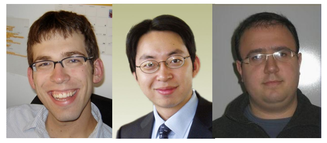
Nano Electromechanical Optoelectronic Tunable VCSEL



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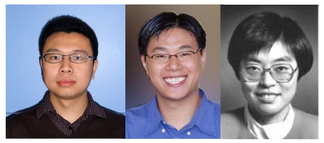
THRUST 3: Materials and Devices



Introduction

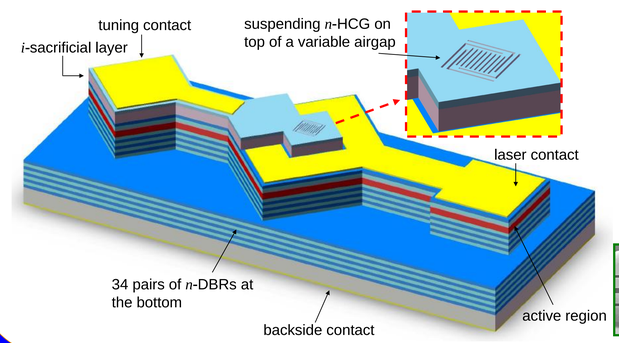
Goal

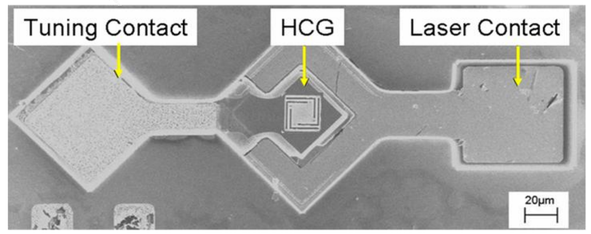
- Developing low cost, low power, fast and continuously tunable WDM sources

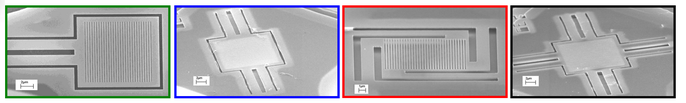
Novelty

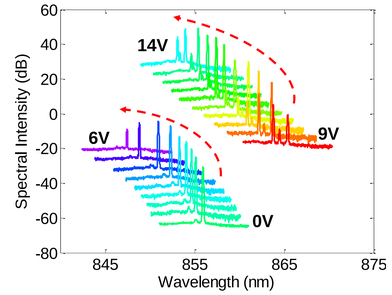
- Integrating a lightweight, mobile, single-layer high-contrast subwavelength grating (HCG) with nano-electromechanical actuators for ultra-fast wavelength tuning
  - Ultra broadband (Δλ/λ >35%) and high reflectivity (R>99%)
  - Scalable with material and wavelength
  - Built-in lithographically-defined polarization control

NEMO Tunable VCSEL







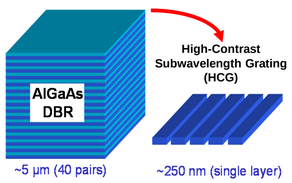


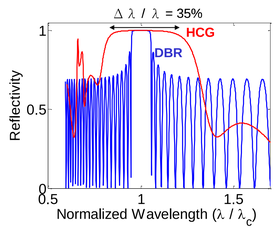
Nature Photonics, vol. 2, p. 180-184 (2008)

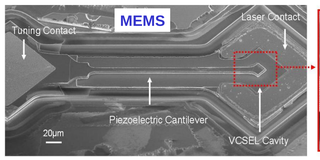
HCG vs. DBR

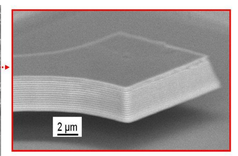
- HCG thickness is <10% of distributed Bragg reflector (DBR)
  - Actuator mass is reduced by >10000 times

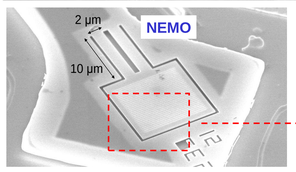
Nature Photonics, vol. 1, p. 119-122 (2007)

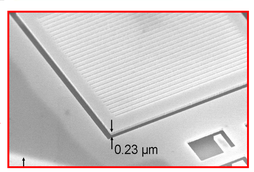




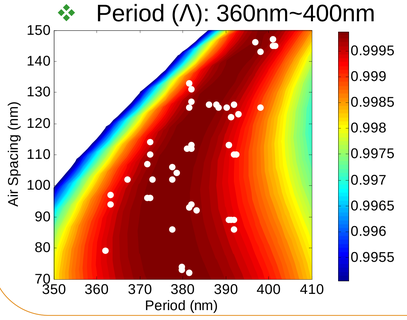


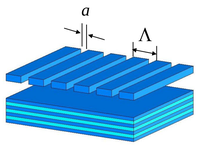






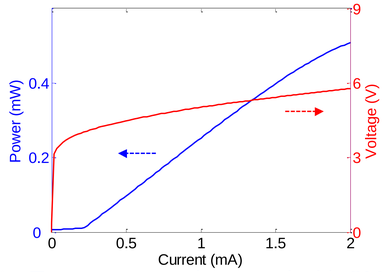
- Very large fabrication tolerance for high reflectivity
  - Air spacing (a): 80nm~120nm (±20%)
  - Period (Λ): 360nm~400nm

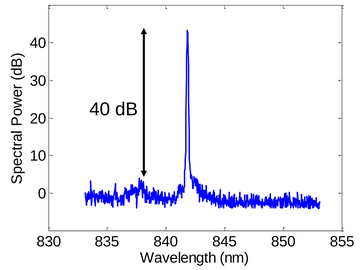




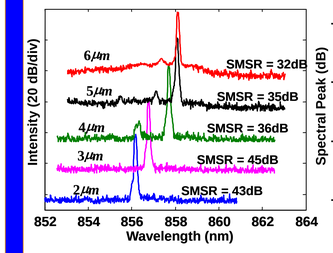
Optical Characteristics of HCG-VCSEL

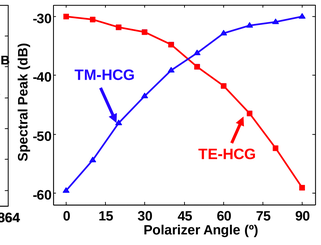
- CW room temperature operation with threshold as low as 0.2 mA and output power up to 1.8 mW and up to 18 nm tuning range
- Single transverse mode emission with 40 dB suppression ratio

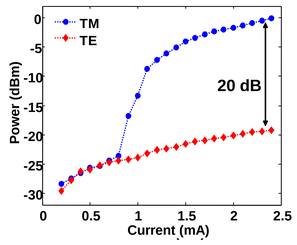




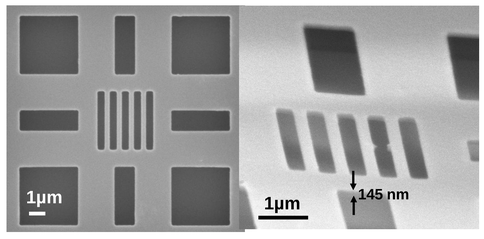
- Transverse mode control with SMSR >30 dB up to 10 μm oxide aperture
- Polarization mode control with suppression ratio ~20 dB

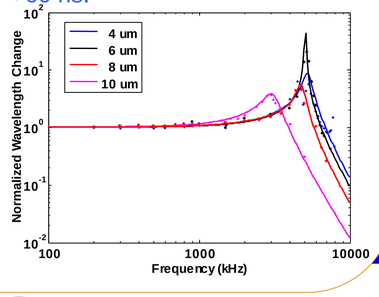






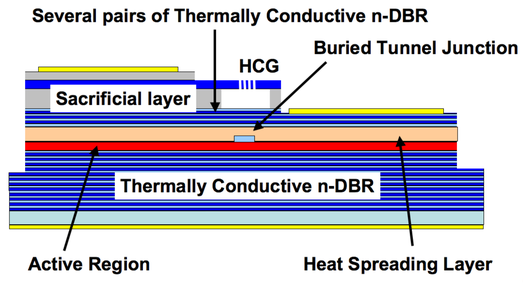
- Only 4 periods of grating (2.9 μm X 3 μm) is sufficient for single mode lasing
- Ultra-compact HCGs show tuning speeds < 60 ns.





HCG Tunable VCSEL at 1550 nm

- Key challenges in VCSEL design at 1550 nm
  - Severe free carrier absorption in *p*-materials at 1550 nm
    - Solution: minimize amount of *p*-materials by replacing them with a tunnel junction and *n*-materials.
  - Heat dissipation from the active region
    - Solution: Use DBR materials with high thermal conductivity and a heat spreader layer near the active region
  - Carrier Confinement
    - Solution: Use a buried tunnel junction to provide confinement
- Preliminary Concept: Integrate epitaxially grown HCG layer into an InP-based 1550 nm VCSEL design with buried tunnel junction and device structure optimized for heat dissipation



Summary

- Demonstrated NEMO tunable VCSEL with single-layer HCG mirror
  - continuous wavelength tuning of 18nm with ultra-fast tuning speed of <60 ns
  - outstanding laser optical performance (threshold current ~200 μA, SMSR >40 dB, Polarization suppression ratio ~20 dB)
  - Large fabrication tolerance (±20%) and ultra small size HCG-mirror (145 nm X 2.9 μm X 3 μm demonstrated)
- NEMO tunable devices can be a key low cost, low power WDM source in optical networks
  - Devices with faster tuning and wider tuning range can be achieved by further optimizing the device structure
- Preliminary studies for HCG tunable VCSELs at 1550 nm underway