

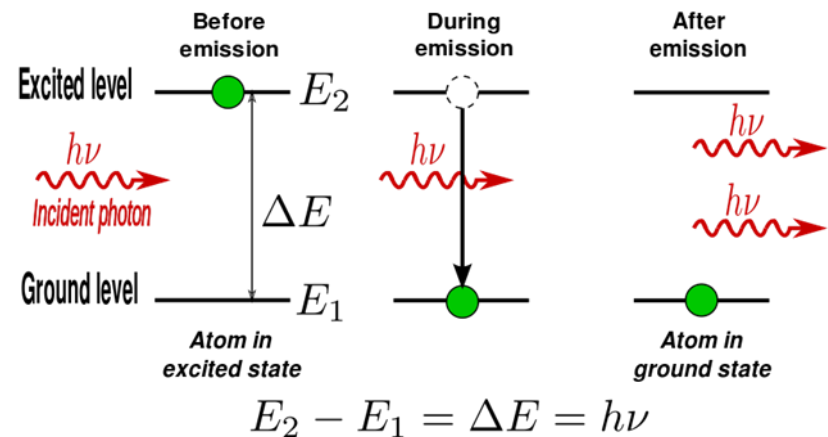


PHY 110 Engineering Physics

Lecture 5
UNIT 2 – laser

Lasers and applications:

- Fundamentals of laser- energy levels in atoms
- Radiation matter interaction
- Absorption of light
- Spontaneous emission of light
- Stimulated emission of light
- Population of energy levels
- Einstein A and B coefficients
- Metastable state
- Population inversion,
- Resonant cavity
- Excitation mechanisms
- Nd – YAG
- He-Ne Laser
- **Semiconductor Laser**
- lasing action
- Properties of laser
- **Applications of laser: holography**



$$R_1 = \frac{R_{st}}{R_{sp}}$$

Ratio of stimulated emission rate to spontaneous emission rate

Ratio of stimulated emission rate to induced absorption rate

$$R_2 = \frac{R_{st}}{R_{abs}}$$

Will give us an Idea about what we need to realize
LASER

To have LASER action dominant Stimulated emission is required and for that we have to have high R_1 and R_2

$$R_2 = \frac{N_2}{N_1}$$

1. Population inversion

2. High photon density

$$R_1 = \frac{B_{21}}{A_{21}} \rho(\nu)$$

3. Increase the life time

1. POPULATION INVERSION by Pumping

2. LARGE PHOTON DENSITY (ρ) using Optical resonant cavity

3. LONG LIFE TIME IN THE EXCITED STATE: by introducing Metastable state

Important characteristics of the laser beam

- **Coherence**
- **Monochromaticity**
- **Collimation**
 - **Directionality**
 - **Negligible divergence**
 - **High intensity**

First Laser: Ruby laser.; a solid state laser with three level system

Types of Lasers

1. Solid state laser
 - a) Ruby laser (first laser)
 - b) Nd-YAG Laser**
2. Gas Laser
 - a) CO₂ laser
 - b) CO Laser
 - c) Nitrogen laser
 - d) Hydrogen laser
 - e) He-Ne Laser (first gas laser)**
3. Liquid laser
 - Dye laser
4. Semiconductor laser
 - Laser diode- pn junction**

In the following which is a three level laser system

- a) Ruby Laser
- b) CO₂ Laser
- c) He-Ne Laser
- d) Nd-YAG Laser

Ans: A

Semiconductor LASER

6

LASER Diode: Portable, need only low input power and operate in the IR to UV region. Widely used nowadays, in fiber optic communication, CD players, CR-ROM drives, high speed laser printing..

1962- low temperature diode laser with GaAs

1970-Room temperature diode laser in CW mode

- Bands of solid are involved not discrete energy levels of atoms
- Holes and electrons combines to produce photon
- Lasing action occur at junction..

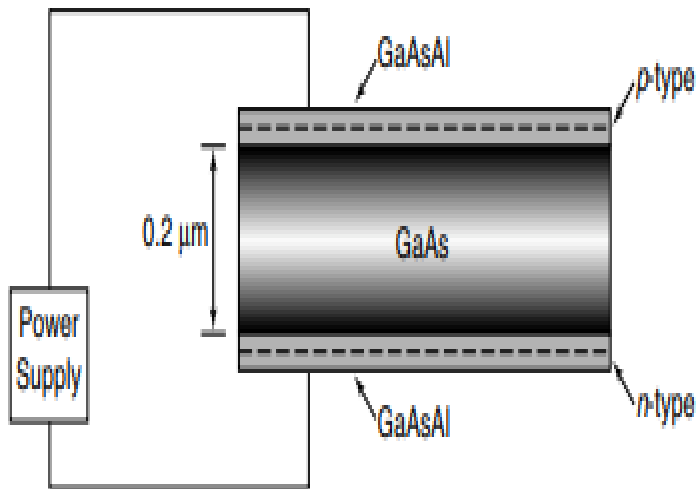


- ✓ Basically a p-n junction diode
- ✓ Small in size 0.1 mm long and hence portable
- ✓ Forward biased condition used
- ✓ Direct bandgap semiconductors are used

Semiconductor LASER

7

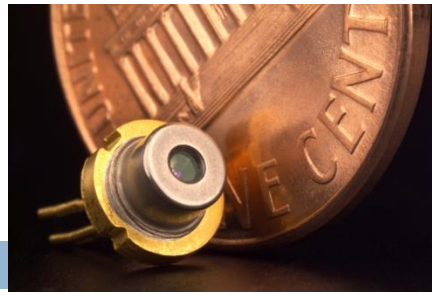
Design of semiconductor Laser



left and right polished.. Reflect and form optical resonator

active layer of gallium arsenide (GaAs), sandwiched in between a n-type GaAsAl and p-type GaAsAl layer

Pumping by electrical current from power supply



Remember

- ❑ Depletion region
- ❑ Charge injection to depletion region

- Direct band gap semiconductor (GaAs)
- Indirect band gap semiconductor (Si)

Gallium arsenide, indium phosphide, gallium antimonide and gallium nitride are all examples of compound semiconductor materials that can be used to create junction diodes that emit light

Si and Ge are indirect band gap material and hence not used

GaAs emit laser emit light 900 nm, IR region

In the following which is a four level laser system

- a) CO₂ Laser
- b) He-Ne Laser
- c) Nd-YAG Laser
- d) All of the above
- e) None of the above

Applications of laser

10

LASERs are used everywhere

1. Science

- To study the properties of material, structure, Raman scattering, material synthesis, thin film preparation by laser ablation, heat treatment for hardening metals, annealing/sintering for densification/phase formation of material.. To study the atmospheric pollutants distribution and identification

2. Industry

- Used for welding, cutting of materials, machining and drilling holes
- Electronic industry: information processing, communication (fiber optic), Information storage (holography), optical memory cards
- In printers, barcode scanners, CD players,
- Guiding missiles to the target

3. Medicine

- Eye surgery, treatment of dental decay, skin diseases

Determine the constants a and b if vector \vec{A} is irrotational vector.

$$\vec{A} = (2xy + 3yz)\hat{i} + (x^2 + axz - 4z^2)\hat{j} - (3xy + byz)\hat{k}$$

Applications of laser

12

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Holography

13

WHAT IS HOLOGRAPHY?

- Holography (from the Greek, whole + write) is the science of producing holograms
- It is an advanced form of photography that allows an image to be recorded in three dimensions.
- The technique of holography can also be used to optically store, retrieve, and process information.

Holography

14

HISTORY

- Dennis Gabor - Father of Holography and Holographic Technologies
- Dennis wrote a paper in 1948 that has become the foundation of modern Holography.
- The most interesting thing about all this is that laser light had not even been invented yet, when he wrote his paper.



Gabor: Nobel Prize 1971

Principle of holography:

- In holography, there are two basic waves that come together to create the interference pattern. One wave is called object wave and another wave is called reference wave. When an object wave meets a reference wave, it creates a standing wave pattern of interference. This is then photographed, which we call a hologram

Holography

16

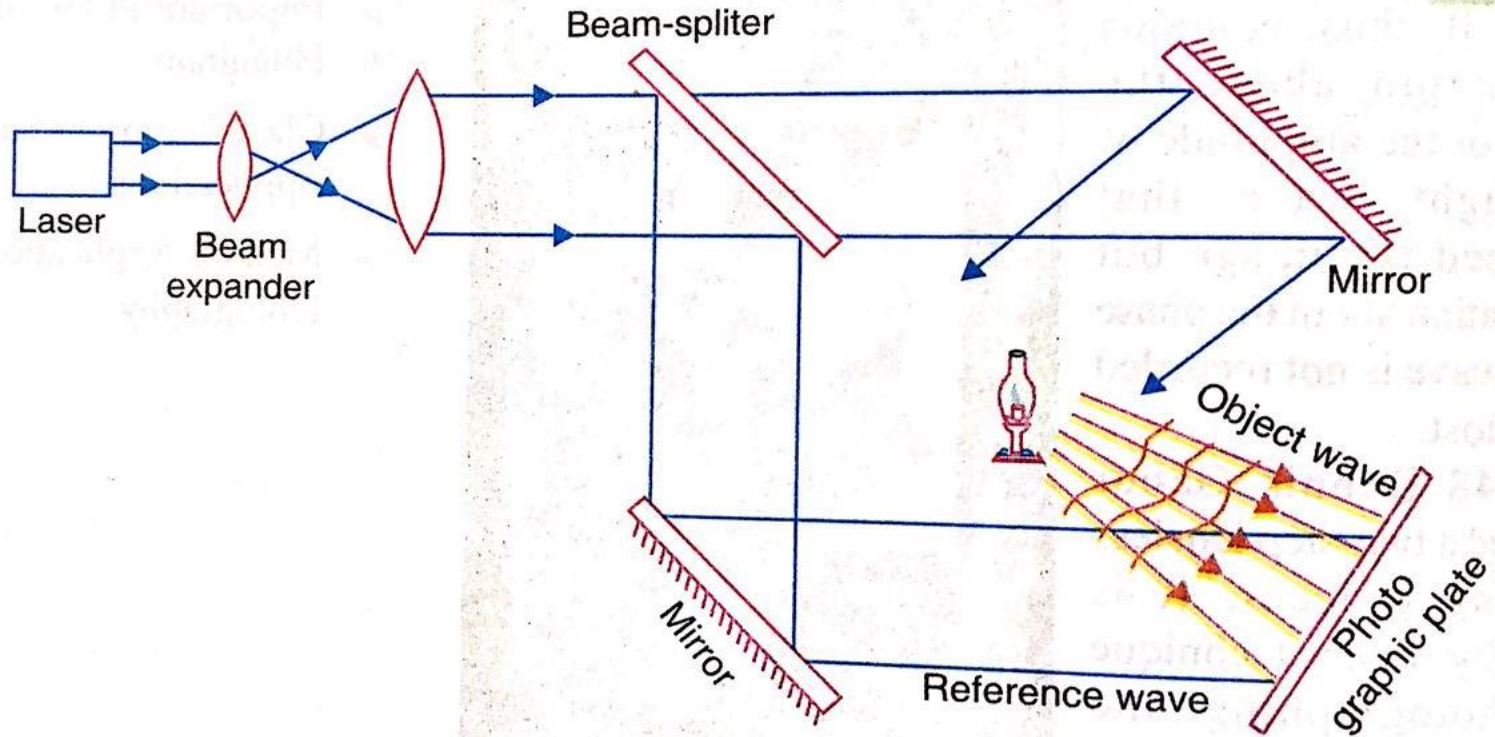
Is a two-step process

1. Recording of the hologram
2. Reconstruction of the image from the hologram

- ☐ No lenses are required compared to conventional photography. But need other more complicated procedures☺.
- ☐ Coherent wave required--- so Laser is needed
- ☐ A reference beam also required along with the laser beam scattered from the object to be imaged– so a beam splitter needed
- ☐ Two mirrors to reflect the beam to photographic plate- interference
- ☐ The photographic plate is a photosensitive material like in conventional photography

Holography-recording

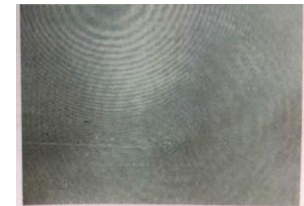
17



Object wave is spherical wave front
Reference wave is plane wave front



Both interfere on the
photographic plane surface



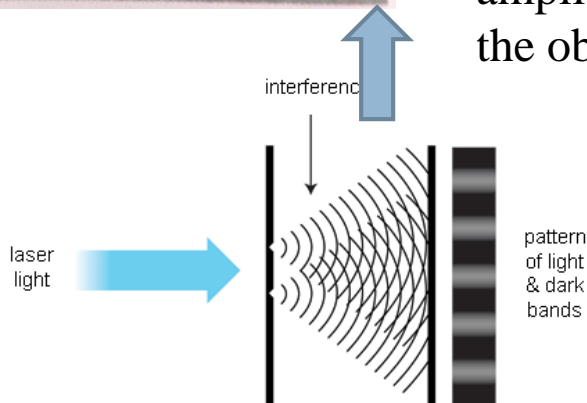
Holography- Recording

18

Hologram



Developed negative is the Hologram.. formed accordance with the light intensity (**amplitude**) reflected from the object and **phase**.. Three dimensional information.. No distinct image of the object. Just the information about the amplitude and phase at each point of the object



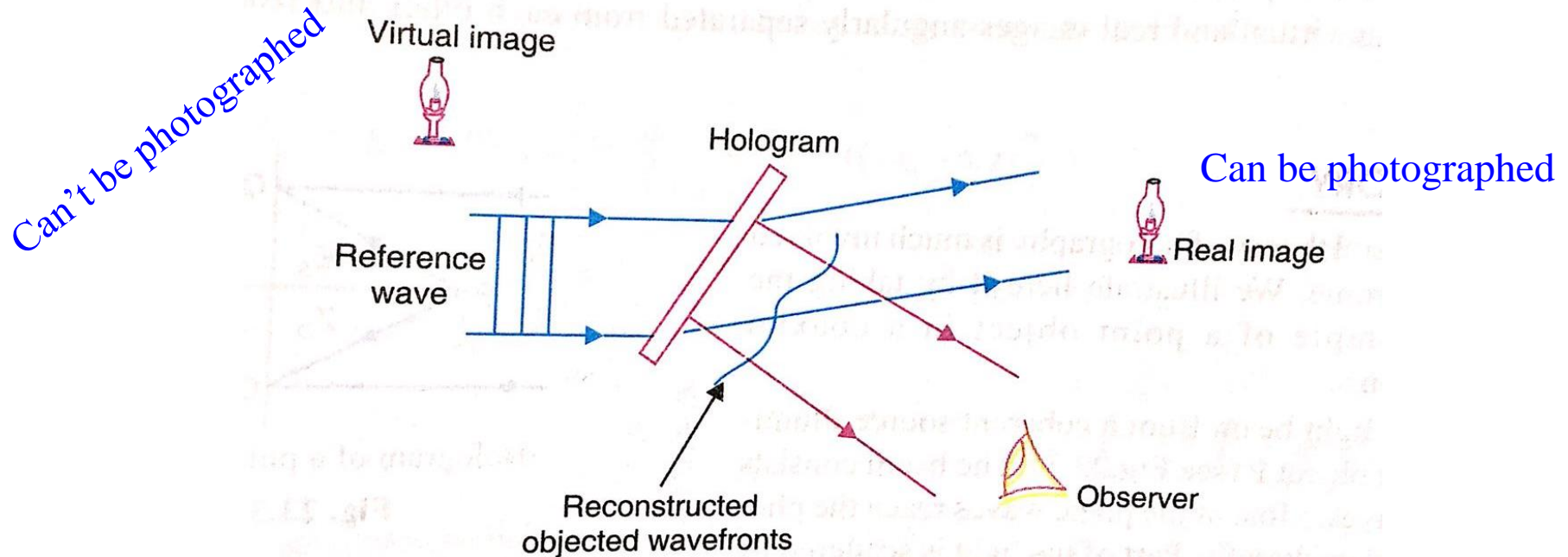
Interference pattern

In photography negative image is formed accordance with the light intensity (**amplitude only**) reflected from the object.. Two dimensional information

Holography-Reconstruction

19

For viewing the image – need reconstruction with the recorded hologram



Interference fringes acts as **diffraction grating**

A diffraction grating defines an optical component with a periodic structure that splits the light into various beams that travel in different directions.



If the image appears between you and the hologram it is a

- a) real image
- b) virtual image
- c) Both
- d) None of these

Ans: A

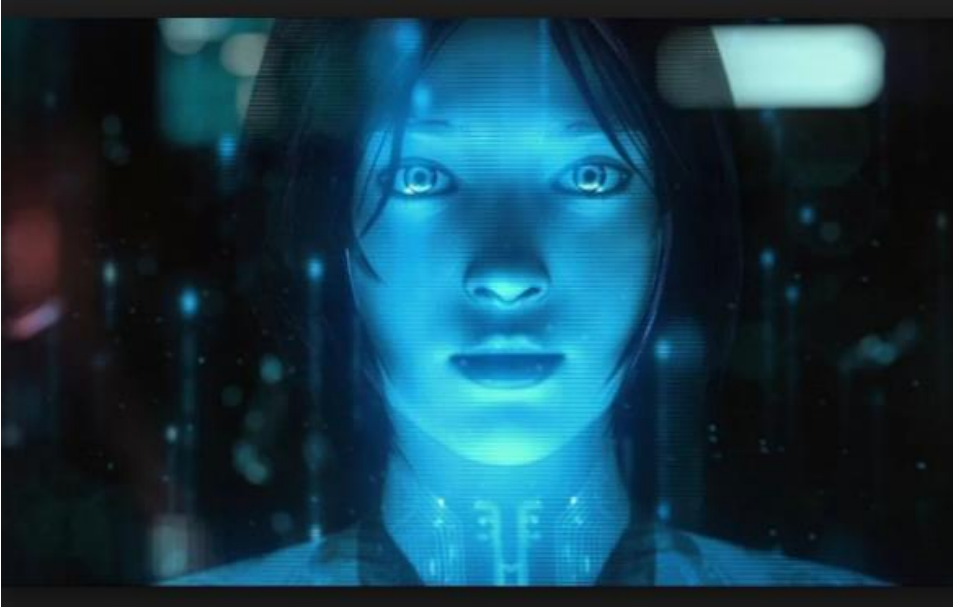
If the hologram is between you and the image, then image is called

- a) real image
- b) virtual image
- c) Both
- d) None of these

Ans: B

Holography-Reconstruction

22



Hologram image photographed



Image developed
from the negative

Holography-Applications

23

Medical applications

- ☐ Ophthalmology
- ☐ Endoscopy
- ☐ Otology
- ☐ Orthopedics

Holographic interferometry is used for **non-destructive testing of materials**

Information storage, optical data storage

The image produced by holography is

- (a) One dimensional
- (b) Two dimensional
- (c) Three dimensional
- (d) None of these

Hologram contains the information about

- (a) Amplitude of the object
- (b) Phase of the object
- (c) Both amplitude and phase of the object
- (d) None of these