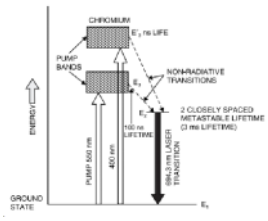
Laser

11 December 2023 20:01

Ruby Laser

33 to 35 solid laser
36 to 38 gas laser
39 liquid laser

Ruby Laser - First Laser (1960):
- Developed by TH Maiman.
- Ruby laser rod: Synthetic pink Ruby crystal (Al2O3 doped with Cr3+ ions).
- Active centers: Cr3+ ions with three energy levels.
- Ruby crystal as a cylindrical rod (4cm length, 0.5 cm diameter).
- Pumped with an intense Xenon flash lamp.



Commercial Ruby Laser:
- End faces grounded and polished, mostly silvered faces for a Fabry-Perot resonator.
- Cooled with a circulating coolant.
- Three-level laser system with E2 metastable state (3ms).

Lasing Process:
- Ground state Cr3+ ions absorb light at pump bands (550nm and 400nm).
- Non-radiative transitions to E2 create population inversion.
- Radiative transitions from E2 to E1 produce red wavelength at 694.3 nm.
- Stimulated emission occurs when pumping exceeds the critical threshold.
- next pulse arrives after population inversion is restored.

Performance and Applications:
- High energy storage capability (long upper laser level lifetime).
- Relatively inefficient
- **Applications include plasma diagnostics and holography.**

ND:YAG Laser

Nd: YAG Laser: Yttrium Aluminum Garnet (YAG) $Y_3Al_5O_{12}$

- **Crystal Host:**E3 METASTABLE STATE**
  - Yttrium Aluminum Garnet (YAG) is the optimal host crystal for neodymium ions.
  - YAG offers low threshold, high gain, and excellent thermal properties.

- **Operation:**
  - Operates in both continuous wave (CW) and high-repetition-rate pulsed mode.
  - Efficiency is about 10 times that of ruby lasers.
  - Replaces ruby in military applications and semiconductor industry tasks.

- **Output:**
  - Produces pulses with variable high repetition rates.
  - Achieves continuous wave (CW) output with over 1 kW power.

- **Efficiency and Pumping:**
  - Can be pumped by a diode laser (GaAs) for high efficiency.

- **Applications:**
  - Used in military rangefinders, semiconductor industry tasks, and efficient marking applications.

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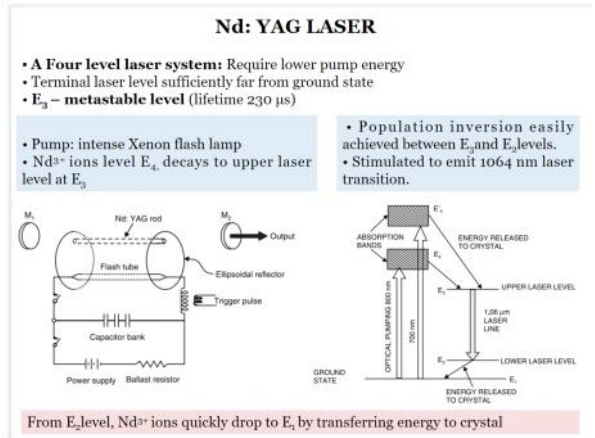


Nd: Glass Laser:

- **Advantages:**
  - Suitable for high-energy pulsed operation due to large size and broadened fluorescent line.
  - Can deliver much higher energies and be doped at high concentrations.

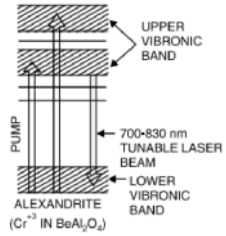
- **Shapes and Sizes:**
  - Available in various forms, from micrometer-sized fibers to large rods and disks.

-The major disadvantage of glass is a low thermal conductivity

- **High Output Energy:**
  - Provides very high output energy per unit volume.

- **Applications in Fusion:**
  - Used in inertial confinement fusion for controlled energy generation.
  - NOVA lasers employed Nd: glass amplifiers for nuclear fusion, achieving high-density and high-temperature conditions.

Alexandrite Laser:



- **Composition:**
  - Chromium-doped chrysoberyl (BeAl2O4 : Cr3+).

- **Tunability:**
  - Tunable due to vibrational levels from strong Cr3+ ion and lattice vibration coupling.

- **Doping and Shape:**
  - Doped at 0.1%, 3×10^25 ions/m^3, rod-shaped (10cm long, 6mm diameter).

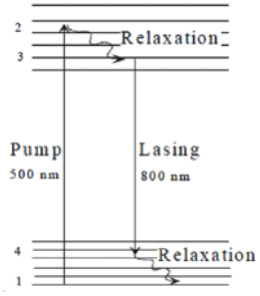
- **Pumping:**
  - Flash lamp pumped with levels at 380 nm & 630 nm.

- **Gain Bandwidth:**
  - Vibronic transitions allow wide gain bandwidth, enabling tunability to desired wavelengths within the emission spectrum.

- **Operation:**
  - Operates in both pulsed and continuous wave (CW) modes.

- **Applications:**
  - Widely used in cancer therapy, kidney stone removal, and pollution detection.

Titanium-Sapphire (Ti: Al2O3) Laser:3 LEVEL LASER



- **Composition:**
  - Titanium-doped aluminum oxide (Ti: Al2O3).

- **Tunability:**
  - Broad vibronic fluorescence band allows tunable laser output between 660–1180 nm, with the peak around 800 nm.

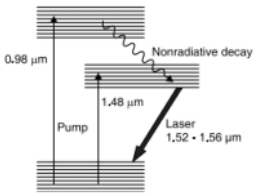
- **Gain Cross Section:**
  - Relatively large gain cross section, half of Nd: YAG at the peak of its tuning range.

- **Energy Level Structure:**
  - Unique energy level structure with no d state energy levels above the upper laser level.

- **Doping and Operation:**
  - Doping concentration ≈0.1% by weight.
  - Operates in both pulsed and continuous wave (CW) modes.

- **Lifetime and Pumping:**
  - Short upper laser level lifetime (3.8 μs).
  - Pumped with an argon ion laser for CW operation or with frequency-doubled Nd: YAG laser for pulsed operation.

Most widely used in laser radar (LIDAR), range finders, remote sensing and spectroscopy.



Fibre laser

- **Active Medium:**
  - Erbium in a glass host.

- **Wavelength:**
  - Operates around 1550 nm (1520-1560 nm range).

- **Applications:**
  - Key in Optical Fiber Communication (OFC) technology.
  - Highly effective in undersea and long-haul OFC links.

Gas Laser
He is lighter and neon is heavier so he helps neon to go up

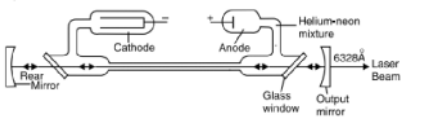
He-Ne Gas Laser:

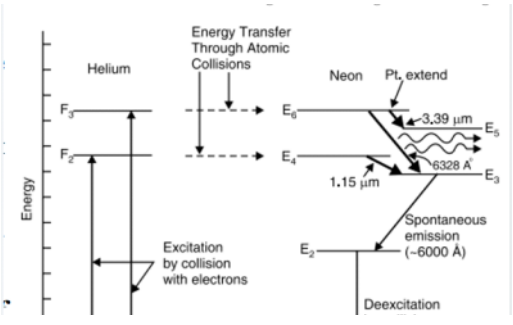
- **Energy Levels and Pumping:**
  - In gases, well-defined and narrow energy levels.
  - Electric discharge through the gas is the common method for excitation.

- **He-Ne Laser:** Ne Active center
  - First gas laser developed, still widely used.
  - Utilizes a mixture of 10 parts He to 1 part Ne.

- **Pumping Scheme:**
  - Four-level pumping scheme.
  - Electric discharge ionizes the gas, and energy is transferred through collisions.

- **Discharge Tube:**
  - About 30 cm long, 1.5 cm in diameter, filled with He-Ne gas mixture (10:1 ratio).
  - High voltage (~10kV) applied to produce discharge.





- **Discharge Tube:**
  - About 30 cm long, 1.5 cm in diameter, filled with He-Ne gas mixture (10:1 ratio).
  - High voltage (~10kV) applied to produce discharge.

- **Population Inversion:**
  - Population inversion between metastable states (E6, E5, E4, and E3 levels).

- **Lasing Transitions:**
  - E6 → E3 produces red laser light at 632.8 nm.
  - E4 → E3 results in a laser beam at 1150 nm.
  - E6 → E5 produces a laser beam in the infrared (IR) region at 3390 nm.

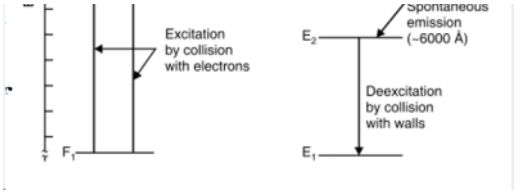
- **Lasing Operation:**
  - E3 decays rapidly to E2, and E2 → E1 transition induced by collisions with tube walls.
  - Discharge tube is narrow to enhance atomic collisions with walls.

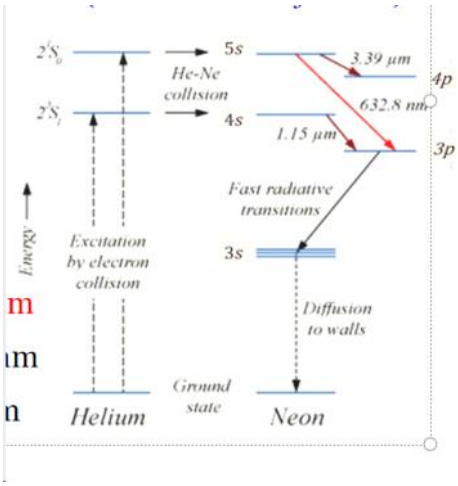
- **Maintaining Population Inversion:**
  - Current in the discharge tube is kept low to avoid overpopulating E2 and causing lasing to cease.

- **Limitations:**
  - Not suitable for high-power applications due to difficulties in maintaining high population inversion.

- **Applications:**
  - Red light at 632.8 nm.
  - Widely used in laboratories, interferometry, laser printing, barcode readers, scanners, surface testing, surveying, and alignment.

Advantages:
  - Simple, cost-effective, and practical.
  - Produces a high-quality beam

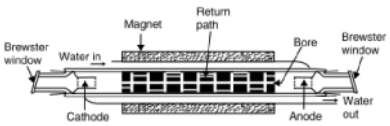


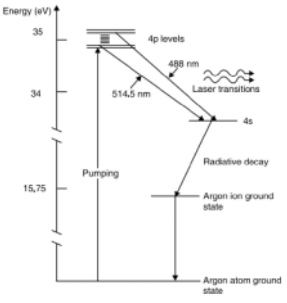


Argon Laser:

- **Operation:**
  - Four-level laser in the visible range (351 - 520 nm).
  - Most powerful continuous-wave (CW) laser in the visible region (around 100W).
  - Widely used in laser light shows.

Active medium; Ar gas
Active centres; ionized Ar-atoms
A narrow water cooled ceramic tube for arc discharge





- **Wavelengths:**
  - Provides 25 visible and 10 UV wavelengths.

- **Excitation and Magnet Setup:**
  - Electric discharge ionizes gas; a magnet concentrates ions along the tube axis.
  - Conditions for population inversion between 4p and 4s levels.

- **Lasing Action:**
  - Emission at common wavelengths: 488 nm (blue) and 515 nm (green).
  - UV emission at 740 Å.

- **Cavity Optics:**
  - Allows selection of any desired wavelength through cavity optics.

- **Pressure Equalization:**
  - Positive ions collected at cathode neutralized and diffuse back to the discharge.
  - Return path provided for pressure equalization.

- **Cooling and Medical Use:**
  - Requires active cooling.

- Widely used in eye surgery for conditions like diabetic retinopathy, retinal detachment, glaucoma, and macular degeneration.

****Krypton (Kr) Laser:****

- **Similarity to Ar-ion Laser:**
- Resembles the Ar-ion laser in energy levels and operation.

- **Wavelengths:**
- Provides various laser wavelengths, including dominant outputs at 4067 Å, 4131 Å, 5309 Å, 5682 Å, 6471 Å, and 6764 Å.

- **Spectrum:**
- Offers a broader spectrum of wavelengths.

- **Applications:**
- Used in multi-color displays.

- **Combination with Ar Laser:**
- Combined with Ar laser, it demonstrates beautiful multi-colored laser shows.

38 AND 39 SLIDE KARNI HAI

Liquid Laser

Tunable Dye Lasers:

- **Active Material:**
- Dye dissolved in a liquid solvent.

- **Advantages:**
- Similar to SSLs but liquid hosts allow easy concentration variation.
- Typical concentrations: 10^-4 to 10^-3 molar solutions.

- **Dye Variety:**
- Over 200 dyes, with Rhodamine 6G being crucial.

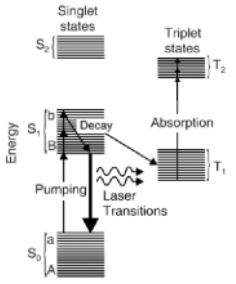
- **Tunability:**
- Wavelength range: 320 - 1200 nm.

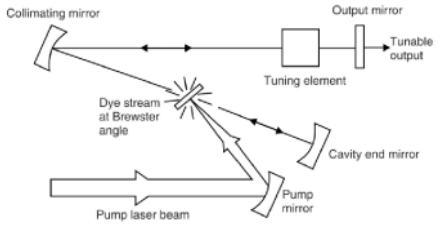
- **Operating Modes:**
- CW and Pulsed.
- Pulsed: 400J in 10 µs.
- CW: Output power ≈ 2W.

- **High Gain, Small Volume:**
- Small volume sufficient for high gain.

- **Excited States and Transitions:**
- Singlet and triplet excited states.
- Optical pumping, non-radiative transitions.

- **Wide Range of Laser Transitions:**
- Operates over a broad range of wavelengths.





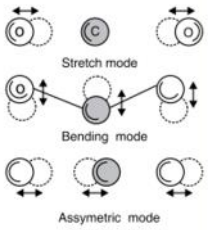
No.	Solid Lasers	Liquid Lasers	Gas Lasers
1.	The active medium is a soild.	The active medium is a liquid or a dye.	The active medium is a gas at low pressure .
2.	Either crystalline or amorphous.	In the form of dye dissolved in organic or inorganic solvent.	Either atomic, ionic or molecular.
3.	Pumping is done usually by optical method.	Liquid laser is excited optically usually by another laser source.	It is excited by electrical discharge method.
4.	Emits a narrow range of wavelengths.	Emits a broad-range of wavelengths.	Emits a narrow range of wavelengths.
5.	Due to imperfections and defects in crystals, inhomogeneties in the output.	Output is optically homogeneous.	Output is highly homogeneous.
6.	Example : Ruby, Nd-YAG, Nd-Glass Fibre laser etc.	Pulse dye laser, Tunable pulsed and CW dye laser etc.	He-Ne, Argon ion, Krypton ion, CO_2 laser etc.

❑ **CO_2 laser**: One of the most powerful & efficient lasers

- **A four level molecular laser**
  - Operates on a set of vibrational-rotational transitions
  - Output in mid IR-region at 10.6 μm and 9.6 μm
  - **Both CW and pulsed modes**;
  - CW power output >100kW and pulsed energies as much as 10kJ

Carbon Dioxide (CO2) Laser

Energy levels of CO_2 molecules



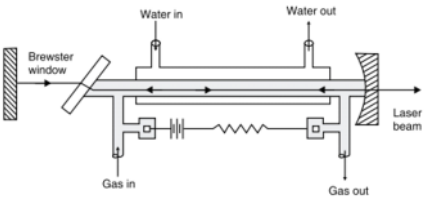
❖ Complex energy spectrum of molecules.

❖ Three independent vibrational oscillations – **Vibrational modes**.

- Stretching mode,
- Bending mode and
- Asymmetric stretching mode

❖ Each mode is quantized; molecules can have 0,1,2 units of vibrational energy in each mode

❖ Each energy state represented by three quantum numbers (m n q) represent the amount of energy associated with each mode. e.g.. (0 2 0) pure Bending Mode with two units of energy.



- **Discharge Tube:**
  - Cross-section: 1.5 cm², Length: 26 cm.

- **Gas Mixture:**
  - CO2, N2, and He in proportions of 1:4:5.
  - Addition of water vapor to regenerate CO2 gas.

- **Electric Discharge:**
  - High DC voltage induces electric discharge in the tube.

- **Gas Breakdown:**
  - Discharge breaks down CO2 molecules into O & CO.

- **Role of N2:**
  - N2 plays a role similar to He in He-Ne lasers.
  - Facilitates energy transfer to CO2 molecules in resonant collisions.