Center for Energy Efficient Electronics Science

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HCG-VCSEL and NEMO Characterization and Design

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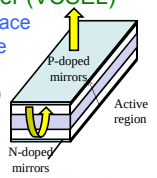
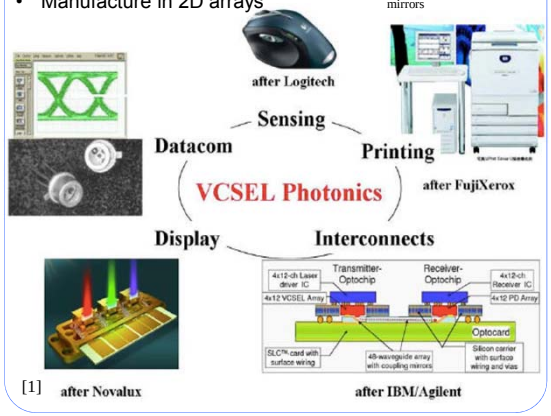
Introduction / Background

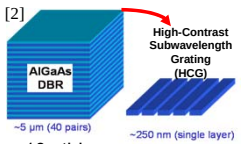
Vertical Cavity Surface Emitting Laser (VCSEL)

- Emits light perpendicular to wafer surface
- Single longitudinal mode achieved due to short cavity
- Wafer scale testing (controllable yield)
- Lower power consumption
- Easier to couple with optical fiber
- Manufacture in 2D arrays

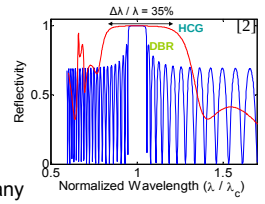




High Contrast Grating (HCG) VCSEL

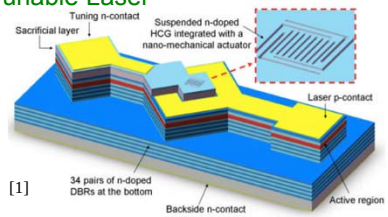


- Replace 30-40 pairs of DBRs with single, layer of HCG



- >10x thinner
- >1000 lighter
- Broader reflection band
- Polarization differentiation
- Angle selective filtering
- Easier to fabricate than many layers of DBRs

Nano Electromechanic Optoelectronic (NEMO) Tunable Laser



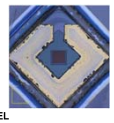
- Couple with mechanical actuator
- Laser emission wavelength tuned by applying voltage bias
- Fast tuning speed (on order of nanoseconds)

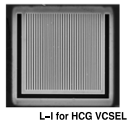
Abstract

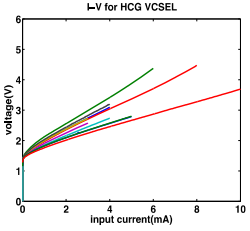
The use of high-index-contrast subwavelength grating (HCG) to replace 30-50 pairs of top distributed Bragg reflector mirrors of the vertical-cavity surface-emitting laser (VCSEL) is an original design of Professor Chang-Hasnain's Laboratory. When a mechanical actuator is integrated with the HCG layer, compact nano-electromechanical optoelectronic (NEMO) tunable VCSEL with precise and continuous wavelength tuning and greater tuning speed is obtained experimentally. The main goal of the project is to find a NEMO device with a wider tuning range (> 40nm) through simulations, and characterize fabricated HCG-VCSEL and NEMO devices. A NEMO device with tuning range > 40nm would be important for bio imaging applications such as Optical Coherence Tomography.

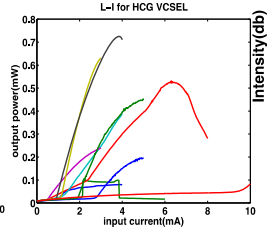
HCG VCSEL and NEMO Characterization

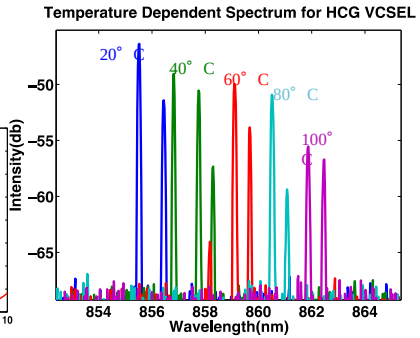
HCG VCSEL



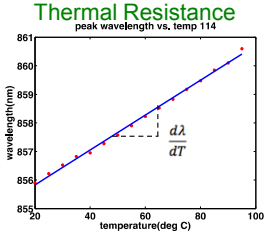


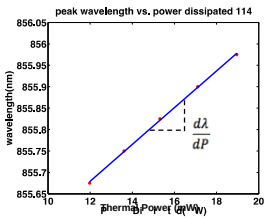


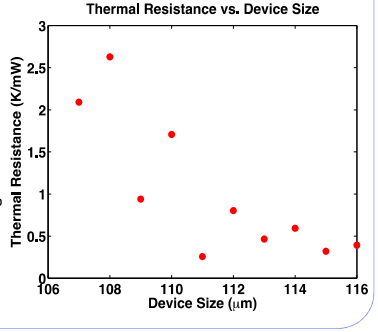




Thermal Resistance



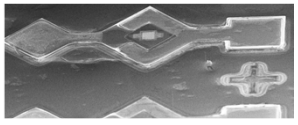


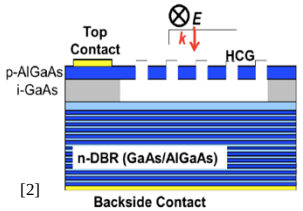


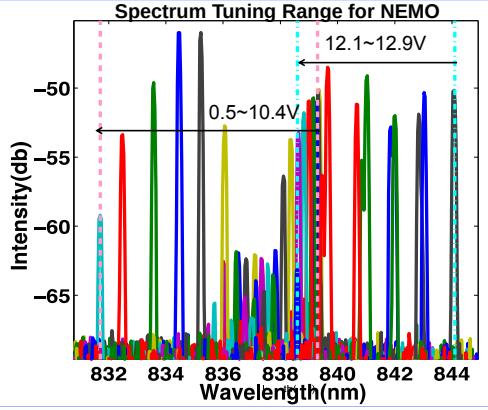
$$\frac{d\lambda}{dP} / \frac{d\lambda}{dT} = \frac{dT}{dP}$$

Device Size (μm)	Thermal Resistance (K/mW)	Aperture area (μm²)
104	2.00	363
114	0.70	609

NEMO V2







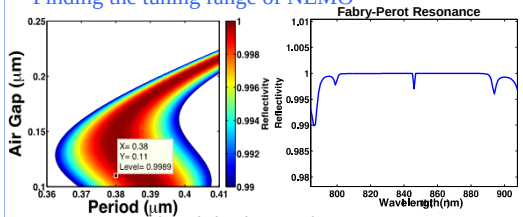
Theoretical Tuning Range Limit for NEMO

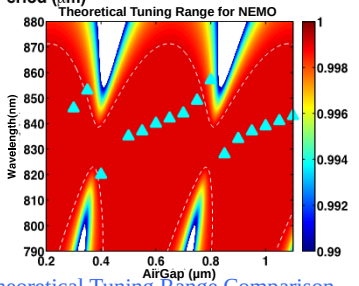
Simulating NEMO using Gsolver

- Used Rigorous Coupled Wave Analysis Method (Gsolver) to simulate different NEMO wafer designs:

Design	HCG thickness (nm)	Sacrificial layer (μm)	No. of pairs of top DBR mirrors	Mode
V2	235	1.1	2	TM
V4	257	1.1	4	TM
V6	257	2.0	2	TM
V9	235	1.1	0	TM

Finding the tuning range of NEMO





Best Theoretical Tuning Range Comparison

Design	Air gap thickness (nm)	Period (nm)	Tuning range (nm)
V2	120	390	**37**
V4	150	390	**25**
V6	**130**	**400**	**45**
V9	110	380	**39**

Conclusion and Future Work

- V6 is the most promising design with >40nm
- V9 is promising and it is special as this design has no top DBR mirrors
- V6 is being fabricated now

References

[1] M. C. Y. Huang, "Nano-electromechanical optoelectronic tunable lasers," Ph.D. dissertation, Dept. EECS, Univ. of California Berkeley, 2007.

[2] Y. Rao, "InP-based Long Wavelength VCSEL using High Contrast Grating," Ph.D. dissertation, Dept. EECS, Univ. of California Berkeley, 2007.

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