Ajay Kumar Garg Engineering College, Ghaziabad

Department of ECE

Sessional Test-2

Course:	B.Tech	Semester:	VI
Session:	2017-18	Section:	EI-K
Subject:	Optical Instrumentation	Sub. Code:	NIC-031
Max Marks:	50	Time:	2 hour

Note : Answer **all** the sections.

Section-A

A. Attempt **all** the parts. **(5x2 =10)**

1. What is an Optical Detector?

Ans:- A device used to detect or measure light or other electromagnetic energy is called Optical detector.

2. What is direct and Indirect band gap energy?

Ans:- The band gap is called direct if the momentum of electrons is same in both CB and VB. In Indirect gap a photon cannot be emitted because the electron must pass through an intermidiate state.

3. How data can be stored optically?

Ans:- There are two sections:- Read section & Write section. And main components are (i) Laser source (ii) Modulator (iii) Beam splitter (iv) Mirror (v) Hologram.

4. What is the phenomenon of Total Internal Reflection?

Ans:- If the incident angle is greater than the critical angle, the wave cannot pass and hence is

entirely reflected.

6. Construct a ruby laser.

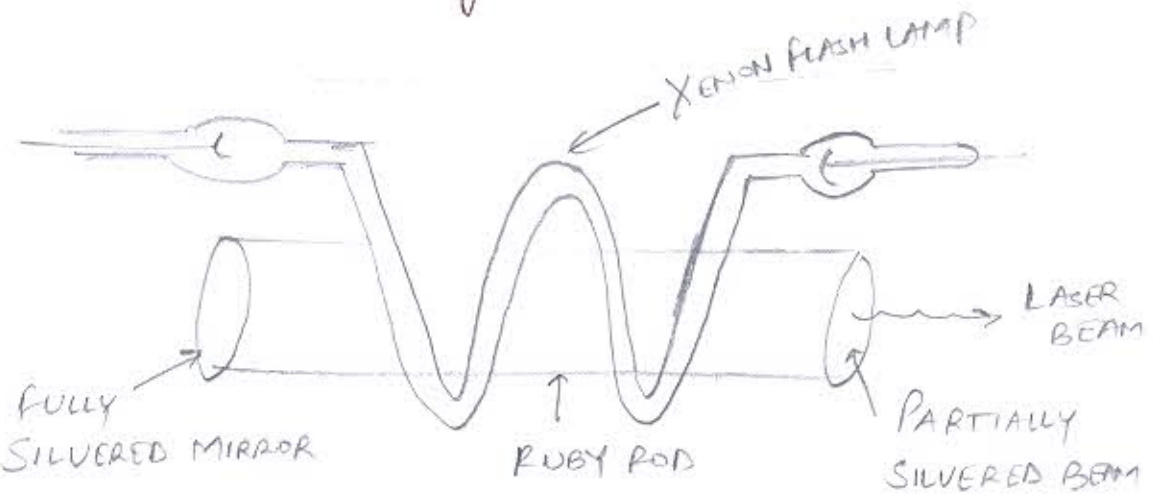


FIG: RUBY LASER

Section-B.

6. Name different type of LED structures. Explain any one of them with proper diagram.

Ans:- There are two types of LED structures:-
(i) Surface emitter LEDs and (ii) Edge emitter LEDs.

Surface emitter LEDs

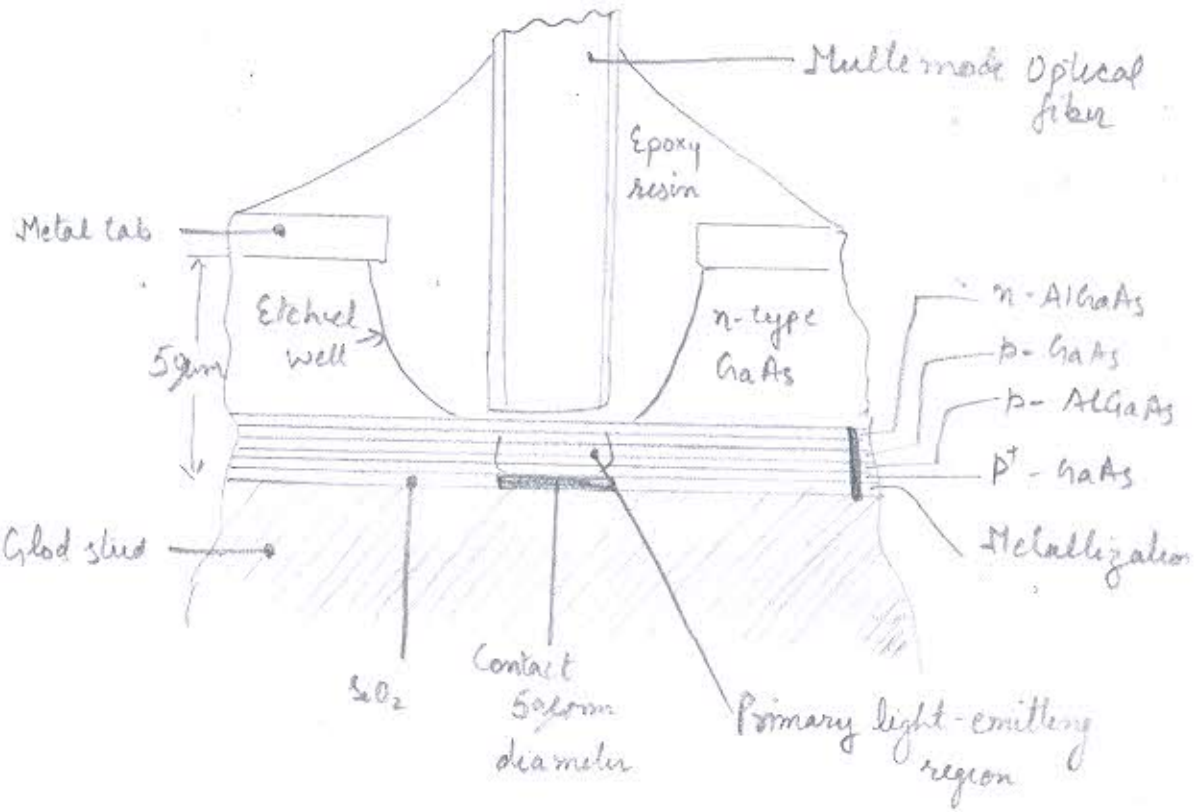
A method for obtaining high radiance is to restrict the emission to a small active region within the device. The technique was to use an etched well in a GaAs substrate in order to prevent heavy absorption of the emitted radiation and to accomodate the fibre. These structures have a low thermal impedance in the active region allowing high current densities and giving high-radiance emission into the optical fiber.

The structure of a high-radiance etched well DH surface emitter for the 0.8 to 0.9 μm wavelength band is shown in figure. The internal absorption in this device is very low due to the larger bandgap-confining layers, and the reflection co-efficient at the back crystal face is high giving good forward radiance. The emission from the active layer is essentially isotropic, although the external emission distribution may be considered lambertian with a beam width of 120° due to refraction from a high to a low refr-

refractive index at the GaAs-fiber interface. The power coupled P_c into a multimode step index fiber may be estimated from the relationship:

$$P_c = \pi (1-r) A R_0 (NA)^2$$

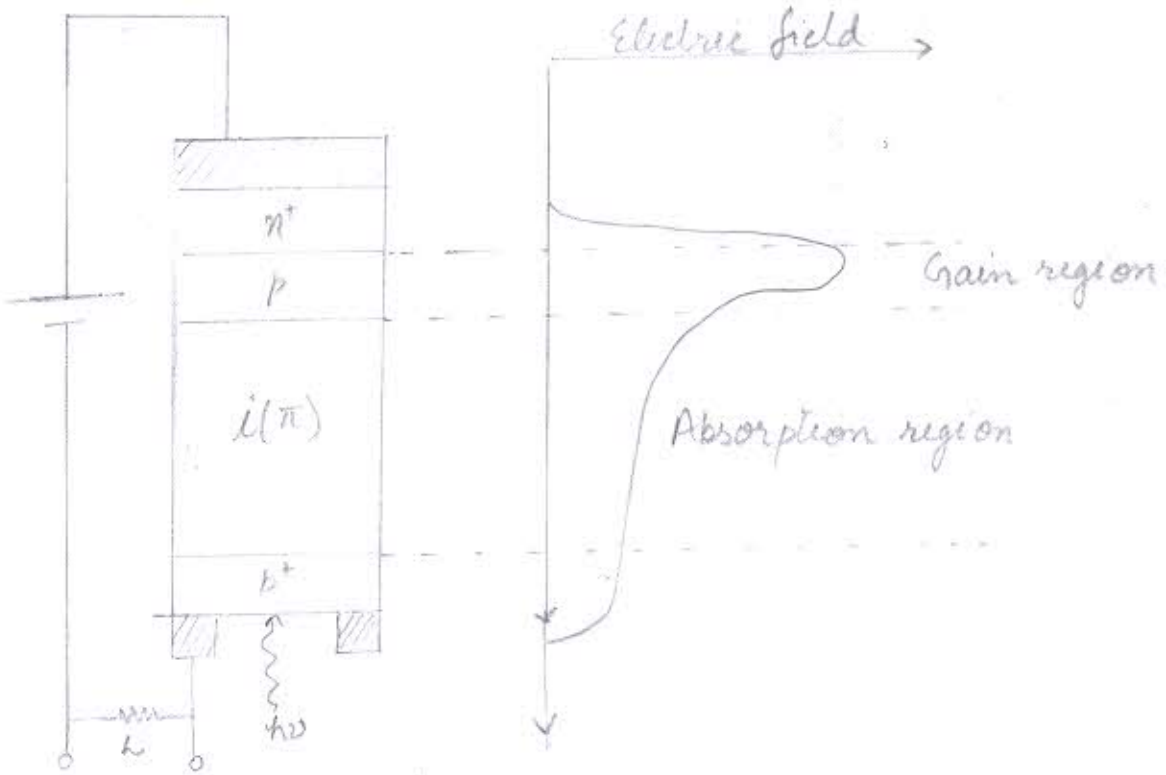
where r is the Fresnel reflection co-efficient at the fiber surface, A is the smaller of the fiber core cross-section or the emission area of the source and R_0 is the radiance of the source.



7 Draw the characteristics of Avalanche photodiode. Explain its working with help of construction diagram.

Ans:- It is npip or pnin photodiode. Here a p-region or an n-region is further added and sandwiched between n-i or p-i regions respectively.

Working → When the primary electron-hole pairs (EHP) generated by incident photons pass through this extra added region, they get accelerated and acquire so much kinetic energy that they ionize the bound electrons in the valence band upon collision and in the process create secondary electron-hole pairs. This phenomenon is known as impact ionization. If the field is high enough, the secondary carrier pairs may also gain sufficient energy to create new pairs. This is known as avalanche effect. Thus the carrier get multiplied, all of which contribute to the photo current.



It is composed of a lightly doped p-type intrinsic layer deposited on a p^+ substrate. A normal p-type diffusion is made in the intrinsic layer which is followed by the construction of an n^+ layer. Such a configuration is called $p^+\pi p n$ reach through structure. When the applied reverse biased voltage is low, most of the potential drop is across the p-π junction. As the bais voltage is increased, the depletion layer widens and the latter just reaches through to the π-region when the electric field at the p-n^+ junction becomes sufficient for impact ionization. Normally, an RAPD is operated in a fully depleted mode. The photons enter the device through the p^+ layer and are absorbed in the intrinsic π-region. The absorbed photons create primary EHPs, which are seprated by the electric field in this region. These carriers drift to the p^+n region where a strong electric field exists. It is the region where carriers are multiplied first by impact ionization and then by Avalanche breakdown.

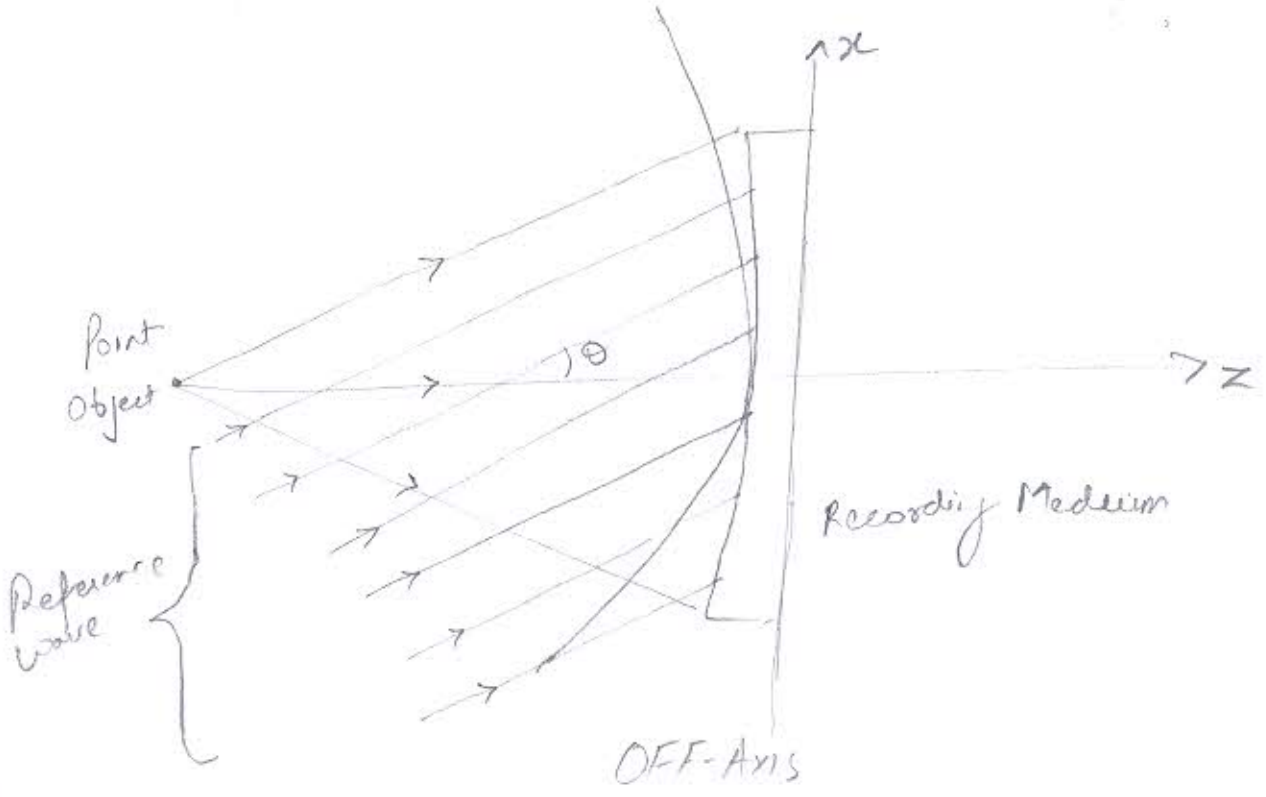
8. Differentiate between On-Axis and Off-axis holography.

Ans: If the plane of recording medium be the $z=0$ plane. let the point object be at a distance 'd' from the recording medium and be lying on the z-axis. If the reference wave is incident at an angle θ to the object wave it is known as OFF-Axis holography and if the reference wave is incident parallel to the object wave, i.e. $\theta=0$, it is known as ON-axis holography.

In OFF-Axis holography $\theta \neq 0$, therefore there is no change in the equation. Therefore, for transmitted wave

$$\psi_t(x,y) = \psi_r(x,y)\, T(x,y)$$

$$= A_r\, e^{-ik_0 x \sin\theta}\left[\frac{A_0^2}{d^2} + A_r^2 + \frac{2A_rA_0}{d}\, \exp -i\left[k_0 d - k_0 x \sin\theta + \frac{k_0}{2d}(x^2+y^2)\right]\right]$$

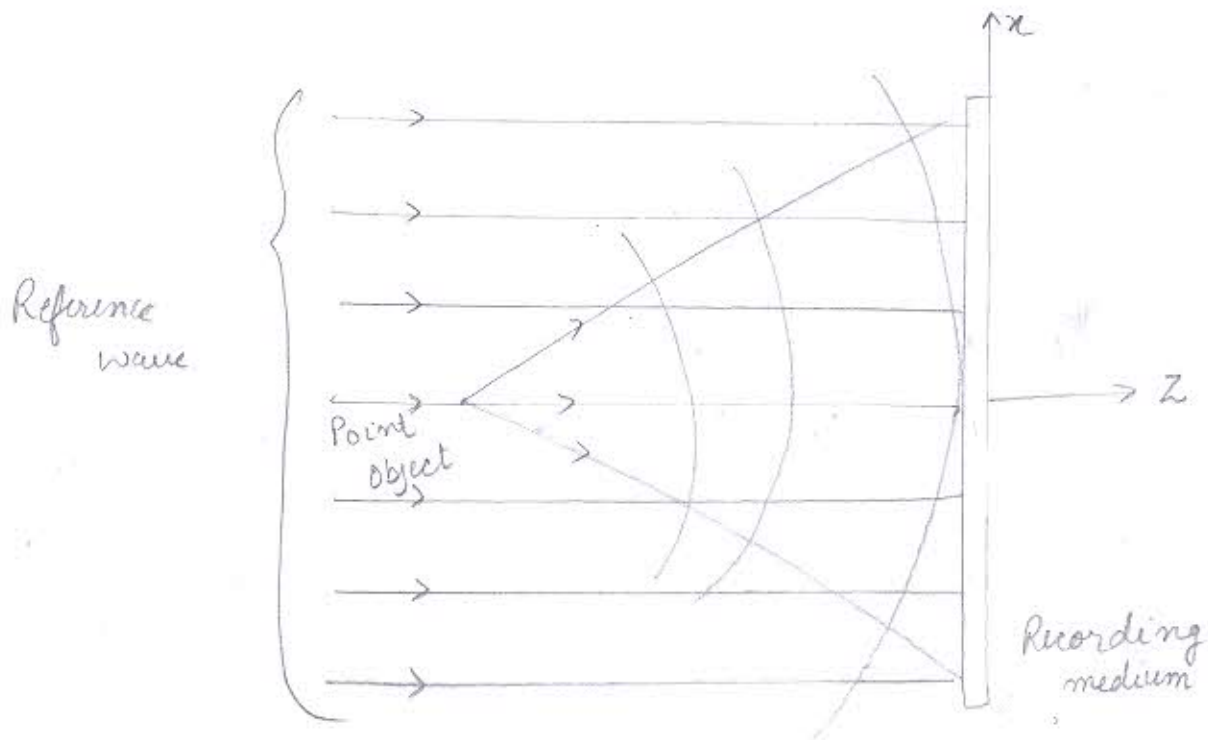


In ON-Axis holography, $\theta = 0$, therefore the transmitted wave now will be

$$\psi_t(x,y) = \psi_R(x,y)\, T(x,y)$$

$$= A_R\left(\frac{A_0}{d^2} + A_R^2\right) + \frac{A_R^2 A_0}{d} \exp(-ik_0 d) \exp\left[-i\frac{k_0}{2d}(x^2+y^2)\right] +$$

$$\frac{A_R^2 A_0}{d} \exp(+ik_0 d) \exp\left[\frac{ik_0}{2d}(x^2+y^2)\right]$$



ON-AXIS

9. An ideal photo-diode has an area of 1×1 cm and is illuminated by monochromatic light with a wavelength of 780 nm and with a power density of 1000 W/m². At 300 K, the open circuit voltage is 0.683 V. What is its reverse saturation current, I_0?

Ans:- Ideal photo diode has $\eta = 100\%$.

Area = 1×1 Cm

For an ideal photodiode, the shunt resistance is infinite so that the shunt current is zero. Since leakage current under reverse bias is small $I_{out} \simeq I_{opt} = \frac{I_0 A \lambda q}{hc}$

Substituting

$I_0 A = 0.01$ Watt and $\lambda = 900$ nm, $I_{out} = 7.2$ mA

$$I_{opt} = I_D = I_s \left[\exp\left(\frac{q V_D}{KT}\right) - 1 \right]$$

using $I_{opt} = 7.2$ mA, $I_s = 10$ nA and $T = 300$

$$V_D = 0.347 \text{ V}.$$

10. A fiber optic gyroscope has a circular coil of diameter 12 cm. The total length of the fiber used in the coil is 400 m. If it is operating at $\lambda = 0.633\,\mu m$, what is the phase shift corresponding to the angular speed of 5×10^{-4} rad/s?

Ans

$$\Delta\phi = \frac{2\pi L D \Omega}{c\lambda}$$

Here $L = 400\ m$, $D = 12\ cm = 0.12\ m$, $\Omega = 5 \times 10^{-4}$ rad/s

$\lambda = 0.633\,\mu m = 0.633 \times 10^{-6}\ m$, $c = 3 \times 10^{8}\ m/s$

$$\Delta\phi = \frac{2 \times 3.14 \times 400 \times 0.12 \times 5 \times 10^{-4}}{3 \times 10^{8} \times 0.633 \times 10^{-6}}$$

$$= 79.36 \times 10^{-5}\ rad.$$

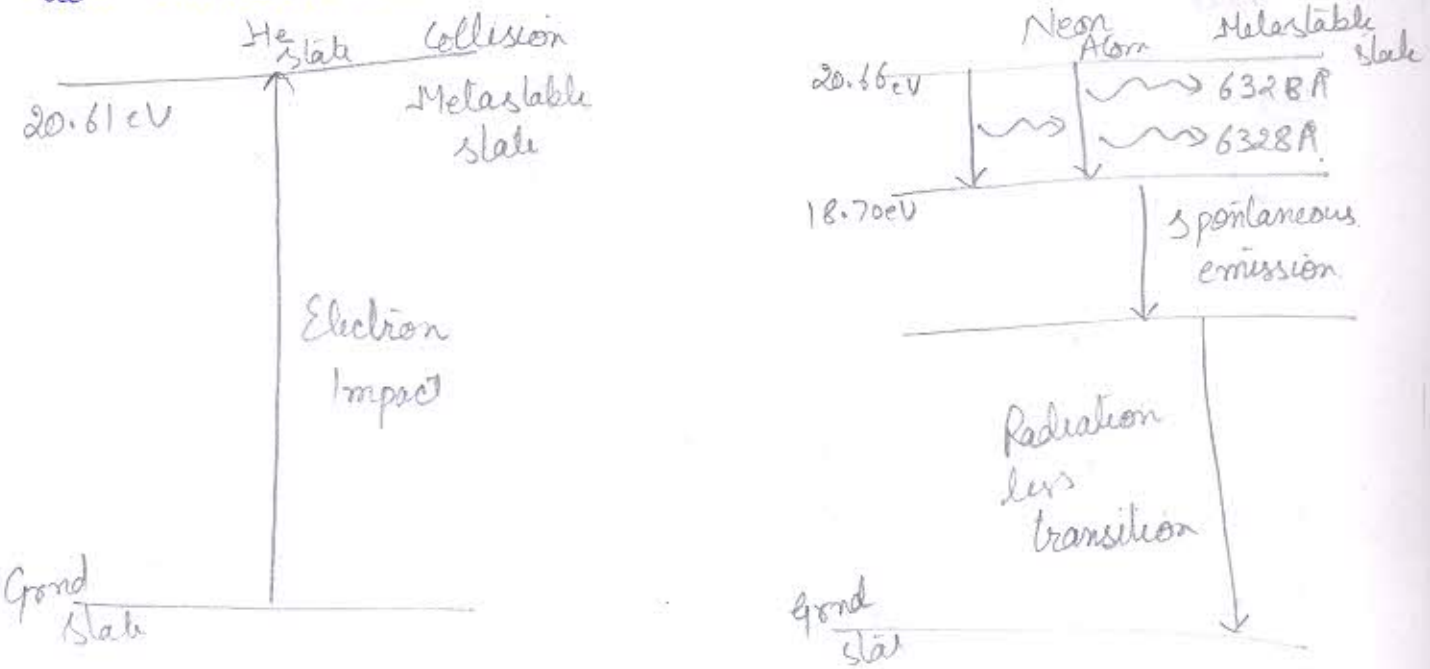
Section- C

11. What is the role of He atom in He-Ne laser? Explain with the help of energy level diagram. Why is it necessary to use a narrow tube?

Ans:- Helium Neon laser is a four level laser. The schematic of a typical He-Ne laser is shown. It consits of a long distance tube of length about 50 cm and diameter 1 Cm. The tube contains a mixture of about 10 parts of helium and 1 part of neon at a low pressure. At both ends of the tube are fitted optically plane and parllel mirrors, one of them being only partially silvered. The spacing of the mirrors is equal to an integral number of half-wavelengths of the laser light. In this population inversion is achieved by electric discharge. An electric discharge is produced in the gas by means by electrodes outside, the tube connected to a source of high-frequency alternating current.

The energy level diagram of He-Ne laser is shown in figure. When a power is switched on, the electrons from the discharge collide and 'pump' the He and Ne atoms to metastable states 20.61 eV and 20.66 eV resp above their ground states. Some of the excited He atoms transfer

their energy to ground state Ne atoms in collisions. Thus the purpose of He atom is to help in achieving a population inversion in the Ne atoms.



When an excited Ne atom passes, from the metastable state at 20.66 eV to an excited state of 18.70 eV, and it emits a photon of wavelength 6328 Å. This photon travels through the gas mixture, and if it is moving parllel to the axis of the tube, is reflected back and forth by the mirror-ends untill it is moving parllel stimuled an excited Ne atom and causes it to emit a fresh 6328 Å photon is phase with the stimulating photon This stimulated transition from 20.66 eV level to 18.70 eV level is the laser transition.

This process is continued and when a beam of coherent radiation becomes sufficiently intense, a position of it escapes through the partially silvered end.

The Ne atom passes from the 18.70 eV level, spontaneously to a lower metastable state emitting in coherent light, and finally the Ne atom comes down to the ground state through collision with the tube walls. This radiation from lower meta stable state to the ground state is radiation less transition.

In He-Ne laser, the laser transition does not terminate at the ground level, hence the power needed for excitation is less than that in a three-level laser.

12. Explain how a hologram is recorded and holographic image is reconstructed from it, with the help of proper diagram.

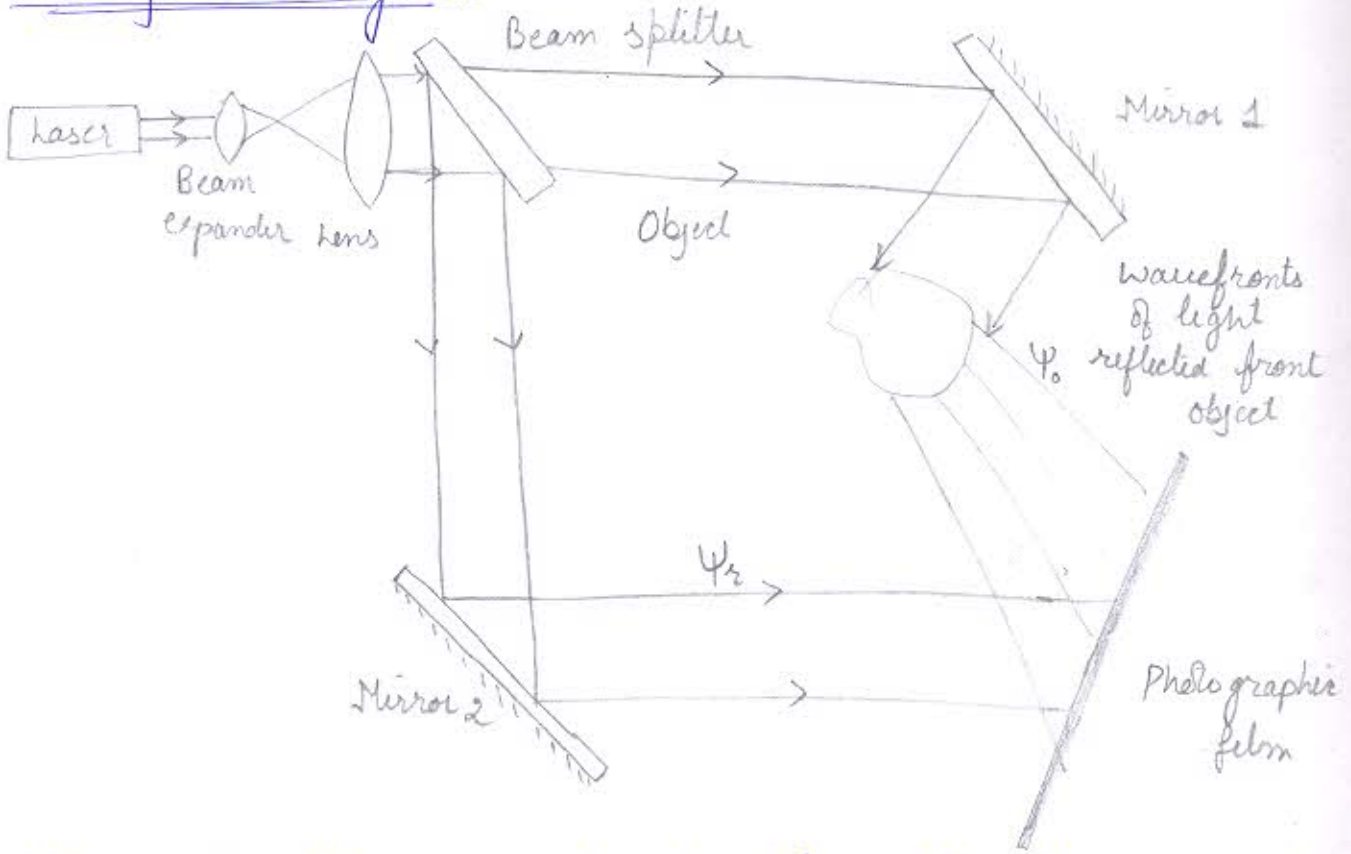
Ans.- Holography is a method in which not only amplitude but also the phase of the light wave is recorded.

The basic technique of holography has two sections

(i) Recording of the hologram

(ii) Reconstruction of the 3D image from the photographic plate.

Recording a Hologram



A photographic plate is exposed simultaneously to waves of light scattered by the 'object' and to the waves of light from a refrence source. The refrence beam is shown here as a plane parllel beam, and is derived from the same light source which illuminates the object.

Because of their high degree of mutual coherence the two sets of waves produce an interference pattern on the plate, which is recorded in the photographic emulsion and forms a hologram.

Let Object wave be

$$\psi_0(x,y) = A_0(x,y)\, e^{-i\phi_0(x,y)}$$

and refrence wave

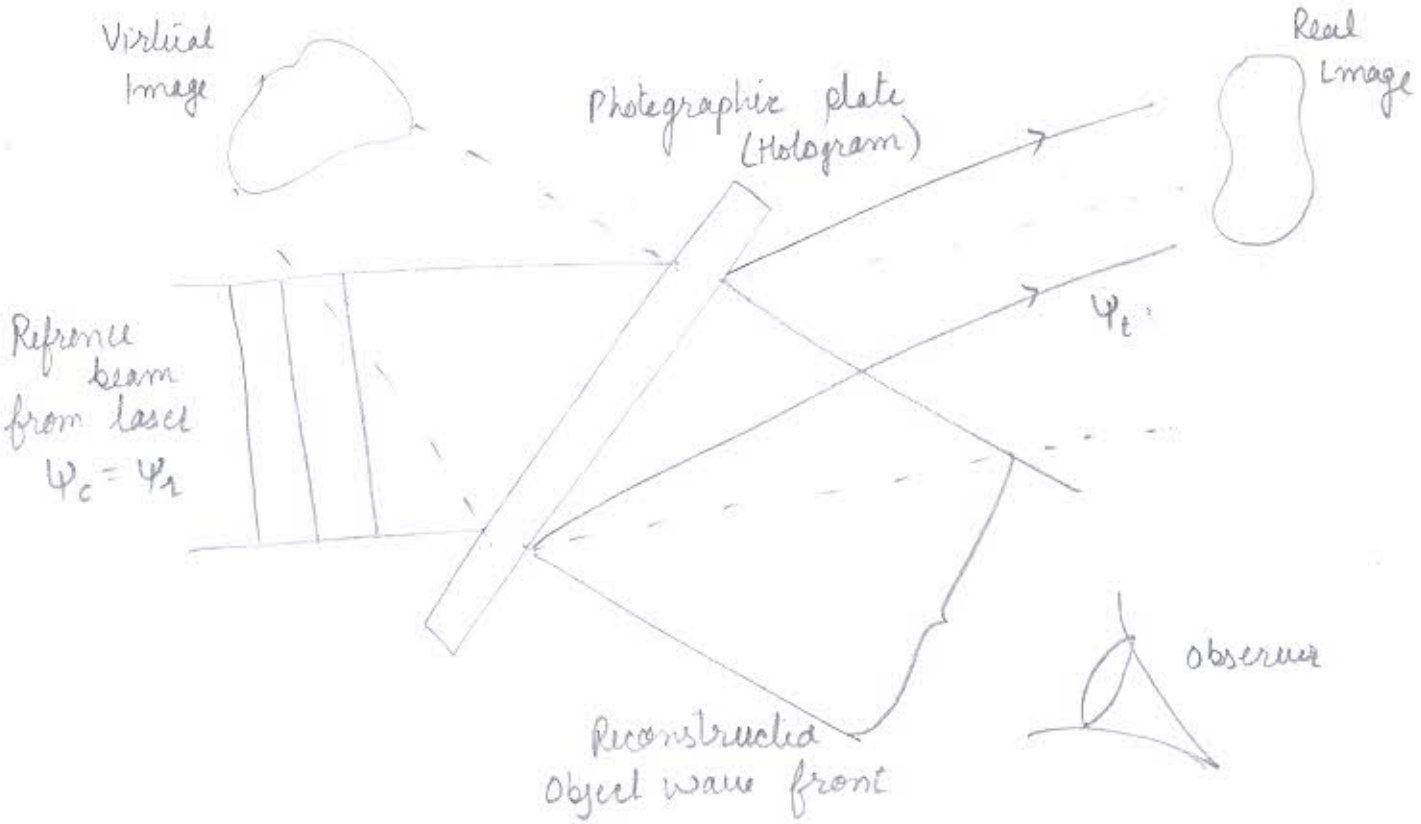
$$\psi_r(x,y) = A_r(x,y)\, e^{-i\phi_r(x,y)}$$

Resultant intensity distribution be

$$I(x,y) = |\psi_0(x,y) + \psi_r(x,y)|^2$$

$$= A_0^2 + A_r^2 + A_r A_0\, e^{-i(\phi_0 - \phi_r)} + A_r A_0\, e^{i(\phi_0 - \phi_r)}$$

$$= A_0^2 + A_r^2 + 2A_r A_0 \cos(\phi_0 - \phi_r)$$



Reconstructing the 3-D Image

The photographic plate is processed and illuminated with only the reference beam present as shown. Most of the light from the reference beam passes straight through the hologram. Some of it is diffracted by the interference pattern in the emulsion. By the normal diffraction grating equation, light of wavelength λ will experience constructive interference ~~fringes~~ at angles such that $\lambda = D \sin\theta$, where D is the local fringe spacing of the interference fringes whose exact shape and distribution depends on the shape of the object and the wavefronts reflected from it. Thus the constructive interference of these diffracted waves reconstructs the original wavefronts from the object and to an observer the wavefronts appear to be coming from the object itself. These wavefronts consitute what is termed as "virtual image".

Just as diffraction grating gives diffracted orders on either side of the 'straight through' position, the hologram generates a second image, this image which is usually inferior in quality to the virtual image, is called the real image.