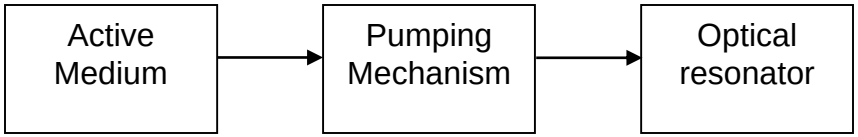
18PYB101J MODULE-5 LECTURE 3

- Essential components of a Laser system
- Types of Laser

Essential components of a laser system



Active medium or Gain medium

It is the system in which population inversion and hence stimulated emission (laser action) is established.

Pumping mechanism

It is the mechanism by which population inversion is achieved.

i.e., it is the method for raising the atoms from lower energy state to higher energy state to achieve laser transition.

Different pumping mechanisms

i. ***Optical pumping***

Exposure to electromagnetic radiation of frequency $\upsilon = (E2-E1)/h$ obtained from discharge flash tube results in pumping

Suitable for solid state lasers

ii. ***Electrical discharge***

By inelastic atom-atom collisions, population inversion is established

Suitable for Gas lasers

iii. Chemical pumping

By suitable chemical reaction in the active medium, population of excited state is made higher compared to that of ground state

Suitable for liquid lasers.

Optical resonator

A pair of mirrors placed on either side of the active medium is known as optical resonator. One mirror is completely silvered and the other is partially silvered. The laser beam comes out through the partially silvered mirror.

Types of Lasers

Based on its pumping action

- Optically pumped laser
- Electrically pumped laser

Basis of the operation mode

- Continuous wave Lasers
- Pulsed Lasers

According to their wavelength

- Visible Region
- Infrared Region
- Ultraviolet Region
- Microwave Region
- X-Ray Region

According to the source

- ✓Dye Lasers
- ✓Gas Lasers
- ✓Chemical Lasers
- ✓Metal vapour Lasers
- ✓Solid state Lasers
- ✓Semi conductor Lasers

other types

Dye lasers

Laser gain medium and type	Operation wavelength(s)	Pump source	Applications
Dye lasers	390-435 nm (stilbene), 460-515 nm (coumarin 102), 570-640 nm (rhodamine 6G), many others	Other laser, flash lamp	Research, spectroscopy, birthmark removal, isotope separation. The tuning range of the laser depends on which dye is used.

Gas lasers

Laser gain medium and type	Operation wavelength(s)	Pump source	Applications and notes
Helium-neon laser	632.8 nm (543.5 nm, 593.9 nm, 611.8 nm, 1.1523 μm, 1.52 μm, 3.3913 μm)	Electrical discharge	Interferometry, holography, spectroscopy, barcode scanning, alignment, optical demonstrations.
Argon laser	454.6 nm, 488.0 nm, 514.5 nm (351 nm,457.9 nm, 465.8 nm, 476.5 nm, 472.7 nm, 528.7 nm)	Electrical discharge	Retinal phototherapy (for diabetes), lithography, confocal microscopy, pumping other lasers.
Krypton laser	416 nm, 530.9 nm, 568.2 nm, 647.1 nm, 676.4 nm, 752.5 nm, 799.3 nm	Electrical discharge	Scientific research, mixed with argon to create "white-light" lasers, light shows.
Xenon ion laser	Many lines throughout visible spectrum extending into the UV and IR.	Electrical discharge	Scientific research.
Nitrogen laser	337.1 nm	Electrical discharge	Pumping of dye lasers, measuring air pollution, scientific research. Nitrogen lasers can operate superradiantly (without a resonator cavity).
Carbon dioxide laser	10.6 μm, (9.4 μm)	Transverse (high power) or longitudinal (low power) electrical discharge	Material processing (cutting, welding, etc.), surgery.
Carbon monoxide laser	2.6 to 4 μm, 4.8 to 8.3 μm	Electrical discharge	Material processing (engraving, welding, etc.), photoacoustic spectroscopy.

Chemical lasers

Laser gain medium and type	Operation wavelength(s)	Pump source	Applications
Hydrogen fluoride laser	2.7 to 2.9 μm for Hydrogen fluoride (<80% Atmospheric transmittance)	Chemical reaction in a burning jet of ethylene and nitrogen trifluoride (NF_3)	Used in research for laser weaponry by the U.S. DOD, operated in continuous wave mode, can have power in the megawatt range.
Deuterium fluoride laser	~3800 nm (3.6 to 4.2 μm) (~90% Atm. transmittance)	chemical reaction	MIRACL, Pulsed Energy Projectile & Tactical High Energy Laser
COIL (Chemical oxygen-iodine laser)	1.315 μm (<70% Atmospheric transmittance)	Chemical reaction in a jet of singlet delta oxygen and iodine	Laser weaponry, scientific and materials research, laser used in the U.S. military's Airborne laser, operated in continuous wave mode, can have power in the megawatt range.

Metal-vapor lasers

Laser gain medium and type	Operation wavelength(s)	Pump source	Applications
Helium-cadmium (HeCd) metal-vapor laser	441.563 nm, 325 nm	Electrical discharge in metal vapor mixed with helium buffer gas.	Printing and typesetting applications, fluorescence excitation examination (ie. in U.S. paper currency printing), scientific research.
Helium-mercury (HeHg) metal-vapor laser	567 nm, 615 nm		Rare, scientific research, amateur laser construction.
Helium-selenium (HeSe) metal-vapor laser	up to 24 wavelengths between red and UV		Rare, scientific research, amateur laser construction.
Copper vapor laser	510.6 nm, 578.2 nm	Electrical discharge	Dermatological uses, high speed photography, pump for dye lasers.
Gold vapor laser	627 nm		Rare, dermatological and photodynamic therapy uses.

Laser gain medium and type	Operation wavelength(s)	Pump source	Applications
Ruby laser	694.3 nm	Flashlamp	Holography, tattoo removal. The first type of visible light laser invented; May 1960.
Nd:YAG laser	1.064 μm, (1.32 μm)	Flashlamp, laser diode	Material processing, rangefinding, laser target designation, surgery, research, pumping other lasers (combined with frequency doubling to produce a green 532 nm beam). One of the most common high power lasers. Usually pulsed (down to fractions of a nanosecond)

Er:YAG laser	2.94 μm	Flashlamp, laser diode	Periodontal scaling, Dentistry
Neodymium doped Yttrium orthovanadate ($Nd:YVO_4$) laser	1.064 μm	laser diode	Mostly used for continuous pumping of mode-locked Ti:sapphire or dye lasers, in combination with frequency doubling. Also used pulsed for marking and micromachining.

Neodymium doped yttrium calcium oxoborate Nd:$YCa_4O(BO_3)_3$ or simply Nd:YCOB	~1.060 μm (~530 nm at second harmonic)	laser diode	Nd:YCOB is a so called "self-frequency doubling" or SFD laser material which is both capable of lasing and which has nonlinear characteristics suitable for second harmonic generation. Such materials have the potential to simplify the design of high brightness green lasers.
Neodymium glass (Nd:Glass) laser	~1.062 μm (Silicate glasses), ~1.054 μm (Phosphate glasses)	Flashlamp, laser diode	Used in extremely high power (terawatt scale), high energy (megajoules) multiple beam systems for inertial confinement fusion. Nd:Glass lasers are usually frequency tripled to the third harmonic at 351 nm in laser fusion devices.

Titanium sapphire (Ti:sapphire) laser	650-1100 nm	Other laser	Spectroscopy, LIDAR, research. This material is often used in highly-tunable mode-locked infrared lasers to produce ultrashort pulses and in amplifier lasers to produce ultrashort and ultra-intense pulses.
Holmium YAG (Ho:YAG) laser	2.1 μm	Laser diode	Tissue ablation, kidney stone removal, dentistry.

Cerium doped lithium strontium(or calcium) aluminum fluoride (Ce:LiSAF, Ce:LiCAF)	~280 to 316 nm	Frequency quadrupled Nd:YAG laser pumped, excimer laser pumped, copper vapor laser pumped.	Remote atmospheric sensing, LIDAR, optics research.
Chromium doped chrysoberyl (alexandrite) laser	Typically tuned in the range of 700 to 820 nm	Flashlamp, laser diode, mercury arc (for CW mode operation)	Dermatological uses, LIDAR, laser machining.

Semiconductor lasers

Laser gain medium and type	Operation wavelength(s)	Pump source	Applications
Semiconductor laser diode (general information)	0.4-20 μm, depending on active region material.	Electrical current	Telecommunications, holography, printing, weapons, machining, welding, pump sources for other lasers.
GaN	0.4 μm		Optical discs.

AlGaAs	0.63-0.9 μm	Electrical current	Optical discs, laser pointers, data communications. 780 nm Compact Disc player laser is the most common laser type in the world. Solid-state laser pumping, machining, medical.
InGaAsP	1.0-2.1 μm		Telecommunications, solid-state laser pumping, machining, medical..
Vertical cavity surface emitting laser (VCSEL)	850 - 1500 nm, depending on material		Telecommunications
Hybrid silicon laser	Mid-infrared		Research

Other types of lasers

Laser gain medium and type	Operation wavelength(s)	Pump source	Applications
Free electron laser	A broad wavelength range (about 100 nm - several mm); one free electron laser may be tunable over a wavelength range	relativistic electron beam	atmospheric research, material science, medical applications.

"Nickel-like" Samarium laser	X-rays at 7.3 nm wavelength	Lasing in ultra-hot samarium plasma formed by double pulse terawatt scale irradiation fluences created by Rutherford Appleton Laboratory's Nd:glass Vulcan laser.	First demonstration of efficient "saturated" operation of a sub–10 nm X-ray laser, possible applications in high resolution microscopy and holography, operation is close to the "water window" at 2.2 to 4.4 nm where observation of DNA structure and the action of viruses and drugs on cells can be examined.

Raman laser, uses inelastic stimulated Raman scattering in a nonlinear media, mostly fiber, for amplification	1-2 μm for fiber version	Other laser, mostly Yb-glass fiber lasers	Complete 1-2 μm wavelength coverage; distributed optical signal amplification for telecommunications; optical solitons generation and amplification