The aim of the experiment was the investigation of plastic relaxation via the formation of dislocations in Si/SiGe multilayer structures. The samples have been grown at the PSI Villingen (Switzerland) and are so-called quantum cascade structures. A series of strained SiGe layers forms quantum wells for holes in the valence band. For especially designed quantum well widths and depths (the latter are determined by the Ge content of the wells and their strain status) minibands are formed under an applied bias, and electroluminescence can be observed. A particular problem of such structures in the SiGe system is the required large number of strained layers with a very high total thickness, which may lead to plastic relaxation. In order to enhance the design freedom for such structures, instead of growing them directly onto Si(001) wafers, they are grown onto a virtual substrate with a different lattice parameter than Si. For this purpose, Si wafers with a strain-relaxed SiGe buffer layer have been used.

For the investigated samples, the plastic relaxation of the remaining strain via formation or multiplication of dislocations during thermal treatment has been investigated, in order to obtain a measure for the thermal budget the structures may undergo during device processing without deterioration. It was planned to use a small furnace available at ROBL beamline to perform this annealing study in-situ, recording reciprocal space maps around selected reflections during annealing at temperatures between 450°C and 850°C. Due to a problem with the furnace, the annealing had to be carried out ex-situ, and the samples have been
measured after subsequent annealing steps. Fig. 1 shows several reciprocal space maps of sample J014 in the as-grown state as well as after annealing at 850°C for 30 minutes. As is obvious from the maps, the shape of the diffusely scattered intensity from the SiGe buffer as well as from the cascade multilayer shows small differences. Also, the average position with respect to the Si substrate is slightly changed, which might hint at a different strain state. It is, however, not clear, whether this is already an effect of annealing and a difference in the dislocation distribution in the samples, or whether the differences rather result from different measurement spots at the samples: as the annealing was ex-situ and the samples had to be aligned after each annealing step, it is likely that slightly different spots are illuminated.

As the samples are grown on a relaxed buffer containing already a high density of dislocations, the threading segments of dislocations penetrate the SiGe cascade structure already in the as-grown sample, leading to a peak broadening in reciprocal space maps. Hence small differences in the relaxation state are difficult to detect in the case of an ex-situ annealing study for samples exhibiting lateral inhomogeneities, as is the case here.

Fig. 1: Reciprocal space maps around (004) and (115) of sample J014 as grown and after annealing at 850°C for 30 min.