ESRF	**Experiment title:** In-situ characterization of the induced lattice strain and the onset of degradation in semiconductor laser devices under operation	**Experiment number:** HS410
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Report:

The aim of the experiment was the in-situ characterisation of the induced lattice strain and the on-set of degradation in semiconductor devices under laser operation using high resolution X-ray diffraction and plane wave topography.

The experiment was the first experiment performed in the end phase of commissioning the high resolution X-ray diffractometer for the vertical scattering geometry. It demonstrated the principal functionality and stability of the diffractometer and the high precision topography slit system. However, the work in the *triple* crystal mode and defined scans by the precision slits were still not available. Thus we worked in the *double* crystal mode. By the slit system in front of the sample we could localise the beam at different precise sample positions. Using narrow detector slits, we got a moderate angular resolution of the diffracted beam.

We investigated three laser stripes on different heat sinks by spatially resolved diffractometry and low resolution topography using 18 keV radiation in order to penetrate the thick metallisation layer. Fig. 1 shows a double crystal curve with open slits, where we find between a “high background” of Bragg-peaks from the central strongly deformed laser stripe region four well pronounced Bragg-peaks. By topography we could relate them to the superlattice and the substrate peaks at the front and back facets.

Further reciprocal space maps (see e.g. fig.2) were measured with open entrance slits and narrow detector slits. The maps demonstrates the strong and inhomogeneous lattice deformation (curvature and lattice strain) along the sample. Unfortunately the use of a narrow detector slit instead of an analyser crystal mixes partially the angular information a the spatial information. Principally the spatial and angular effects could be better separated only by simultaneous use of entrance and detector slits, but than the maps have to be repeated for each position, just not practicable with a reasonable time expense. This problem can be avoided in the next experiment by working in the now available *triple crystal* mode.

Further we measured the diffraction curves under laser operation, at selected stripe positions (now with

narrow entrance and exit slits, in dependence on the carrier current). From the absolute shift of the Bragg positions and their relative distance we could determine the thermal induced lattice expansion before and during laser degradation. We observed a strong gradient of the lattice expansion along the stripes, with its maximal difference between the back and front facets (See fig. 3). Further different kinds of topographs accompanied the degradation process of the lasers (here we show the topograph of a "continues "zebra" scan after complete degradation of one sample (fig. 4).
Concluding, we found 1. a laterally strongly inhomogenous lattice distortion along the laser stripes due to the mounting and bonding. Secondly we detected the temperature behaviour in the stripes in dependence on the current carrier showing a lateral gradient of the thermal induced lattice expansion.
We propose the continuation of experiment by using the now available triple crystal arrangement in order to separate precisely scattering in different directions from scattering by different sample regions. Also the detection of thickness fringes and their modulation for the essential study of the local thermal induced lattice distortion in the active layer *zone* requires the triple crystal mode, we plan for the next experiment.

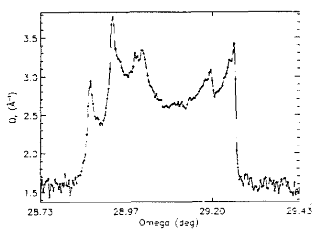

Fig. 1: Double crystal curve of a mounted laser (008-reflection).

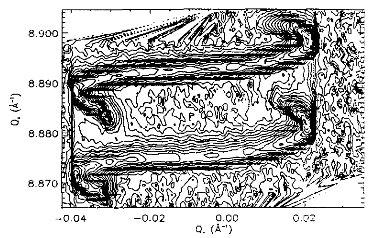

Fig. 2: Reciprocal space map of a mounted laser (008-reflection).

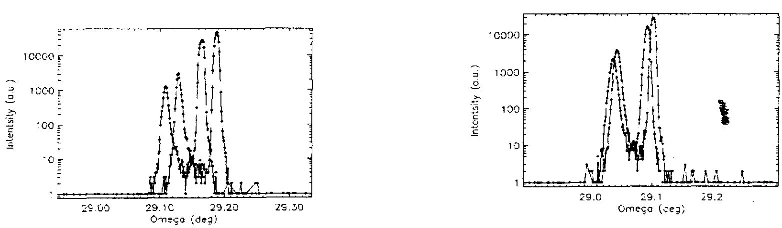

Fig. 3: Truncation rod pattern of the 008-reflection for two different carrier currents; left: at the front facet, right: at the rear facet.

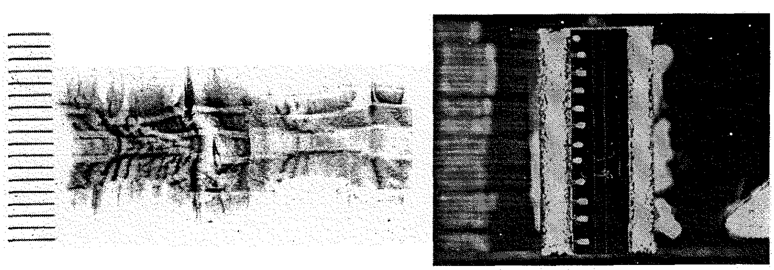

Fig. 4: right: mounted laser, left: continuous "zebra"-scan through the 008-reflection curve after degradation.