Optimization of Laser Gain Material

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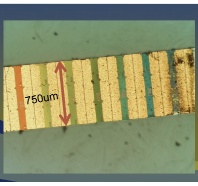


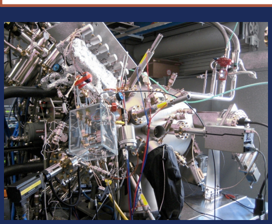
Ridge Laser

Introduction:

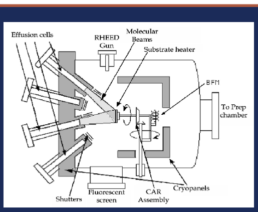
Current electronic technologies face a problem: the ubiquitous copper components are reaching their bandwidth limits, and the need for faster information processing and transmission is growing. Light can be used as a more rapid means of carrying information and is a suitable replacement for copper due to its capability for higher bandwidth and speed. Current optical transmission systems for short to midrange communications use Vertical Cavity Surface Emitting Lasers (VCSELs). The ultimate goal of the research is to develop a faster and more efficient VCSEL. For this project a setup was built to test simple ridge lasers and utilized to obtain information that would help determine optimal material compositions that could lead to better VCSELs. The material growth was performed using Molecular Beam Epitaxy (MBE) and the processing was done via photolithography. A baseline characterization of the material was obtained and will be used to contrast future materials.

Growth by Molecular Beam Epitaxy (MBE):

The lasers are grown or fabricated using MBE, which consists of "beaming" evaporated materials onto a wafer with great precision of material composition.



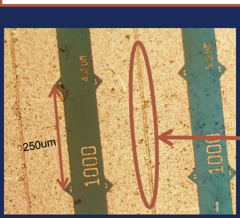
GEN III MBE machine



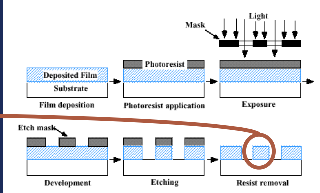
MBE machine diagram
http://mxp.physics.umn.edu/s07/Projects/S07_Graphene/images/MBE.gif

Processing by Photolithography:

Photolithography is used to create the "ridge" of the ridge laser



Ridge Laser close-up



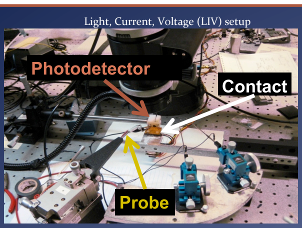
Photolithography diagram
http://www.hitequest.com/Kiss/photolithography.gif

Testing:

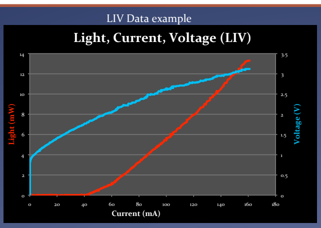
Three methods were used for testing the laser material:

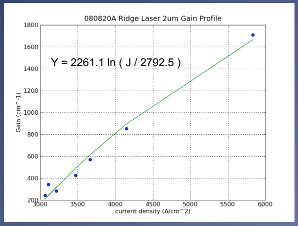
- Light, Current (I), Voltage (LIV) to determine turn-on current and Differential Quantum Efficiency (DQE, the inverse light vs. current slope) for different length ridge lasers to obtain laser gain profile.
- Relative Intensity Noise (RIN) to determine resonant relaxation frequencies and the magnitude of negative nonlinear effects of the active region in the laser.
- Electrochemical Capacitance-Voltage (ECV) to determine carrier concentration of the material. ECV machine had to be calibrated to the effective etching area.

Light, Current, Voltage (LIV) setup



LIV Data example

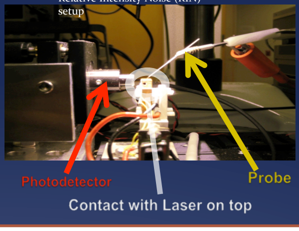




Gain Profile:

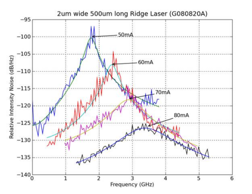
- Slope of gain profile provides speed of laser at differing current densities: greater slope = faster laser.
- Future results will be compared to this baseline data to determine faster material compositions.

Relative Intensity Noise (RIN) setup



Contact with Laser on top

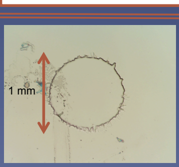
RIN Data example



Graph courtesy of Yan Zheng, UCSB

RIN Data:

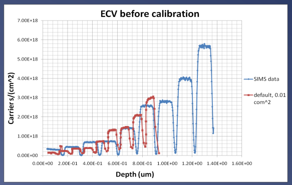
- The change in the "sharpness " of the peak (peak = resonant relaxation frequency) give the magnitude of nonlinear effects. Try to minimize.
- The shift of the peak with respect to change in current describes high speed capabilities of laser. Try to maximize.

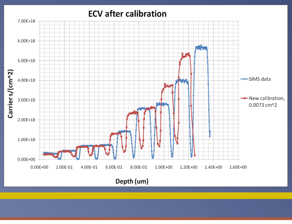


ECV etching area

ECV calibration:

- The effective etching area differed from the default setting, so a microscope picture of the etched area of a sample provided the correct area.
- To the right: Improvement of results after calibration along with SIMS (Secondary Ion Mass Spectrometry).





Conclusions and Future plans:

- Baseline data was obtained.
- Next step: grow new lasers with differing levels of doping (Carbon, p-type) and strain (%In in InGaAs) in the active region.
- Test new lasers and compare with baseline data.
- Select best material composition and build a faster Vertical Cavity Surface Emitting Laser (VCSEL).

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- Thank you to all that have read through this poster (glancing at the pictures also counts).

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