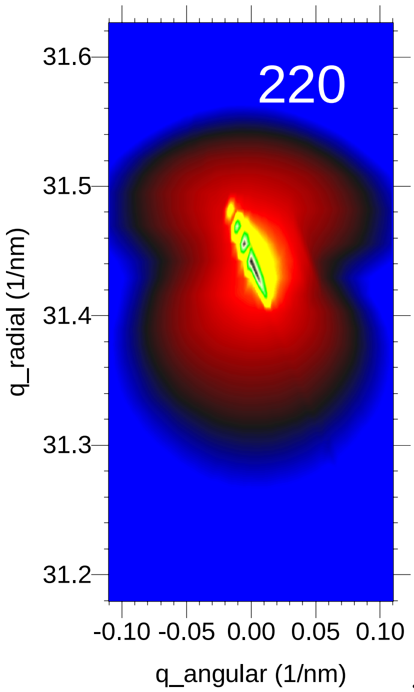

Figure 2: *Grazing incidence in-plane map in the vicinity of the 220 reciprocal lattice point. The rather broad intensity distribution indicates that the QDs are laterally uncorrelated. .*

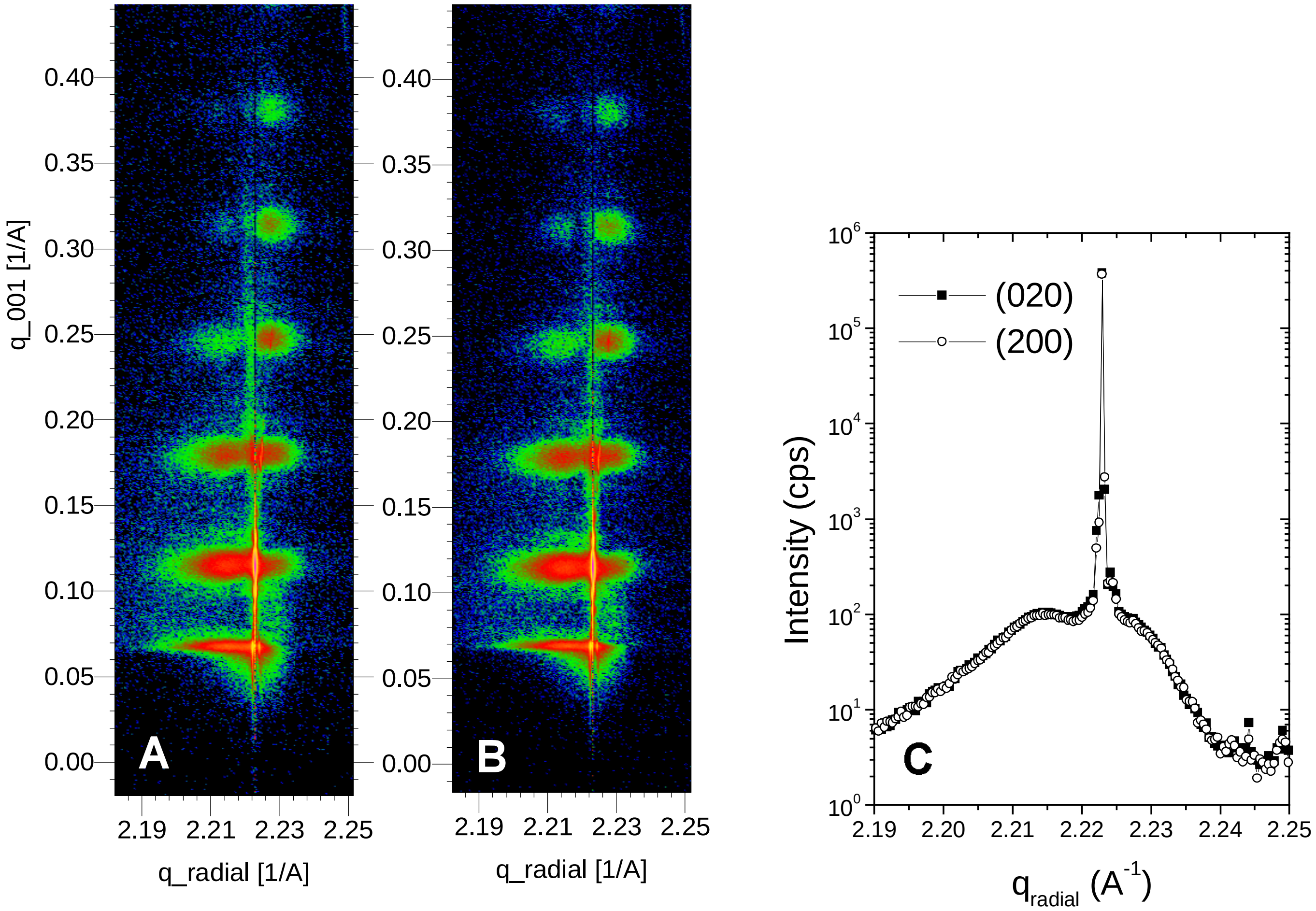

Figure 3: *Diffusely scattered intensity around the 200 (A) and 020 (B) reciprocal lattice point (α_i=0.5°). Nearly no difference between both ⟨100⟩ directions (as well for both ⟨110⟩ directions – not shown here) suggests a symmetric shape with respect to these directions (see also (C)). The GaAs substrate reflection occurs at q_{radial}=2.223Å^{-1}. The intensity distribution inside the RDS sheets indicates compressed and dilatated areas of the sample.*