UNIT III - LASER FUNDAMENTALS

PART A

1. What is meant by coherence in laser light?
A coherent light is pure sine wave and during its transmission it can maintain constant phase difference between any two points in space as well as in a given time interval at any point along the transmission path. Thus it is traveling in a continuous manner without undergoing abrupt change in phase. Thus the laser light is a coherent light.

2. Which gives the special characteristics for laser light?
Stimulated emission is responsible for the characteristics of laser light. Stimulated emission means the emission of light photon by the stimulation of an atom to undergo laser transition through a phase whose energy is equal to the emitted photon’s energy or equal to the energy difference between the laser transition levels.

3. What is modelocking? Give the principle of modelocking?
Modelocking is a technique in optics by which a laser can be made to produce pulses of light of extremely short duration, on the order of picoseconds (10-12s) or femtoseconds (10-15s).The basis of the technique is to induce a fixed phase relationship between the modes of the laser\'s resonant cavity. The laser is then said to be phase-locked or mode-locked. Interference between these modes causes the laser light to be produced as a train of pulses. Depending on the properties of the laser, these pulses may be of extremely brief duration, as short as a few femtoseconds.

4. What are the different Modelocking methods?
Methods for producing modelocking in a laser may be classified as either active or passive. Active methods typically involve using an external signal to induce a modulation of the intra-cavity light. Passive methods do not use an external signal, but rely on placing some element into the laser cavity which causes self-modulation of the light .

5. What is active modelocking?
The most common active modelocking technique places a standing wave acousto-optic modulator into the laser cavity. When driven with an electrical signal, this produces a sinusoidal amplitude modulation of the light in the cavity.

6.What is passive modelocking?
Passive mode-locking techniques are those that do not require a signal external to the laser (such as the driving signal of a modulator) to produce pulses. Rather, they use the light in the cavity to cause achange in some intracavity element, which will then itself produce a change in the intracavity light. The most common type of device which will do this is a saturable absorber.

7. What is Q switching?
Q-switching, sometimes known as giant pulse formation, is a technique by which a laser can be made to produce a pulsed output beam. The technique allows the production of light pulses with extremely high peak power, much higher than would be produced by the same laser if it were operating in a continuous

wave mode. Compared to modelocking, another technique for pulse generation with lasers, Q-switching leads to much lower pulse repetition rates, much higher pulse energies, and much longer pulse durations. Both techniques are sometimes applied at once .

8. What is the principle of Q-switching ?
Q-switching is achieved by putting some type of variable attenuator inside the laser\'s optical resonator. When the attenuator is functioning, light which leaves the gain medium does not return, and lasing cannot begin. This attenuation inside the cavity corresponds to a decrease in the Q factor or quality factor of the optical resonator. A high Q factor corresponds to low resonator losses per roundtrip, and vice versa. The variable attenuator is commonly called a \"Q-switch\", when used for this purpose.

9. What is Active Q-switching?
Here, the Q-switch is an externally-controlled variable attenuator. This may be a mechanical device or some form of modulator such as an acousto-optic device or an electro-optic device—a Pockels cell or Kerr cell. The reduction of losses is triggered by an external event, typically an electrical signal. The pulse repetition rate can therefore be externally controlled.

10. What is Passive Q-switching?
In this case, the Q-switch is a saturable absorber, e.g. an ion-doped crystal material (e.g. Cr:YAG for Q-switching of Nd:YAG lasers), a bleachable die, or a passive semiconductor device. Initially, the loss of the absorber is high, but still low enough to permit some lasing once a large amount of energy is stored in the gain medium. As the laser power increases, it saturates the absorber, i.e., rapidly reduces the resonator loss, so that the power can increase even faster.

11. What are the applications of Q switching?
Q-switched lasers are often used in applications which demand high laser intensities in nanosecond pulses, such as dentistry, metal cutting or pulsed holography. However, Q-switched lasers can also be used for measurement purposes, e.g. for distance measurements (range finding) by measuring the time it takes for the pulse to get to some target and the reflected light to get back to the sender.
12.What is dye laser?
Dye lasers use an organic dye as the gain medium. The wide gain spectrum of available dyes allows these lasers to be highly tunable, or to produce very short-duration pulses .

13.What is solid-state lasers?
Solid state laser materials are commonly made by doping a crystalline solid host with ions that provide the required energy states. For example, the first working laser was made from ruby, or chromium-doped sapphire. Another common type is made from Neodymium-doped yttrium aluminium garnet (YAG), known as Nd:YAG. Nd:YAG lasers can produce high powers in the infrared spectrum at 1064 nm. They are used for cutting, welding and marking of metals and other materials, and also in spectroscopy and for pumping dye lasers. Nd:YAG lasers are also commonly frequency doubled to produce 532 nm when a visible (green) coherent source is required.

14.What is free electron laser?
Free electron lasers such as in figure have the ability to generate wavelengths from the microwave to the X-ray region. They operate by having an electron beam in an optical cavity pass through a wiggler

magnetic field. The change in direction exerted by the magnetic field on the electrons causes them to emit photons.
Figure Free Electron Laser Diagram

15.What is gas laser?
Gas lasers consist of a gas filled tube placed in the laser cavity. A voltage (the external pump source) is applied to the tube to excite the atoms in the gas to a population inversion. The light emitted from this type of laser is normally continuous wave (CW). One should note that if brewster angle windows are attached to the gas discharge tube, some laser radiation may be reflected out the side of the laser cavity. Large gas lasers known as gas dynamic lasers use a combustion chamber and supersonic nozzle for population inversion.

16. What is meant by quantum well laser?
Quantum well laser cavity has dimensions of 50-100À.They have low threshold current.

17. Why gain guided lasers are not in practice?
Due to their instability, higher spectral width and highly astigmatic, they are not used.

18. What are the merits of index guided lasers?
a) Highly stable b) Optical confinement is very high. c) Very narrow spectral width d) High directionality

20. What is Brewster Windows?
Windows at the ends of a gas laser, used to produce polarized electromagnetic radiation. The window is at Brewster angle to the optical axis of the laser, so only one type of polarization can pass through.

21.What is Beam Divergence ?
Beam Divergence is the angle of beam spread, measured in (milli)radians. Can be approximated for small angle by the ratio of the beam diameter to the distance from the laser aperture.

22. What is Ion Laser?
Ion laser is a laser in which the active medium is composed of ions of a Nobel gas (like Ar+ or Kr+). The gas is usually excited by high discharge voltage at the ends of a small bore tube.

23.What is Irradiance (E) ?
Irradiance is the radiant flux (radiant power) per unit area incident upon a given surface. Units: Watts per square centimeter. (Sometimes referred to as power density, although not exactly correct).
24. What is Laser Rod ?
A solid-state, rod-shaped active medium in which ion excitation is caused by a source of intense light (optical pumping), such as a flash lamp. Various materials are used for the rod, the earliest of which was synthetic ruby crystal (see Solid State Laser).

25. What is Laser Pulse ?
A discontinuous burst of laser radiation, as opposed to a continuous beam. A true laser pulse achieves higher peak powers than that attainable in a CW output.

UNIT - III

LASER FUNDAMENTALS.

1. Explain the basic characteristics of of lasers. Derive an expression for threshold gain for laser.

* Three basic process - Absorption
  Spontaneous emission
  stimulated emission.

* Laser Action - Amplification of light by an active medium through stimulated emission.

* Condition for Amplification - $N_2 > N_1$

Threshold condition for laser osillation - $R_1 = 1.0$, $R_2 < 1.0$

→ $I = I_0 R_1 R_2 e^{2(\gamma - \alpha)L}$

$$\gamma = \alpha - \frac{1}{2L} \ln R_1 R_2$$

γ - gain co-efficient at threshold condition of oscillation.

2) Explain the working principle of semiconductor laser with a neat diagram.

Semiconductor lasers - Small, efficient, dimension < mm.
Wavelength 1.6 - 1.55 μm
Operate on clockwise basis.

principle - Electrical pumping.
Passing electric current through laser medium
Inversion - steady state basis.
Double-heterostructure device.

Purpose of additional layers - More effectively guide

fabrication - Length 0.2 to 1 mm, Thickness 5 to 1000 nm

3. Explain the properties of laser ?

Properties : ⇒ Monochromaticity – high,

- Narrow spectral width.
- Line width 10^9 Hz.

⇒ Directionality – highly collimated

- Light spreads into solid angle of 4π

⇒ Spatial profile of Laser beam – cross section of laser beam.

- Tranverse Electro Magnetic Magnetic

⇒ Temporal behavior of laser output – CW type (continuous wave)

- Gas active medium.

⇒ Coherence – Linked to the orderliness of light waves.

- Mutual coherence function.

⇒ Radiance – power emitted unit area.

focusing – irradiance. $r_s = f\theta$.

- diffraction limit.

⇒ Power – high levels of o/p power.

4) What are the types of laser modes and Explain in detail with neat sketches.

Laser mode – possible electromagnetic wave within the laser cavity.

Types : Longitudinal / Axial mode.

Transverse mode.

Longitudinal mode – Axial standing electromagnetic waves.

single frequency laser.

Single longitudinal wave.

Transverse mode – particular intensity pattern of radiation in a plane perpendicular to the propag of beam

Classification of transverse mode - TE, TM, TEM, Hybrid mode.

- TE - Transverse Electric
- TM - " Magnetic
- TEM - " Electromagnetic.

5) Explain in detail about Resonator configuration.

Resonator Configuration - Optical resonator
- Laser cavity.
- high gain.

Simple laser resonator diagram

Laser radiation automatically generated at one (or) several frequencies - Gain pulling

features of an optimized laser resonator design -

Compactness, Accomodation, minimizing the alignment

resonator length determining the pulse repetation rate.

Minimizing adverse effect of thermal lensing.

6) Define (i) Q switching (ii) Mode locking (iii) Cavity dumping.

Q switching - $Q = \frac{\text{Energy stored in dominant mode} \times \omega}{\text{Energy dissipated per second in the mode}}$

- maintaining the population inversion to a very high
- value above the threshold population.

Energy of the pulse $E = \frac{1}{2} h\nu (N_a - N_t) V$.

Mode locking - Due to broadened nature, laser source can support oscillations in many mode.

Total irradiance is very small due to out of phase

Time spacing $\frac{2L}{c}$ & pulse duration $1/N$ $(2L/c)$

Cavity dumping – method for producing short pulses with duration in ns to ms.

→ laser to yield pulse upto MHz range.

→ At high repetition rate, avg power may close

→ Peak power reach the value much higher than the average power.

7) Explain the working principle of Gas laser with neat diagram.

Gas laser – Continuous laser beam, He-Ne laser is used.

Aiming laser.

Ratio of He-Ne mixture 10:1.

→ Working – Electric discharge in the gas tube, (G), (N).

Eo atom are excited to Level E_3.

diagram.

Stimulated emission b/w E_3 & E_2.

8) Explain the working principle of solid laser with neat diagram

Solid laser – Ruby laser – Three level solid state laser.

– Single pulse with long duration.

Construction: Al_2O_3 with 0.05% of chromium & its cylinder.

pumping source – flash tube.

Chromium atoms – light having wavelength of 5600 Å.