ESRF	**Experiment title:** Real time observation of the degradation of novel laser diodes under operation	**Experiment number:** HS-574
Beamline: ID19	**Date of experiment:** from: 01-May-98 to: 04-May-98	**Date of report:** 26/2/99
Shifts: 9	**Local contact(s):** Angel MAZUELAS	*Received at ESRF:*

Names and affiliations of applicants (* indicates experimentalists):

Fernando BRIONES, Instituto de Microelectronica de Madrid (IMM)
briones@imm.cnm.csic.es
c/ Isaac Newton 8 (PTM), E-28760 Tres Cantos (Madrid), Spain
Tel. 34 91 806.07-00 Fax. –01

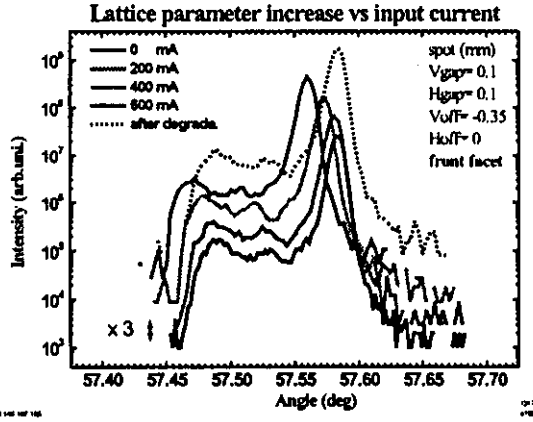
Maria Luisa DOTOR * IMM marisa@imm.cnm.csic.es
Dolores GOLMAYO * IMM lola@imm.cnm.csic.es

Angel MAZUELAS * ESRF mazuelas@esrf.fr

Report: We studied some of the new approaches to semiconductor lasers such as **pseudoquaternary waveguiding** lasers. We aim to correlate the actual structural features (composition, strain, etc..) **before, during and after operation**, both with the growth parameters and with the optical properties and device characteristics. Especially interesting is the **real time observation of the laser degradation due to the formation of misfit dislocations**. Our study required the measurement of theta-2theta scans with analyzer, obtained with a very high spatial resolution in order to measure within the laser stripe (only 1000 micrometers long times 100 micrometers wide) and X-ray topographies through the metallic contact before and during laser diode operation. The main novel feature in these semiconductor lasers was the pseudoquaternary waveguiding of GaInAs/InP in form of short period superlattices, which substitute the conventionally used GaInAsP quaternary alloys. Another novel feature is the InAs/GaAs Multiple Quantum Well (MQW). In these structures the interfaces between layers can have a lattice mismatch as high as 7.2%, which may lead to relaxation by the formation of misfit dislocations, both during the crystal growth, the device processing, and the laser diode operation. How detrimental are misfit dislocations to laser performance is a a key point that is not clearly understood yet, and our experiment aims to clarify it.

Results After sample alignment and careful definition of the laser stripe limits with respect to the X-ray micro spot, a series of theta-2theta scans with analyzer were taken at 5 different points along the laser stripe. Then, the laser driving current was increased and again the 5 theta-2theta scans were measured and a topograph was taken. The theta-2theta scans show the InP peak and the epitaxial layer peak around the (008) reflection at 10keV. For the same laser stripe position, these two peaks change with the laser driving current Fig.1, indicating a change in the lattice constant.

The figure shows how the peaks shift to smaller angles (larger lattice constant) for increasing current. After the laser died, the measurement was repeated once the laser had cooled off. Again at room temperature, the peak position comes back to the original value, thus excluding other possible factors for the peak shift. Taking into account the thermal expansion coefficient of InP, the temperature change in the epilayer is calculated (Fig.2).



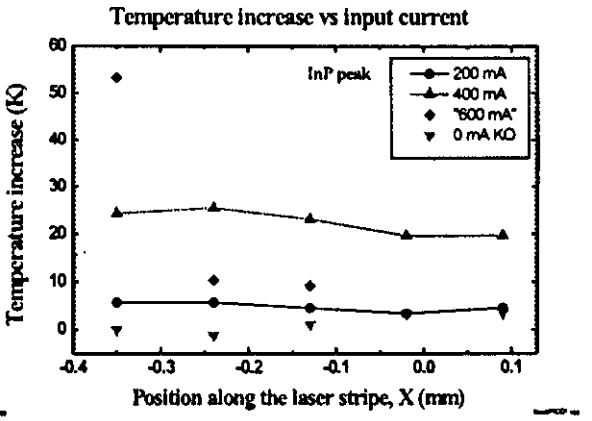


Fig.1. Theta-2theta scans for different driving current, taken at the front facet of the laser.
Fig.2. Temperature increase in the epilayer calculated from the lattice constant change and the thermal expansion coefficient.

These figures show that the temperature is quite uniform along the laser stripe, and the temperature increases with driving current an average of 55 K at 600 mA.

Topography Several topographies were taken at different driving current of the laser, i.e. at different positions of the laser characteristic curve. The topographies were taken at the (008) reflection of the InP substrate with Kodak SR X-ray film, at a sample to film distance of 50 cm. The laser diode was tested before taking the topographies up to a current of 300 mA for few seconds. The topographies show lines with a contrast characteristic of misfit dislocations. This contrast changes for increasing driving current, as it is seen in Fig.3, where we plot the topographies taken at different driving current: a) is for 300 mA, b) is for 600 mA, and c) is once the laser diode was dead. A detailed analysis of these topographies is under way, which will allow to estimate misfit dislocation density, as well as the correlation with the laser diode degradation process.

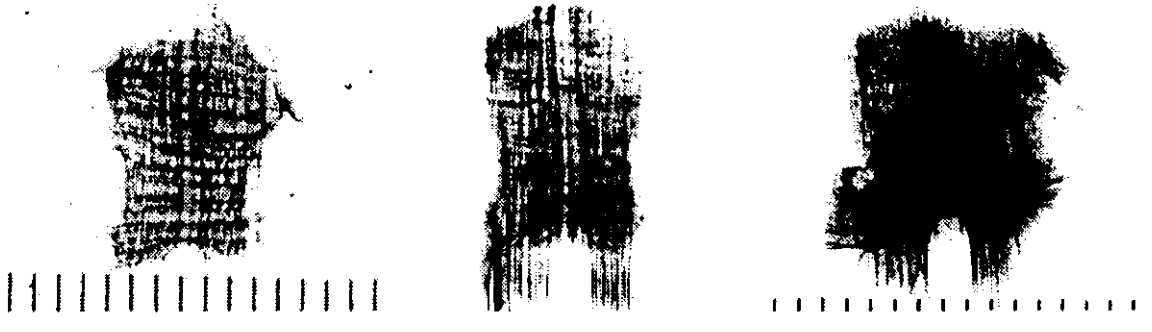


Fig.3. Topograph taken at the peak of the InP substrate (008) reflection at 300, 600 mA and After laser diode degradation. The unit of the scale is 100 micrometers.

Conclusions We have studied laser diodes under operation to determine in real time the heat load along the laser stripe as a function of the laser driving current. We have also observed the laser degradation by the formation of misfit dislocations with increasing laser diode driving current.