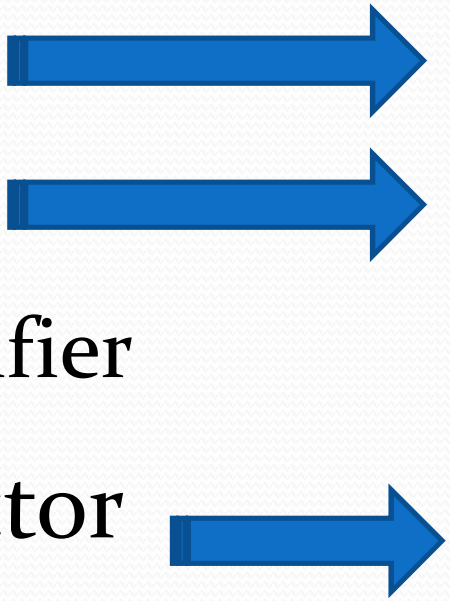
Course No: EEE 6503
Course Name: LASER Theory

Solid-State Lasers & Semiconductor Lasers

Md. Tanjib Atique Khan
St No: 0412062250

Presentation Outline

- Solid-State Laser
  - Ruby Laser
  - YAG Laser
  - Fiber Amplifier
- Semiconductor Laser



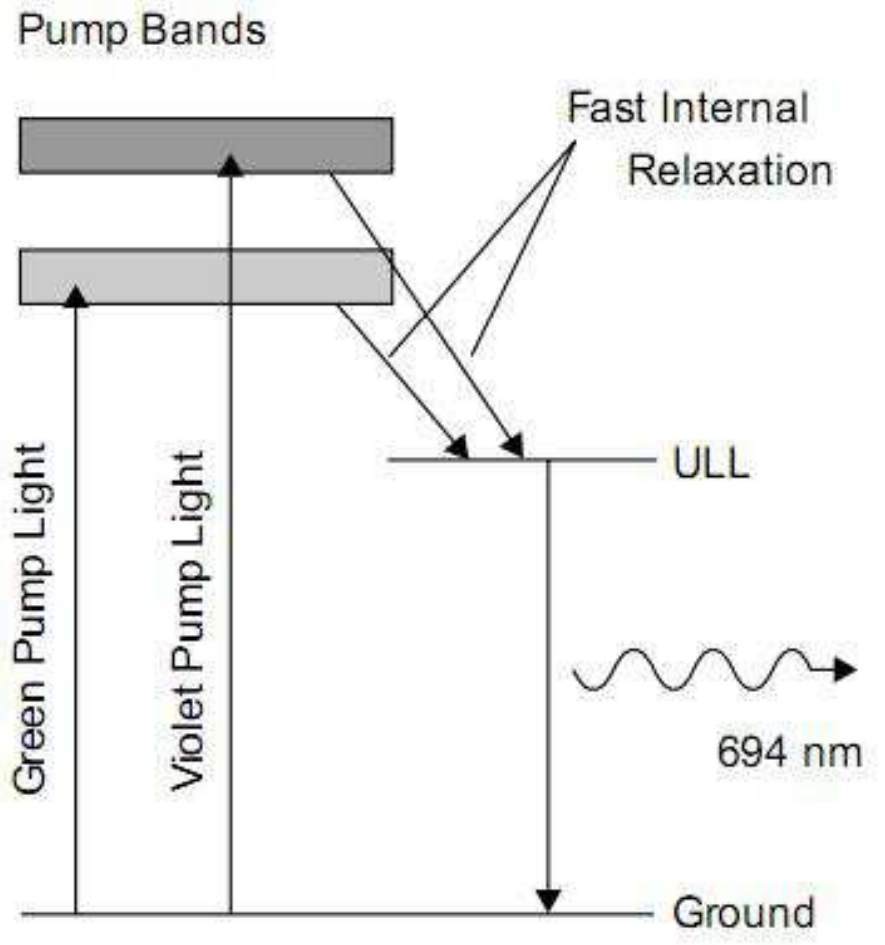
- Lasing Medium
- Optics and Cavities
- Laser Structure
- Power Supplies
- Output Characteristic
- Application

Solid-State Laser

- Oldest technology to produce laser
- Crystal doped with lasing ion
- Two of the most important solid-state lasers
  - Ruby laser
  - YAG laser

Ruby Laser

- Lasing Medium:
  - Al_2O_3 doped with Cr^{3+}
  - Three-level lasing system
  - High pumping threshold
  - Operate in pulsed mode
  - Emit a photon of 694.3 nm



Ruby Laser (Cont.)

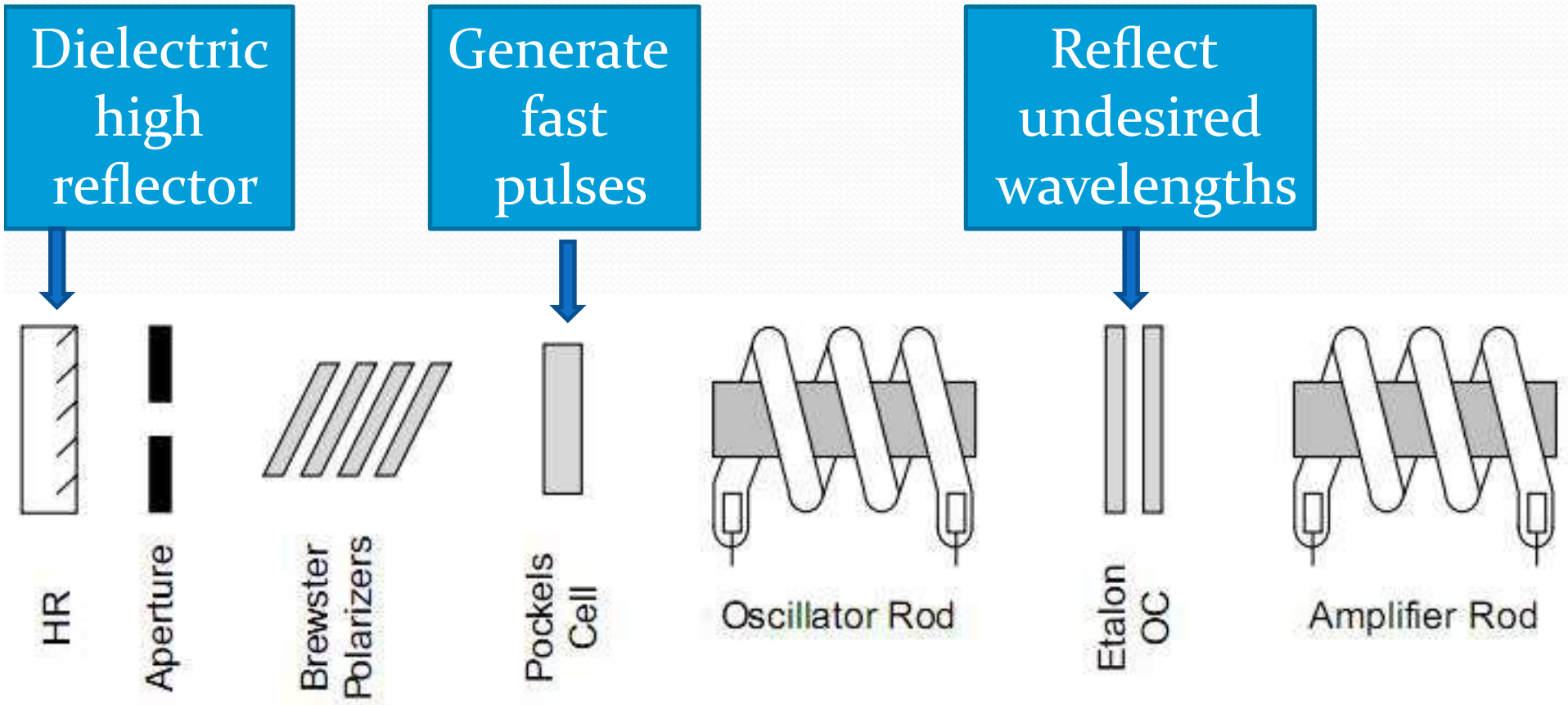
- Optics and Cavities:
  - Mirrors with dielectric coating
  - Integral mirrors at the ends of the rod
  - Front of the rod coated for partial transmission
  - Thermal lensing causes spherical lensing effect
  - Cavity reflectors are concave to compensate for this effect

Ruby Laser (Cont.)

- Optics and Cavities:
  - A special configuration used with two optically pumped rods
    1. An oscillator producing a clean beam
    2. An amplifier to increase the output of the oscillator

Ruby Laser (Cont.)

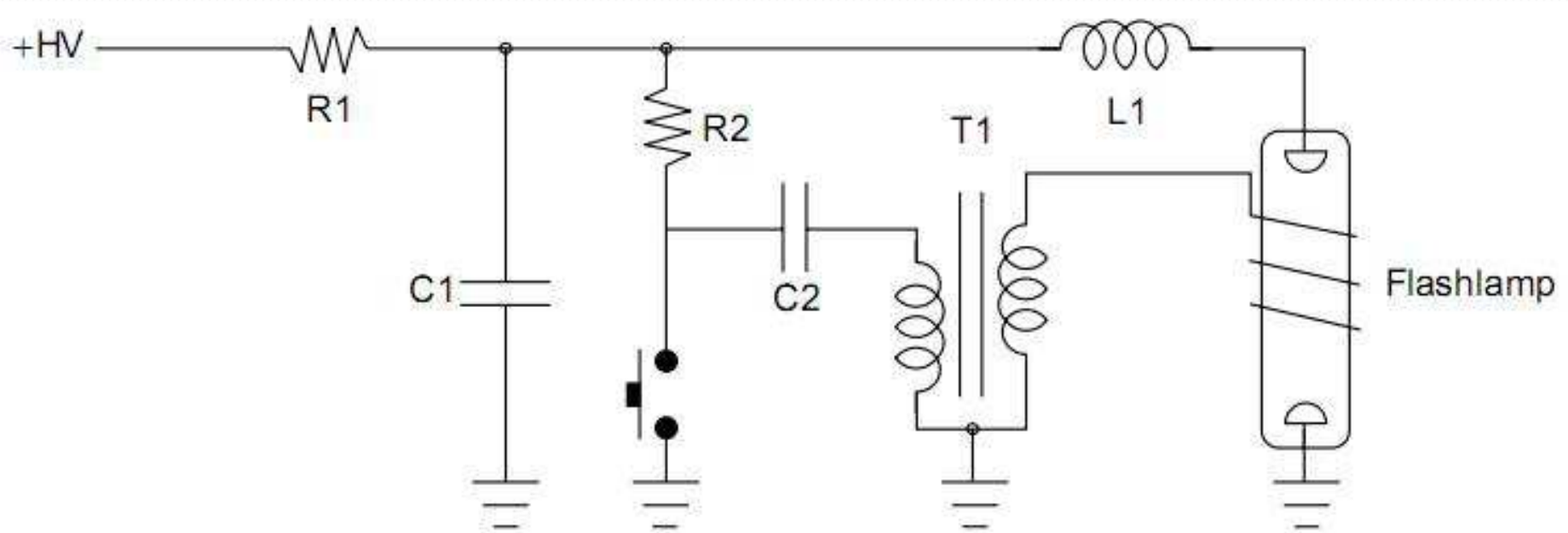
- Laser Structure:



Double-pulse Ruby Laser

Ruby Laser (Cont.)

- Power Supplies:
  - Helical-shaped flashlamp pumping
  - Xenon is used as the gas
  - Generates blue light



Ruby Laser (Cont.)

- Output Characteristics:
  - Operate in high-order transverse modes
  - Spectral width 20-40 MHz
  - Q-switching decreases energy , but peak power increases.
  - Pulses can be of 10ns.
  - Peak powers of 100 MW to over 1GW

Ruby Laser (Cont.)

- Applications:
  - Research purpose
  - Sources for holography
  - Double-pulse ruby laser to record deformation of test material
  - Range finder in tanks like U.S.M-60

YAG laser

- Active lasing ion is Neodymium, (Nd^{3+})
- YAG is used to describe all lasers with lasing ion Nd^{3+}
- Four-level lasing system
- Multiple pump levels, pumping light is red and near-infrared
- Lower pumping threshold, can oscillate in CW mode

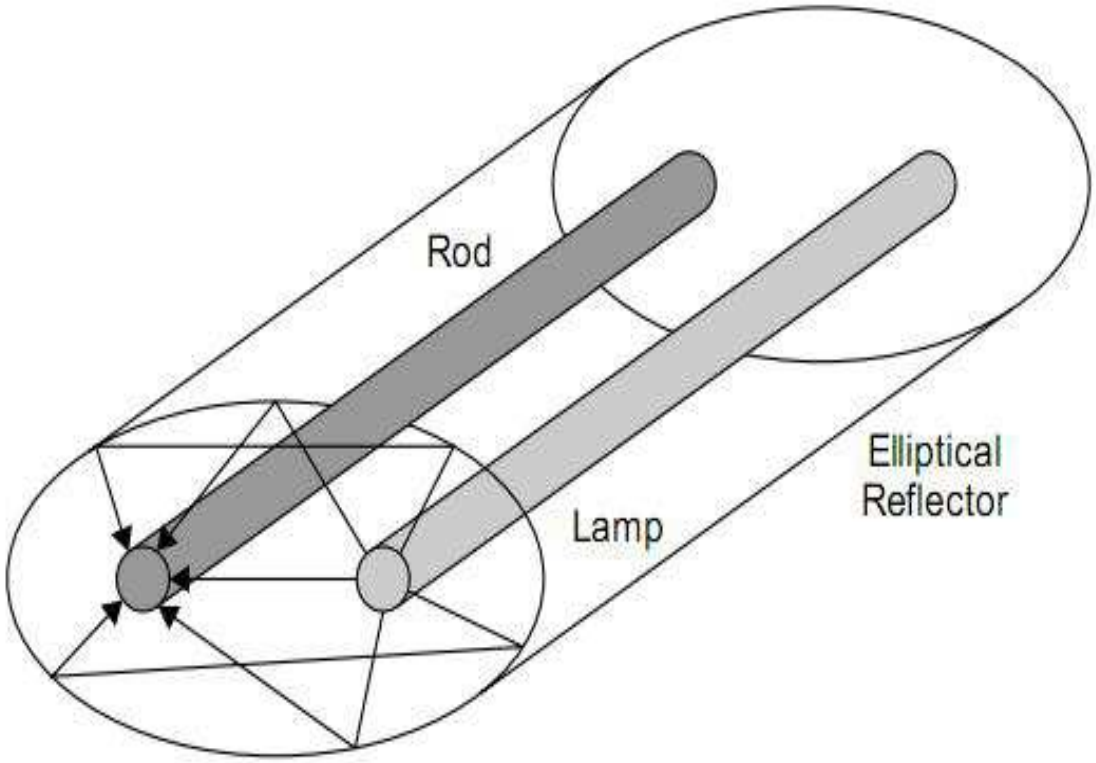
Common Name	Chemical Formula and Name	Wavelength (nm)
YAG	$Y_3Al_5O_{12}$ (yttrium aluminum garnet)	1064
Vanadate	YVO (yttrium o-vanadate)	1064
Glass	Various phosphate and silicate glasses	1060/1054
YLF	YLF (yttrium lithium fluoride)	1053

YAG laser (Cont.)

- Optics and Cavities:
  - Consists of two mirrors
  - One or both are slightly spherical, compensate for thermal lensing effect
  - Dielectric reflective coatings on cavity mirrors
  - Q-switch allows production of fast, intense pulses

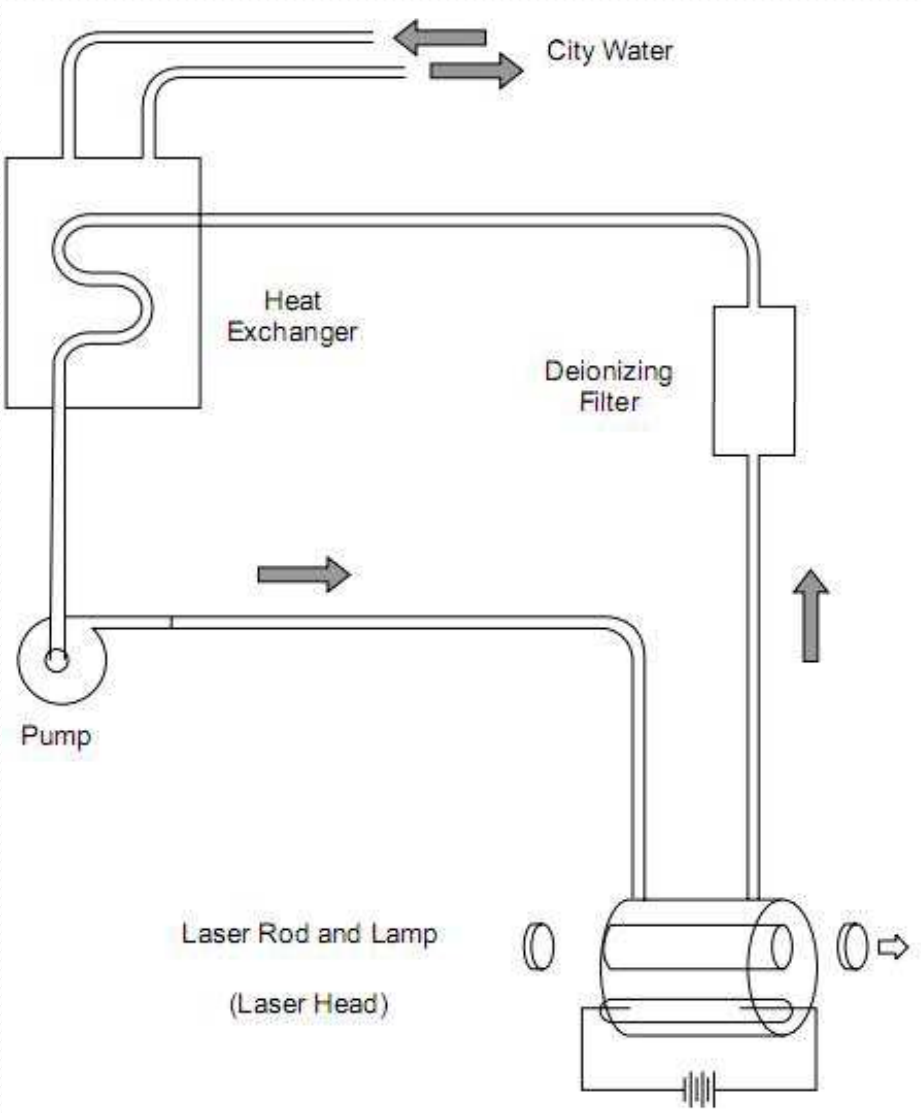
YAG laser (Cont.)

- Laser Structure:
  - Linear Krypton-filled CW arc lamp for pumping
  - Pump light coupled to the YAG rod via elliptical reflector
  - YAG rod and lamp placed at a focus of the reflector
  - Reflectors coated with pure gold



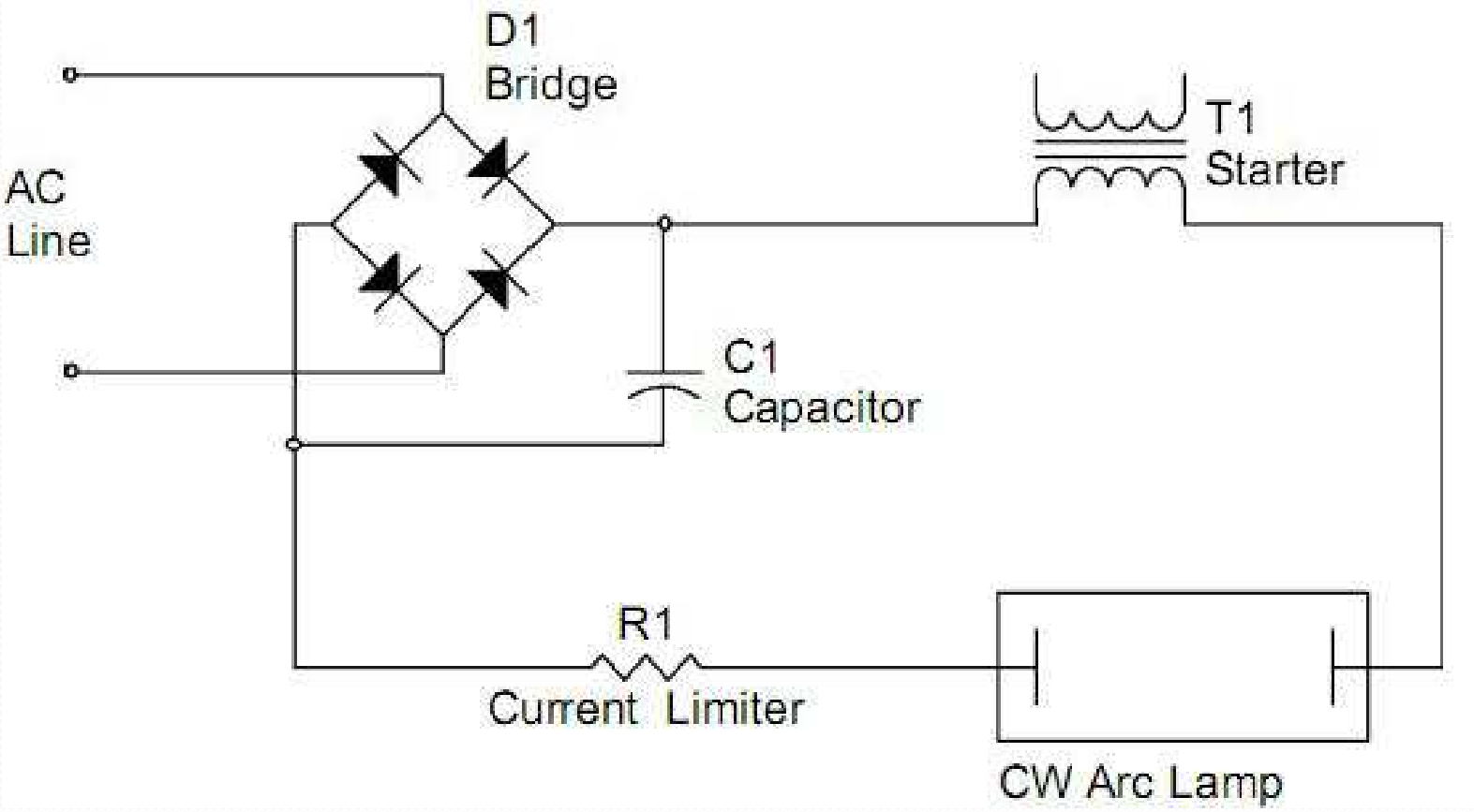
YAG laser (Cont.)

- Cooling system:
  - Lamp produces kilowatts of heat
  - Deionized water used for cooling to avoid short -citcuit
  - Heat is exchanged with a supply of city water



YAG laser (Cont.)

- Power Supplies:



YAG laser (Cont.)

- Applications:
  - Cutting, drilling and trimming
  - Marking applications
  - Laser light displays and cloud writing

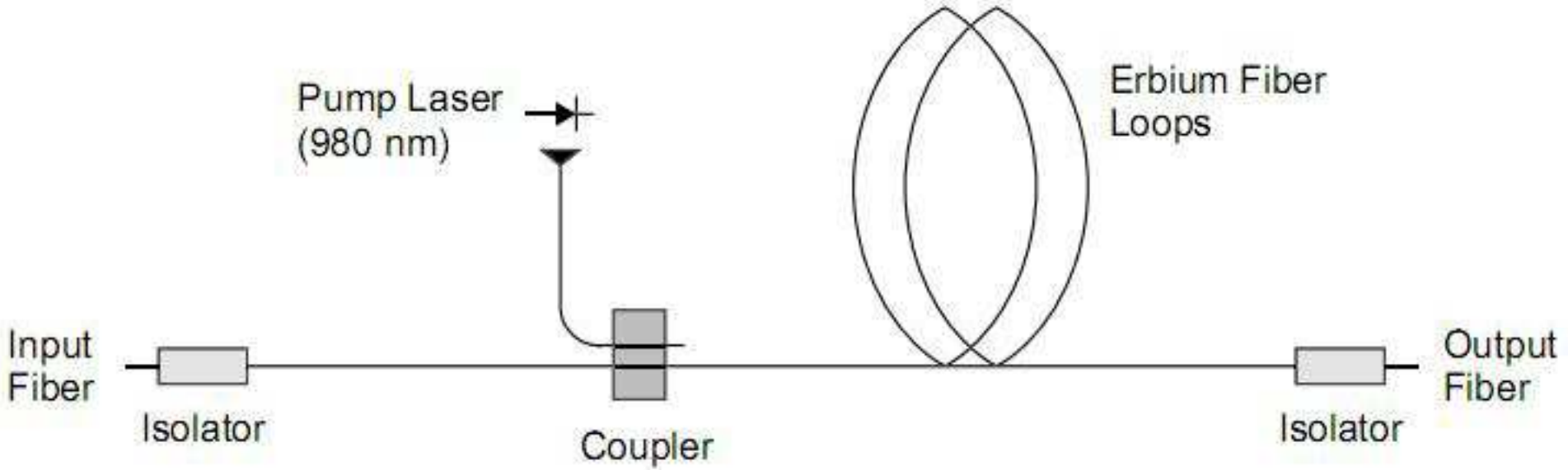
YAG laser (Cont.)

- Cautions:
  - The laser light produced can penetrate the eye readily
  - Q-switched laser pulses can damage tissue rapidly
  - High-pressure arc lamps may explode during lamp changing

Fiber Amplifier

- A solid-state amplifier
- Boosts weak signals in fiber optic cables
- 10 to 20-m section of glass fiber doped with erbium ions (Er^{3+})
- A pump laser at 980 nm is coupled to the amplifier fiber
- Er^{3+} absorbs pump light

Fiber Amplifier



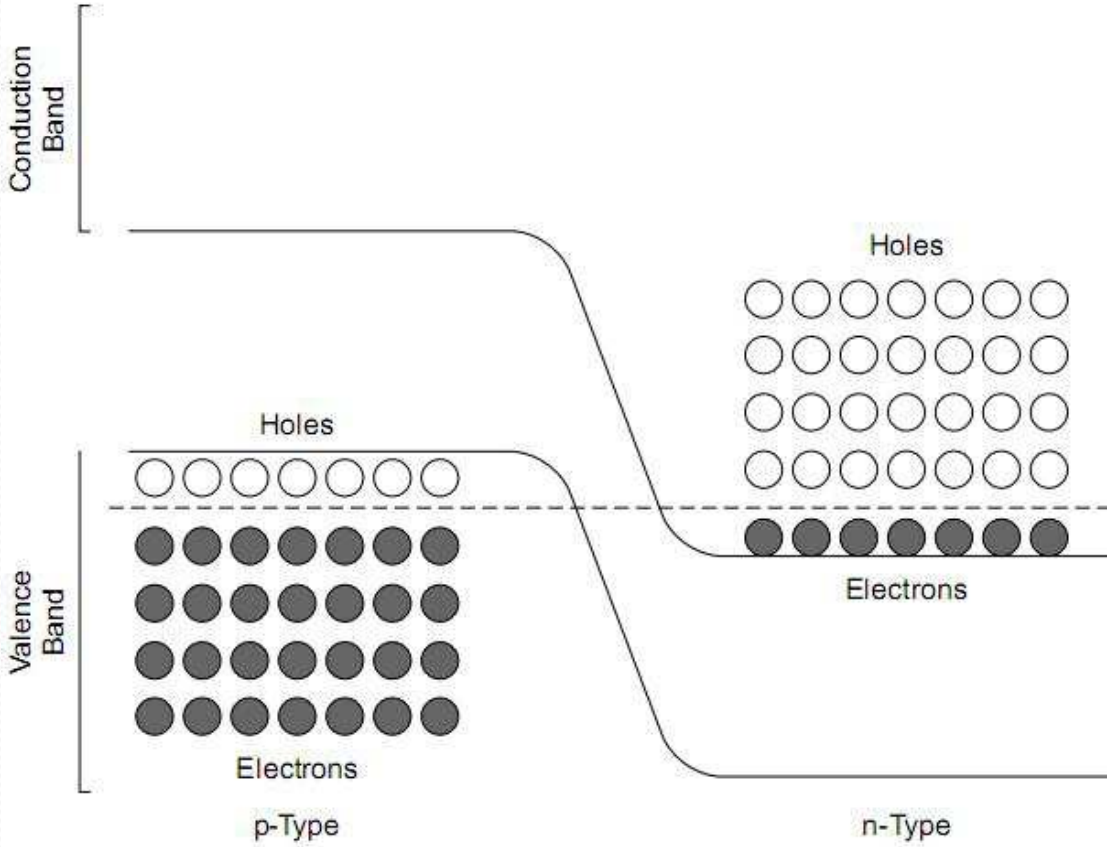
- Incoming signal amplified by stimulated emission at 1549 nm
- Er:glass amplifier can lase if provided with a suitable feedback mechanism

Semiconductor Laser

- Most widely used
- Inexpensive
- Can be made very small
- Simple power supply
- Output light infrared or red
- Blue and violate is also possible

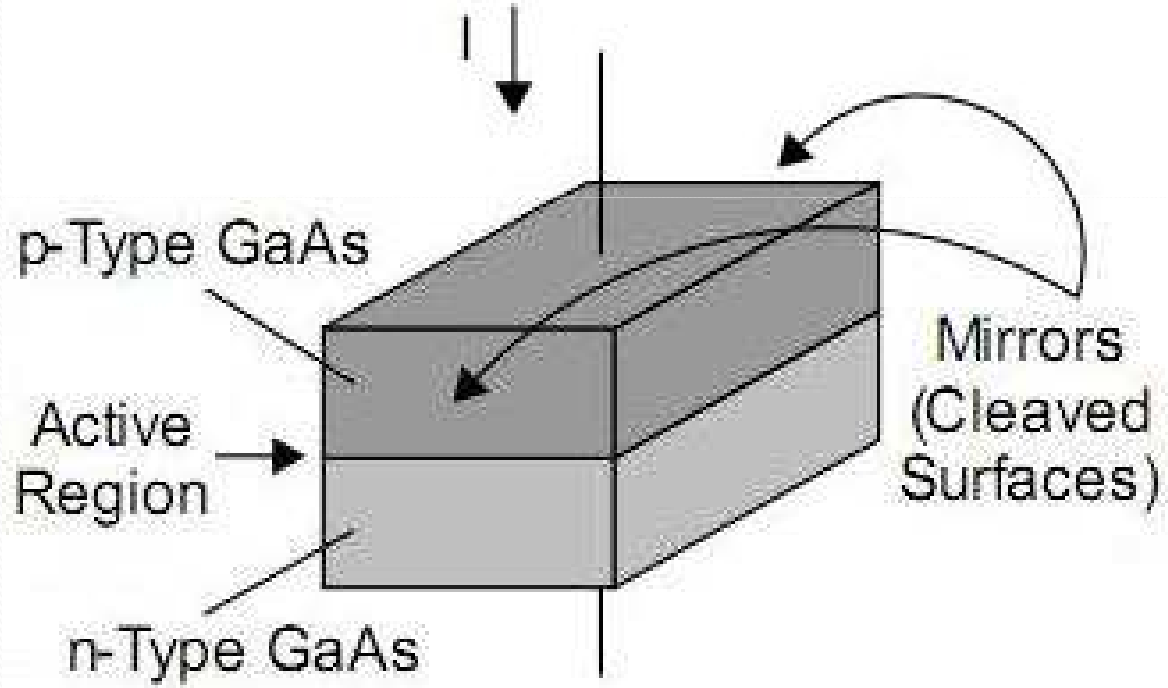
Semiconductor Laser (Cont.)

- Lasing Medium:
  - A degenerately doped p-n junction
  - When positive bias exceeds bandgap, population inver -sion takes place
  - Stimulated emission causes lasing action



Semiconductor Laser (Cont.)

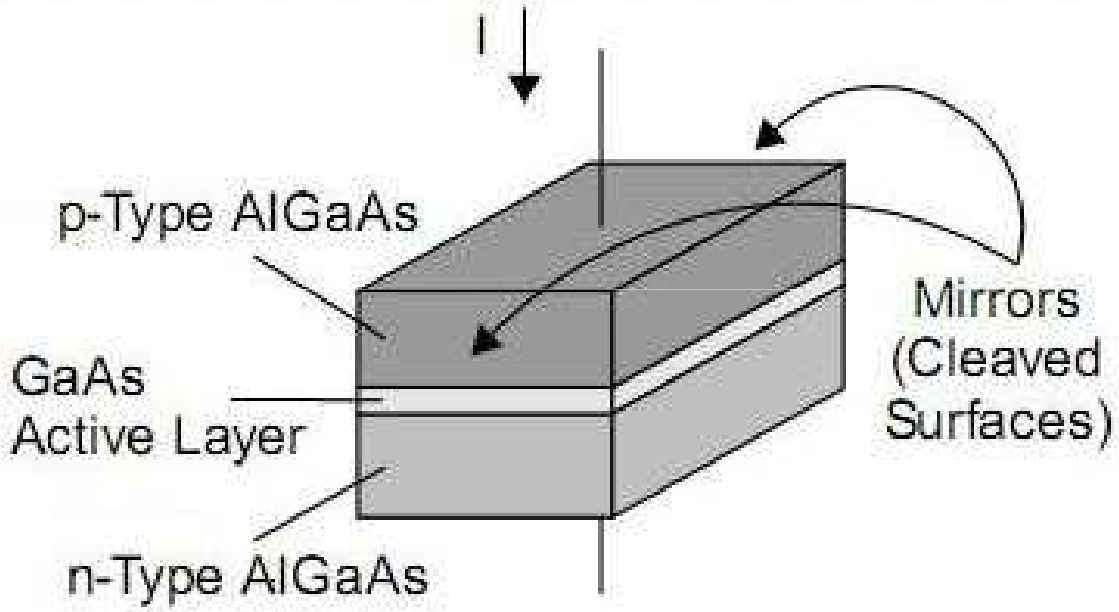
- Laser Structure:
- Homojunction laser diode:
  - Simplest structure
  - A single junction
  - Cleaving crystal at right angles to laser axis



  - Requires large threshold current
  - CW operation needs cryogenic cooling

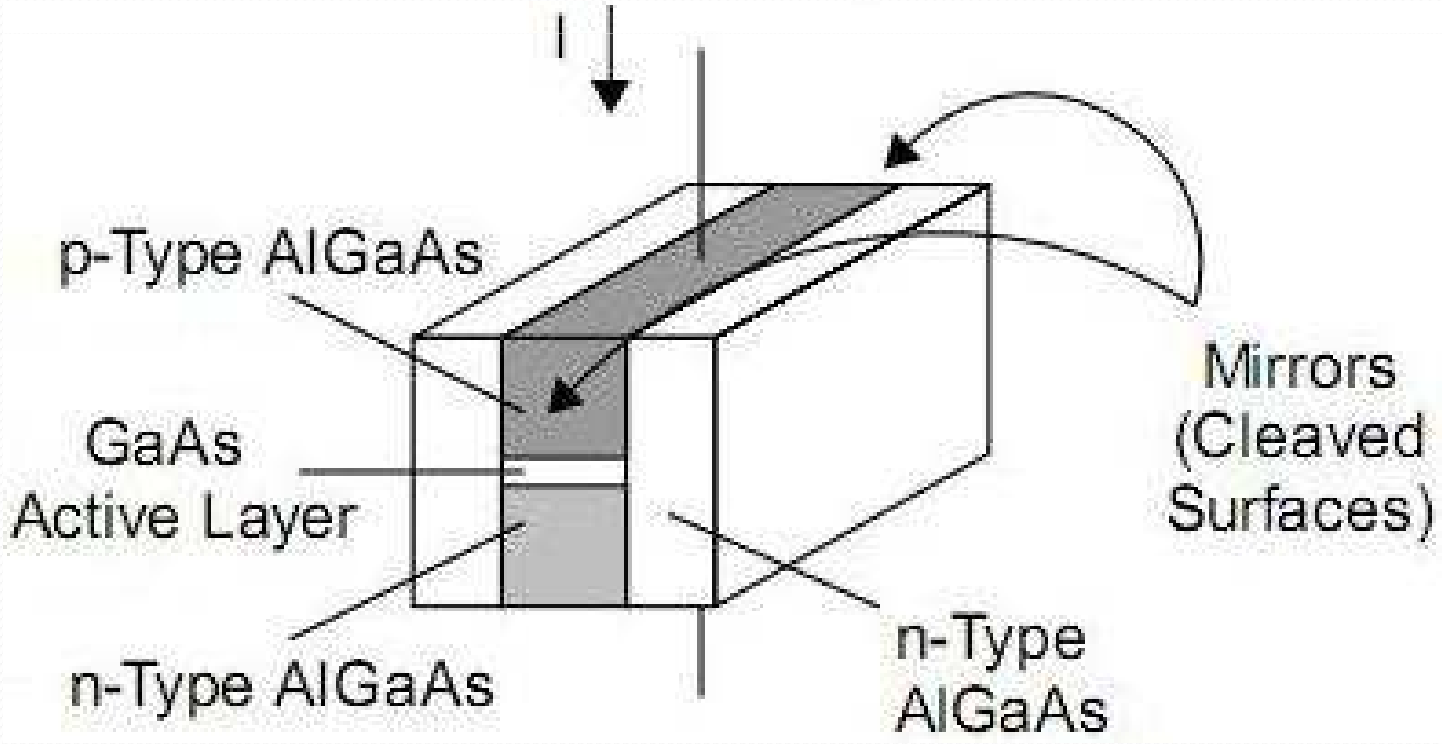
Semiconductor Laser (Cont.)

- Double heterostructure laser diode:
  - Two interfaces of different refracting indexes, one on top and one below the active region
  - Stripe contact used to make electrical connection
  - Low threshold current
  - Operates at room temperatures



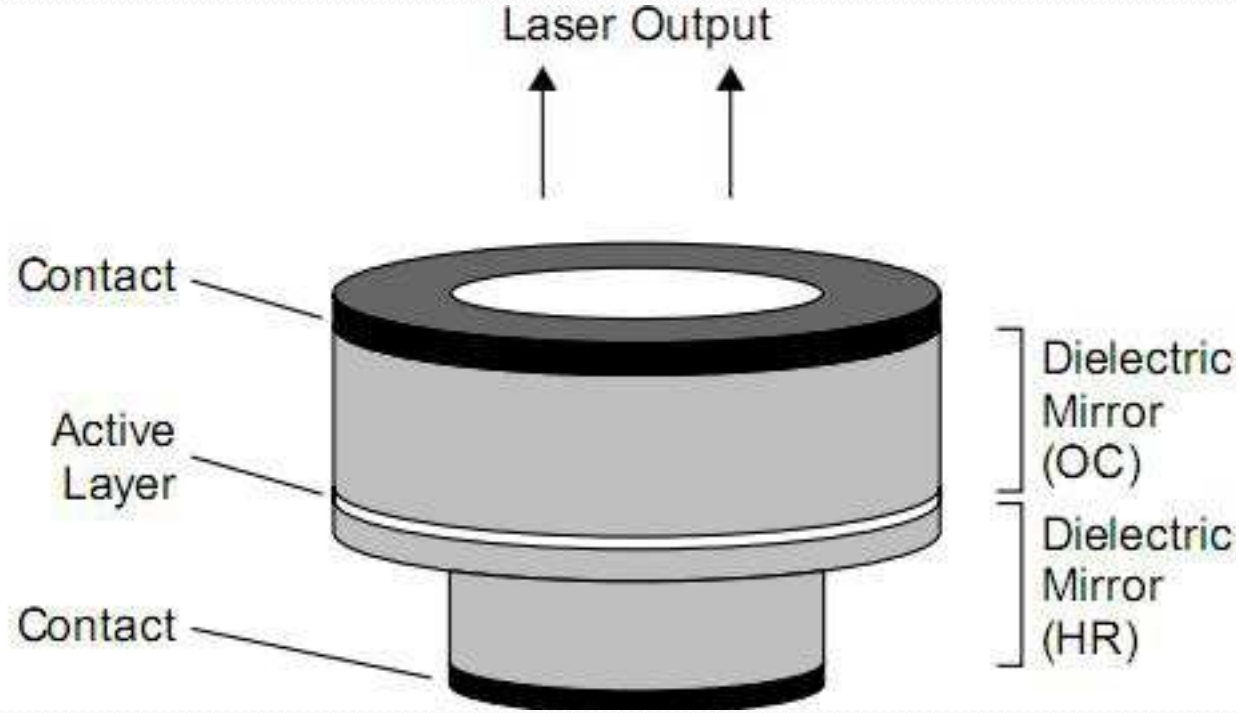
Semiconductor Laser (Cont.)

- Buried heterostructure laser diode:
  - All three layers confined on both sides
  - Better light confinement



Semiconductor Laser (Cont.)

- Vertical Cavity Surface Emitting Laser (VCSEL):
  - Light produces from the entire top of semiconductor crystal
  - Narrow spectral line width
  - Low threshold currents
  - Possible to fabricate on a single wafer like microchips

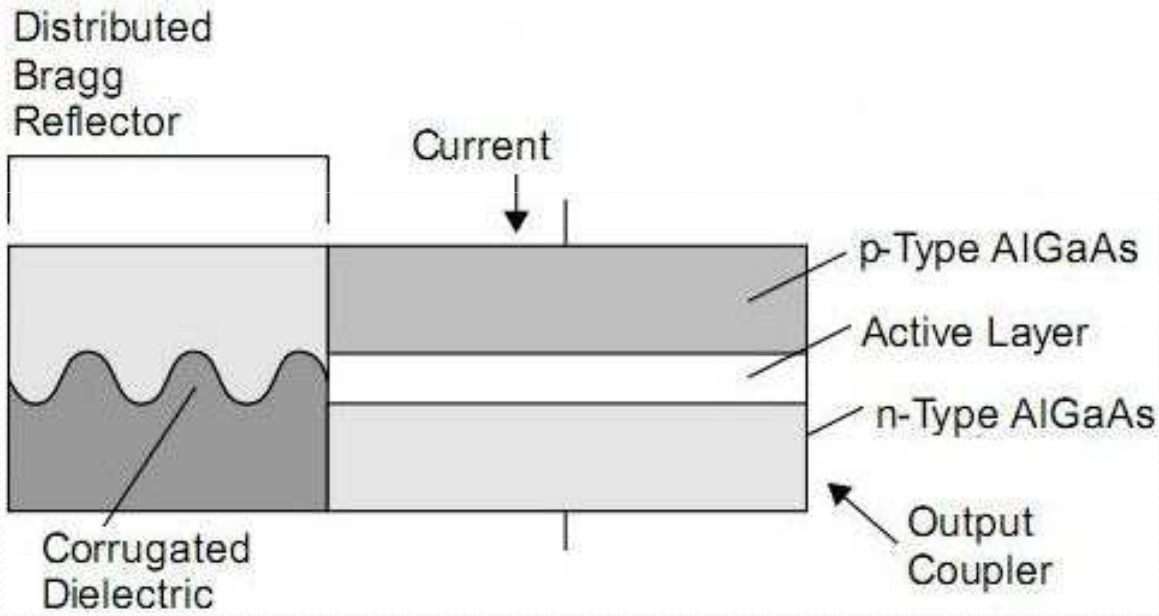


Semiconductor Laser (Cont.)

- Optics:
  - Cleaved surfaces act as cavity reflector of 33% reflection
  - Rear surface coated with multi-layer dielectric mirror
  - Inherent spectral width is quite large
  - Wavelength selective optics is needed
  - Two techniques are used
    - Distributed Bragg Reflector (DBR)
    - Distributed Feedback (DFB)

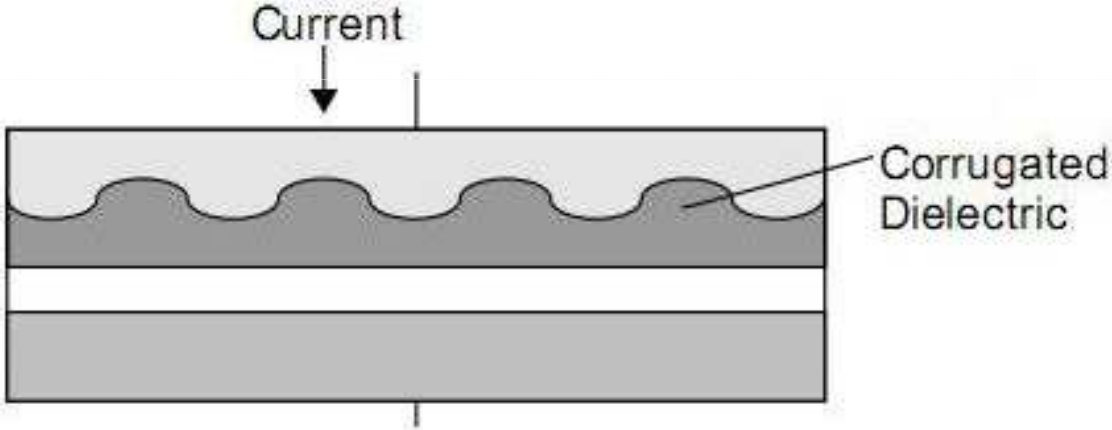
Semiconductor Laser (Cont.)

- Distributed Bragg Reflector (DBR):
  - Corrugated surface from dielectric materials
  - Reflection of light at interface causes constructive interference at a well-defined wavelength.
  - Acts like a high-performance dielectric mirror



Semiconductor Laser (Cont.)

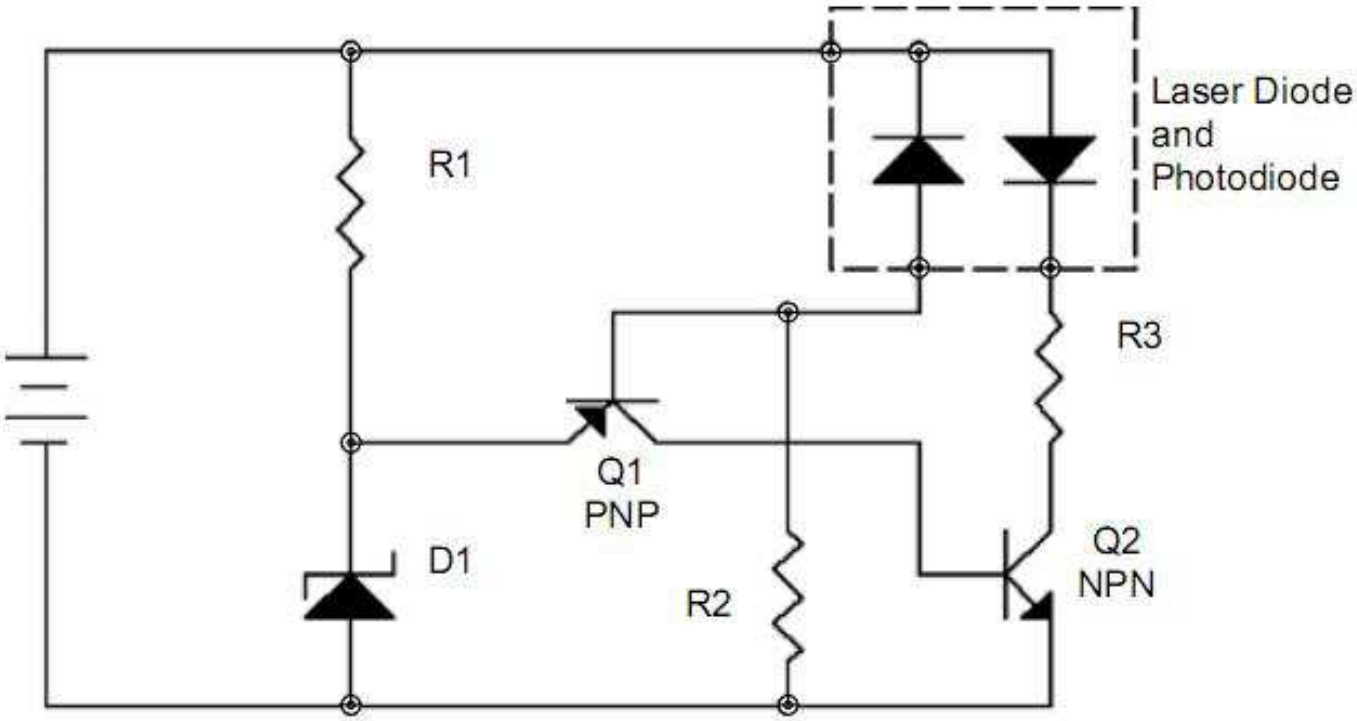
- Distributed feedback (DFB):
  - Corrugated structure
  - Reflects light partially at each interface
  - Optical feedback is distributed along the cavity



  - Wavelength of the grating is determined by the spacing of the corrugations
  - Separate HR and OC are not required

Semiconductor Laser (Cont.)

- Power Supplies:
  - Provide both current and light output regulation
  - Advanced power supplies include temperature controller

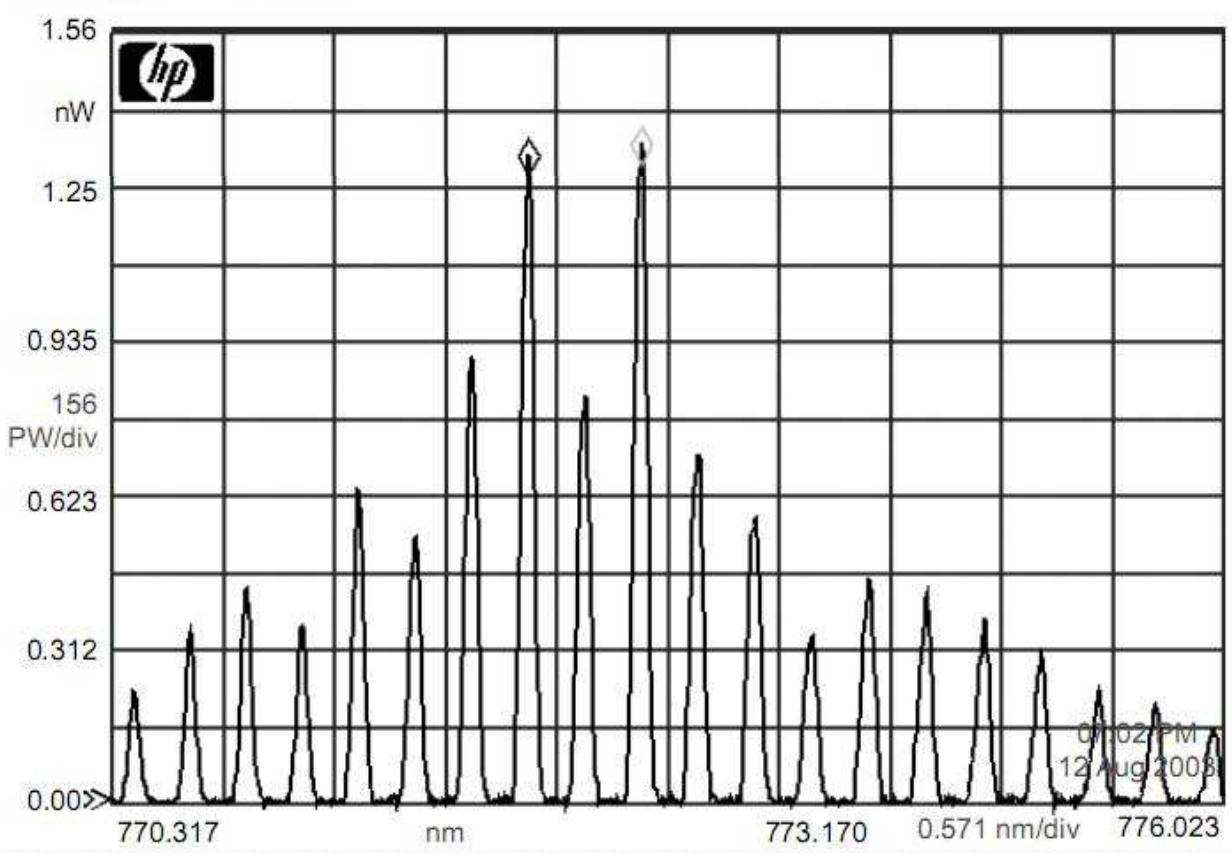


Semiconductor Laser (Cont.)

- Output Characteristics:
  - Elliptically shaped output beam
  - VCSELs feature a circular beam
  - Use external lens to collimate output
  - Wavelength of output shifts to long wavelengths as temperature increases
  - For single-longitudinal-mode , output wavelength can shift abruptly as the temperature fluctuates. This phenomenon is called **Mode Hopping**

Semiconductor Laser (Cont.)

- Output Characteristics:
  - Several longitudinal modes oscillate simultaneously
  - At high drive currents, a dominant mode appears



Semiconductor Laser (Cont.)

- Applications:
  - CD and DVD players
  - Laser pointers
  - Scanning applications
  - Pump another solid-state laser


Thank you