Surface emitting diode laser

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Grating surface emitting diode laser (GSEL)

Vertical cavity surface emitting laser (VCSEL)
- Distributed Bragg reflectors
  \[ R = 99.9\% \]
Energy level scheme

Conduction band

Photon $hv = E_G$

Phonon defect level

Photon
Materials and bandgaps
Characteristics

- Laser wavelength: 0.6 – 1.6 µm
- Cavity length: 1 - 3 \( \lambda \), so single mode lasing
- Low threshold currents: 0.5 – 10 mA
- Gain coefficient: 5000 – 10,000 m\(^{-1}\)
- Inherent loss: 2000 m\(^{-1}\)
- Typical output power: 2 mW
Applications

- GaAs (1.42 eV)
  - CD (780nm) and DVD (640nm)
  - laser pointers
  - pumping

- InP (1.35 eV)
  - 1.55 µm communications

- GaN (3.49 eV)
  - Blue-Ray discs (405 nm)
Comparison with edge-emitting diode laser

<table>
<thead>
<tr>
<th>Property</th>
<th>VCSEL</th>
<th>Edge emitter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam shape</td>
<td>circular</td>
<td>elliptical</td>
</tr>
<tr>
<td>Beam divergence (FWHM)</td>
<td>13°</td>
<td>20° × 60°</td>
</tr>
<tr>
<td>Power consumption</td>
<td>20 mW</td>
<td>100 mW</td>
</tr>
<tr>
<td>Power emitted</td>
<td>2 mW</td>
<td>100 mW</td>
</tr>
<tr>
<td>Spectral width</td>
<td>10^{-3} Å</td>
<td>10^{-3} Å</td>
</tr>
<tr>
<td>Spectral temperature dependence</td>
<td>0.6 Å/°C</td>
<td>3 Å/°C</td>
</tr>
<tr>
<td>Mode hopping</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>Processing</td>
<td>standard GaAs</td>
<td>cleaved facets</td>
</tr>
<tr>
<td>Testing</td>
<td>on wafer</td>
<td>component only</td>
</tr>
<tr>
<td>Arrays</td>
<td>1D and 2D</td>
<td>1D only</td>
</tr>
<tr>
<td>Speed</td>
<td>2.5–10 Gigabits/s</td>
<td>500 Megabits/s</td>
</tr>
<tr>
<td>Cost</td>
<td>&lt;$1</td>
<td>$500</td>
</tr>
</tbody>
</table>
Recent Experiment

VCSELs Arrays as micromanipulators in Chip-Based Biosystems

“Biomedical Microdevices 2003”

VCSEL is useful because it does not damage the cells, and can easily be placed in an array.

Trapping and translation of nine yeast cells using a 3 x 3 VCSEL array as optical tweezers.
Questions?