Edge- and Surface-emitting Laser Diodes

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Laser Diodes

Edge-Emitting

Surface-Emitting (VCSEL)

www.ifkp.tu-berlin.de

www.fi.isc.cnr.it/users/giovanni.giacomelli/Semic/Samples/samples.html
(a) The energy band diagram of a doped p-n with no bias. (b) Band diagram with a sufficiently large forward bias to cause population inversion and hence stimulated emission.
(a) The density of states and energy distribution of electrons and holes in the CB and VB at T=0 in the SCL under forward bias.
(b) A schematic illustration of GsAs homojunction laser diode. The cleaved surfaces act as reflecting mirrors.
Optical Power

LED

Optical Power

Stimulated emission

Spontaneous emission

Laser

Optical Power

Laser

Optical Power
(a) A double heterostructure diode has two junctions which are between two different bandgap semiconductors (GaAs and AlGaAs).

(b) Simplified energy band diagram under a large forward bias. Lasing recombination takes place in the $p$-GaAs layer, the active layer.

(c) Higher bandgap materials have a lower refractive index.

(d) AlGaAs layers provide lateral optical confinement.
The next evolution in leading-edge orthodontic care.

Dental care

- **Fast and easy to use.** The Spectralase gently vaporizes away target tissue with just a few simple brush strokes, instantly removing gingival tissues to expose tooth surfaces for bonding.
VCSEL, Device Structure

History:
1979: First realization
1988: First VCSEL at room temperature
1996: First commercial VCSEL sold
2005: 50M VCSEL units sold

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Stripe laser</th>
<th>Surface-emitting</th>
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<tbody>
<tr>
<td>Active layer area</td>
<td>$3 \times 300 \mu m^2$</td>
<td>$5 \times 5 \mu m^2$</td>
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<tr>
<td>Active volume</td>
<td>$60 \mu m^3$</td>
<td>$0.07 \mu m^3$</td>
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<tr>
<td>Cavity length</td>
<td>$300 \mu m$</td>
<td>$1 \mu m$</td>
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<tr>
<td>Reflectivity</td>
<td>0.3</td>
<td>0.99 – 0.999</td>
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Distributed Bragg Reflectors

Dielectric Mirrors

Current density:
High Reflectivity is very important!

Dielectric Mirrors

P-Mirror

Effective Cavity

N-Mirror

Active region

Threshold current density $J_{th}$ (kA/cm$^2$)

- $R = 0.8$
- $R = 0.9$
- $R = 0.99$

$\lambda_R = 0.87 \mu$m
$L = 7.0 \mu$m

$0 \to 7$ Thickness of active layer $d$ (\mu$m)

$10^1 \to 10^2$ Threshold current density $J_{th}$ (kA/cm$^2$)

Finistar, Application Notes, Optical Modes In VCSELs

D. R. VIJ, Analysis and Design of VCSELs, 2003
Application Example

Single-mode VCSEL
1550 nm wavelength
10Gbps data-rate
Low Currents

Use in:
Fiber Communication, etc.
Advantages

- Ultralow threshold current (<mA)
- Narrow output beam
- On-wafer testing is possible
- 2-D arrays are possible

vcsei-www.pi.titech.ac.jp
Multiple-Wavelength VCSEL-Array

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Measurements
Conclusion

• Diode Lasers are cheap and easy to fabricate
• Are widespread in consumer applications
• Available in various wavelengths and powers
• A lot of room for improvement!!!