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# High Performance Grating-Outcoupled Surface Emitting(GSE) Lasers Using Quantum Well Intermixing

## Update 6/25/04

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Agilent Technologies

A Collaboration with Photodigm Inc. and Agilent Technologies

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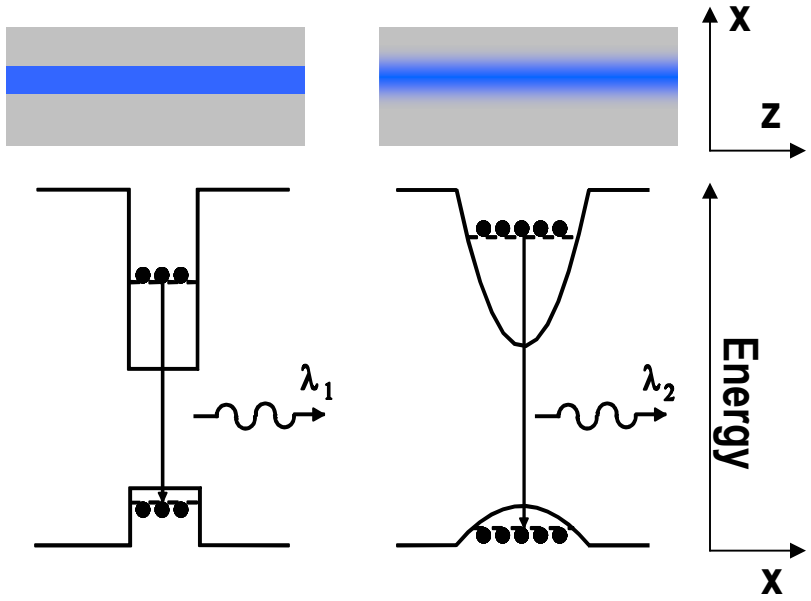
# Quantum Well Intermixing (QWI)




- Applications:
  - Multi-wavelength laser arrays
  - Quantum well lasers
  - Waveguide demultiplexer
  - Photodetectors
  - Modulators
- Our Interests
  - GSE lasers
  - Multi-wavelength cross-grating GSE lasers

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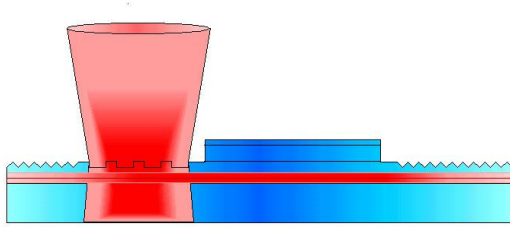
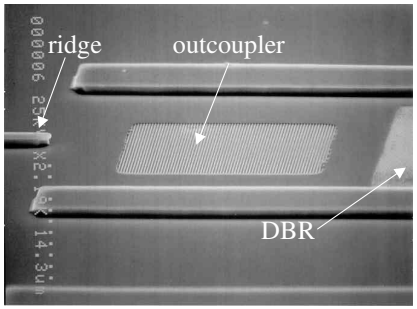
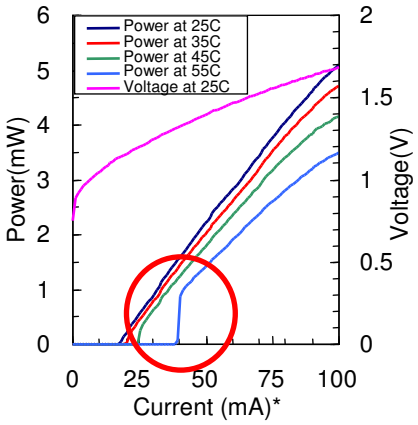
# Grating-outcoupled Surface Emitting (GSE) lasers

- 1st order feedback grating + 2nd order outcoupler grating
- Problem: "snap-on" behavior at high temperature due to a combination of low DBR reflectivity and the saturated absorption of the quantum wells in the passive DBR and outcoupler regions.
- Solutions:
  - Increasing DBR reflectivity
  - Quantum Well Intermixing in passive DBR and outcoupler sections
- Perspective:
  - Lower threshold (10 mA)
  - Higher slope efficiency (0.2 W/A)
  - Higher temperature operation (>100C)
  - Higher modulation speed (> 5 Gbps)
  - No "snap-on" behavior

* Data provided by Photodigm Inc.



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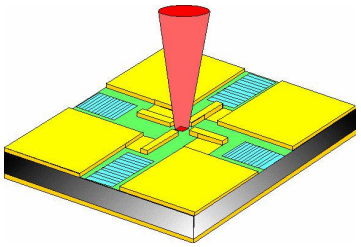
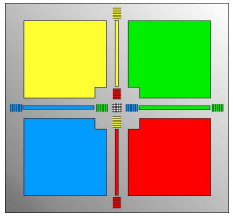
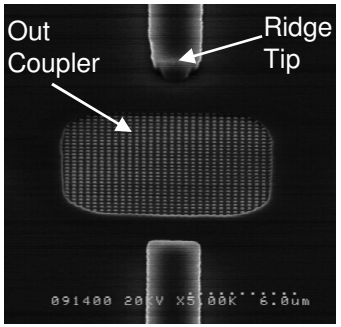
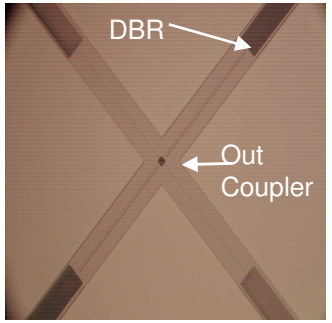
# Multi-Wavelength Cross-Grating GSE Lasers

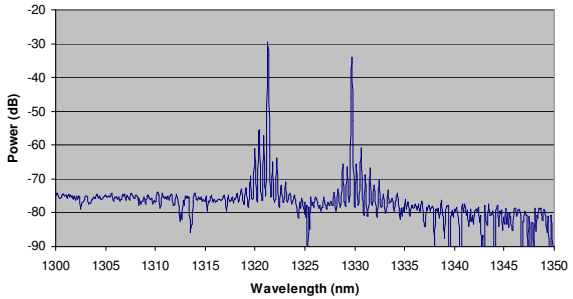
- Monolithic multi-wavelength optical sources:
  - WDM: 0.8 nm spacing
  - CWDM: 20 nm spacing
- Current 2-wavelength Cross Grating GSE:
  - 8 nm spacing
  - > 0.5 mW output power
- Using QWI:
  - Higher power, lower threshold
  - 20 nm spacing for CWDM application
- Future goal: 4 wavelengths emitting from one single aperture
  - Cover 80 nm wavelength range





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# Research Plan

**Phase I**

- Experiment ion implantation approach to develop processes of selective intermixing without severe PL intensity saturation.
- Fabricate ridge waveguide lasers from the GSE wafer structure using QWI.

**Phase II**

- Develop QWI processes for GSE lasers to improve their performances.
- Investigate the reproducibility of the processes.

**Phase III**

- Apply QWI to the active regions of GSE lasers to modify the lasing wavelengths.
- Develop GSE Laser arrays with multiple lasing wavelengths using QWI.

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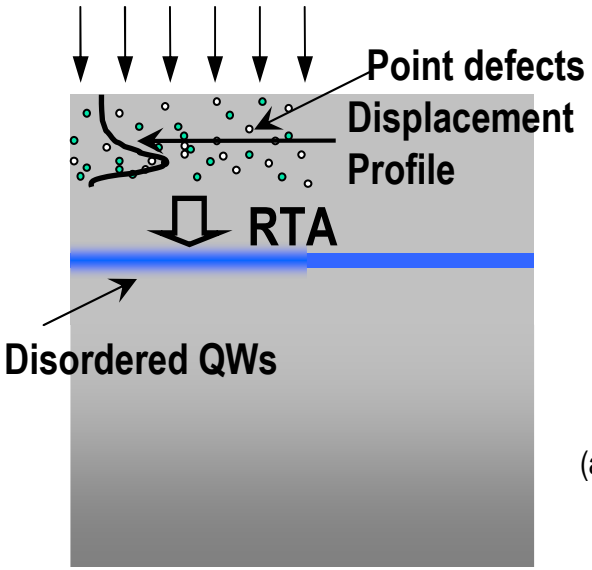
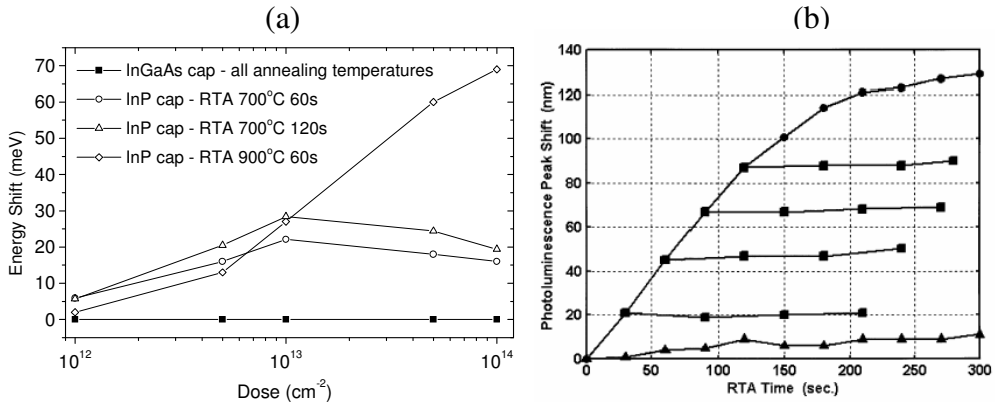
# QWI by Ion Implantation




(a) Energy shifts of InGaAs/AlGaInAs quantum wells as a function of dose for 20 keV P ion cap implants at 25C for different annealing temperatures and cap layers. (Carmody (2003), Defect Engineering of InP and InGaAs for Optoelectronic Applications, PhD thesis, Canberra, Australian National University)

(b) PL wavelength peak shift as a function of anneal time for InGaAsP MQW. (Skogen et al., Journal of Quantum Electronics, Vol. 9, No. 5,p1183 – 1190 (2003))

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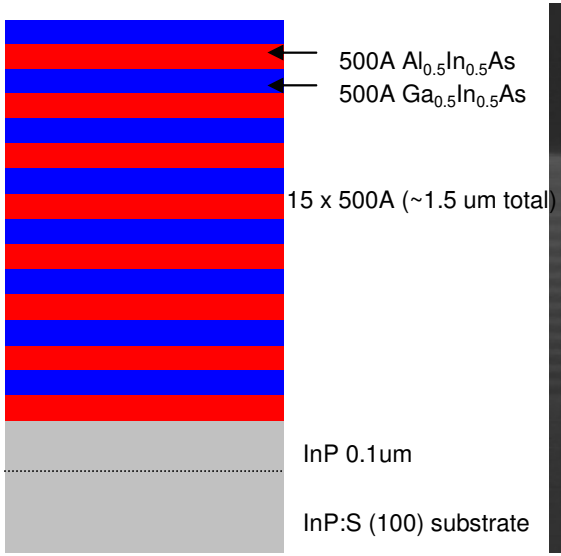
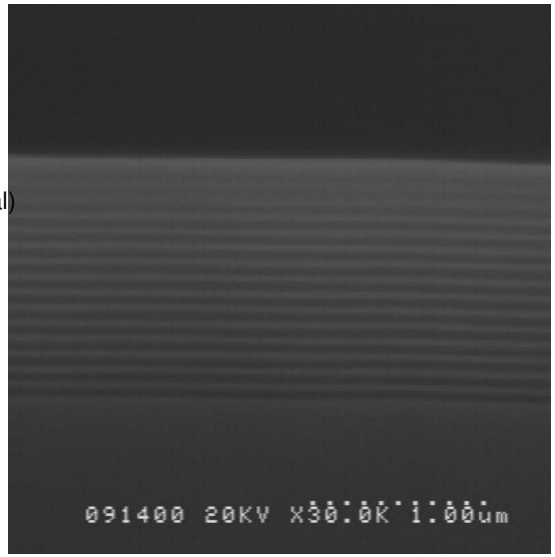
# QWI Experiment Results (1)

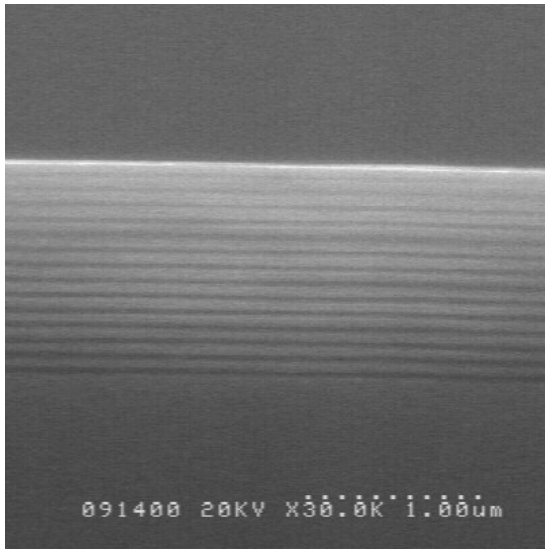
**Super Lattice Structure**




**SEM picture before RTA**




**SEM picture after RTA at 700 C for 10 mins**




**OMLW 2572 A-A (AlInAs on surface)**

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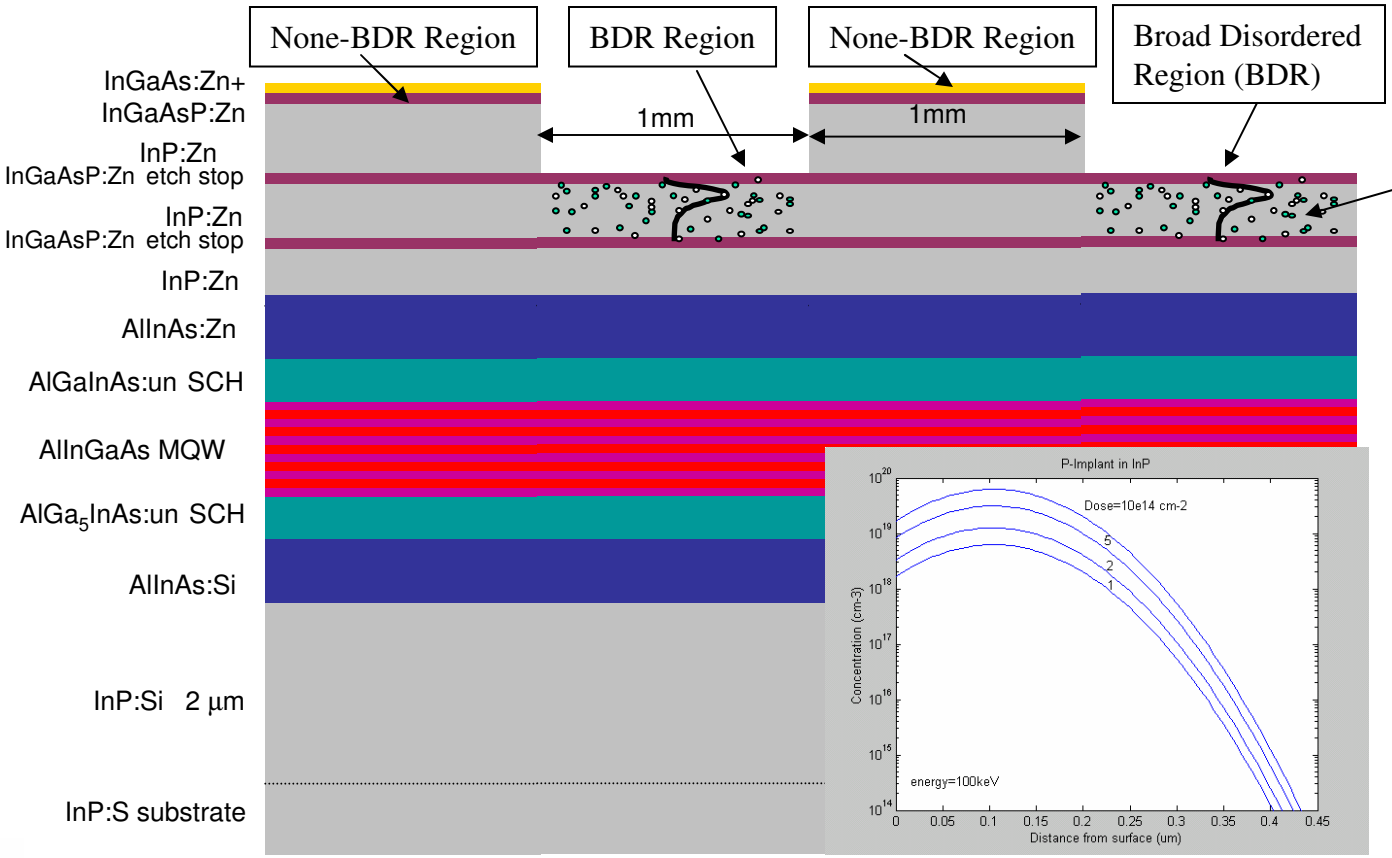
# Wafer Structures for QWI Experiments (2)




**Ion implantation: 100keV energy, dose 5e14 cm-2, substrate temp 200C.**

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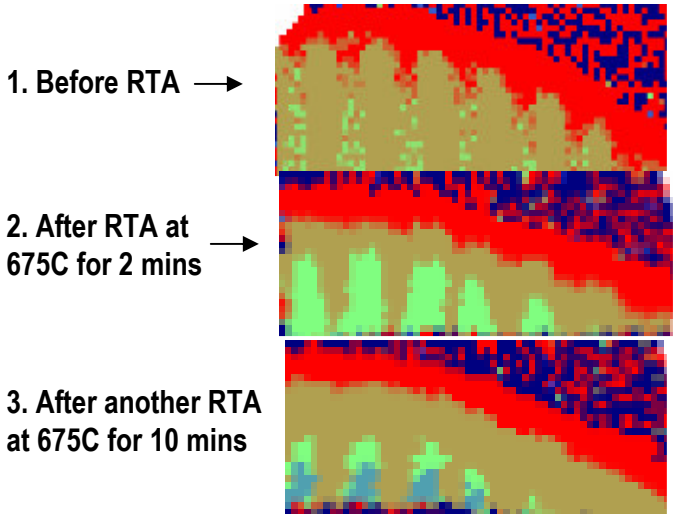
# Summary of Experimental Data

**Summary of wavelength shifts of wafer 2709B-A after QWI**

| RTA @ 675C Time | Wavelength shift (nm) in **BDR** (broad disorder region) (Total 9 channels) | | | | |
|---|---|---|---|---|---|
| | 7-1 | 7-2 | 7-3 | 7-4 | 8-1 |
| 2min | 8.6 | 8.6 | 8.6 | 8.6 | 8.6 |
| 10 min | 8.5 | 8.5 | 8.5 | 8.5 | 0 |
| Total shift for 12 mins | 17.1 | 17.1 | 17.1 | 17.1 | 8.6 |

**PL Spectrum Maps of 2709B-A**

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