Lens Like Grating Surface Emitting Laser (LLGSE)

Susan Wilson, Jin Wang, Gary Evans, Jay Kirk, and Jerome Butler
Southern Methodist University, Dallas, TX

SMU Photonics

Taha Masood, Steve Patterson, and Duane Carter
Photodigm, Inc., Richardson, TX

Photodigm

Andrew MacInnes, Tony Balistreri, and Tso-Min Chou
TriQuint Semiconductor, Richardson, TX

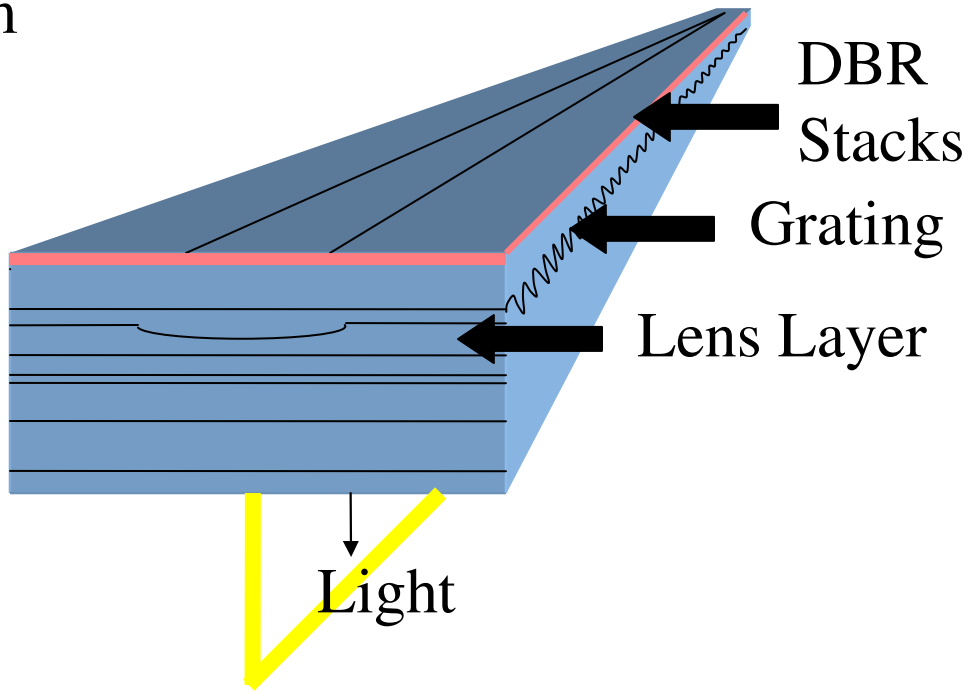
TriQuint SEMICONDUCTOR

Sponsored by: Air Force Research Laboratory's
Directed Energy Directorate
Contract F29601-98-C-0063

Research based on previous work by: Alan H. Paxton
Ref: U.S. Patent 5,727,016, "Spatially Coherent Diode Laser with Lenslike Media and Feedback from Straight-Toothed Gratings," Issued March 10, 1998

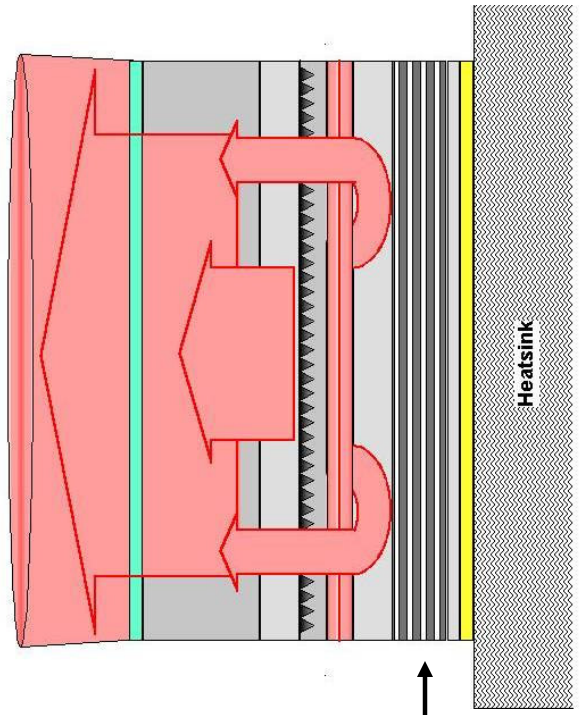
LLGSE Goals

- Wavelength 975 nm
- Single Frequency
- 10 Watts CW
- Backside Emission



Applications

- Pumping of Yb fiber lasers
- Diode pumped solid state lasers
- Welding/cutting
- Frequency Doubled Visible Source

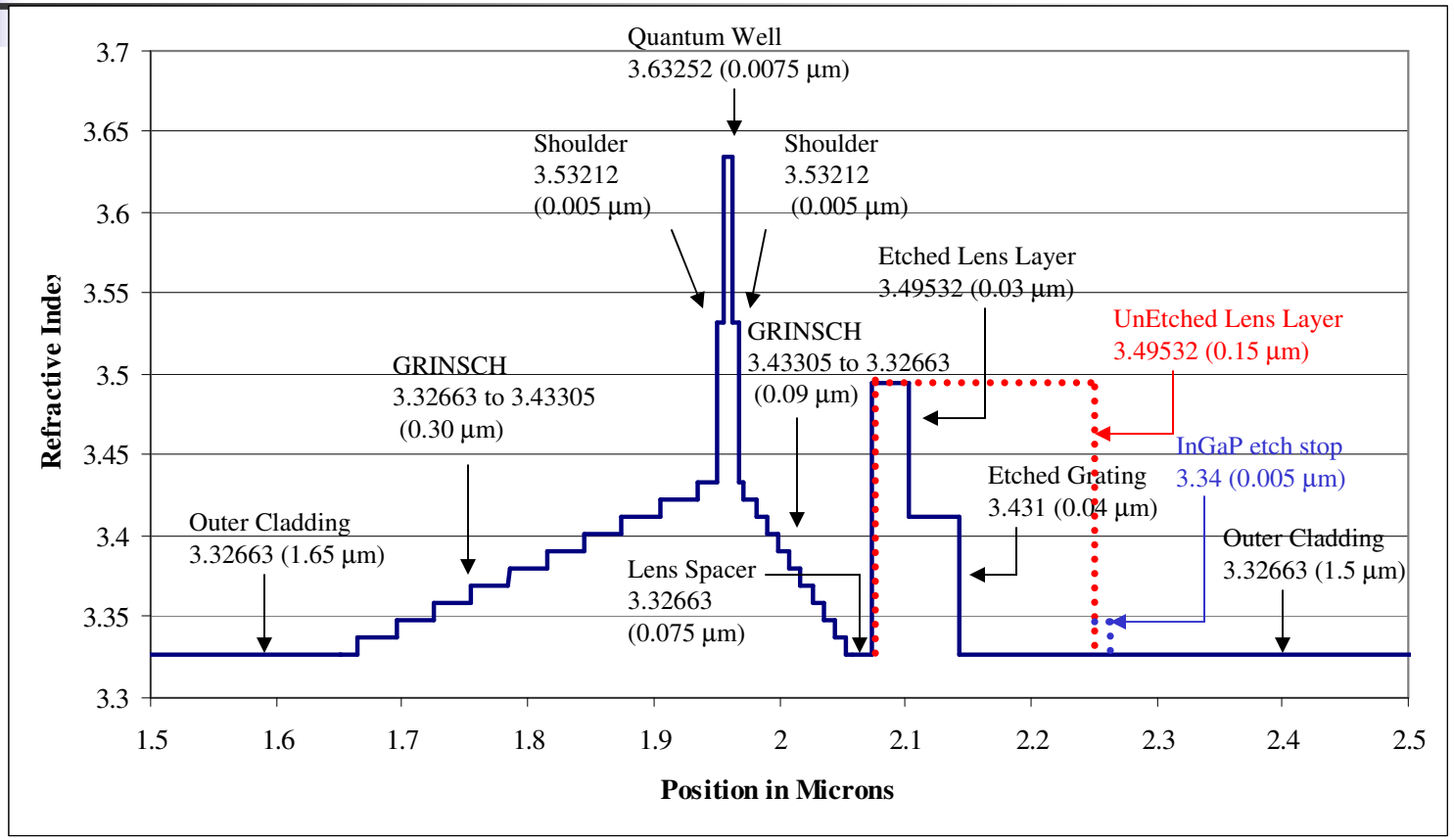


Reflector Stack
For One-Way
Transmission

Program History

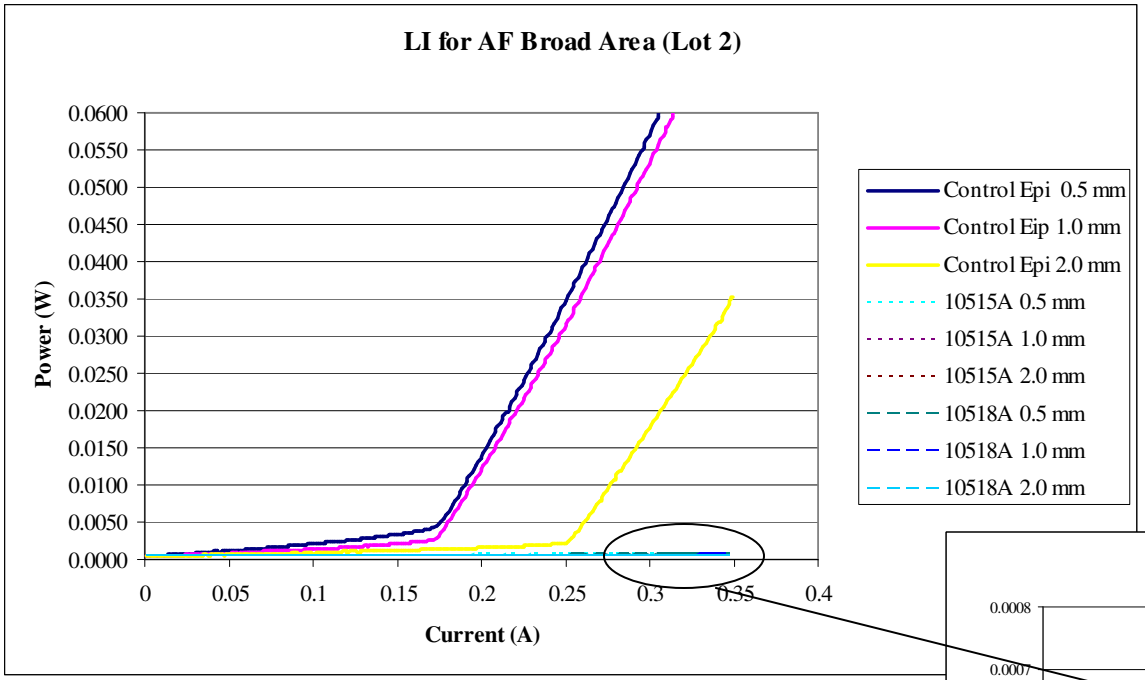
- Modeled and designed LLGSE laser structure
- Designed mask layout
- Developed processes for etching lens channel, second order gratings, and backside processing
- Fabricated and tested devices - no lasing was observed
- Reviewed design and modeling
- Verified Process
- New p-side design has demonstrated lasing for simple broad area configuration, regrowth, and regrowth over gratings

Proposed Asymmetric Structure with Lens and Grating on p-side of device

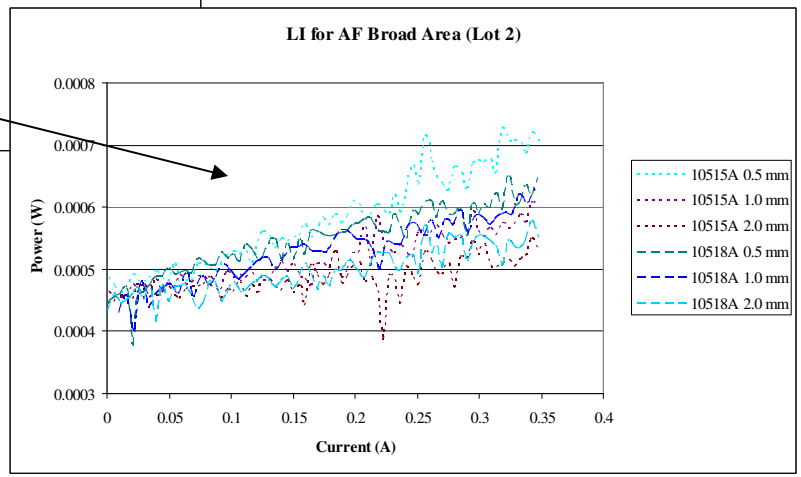


Proposed structure facilitates qualifying epi and λ as well as fabricating LLGSE devices. Broad area Fabry Perot lasers can be fabricated with unetched lens and etch stop layers intact or LLGSE lasers can be fabricated by etching back to the lens layer and processing a parabolic-like lens and second order grating in the lens layer.

Process Verification – Broad Area LI Results



- Previously grown 980 Control Epi lasing
- Epi grown for LLGSE SMU, SBIR Phase I, and SBIR Phase II programs not lasing

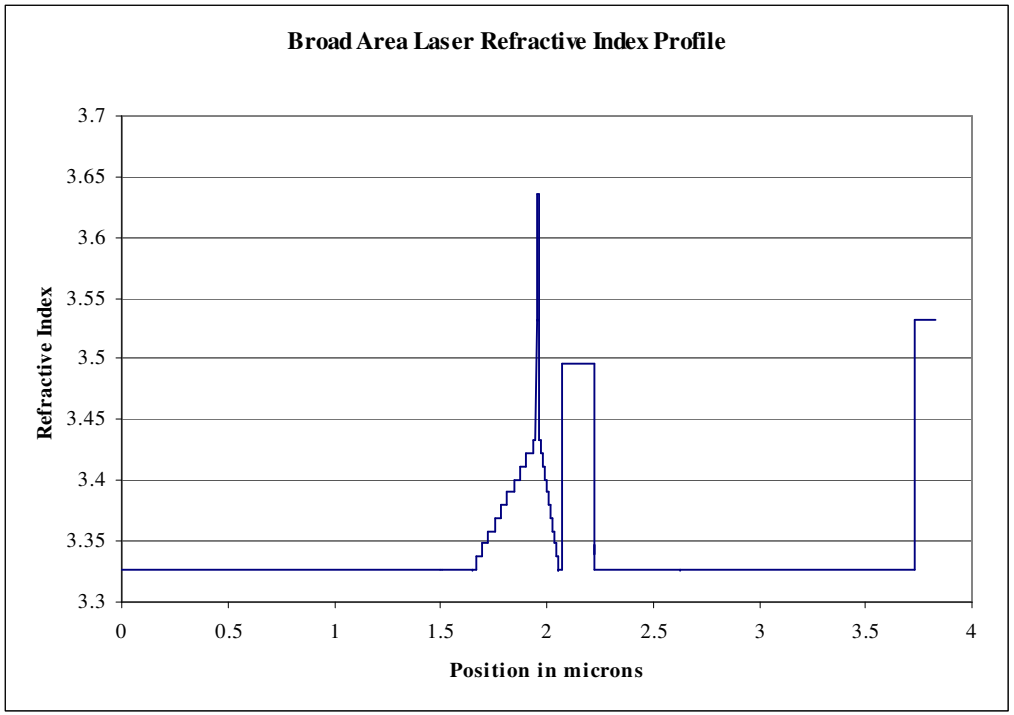


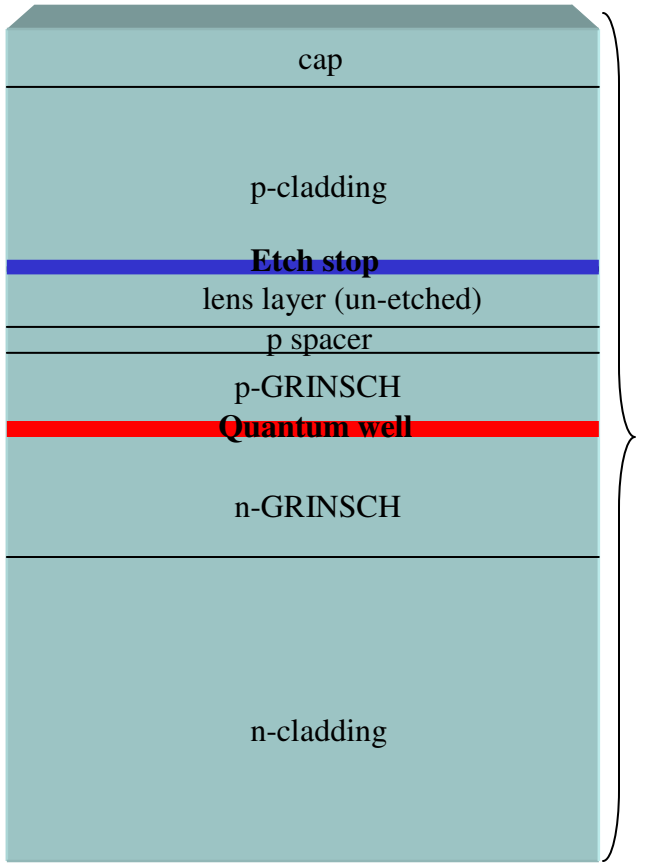
Epi Qualification

- Purpose
  - Quantify the material parameters of the growth
  - Establish a performance baseline
- Typical Procedure
  1. Cleave a small piece off of wafer
  2. Fabricate simple Broad Area Fabry Perot Lasers
  3. Test laser devices
  4. Extract material parameters based on measurements

Broad Area Laser Structure – Full Growth

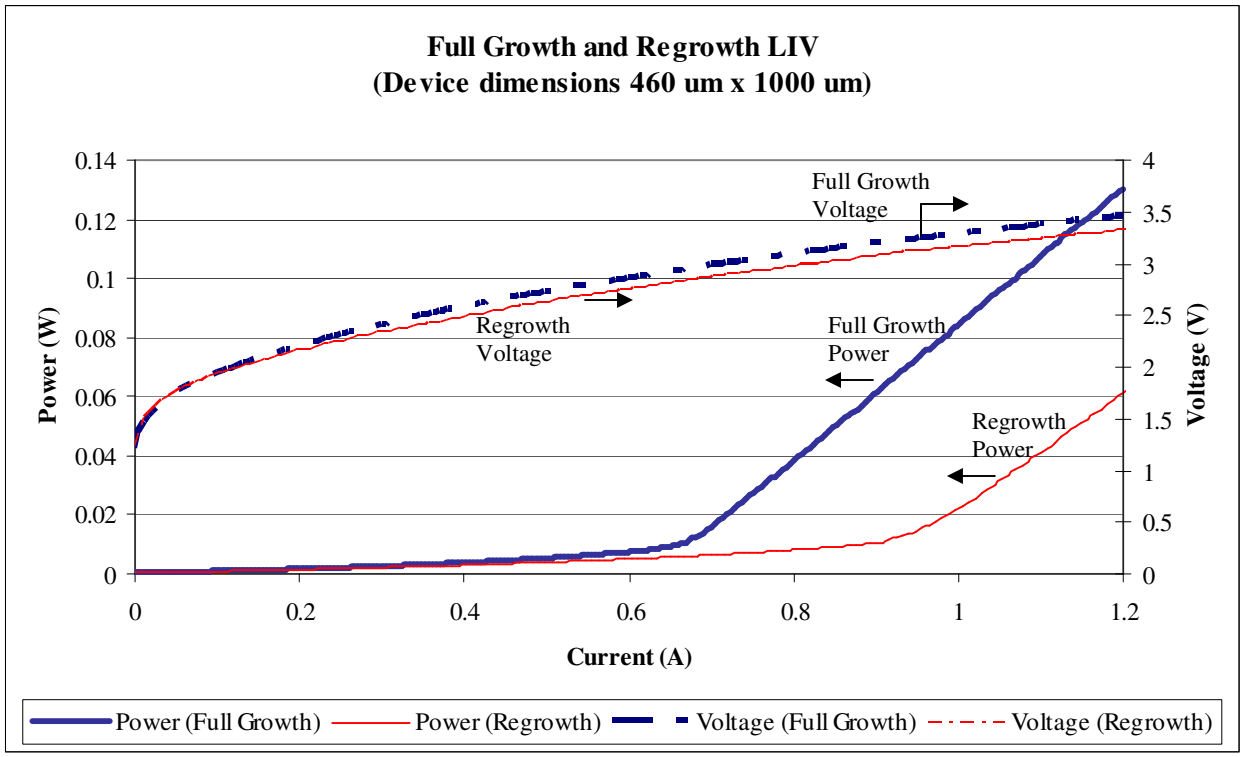
(Simplified Version of LLGSE with no etched lens and no grating)





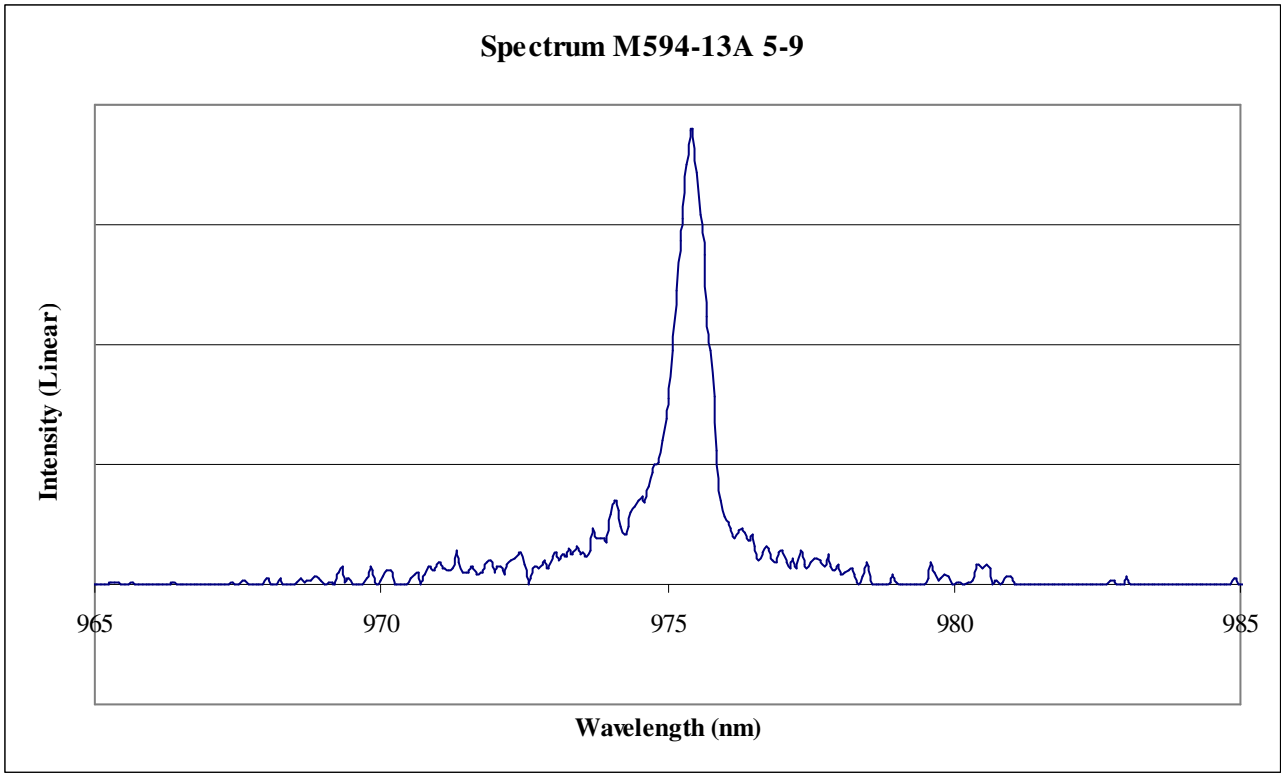
This laser structure was grown on a GaAs substrate using metal organic chemical vapor deposition. The growth was performed by TriQuint Semiconductor in Richardson, Texas.

Broad Area – Full Growth and Regrowth LIV



Unmounted Devices - pulse testing at 1% duty cycle, 20° C

Broad Area Spectrum

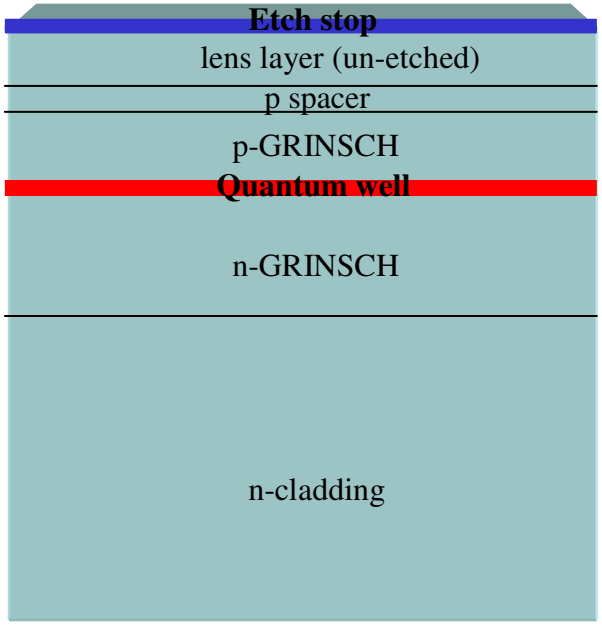


Spectrum at 1.0 A, 20℃ for a 2000 µm long device

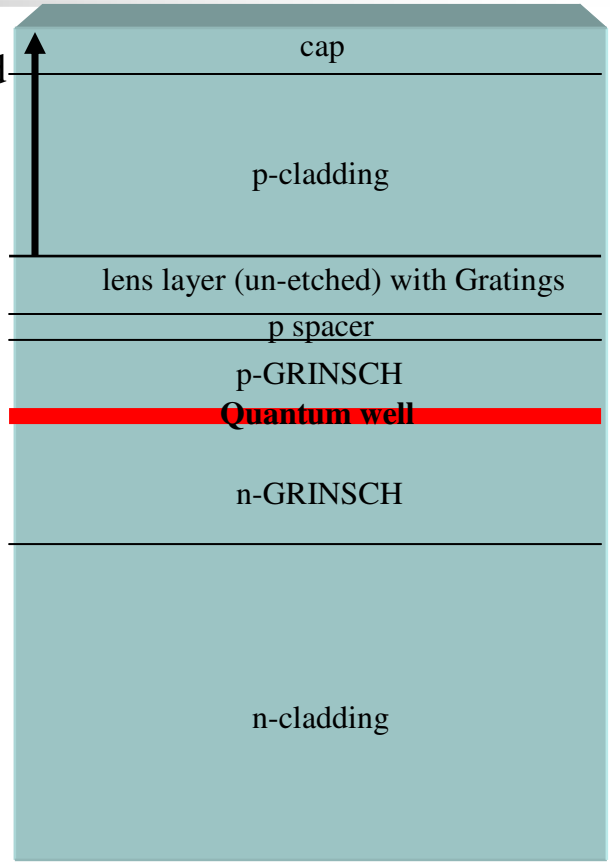
ReGrowth over Gratings Experiment

(GSE laser with un-etched lens and 700 Å deep grating with Λ = 2917 Å)

Base Structure Grown excludes the p-cladding and p-cap



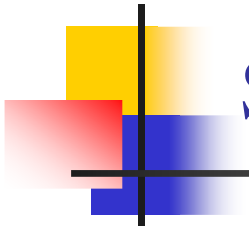
The cap and p-cladding layers will be regrown over the etched gratings



The etch stop layer will be removed by wet etching and gratings will be fabricated in the lens layer using holography and ion beam etching (IBE).

Current Work

- Optimizing grating holography process
  - Optimize exposure and develop times using diffraction efficiency measurement
- Etching Process
  - Working issue of “batman ears” on top of grating
- Cleaning Process
  - Wafer cleaning before grating process
  - Wafer cleaning after etching process



Summary

Lessons Learned

- Qualify epi in simplest configuration possible asap
- Plan time for developing processes then multiply time estimate by π
- Inspect and measure at every step during process development

Current and Future Work

- Fabricate holographic gratings
- Demonstrate regrowth over IBE gratings
- Fabricate and test GSE devices
- Develop model for 2^{nd} order DFB gratings with gain