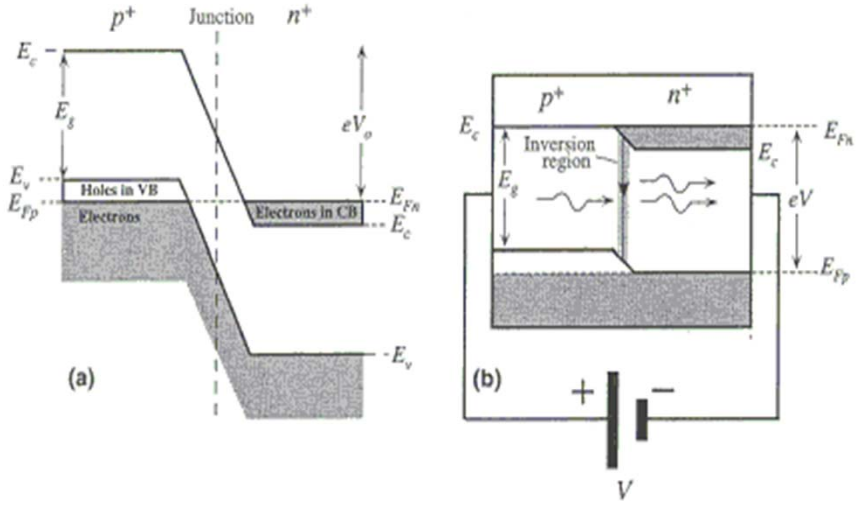
Laser Diodes

Logan Woods

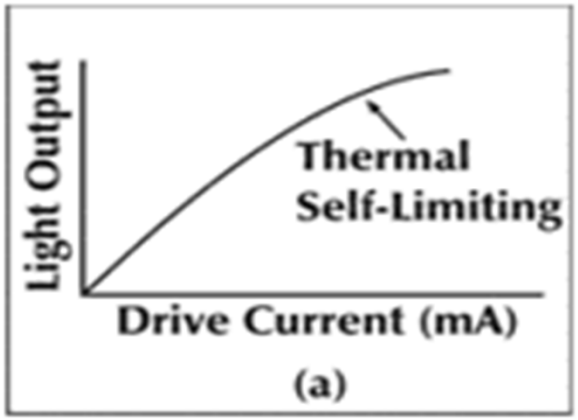
Overview

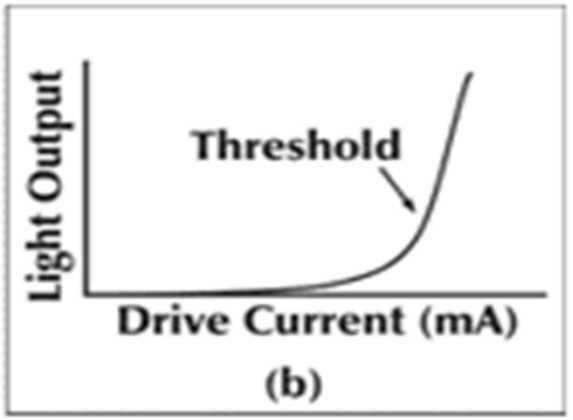
- pn junction (diode) with depletion region
- Powered by charge injection or optical pumping
- Recombination creates photon with specified wavelength



LED vs. Laser Diode

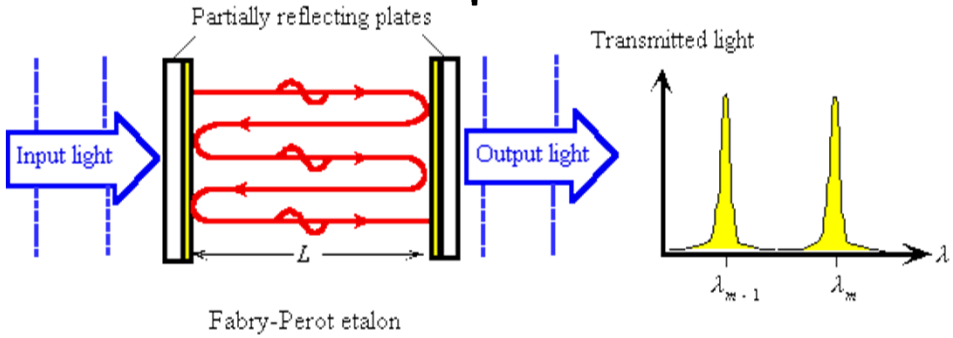
LED	Laser
Incoherent light out of phase	Coherent light in phase
Linear output until thermal limitations	Low output until threshold current
Lower efficiency(38% Theoretically)	Higher efficiency (80% Theoretically)
Wider spectrum	Narrow spectrum (<5nm)
Spontaneous Emission	Stimulated Emission
Higher Divergence	Low Divergence





Basic Manufacturing

- Direct-bandgap semiconductors allow photon emission
- Usually use III-V Compound semiconductors (GaAs, InP, GaSb, GaN)
- Checkerboard pattern of alternating atoms
- Fabry-Perot resonator used to reflect photons several times before emission



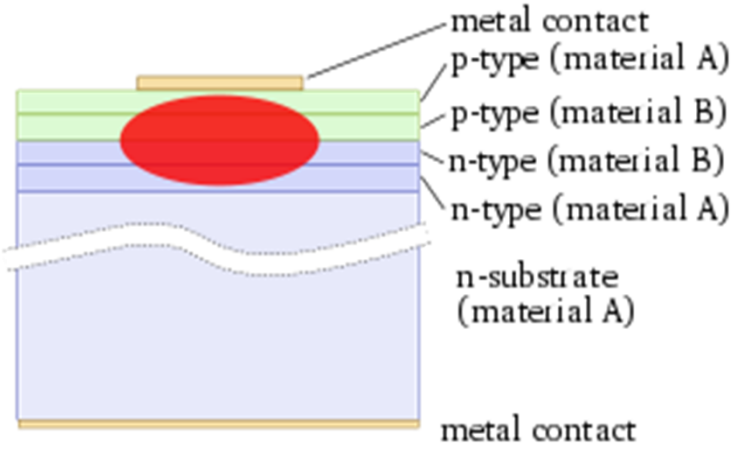
Transmitted light through a Fabry-Perot optical cavity.

Types of Laser Diodes

- Double Heterostructure Lasers
- Quantum Well Lasers
- Quantum Cascade Lasers
- Separate Confinement Heterostructure Lasers
- Distributed Feedback Lasers
- Vertical Cavity Surface Emitting Lasers
- Vertical External Cavity Surface Emitting Lasers

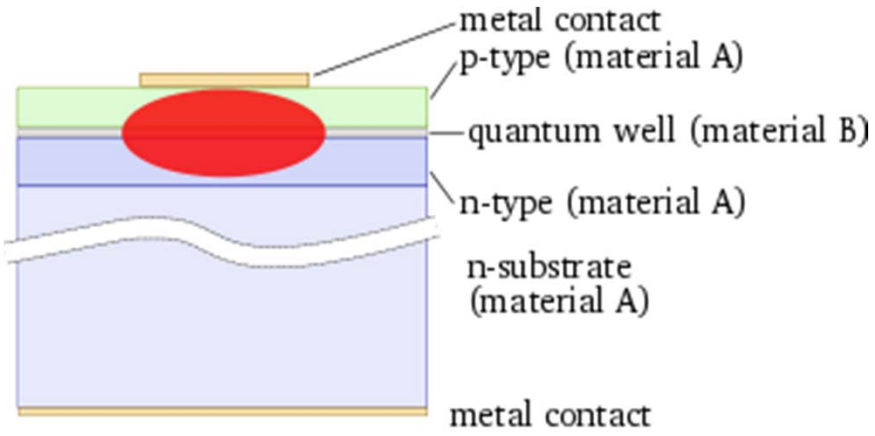
Double Heterostructure Lasers

- Low bandgap material between 2 high bandgap layers (GaAs with AlGaAs)
- Advantage: active region is confined to middle resulting in less scattering due to reflection at heterostructures



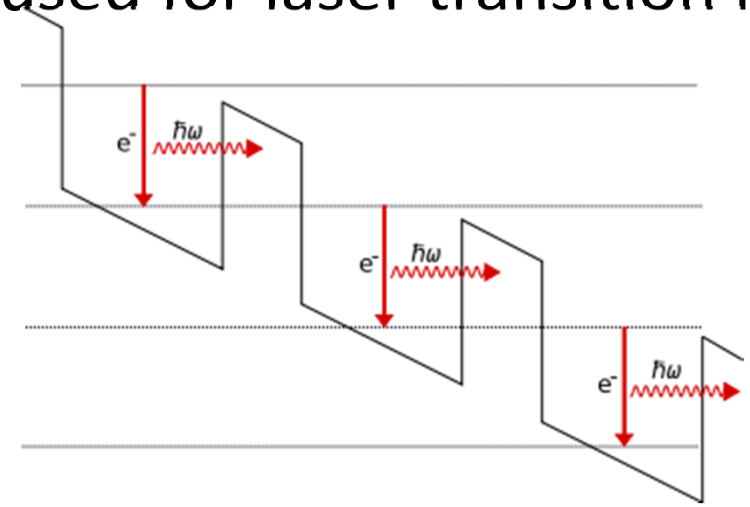
Quantum Well Lasers

- Thin middle layer produces Quantum Well which aids in recombination
- Abrupt edge concentrates electrons in energy states that contribute to lasing
- Multiple quantum wells improve overlap of gain region with optical waveguide mode



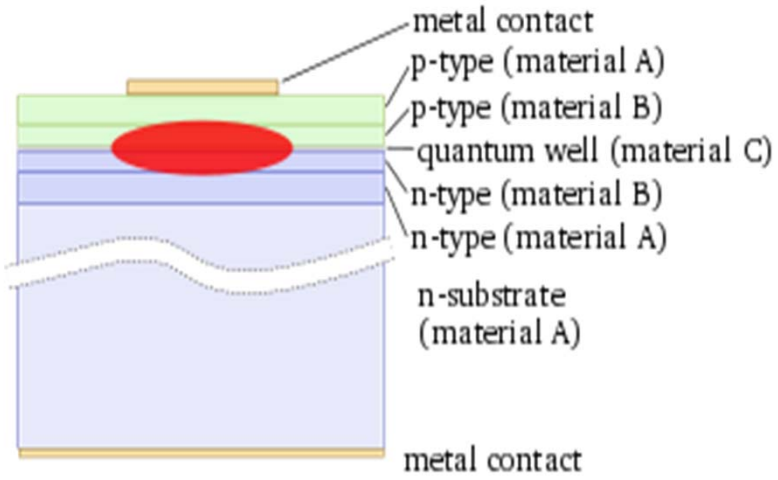
Quantum Cascade Lasers

- Long wavelength possible (2.75–250 µm and even 355 µm with a magnetic field)
- Tuned with altering thickness of layers (Heterojunction lasers)
- Different from Quantum Well in that the Energy levels are used for laser transition not bandgap



Separate Confinement Heterostructure Lasers (SCH)

- Almost all commercial diodes since 1990s are SCH
- Simple Quantum Well with 2 additional layers with lower refractive indexes to confine the light

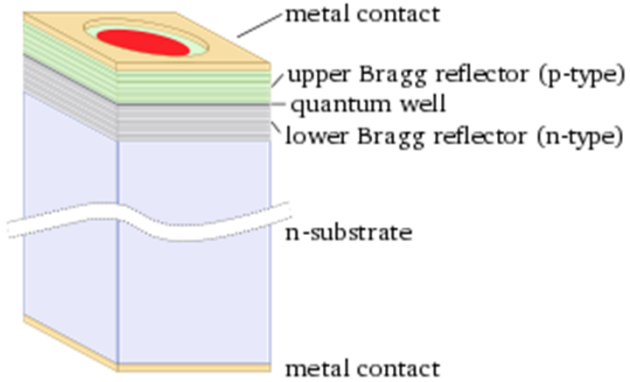


Distributed Feedback Lasers

- Diffraction grating near pn junction is used to stabilize the wavelength
- Works by causing a single wavelength to be fed back to gain region and produce lasing
- Reflection mirror is not required, instead one side has an anti reflection coating
- Used for precise and stable wavelength

Vertical Cavity Surface Emitting Lasers(VCSELs)

- Optical cavity axis is along the current flow rather than perpendicular
- Very short active region
- Dielectric mirrors made from alternating high and low refractive indexes act as reflectors
- High degree of wavelength selective reflectance
- Lower output power than edge emitting lasers



Vertical External Cavity Surface Emitting Lasers (VECSELs)

- Like VCSELs but one mirror is external (~1cm) to diode
- Small gain region in direction of progation (<100nm vs 250µm to 2mm for other types)
- Large cross section single mode beam
- Useful for projection displays

Applications

- Telecommunication for fiber optic light source
- Infrared lasers in CD and DVD players
- Violet lasers in HD DVD and blu-ray
- Measuring instruments (rangefinders, bar code readers, etc.)
- Laser surgery
- Laser pointers
- Many others

Applications

Laser Diodes in Medicine

- Coherent light penetrates skin unlike incoherent LED light
- Inserts bio-photons into damaged cells to produce ATP, and promote cell division, the immune system, and hormone production
- Operates at 600-1060nm to avoid x and gamma rays

Sources

- http://en.wikipedia.org/wiki/Laser_diode
- http://www.repairfaq.org/sam/laserdio.htm
- http://www.superpulsedpractice.com/laser_led.htm
- http://www.askkia.com/articles/what-is-a-diode.html