High Power Grating Surface Emitting Laser
Weekly Meeting Update – October 22, 2004

Student: Susan Wilson, Electrical Engineering
Advisor: Dr. Gary Evans **SMU Photonics**

Co-Advisors: Jay Kirk and Dr. Jerome Butler

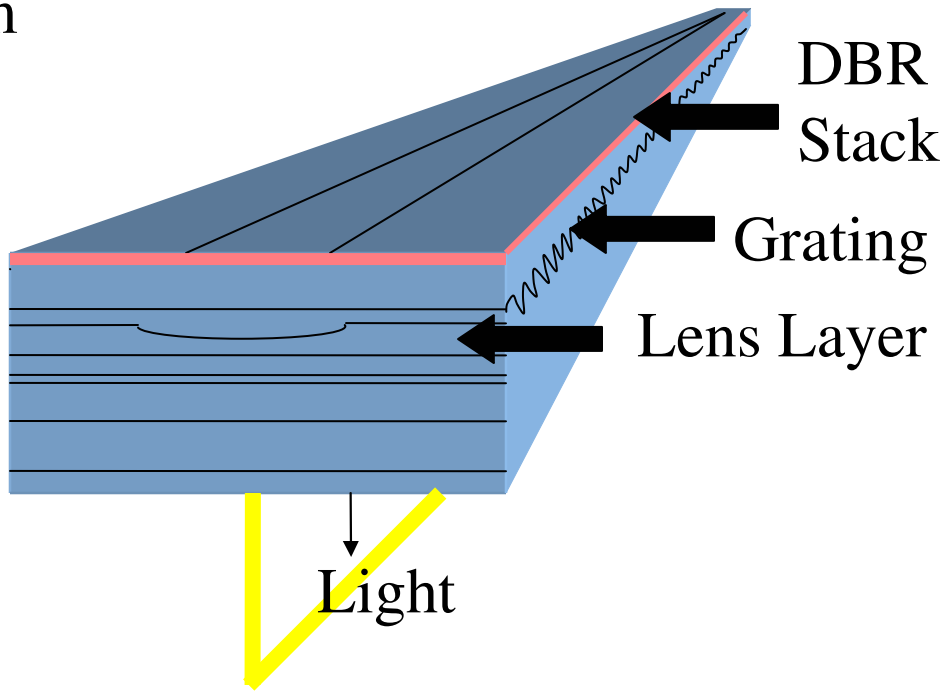
Collaborators: Taha Masood and Scott McWilliams **Photodigm**
Photodigm, Inc., Richardson, TX

Research Sponsored by: Air Force Research Laboratory's
Directed Energy Directorate

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

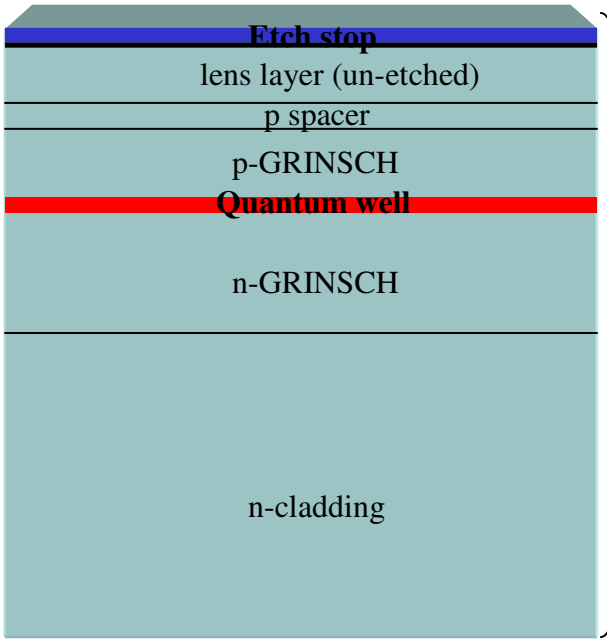
Proposed Device Goals

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



2nd Order Out-Coupling Grating Fabrication

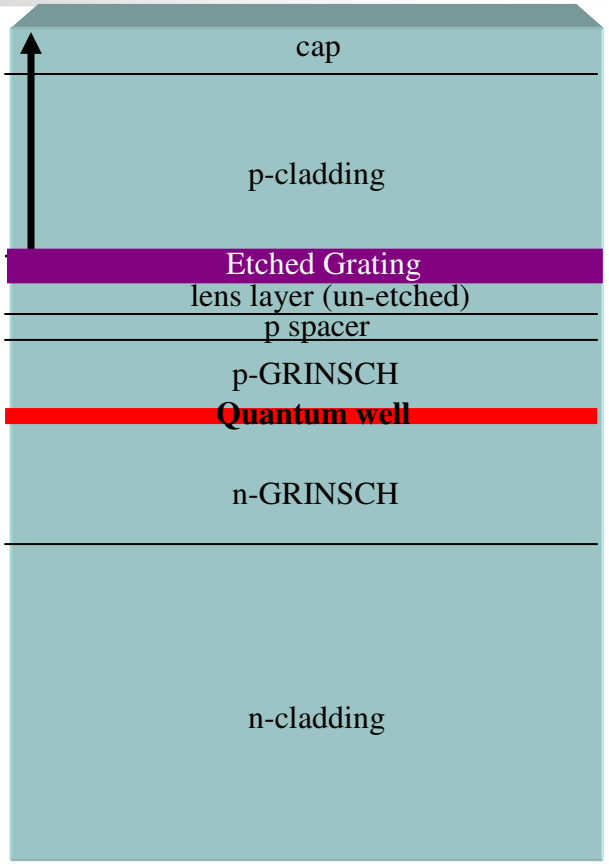
Base Structure ~ 2.3 µm



0 µm

MOCVD Growth by: TriQuint SEMICONDUCTOR

The etch stop will be removed and the grating will be fabricated in the top of the lens layer. The cap and p-cladding layers will be grown over the etched grating and devices fabricated.



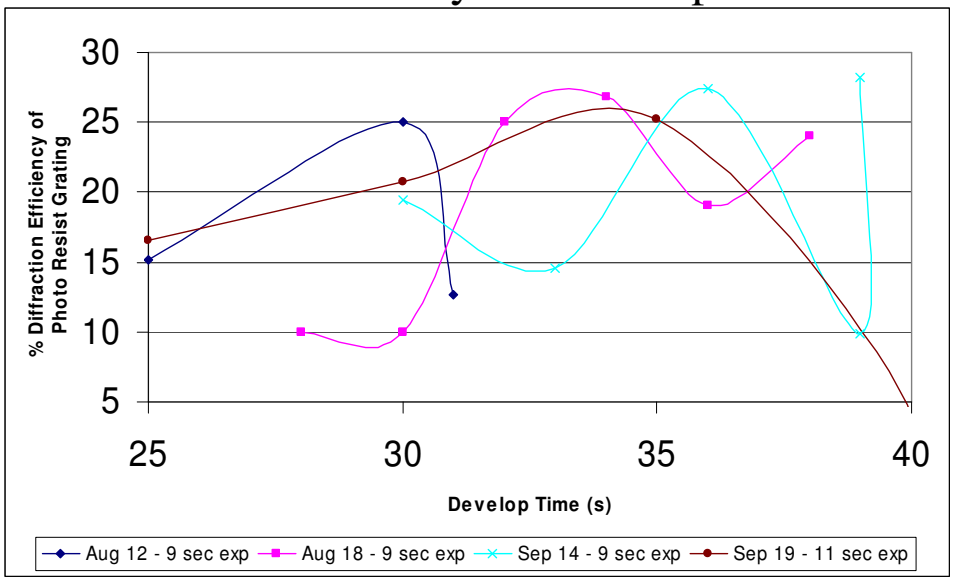
A second order out-coupling grating will be fabricated in the base structure's lens layer and the remaining laser structure layers (p-cladding and cap) will be grown on top of the etched grating.

Grating Process – Holographic Grating Pattern in Photo Resist

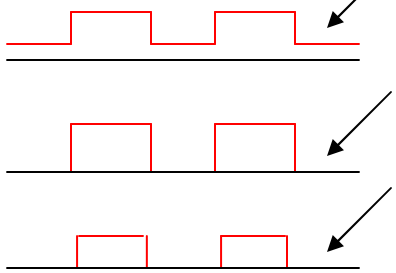
Process uses Diffraction Efficiency measurement to select best develop time

- Clean Wafer
- Spin thin film of Photo Resist:Thinner mixture
- Soft bake
- Measure exposing laser light intensity to set dose
- Expose photo resist with grating pattern
- Develop
- Measure Diffraction Efficiency
  - ratio of diffracted light intensity to incident light intensity

Diffraction Efficiency vs. Develop Time



Diffraction Efficiency correlation:



Low side of peak - resist not clear in bottom of grating

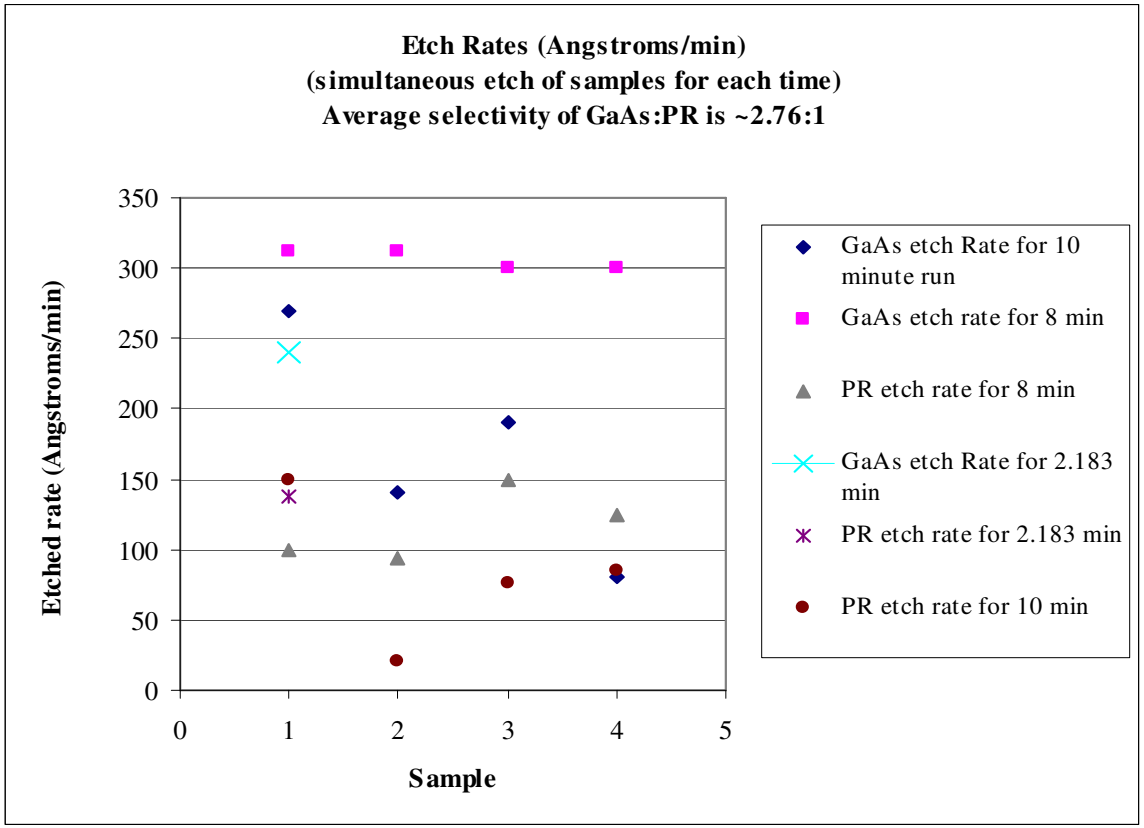
Peak - resist just clear in bottom of grating

High side of peak - resist is well clear of bottom of grating and sidewalls start to develop away

Grating Process – Ion Beam Etching

Process uses Argon gas, 50 mA, and 300 V.

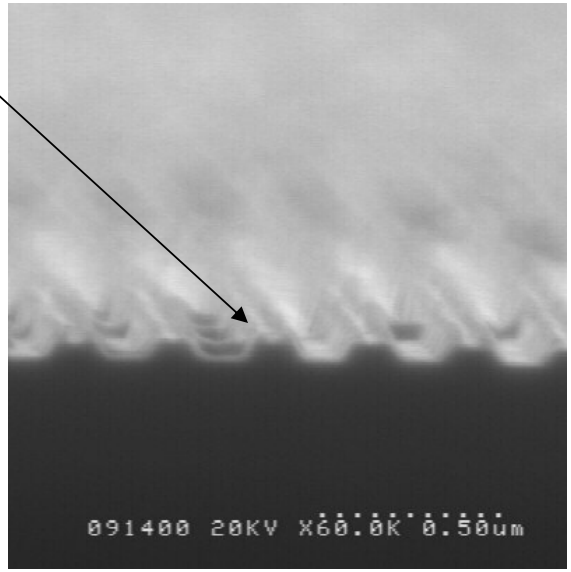
- Hard bake photo resist pattern
- Mount sample
- Ion Beam etch



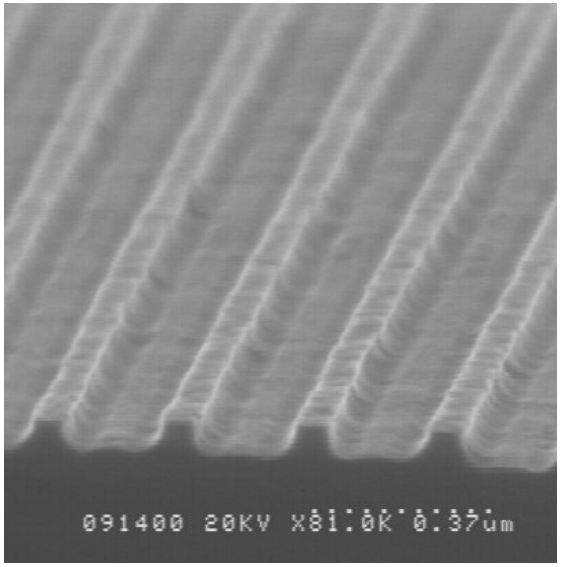
Grating Process – Surface Clean after Grating Etch

Surface Cleaning prior to growing the additional epitaxial layers is critical. Process developed at SMU to reduce "ears" on grating ridges produced during IBE process:

- O_2 Plasma Ashing
- Acetone Boil
- BOE Clean
- Wet Etch



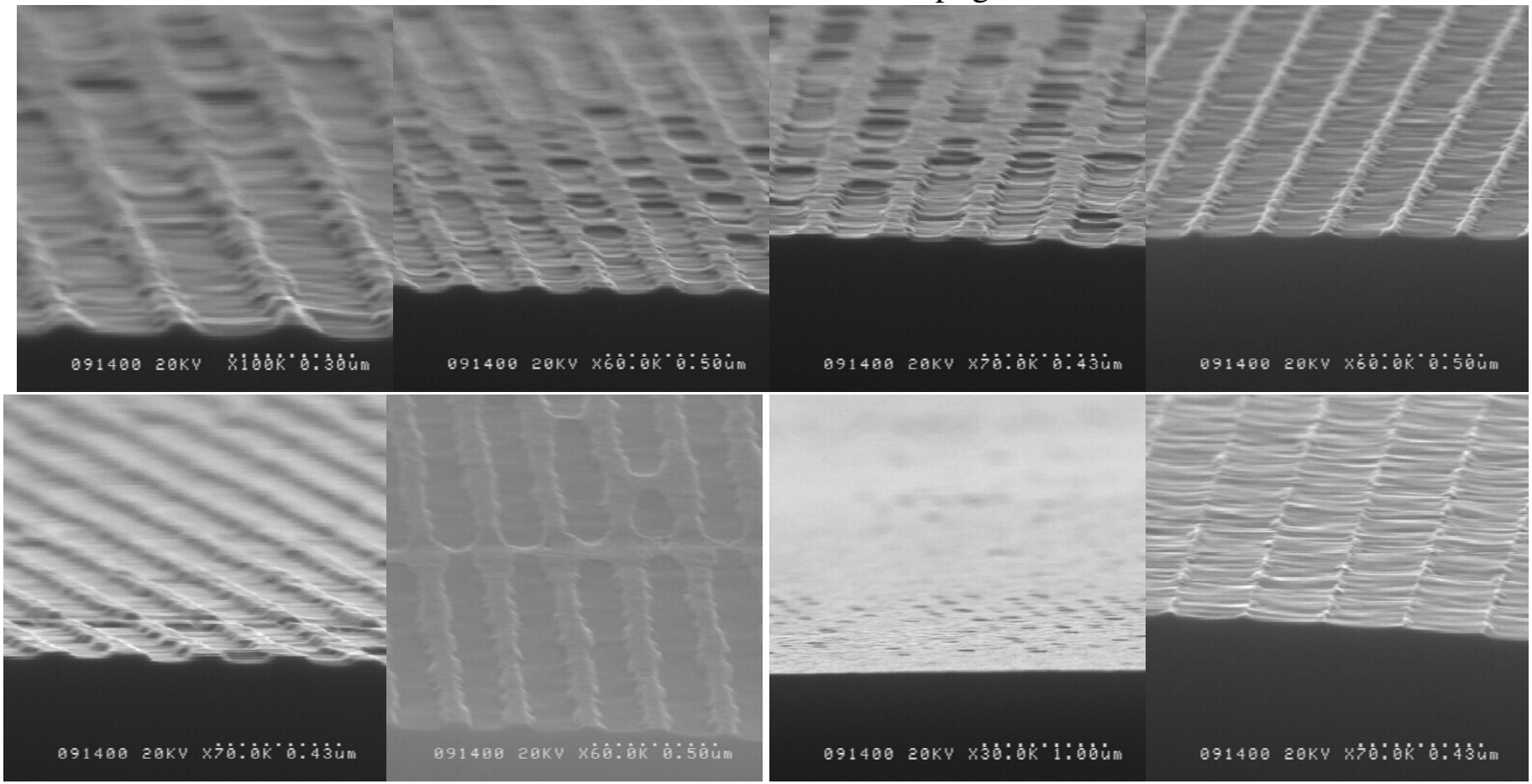
Before clean up



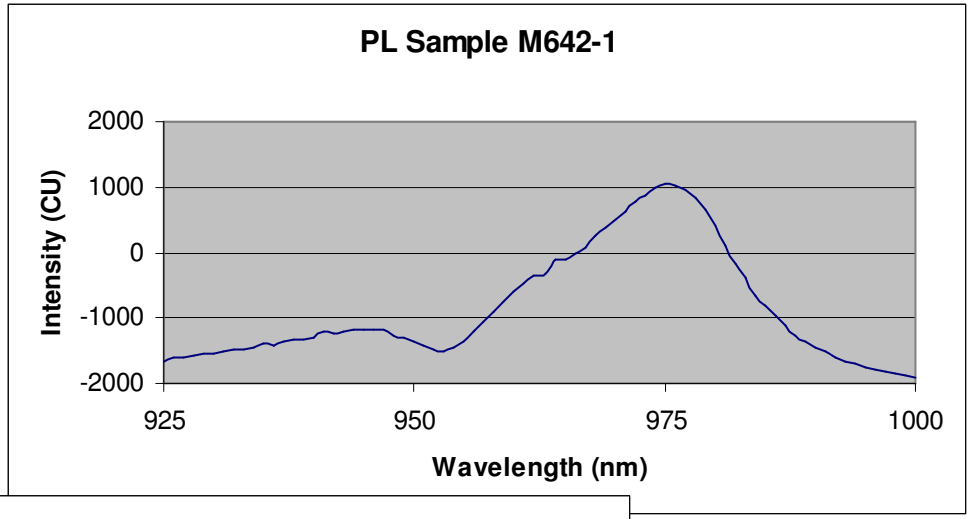
After clean up
081504

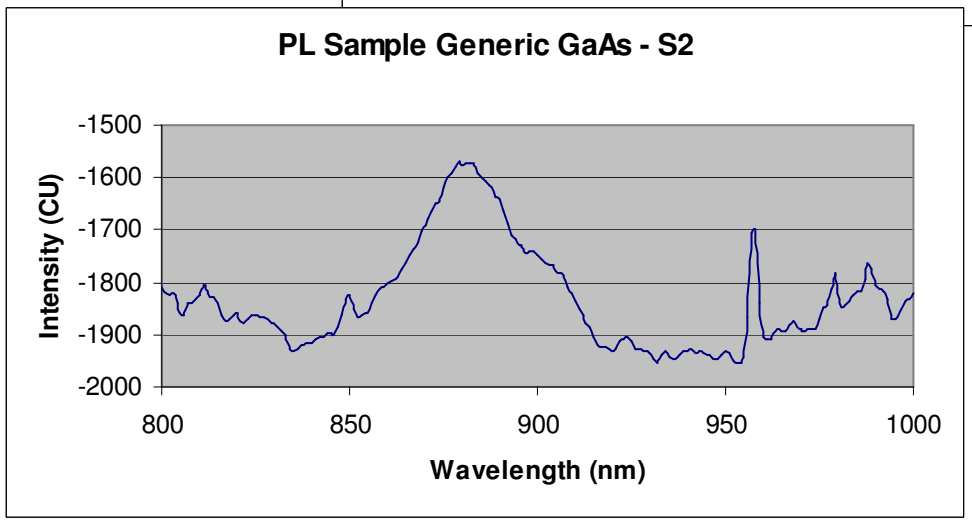
Repeat Grating Process & Vary Wet Etch times – Samples 083104

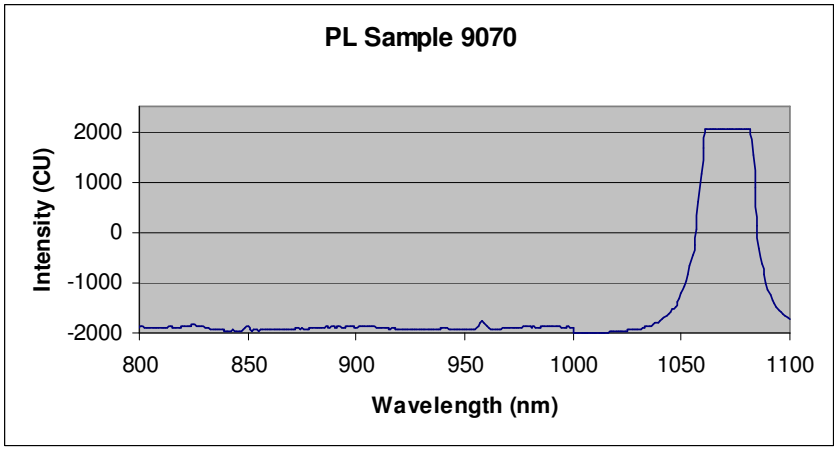
Diffraction Efficiencies after final clean were 0 – 2.4%
Miscellaneous GaAs wafers were used instead of epi grade GaAs



SMU PL Measurements







Repeat Grating Process – No Wet Etch – Sample 092904

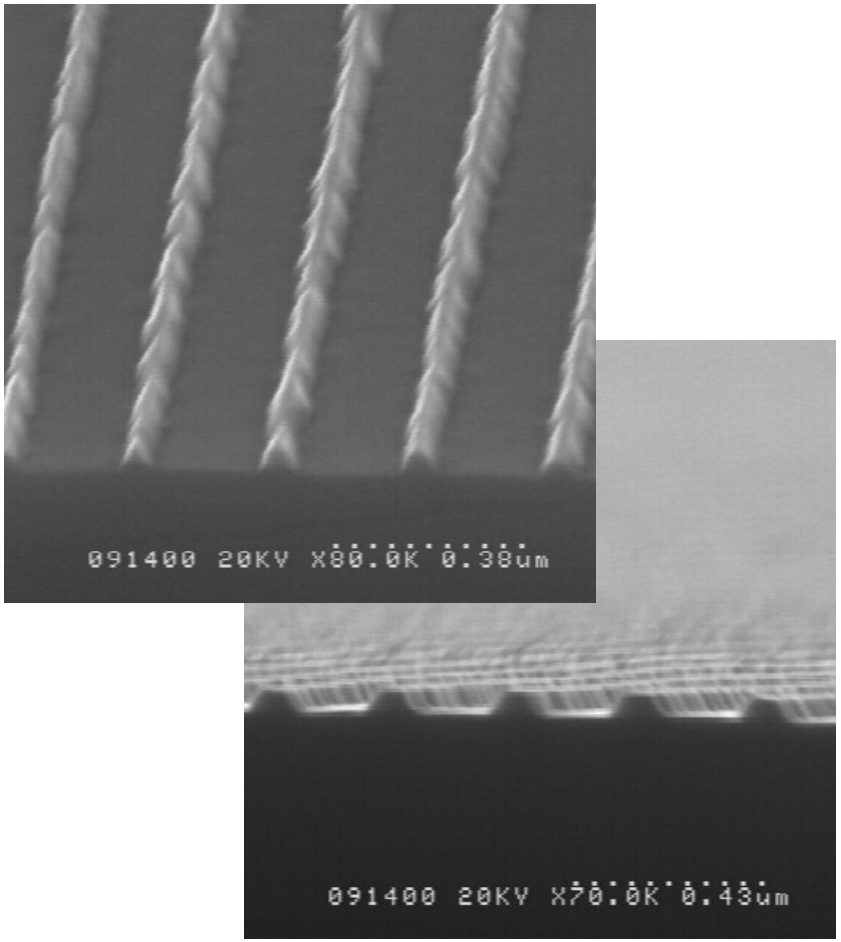
9-29-04 IBE Grating
Material: 9070 Epi Piece
Period: 2918 Å

Diffraction Efficiencies:
PR Grating: 22.18%
After etch with PR: 8%
After etch, acetone boil: 11.7%

Estimated Grating Depth: 571 Å
(Target was 700 Å)

Estimated Duty Cycle: Top View 10.3%
Side View 15.6%

Estimated Etch Rate: 186 Å/min
(generic setup rate: 240 Å/min)



Improve Grating Process – No Wet Etch – Sample 101204 w/thicker Photo Resist

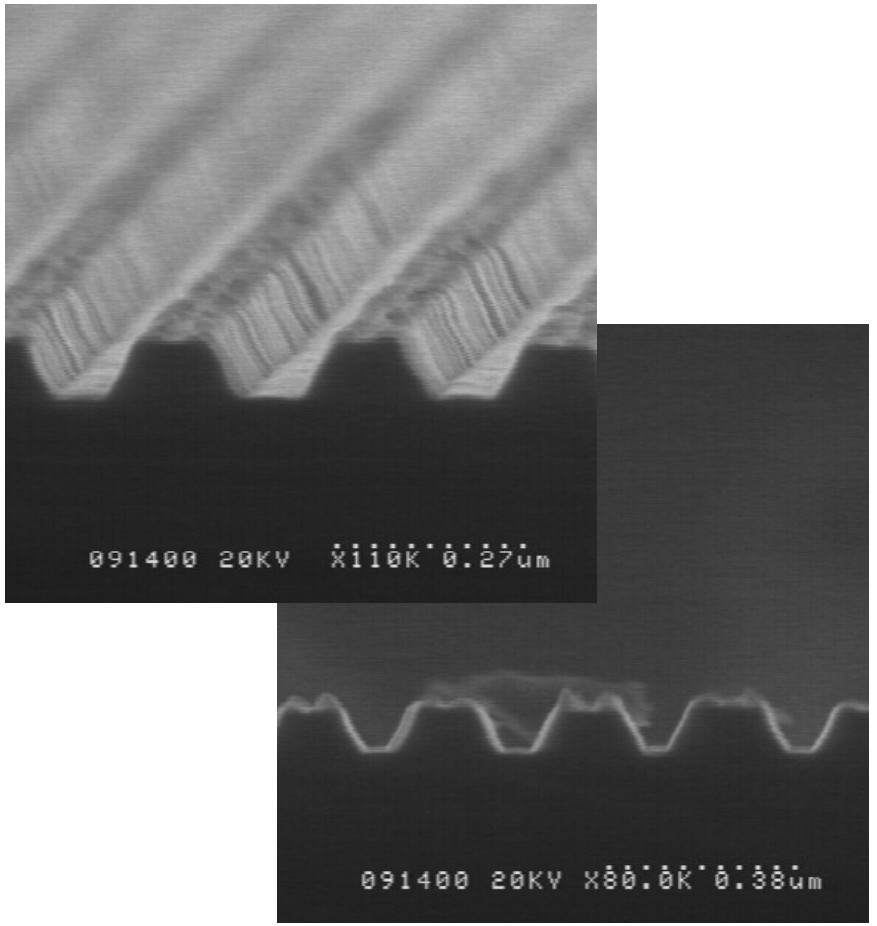
Used thicker photo resist (1805:thinner mixed 11:20) to improve duty cycle
10-12-04 IBE Grating
Material: M642 Epi Piece
Period: 2918 Å

Diffraction Efficiencies:
PR Grating: 28.06%
After etch with PR: 3.54%
After etch, acetone boil: 12.37%

Estimated Grating Depth: 992 Å
(Target was 744 Å)

Estimated Duty Cycle: Side View 68%

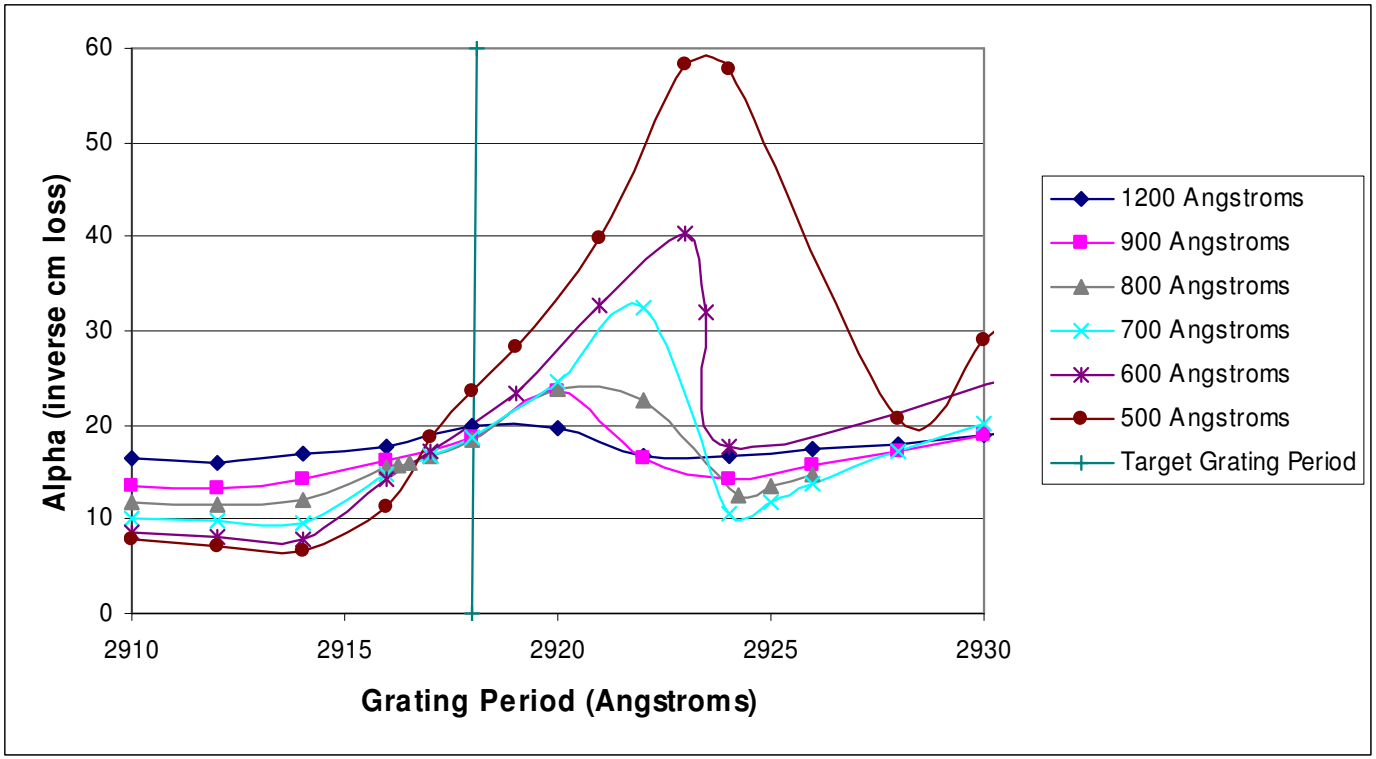
Estimated Etch Rate: 248 Å/min
(generic witness etch rate: 237.5 Å/min)



Future Process Work

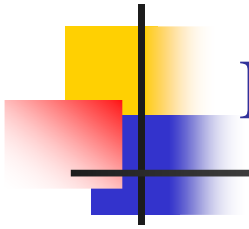
- Repeat Grating process with thicker resist and full surface clean including wet etch
- Fabricate gratings on epi for regrowth

Modeled Loss vs. Grating Period for Different Grating Depths



Total loss per cm includes light that back scatters off of grating and light radiating up and down. The target grating period of 2918 Å is based on the lasing free space wavelength of the material and the experimentally determined effective index of the structure. $n_{eff} = \lambda_0/\Lambda$

Values generated using custom software "Bscan" written by Dr. Jerome Butler.



Future Modeling Work

- Run Bscan to find Pup and Pdown if possible
- Run Bscan to find effect of different duty cycles