VCSELs

Vertical Cavity Surface Emitting Lasers

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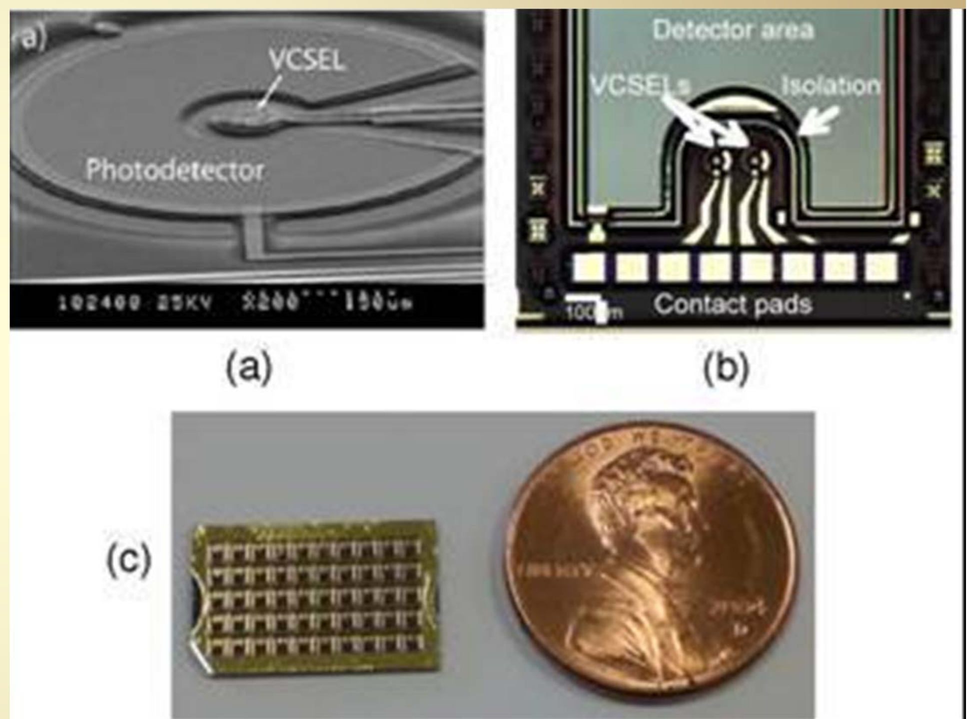
Applications

- Fiber Technologies
  - Multimode Fiber
  - Fiber Communications
  - Plastic Optical Fiber
    - Red VCSELs
- Bio-Sensing
  - Glucose monitoring
  - Cancer/tumor sensing
  - Tissue mapping
  - Neural network mapping

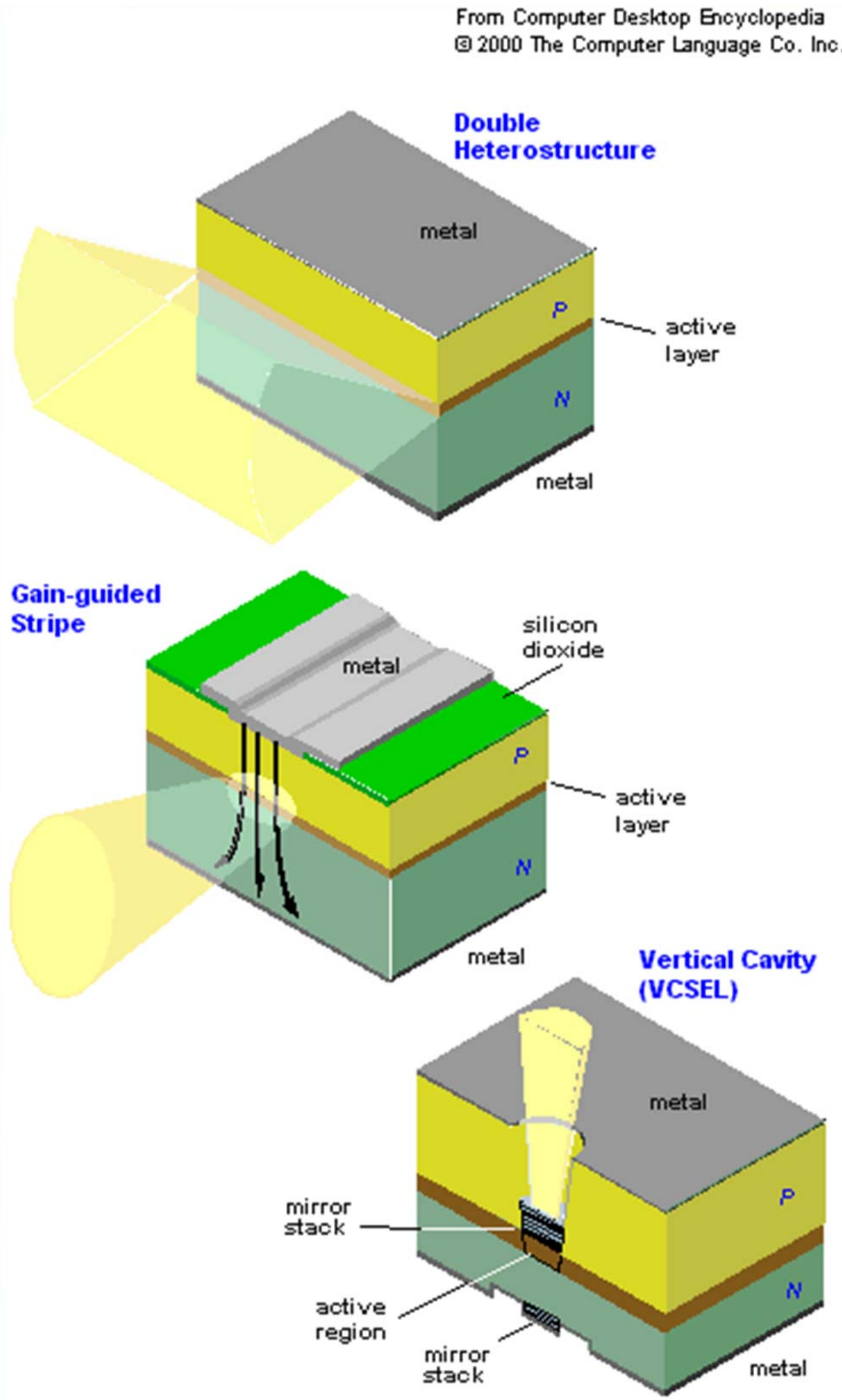


[7,8]

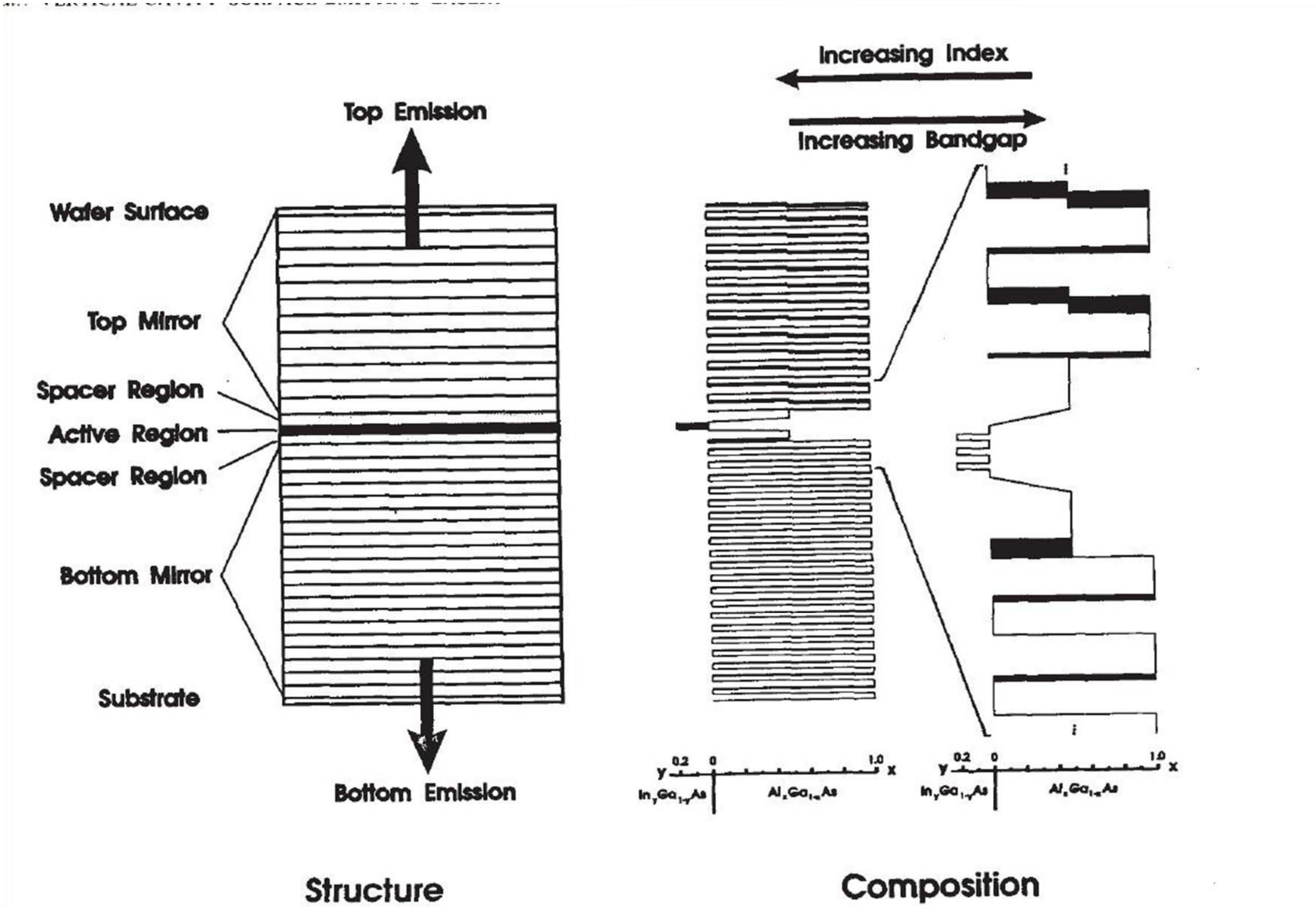
VCSEL vs. Edge

- Light comes from surface rather than edge
- VCSEL has a tighter circular beam
- VCSEL can couple to fiber technologies easier (common application)
- Ability to be placed into 2-D arrays
- Can be tested during fabrication (on-wafer)

[1,6,10]



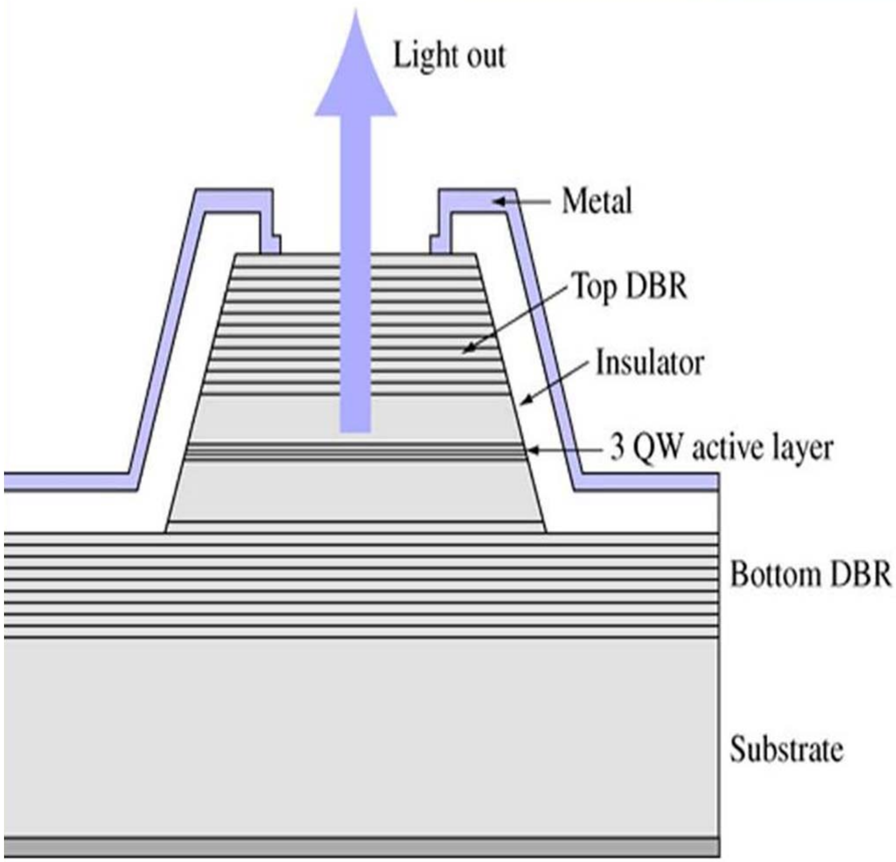
Structure



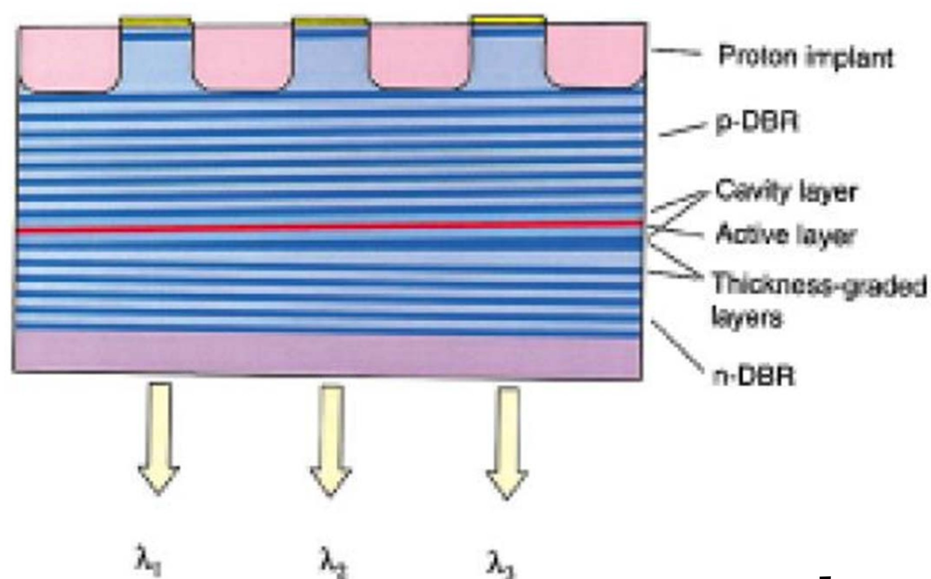
- Mostly Grown by Molecular Beam Epitaxy
- Thin active layer (λ/4)
- Narrow p-i-n structure makes possible low-resistance active region
- Low current density requirement (Low operating current)
- High operation temperature negatively effects optical power
- Can be modulated by varying bias current

[1,7]

Structure

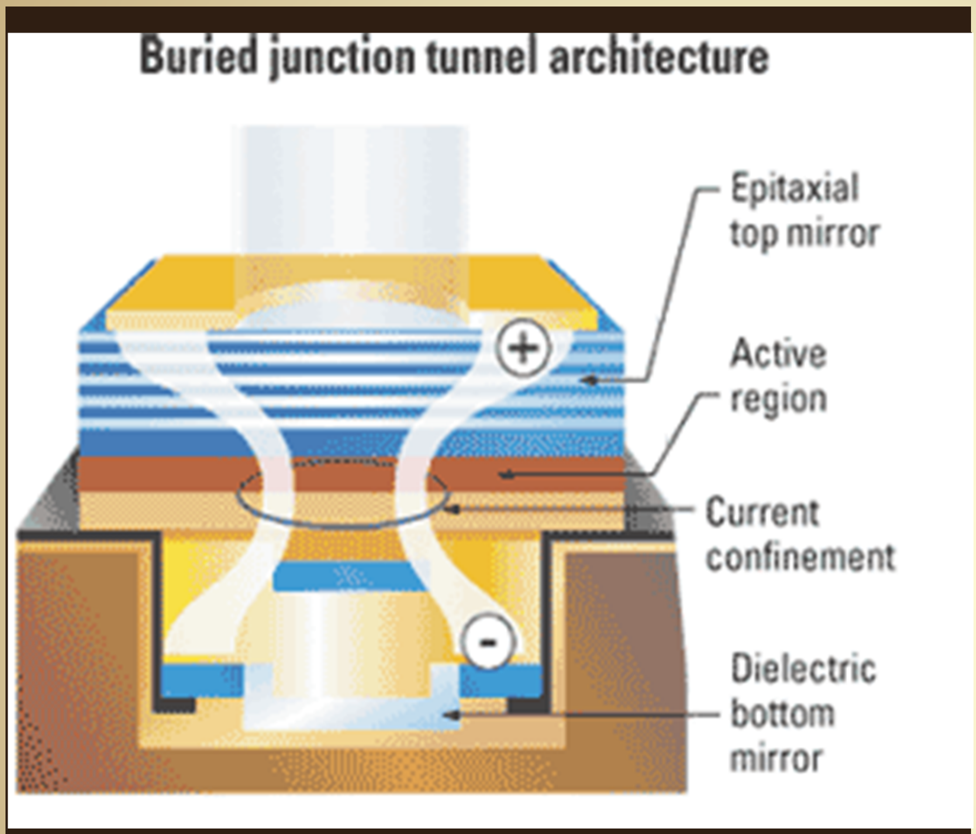


- GaAs materials are favored
- Active Region: InGaAs
- DBR Layers: AlGaAs
- Common wavelength range from 650nm to 1300nm
- Wavelength can be modulated via DBR compositions within a wafer



[1,4,10]

Current Control

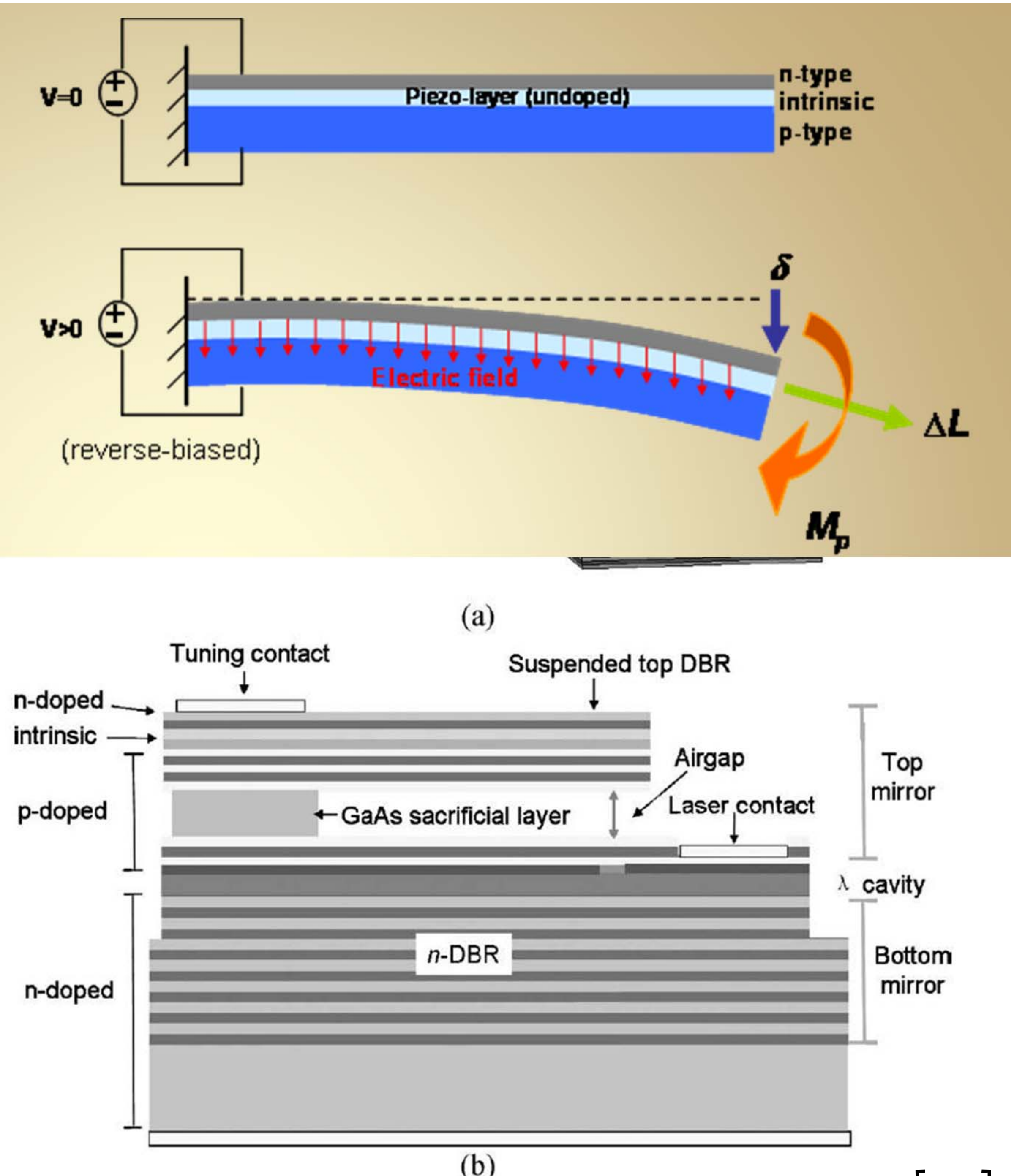


- Ion-implanted VCELS
  - Often H+ implanted
  - Destroys lattice structure around aperture
- Oxide VCSELs
  - Oxidize material around aperture
  - Easily done within an AlGaAs layer with high Al content
  - Non-uniform Al concentrations cause defects in oxide and thus aperture defects
- Buried junction tunnels
  - Heavily doped n-p junction placed within optical field
  - Reduction in electrical resistance, and optical absorption loss
  - Lowers thermal conductivity (self-heating can become a problem)

[2,4,9]

Tunable VCSEL – MEMS/Cantilever

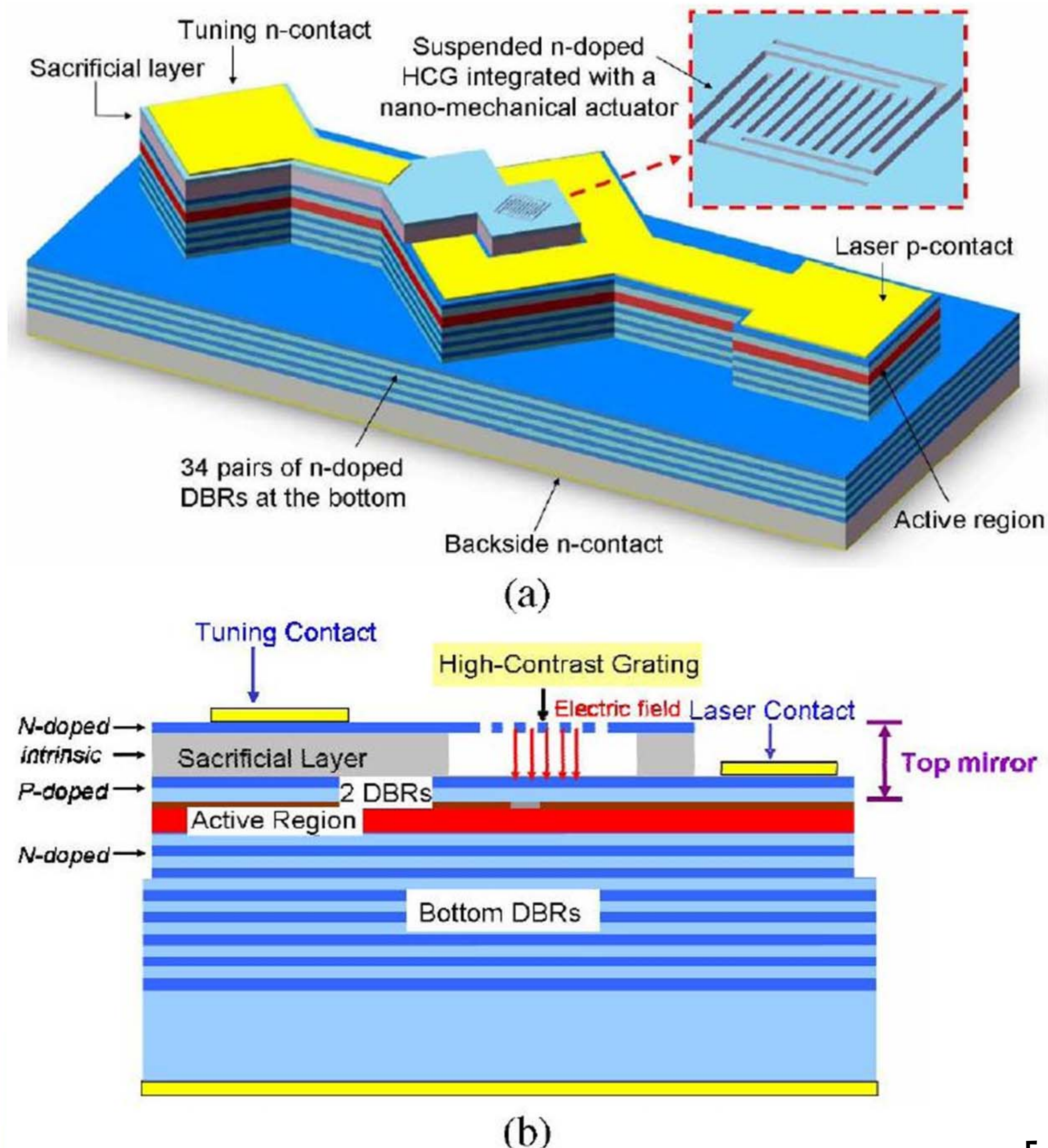
- Top mirror is replaced by a p-DBR/airgap/n-DBR structure
- Uses piezoelectric properties of AlGaAs in order to physically change the shape of the top mirror
- Low fabrication tolerance
- Cantilever structure is moved by applying a voltage between the n-DBR and p-DBR, across the airgap
- Maximum deflection is 1/3 the airgap size (1/3 rule)
- Limited by airgap size, a large airgap narrows Fabry-Perot mode and thus smaller tuning range
- Optimal designs exist with approximately 5% change in wavelength



[3,4]

Tunable VCSEL –
High-Index-Grating

- Surface grating of different refraction index materials can replace a DBR mirror or with conjunction with smaller top DBR
- 10-20 times thinner than a typical DBR
- Large Fabrication tolerances
- Very high reflectivity can be achieved (>99.95%)
- Experimental tuning range of 18nm with 35-40nm theoretically achievable
- Maximum tuning not governed by 1/3 rule



[5]

Sources

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