The aim of our experiment is to measure the thermal expansion coefficient of a pure semiconductor multilayer before and after preparation of a lateral nanostructure. In this experiment our nanostructure sample consists of a multilayer system with 5 periods of an InGaAs/GaAs multi-quantum-well grown on [001] a GaAs substrate. The Indium concentration amounts to 22 %. The surface nanostructure of the sample was prepared via holographic exposure and subsequent wet chemical etching with a lateral periodicity of 300 nm. The sample has a total superlattice thickness of 54.7 nm.

The samples were measured at HASYLAB’s BW-2 Beamline. The samples were mounted onto an evacuated heating stage (Anton-Paar DHS 900). We used coplanar x-ray diffraction in order to measure the rocking curves (ω/2θ-scan) of the symmetric 004 and 002 reflections. Our scan direction corresponds to a longitudinal scan, i.e. it will show the oscillations of the superlattice but not the grating peaks. The curves were recorded at two different temperatures, i.e. at 25°C and at 400°C. Considering the smallness of the expected effect we used an analyzer crystal (Si-111) in front of a scintillation counter. Our beamsize was 1mm² and the energy was set to 8 keV.

First, we measured the region of the non-patterened area of the sample followed by measurement for the patterned part of the sample. The patterned area can be identified by the appearance of grating peak measuring an ω -scan as seen in Fig.1. Two typical diffraction curves of the patterned sample area measured at room temperature and at 400°C are shown in Figure 2.
Both curves show distinct superlattice peaks in addition to the Bragg peak of the GaAs substrate. The angular distance between the superlattice peaks are inversely proportional to the thickness superlattice period. Due to thermal expansion this angular distance is supposed to change at different temperatures, i.e. the thermal expansion coefficient of the superlattice can be measured from the change of the angular distance between the superlattice peaks.

From previous measurements the thermal expansion coefficient of the bulk material (GaAs) has been determined. It amounts to $\alpha_{\text{substrate}} = 6.4 \times 10^{-4} \text{K}^{-1}$. Known values for the materials used in the superlattice are $\alpha_{\text{GaAs}} = 6.4 \times 10^{-4} \text{K}^{-1}$ and $\alpha_{\text{AlGaAs}} = 5.98 \times 10^{-4} \text{K}^{-1}$. Since the multilayer has been grown pseudomorphically onto the substrate, the unit cell is tetragonally strained. This means a rise in the vertical lattice parameter and consequently a rise in the vertical TEC compared to the mean values of the given bulk data above. Previous work shows an increase of the TEC of up to 30% compared to non-strained materials due to the tetragonal deformation [1]. This has also been theoretically investigated [2].

Preliminary evaluation of the data recorded at HASYLAB suggests that the thermal expansion coefficient of the patterned and non-patterned multilayer systems are different. For the patterned part of the sample one gets a thermal expansion coefficient of the superlattice of $\alpha_{\text{pattern}} = 9.837 \times 10^{-4} \text{K}^{-1}$ and for the non-patterned part one gets $\alpha_{\text{unpatterned}} = 1.231 \times 10^{-5} \text{K}^{-1}$.

The origin of this difference can be explained by the lateral relaxation of the ternary component within the superlattice after lateral patterning.

![Figure 2: 002 Reflection at two different temperatures (ω/2θ-scan) revealing the superlattice structure](image)

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Literature:  