

"SYLLABUS" Eng. Physics

UNIT-IWAVE NATURE OF PARTICLESAND THE SCHRÖDINGER EQN

- TOPICS
- i. Introduction to Quantum mechanics,
 - ii. Wave nature of particles,
 - iii. Operators,
 - iv. Time (dependent and Independent),
 - v. Schrödinger eqn for wavefunctⁿ,
 - vi. Particle in a one dimensional box,
 - vii. Born Interpretation,
 - viii. V_g & V_p relatⁿ, Uncertainty principle,

UNIT-IIINTRODUCTION OF SOLID

- i) free electron theory of metals
- ii) band theory of solids
- iii) fermi level of intrinsic & extrinsic semiconductors
- iv) Frenkel-Perry Model
- v) Density of states
- vi) V-I characteristics of PN junction diode & zener diode
- vii) V-I characteristics of Solid cell

UNIT-IIWAVE OPTICS

- TOPICS
- i. Huygen Principle,
 - ii. Principle of Superposition,
 - iii. Interference of light,
 - iv. Young's double slit Experiment,
 - v. Newton's rings,
 - vi. Michelson Interferometer
 - vii. Mach-Zehnder Interferometer
 - viii. Single - slit & Double Fraunhofer diffraction
 - ix - N-slit Diffraction & coupling
 - x - Rayleigh Criteria
 - xi - Resolving Power of eye.

(VIII) Hall EffectUNIT-IVLASER

- i) Properties of laser
- ii) Principle of laser
- iii) Extinction coefficient
- iv) Ruby laser
- v) He-Ne laser
- vi) CO₂ laser
- vii) Optical fibre
- viii) Mono-chromaticity
- ix) directionality and brightness
- x) Laser speckles
- xi) Applications of laser in science
- xii) Numericals.
- xiii) Electric Dipole
- xiv) P-N Junction Diode
- xv) Solar Cell

UNIT-V ELECTROSTATICSIN VACUUM

- i) Coulomb's law
- ii) Electric field
- iii) Gauss's theorem
- iv) Electric Potential
- v) Capacitance
- vi) Capacitors
- vii) Energy stored in capacitor

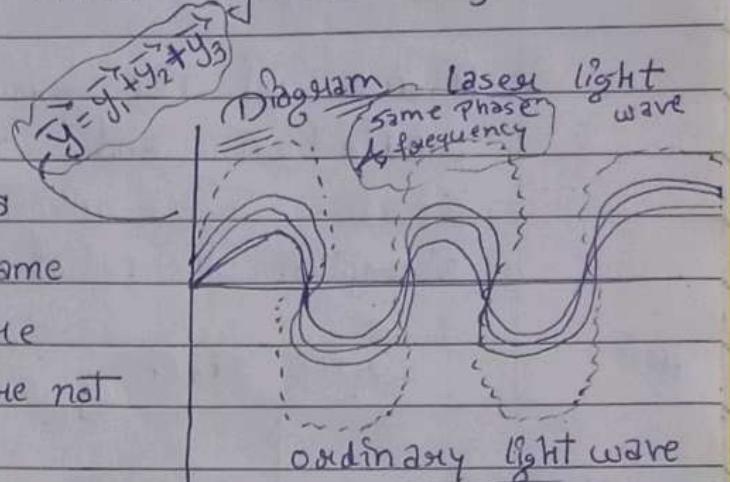
11/04/25 Monday Tuesday

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Laser light always travel at straight

UNIT - IV
LASER { light amplification by stimulated emission of radiation}

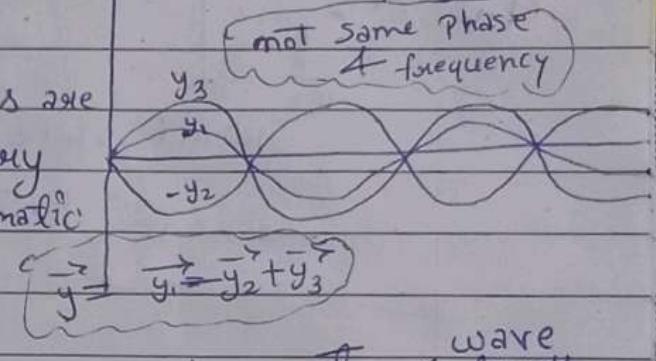
Properties of laser light



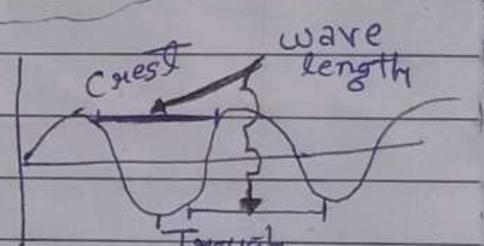
① Cohesive: Laser light waves are coherent waves (having same phase & frequency), whereas ordinary light waves are not coherent.

② Monochromatic: Laser light waves are monochromatic, whereas ordinary light waves are not monochromatic.

Means (Single wave length)
Closed



③ Directionality: Laser light does not diverge with distance, whereas ordinary light diverges.



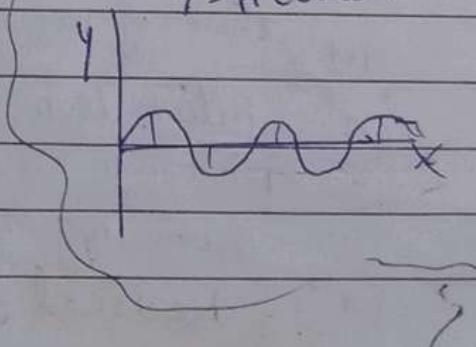
④ Intensity: Intensity of laser light is very high as compare to ordinary light.

$$I \propto A^2$$

⑤ Distance: Laser light travel longer distance as compare to ordinary light.

$$y = A \sin \omega t$$

$$y = A \cos \omega t$$



Phenomenon of Absorption

Spontaneous
Stimulated

12/Max/25 WEDNESDAY

Radiation Application

Helium Leon

Laser used for
Barcode reading

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carbon
dioxide

Medical field) Surgery

Ndyabi Welding

(laser Shows

Temporary
Close

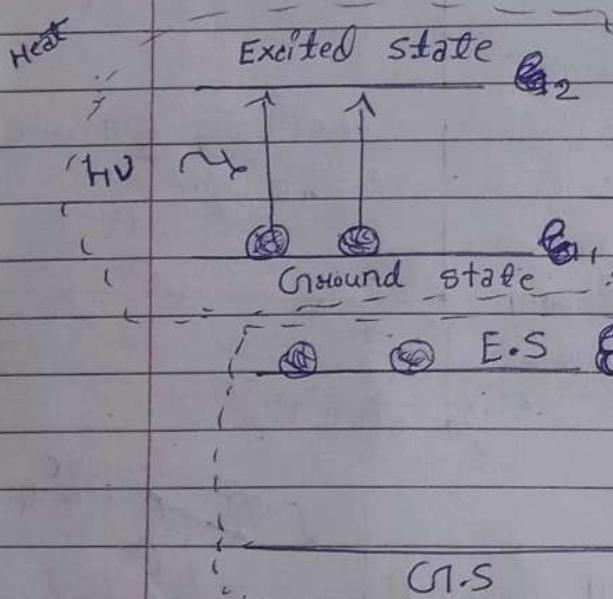
Skin Tightening

Industries

① Absorption Radiation

⇒ Atoms of the ground state absorb radiation and raise to the excited state. This phenomenon is called absorption of radiation.

Excited state
is unstable state



$$E = h\nu$$

frequency
Energy (Plank's
Electron constant
Charge)

ground state
Excited state
Probability

Surrounding Temp.

$15^\circ\text{C} \rightarrow 100^\circ\text{C}$
water g-state e-state

Energy given
to the volume

② Probability of Absorption Radiation

Probability of radiation depends on Energy density that is $P_{12} \propto \mu(\nu)$

$\mu(\nu)$ funcn

$$P_{12} = B_{12} \mu(\nu)$$

B_{12} = Einstein

Coefficient of
absorption radiation

Application of Laser

① Helium Leon laser

④ laser shows

② Distance measure

⑥ Skin Tightening

③ Surgery

⑦ Industries

④ Medical field CO_2 Nd yag

⑧ welding

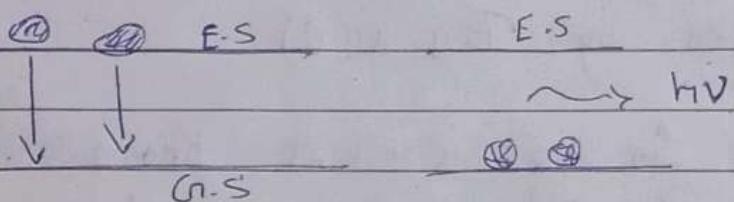
12 marks

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Excited state
realises photon
to the ground state

② Spontaneous emission:

Atoms of excited state realises photon and come down to the ground state

This phenomenon is called spontaneous emission



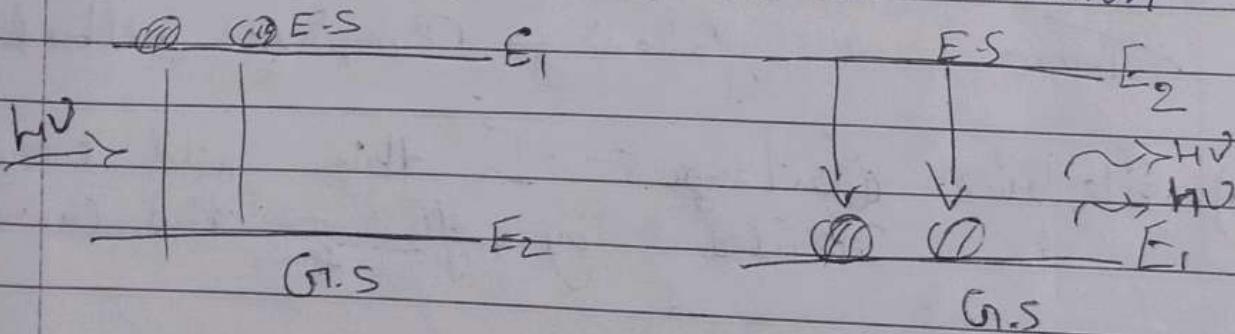
→ Probability of Spontaneous emission:

Probability of Spontaneous emission does not depend on Energy density

Probability of spontaneous emission is represented by ~~A₂₁~~ if it is called Einstein Coefficient of spontaneous emission.

Stimulated Emission:

When atom is at higher energy state and other photon are incident on it, then whenever this atom comes down to ground state, it emits two photon of same frequency and phase, this phenomenon is called stimulated emission



Probability of stimulated emission

→ It is directly proportional to energy density $u(v)$.
It is given by $B_{21} u(v)$

where B_{21} is a constant known as Einstein coefficient of stimulated emission.

⇒ Total probability of an atom of higher energy state to come down to the ground state is given by

$$P_{21} = A_{21} + B_{21} u(v)$$

Q1+ What do you mean by Population Inversion and also write the pumping method

A1+ Accumulation of atoms at higher energy state is known as population inversion.

[Process of achieving Population Inversion is called Pumping]

There are following Pumping methods.

i) Electrical discharge: In this method energy is provided by flowing the current

21 marks

2) OPTICAL PUMPING Energy is provided by flashing the lamp.

3) Collision Energy is provided by Colliding the atoms.

Relation between A_{21} & B_{21} Coefficient

Let N_1 atoms are at the ground state and N_2 atoms are at excited state Probability of N_1 atoms to move to excited state

$$N_1 P_{12} = N_1 B_{12} u(v) \quad (1)$$

Probability of N_2 atoms to come down to ground state

$$N_2 P_{21} = N_2 [A_{21} + B_{21} u(v)] \quad (2)$$

In thermodynamic equilibrium condition

$$N_1 P_{12} = N_2 P_{21}$$

$$N_1 B_{12} u(v) = N_2 [A_{21} + B_{21} u(v)]$$

$$N_1 B_{12} u(v) = N_2 A_{21} + N_2 B_{21} u(v)$$

$$(N_1 B_{12} - N_2 B_{21}) u(v) = N_2 A_{21}$$

21/ March/25
Carbon Black

Black Body
Absorbed & Emitted radiation
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$$\mu(\nu) = \frac{N_2 A_{21}}{N_1 B_{12} - N_2 B_{21}}$$

$$\mu(\nu) = \frac{A_{21}}{\left[\frac{N_1}{N_2} B_{12} - B_{21} \right]}$$

$$\mu(\nu) = \frac{A_{21}}{B_{21} \left[\frac{N_1}{N_2} \frac{B_{12}}{B_{21}} - 1 \right]}$$

In thermodynamic equilibrium condition

$$B_{12} = B_{21}$$

$$\text{In } \mu(\nu) = \frac{A_{21}}{B_{21} \left[\frac{N_1}{N_2} - 1 \right]} \quad \textcircled{3}$$

By Maxwell Boltzmann's

$$N_1 \propto e^{-E_1/kT}$$

where k is Boltzmann constant and T is Temperature

So

$$N_1 \propto e^{-E_1/kT} \text{ and } N_2 \propto e^{-E_2/kT}$$

$$\frac{N_1}{N_2} = \frac{e^{-E_1/kT}}{e^{-E_2/kT}} = e^{(E_2 - E_1)/kT}$$

$$\frac{N_1}{N_2} = e^{-hv/kT}$$

E - photoelectric

$$(E = h\nu)$$

$$(E_2 - E_1 = h\nu)$$

By placing value in eqn (3)

$$\mu(\nu) = \frac{A_{21}}{B_{21} \left[e^{-hv/kT} - 1 \right]} \quad \textcircled{4}$$

By Comparing Eqn 4

According to Planck

$$I(v) = \frac{8\pi h v^3}{c^3 [e^{hv/kT} - 1]} \quad (5)$$

where $B\pi$ is
constant
 $\propto h$ is plank's constant
or c = speed of
light

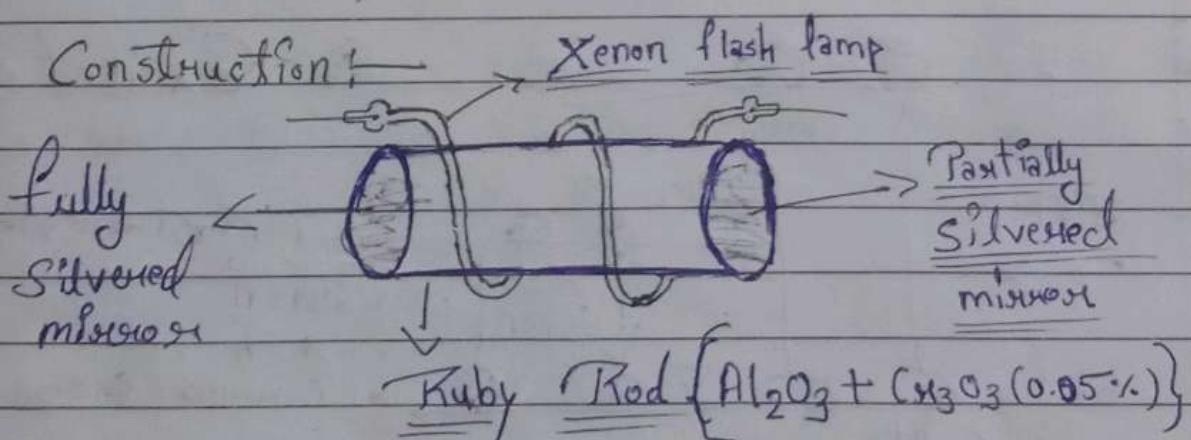
By Comparing Eqn 4 + 5

$$\frac{A_{21}}{B_{21} [e^{hv/kT} - 1]} = \frac{8\pi h v^3}{c^3 [e^{hv/kT} - 1]}$$

$$\frac{A_{21}}{B_{21}} = \frac{8\pi h v^3}{c^3} \Rightarrow \left(\frac{A_{21}}{B_{21}} \propto v^3 \right) \text{ for other term constant}$$

Ruby Laser

Q) Explain Construction & Working of Ruby laser?
Write any three deficiency of laser.



5500 Å
 Green Colour
 Steel Conducting material
 Chromium Nitrate Catalyst
 E_3
 E_2
 E_1
 Date: / / Page no: _____

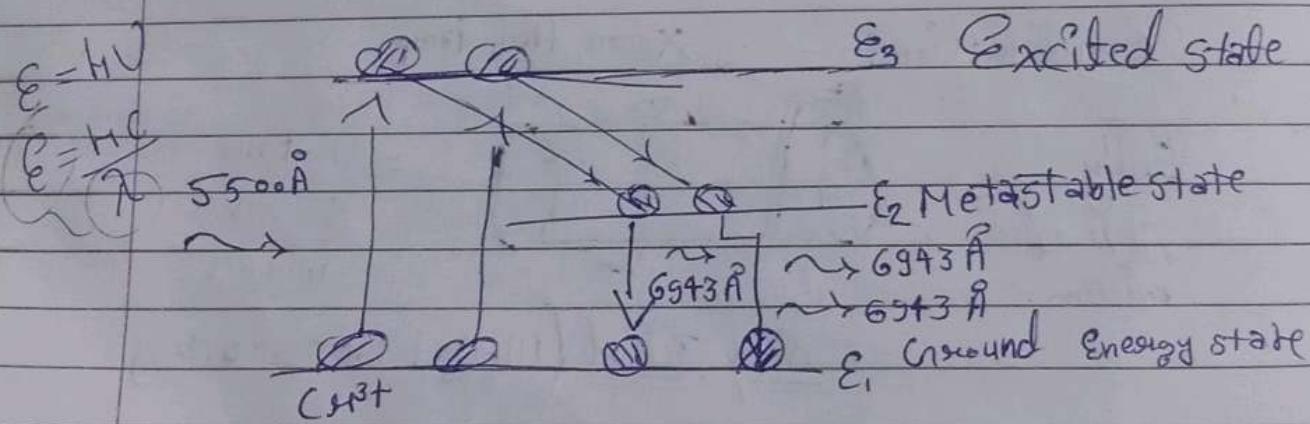
This laser it is consist of ~~the~~ a ruby rod which is made by Al_2O_3 and it is doped with Cr_2O_3 (0.05%).

A Xenon flash lamp is bounded on a ruby rod to provide optical Pumping.

There is a fully silvered mirror at one end and partially silvered mirror at the other end of the ruby rod.

It is three Energy level Crystalline

It is a ~~cristal~~ crystalline laser
 { crystalline is one laser where crystal material is used}.



from E_3 to E_2
 By transforming Energy to Crystal Lattice
 Energy level diagram.

$E_3 \{ E_2$
 $E_1 \}$

Ruby laser — pink Beam

251 mules

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- # Initially Cr^{3+} ions are at the ground state & then by absorbing the photon of wavelength 5500\AA this Cr^{3+} ions raise to the excited state.
- # zircon flash lamp is provide optical pumping
- # from E_3 Energy state Cr^{3+} ions transfer some of their energy to crystal lattice and comedown to metastable state (E_2) (excited state)
- # From E_2 Energy state initially Cr^{3+} ion comes down to ground state by spontaneous emission of wave length 6943\AA .
- # If this photon's find other metastable state Cr^{3+} ion then the other will come down to ground state by stimulated emission
- # When this photon strikes on the transparent section they come out in the form a laser beam

~~Defects~~ Deficiencies of the laser

- ① It is not operating in continuous mode
- ② High Pumping Power is required because only green component of light is utilized

③ Efficiency of this laser is lower than Li^+ (Helium Neon Laser)

5 Marks

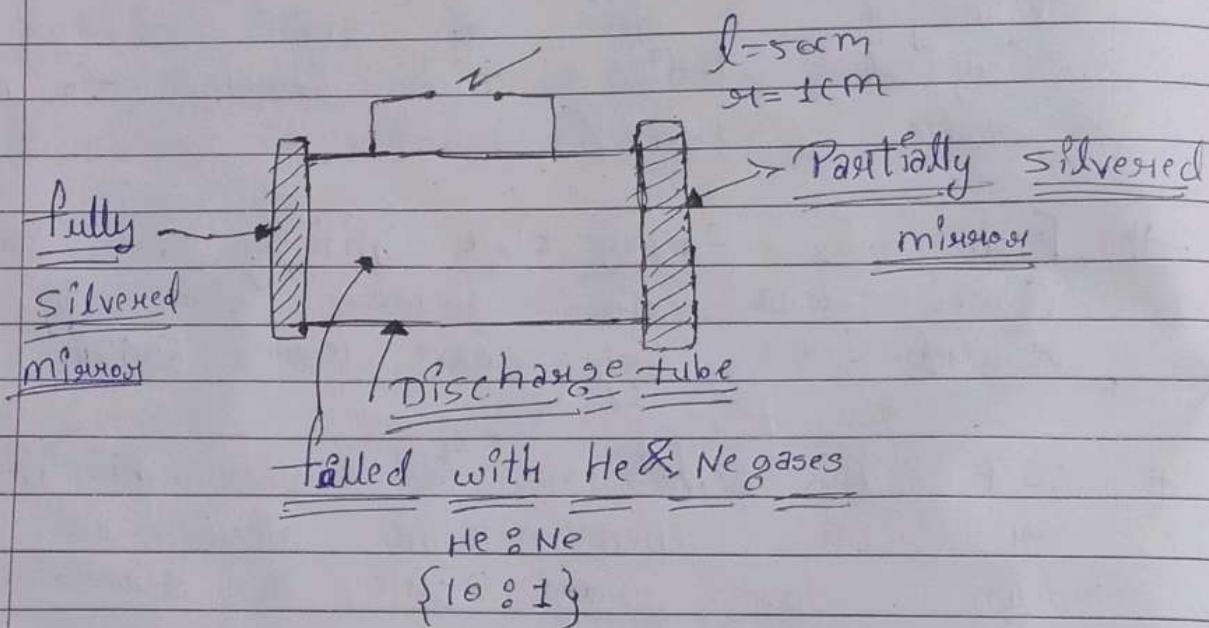
② He-Ne Laser:

MST

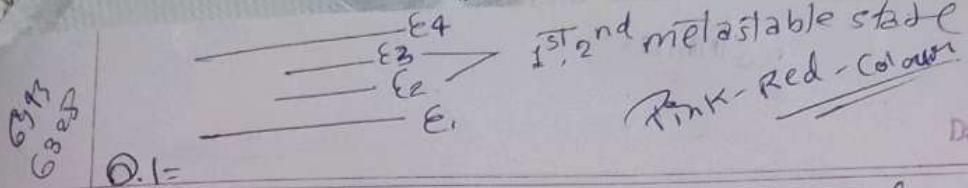
Q.1

Explain He-Ne laser under the following Heads

- ① Construction, ② Working, ③ Application



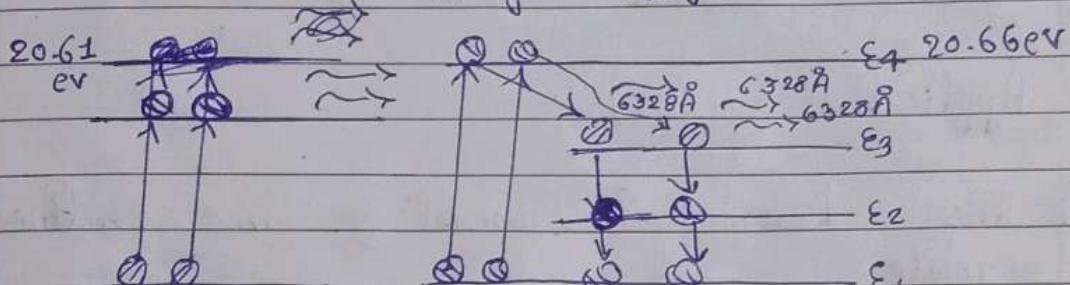
- # It is a gaseous laser
- # It consists of a discharge tube of length 50 cm & diameter 1 cm
- # This tube is filled with He & Ne gases in the ratios of 10:1
- # There is a fully silvered mirror at one end and partially silvered mirror on the other end of the discharge tube.
- # Two electrodes are connected with discharge tube to provide electrical discharge.



It is four energy level laser.

26 Maules

Working of He-Ne Laser!
Transfer energy by collision to Ne atoms



Energy level diagram

⇒ Initially, He & Ne atoms are at the ground state. Then we flow current through the mixture of He & Ne gases.

⇒ By Absorbing the energy He & Ne atoms are raised to excited state.

⇒ Ne atoms are excited by two ways, one due to flow of the current and second due to collision by He atoms.

⇒ From Excited state E₄ (20.66 eV). Ne atoms come down to E₃ energy level by spontaneous emission of photon wavelength 6328 Å. If this strikes on other E₄ energy level Ne atom then the other will come down by stimulated emission of two photons. (6328 Å)

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⇒ From E_3 Energy level Ne-atoms come down to E_2 level and then E_1 level by transferring their energy to other ground state atom.

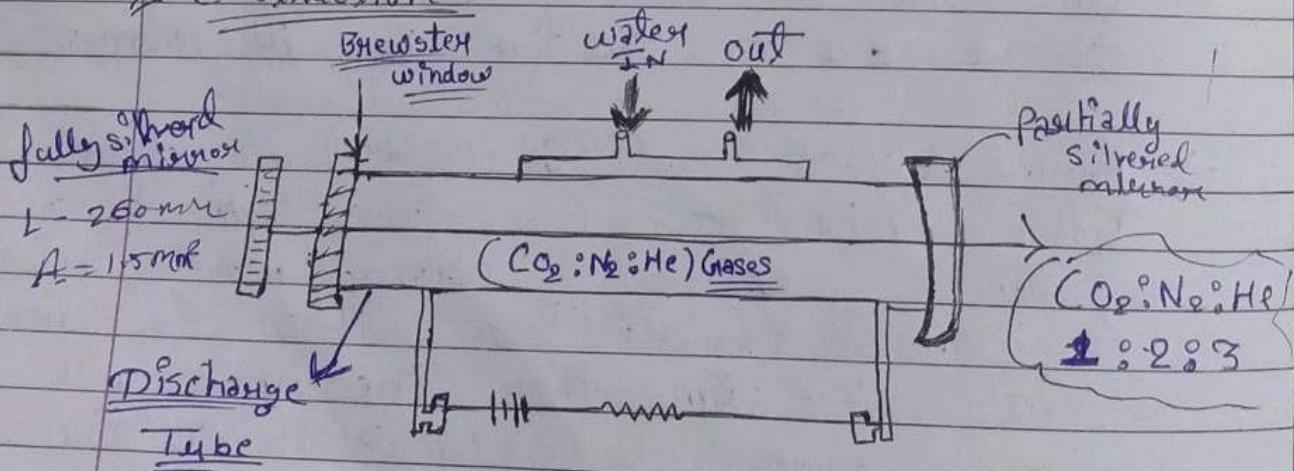
Application (USES) :

- ⇒ This Laser is operating in Continuous mode
- ⇒ This laser is mainly use for Bar code Reading
- ⇒ Efficiency of this laser is higher than Ruby laser.
- ⇒ This laser is used for cutting object
- ⇒ This laser is used for Industrial work and Research or study work.

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CO_2 LASER

Construction



①

②

③

- ⇒ It is a gaseous laser.
- ⇒ It consists of a discharge tube of length 260m and cross section area in about 1.5 mm^2
- ⇒ This tube is filled with Carbon dioxide (CO_2), Nitrogen (N_2) and Helium (He) gases in the ratio of $1:2:3$.
- ⇒ Electrical discharge method is used for pumping of CO_2 and N_2 molecules.
- ⇒ This is four energy level laser.

WORKING:-

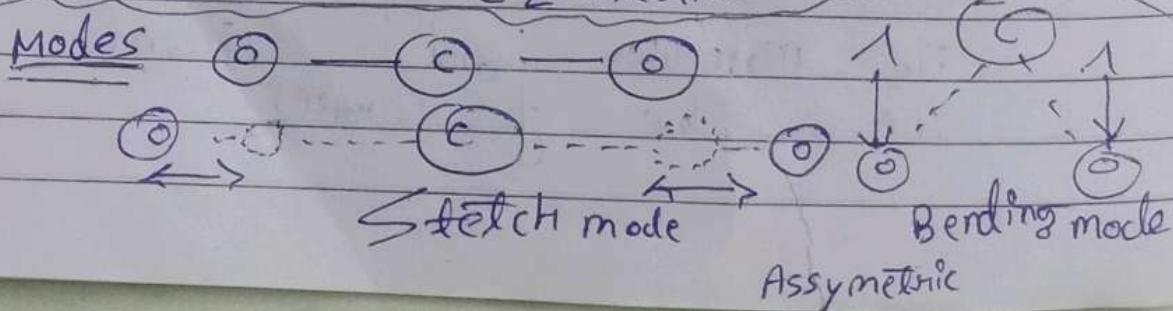
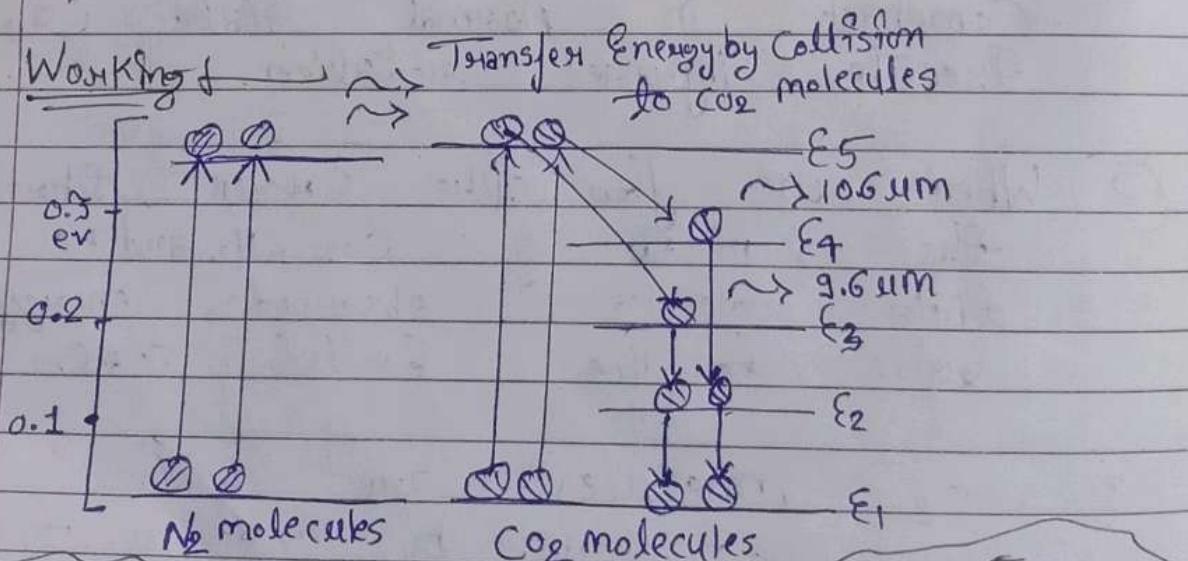
- ① When Energy is given to the CO_2 molecules then it starts vibration in different modes such as stretch mode, bending mode & asymmetric mode. To come back in normal state CO_2 molecules execute infrared radiation.
- ② When we flow the current through the mixture of CO_2 , N_2 and He gases their molecules absorbed energy and raise to the excited state.
- ③ CO_2 molecules are excited by two ways one - by collision through N_2 molecules and second by the flow of current.

(4) At E_5 Energy level CO_2 molecules start releases photon of wavelength $10.6 \mu\text{m}$ or $9.6 \mu\text{m}$ and comedown to E_4 Energy level or E_3 Energy level

(5) Now from here CO_2 molecules come down to E_2 level and then E_1 Energy level by transferring their Energy to other ground state molecules and He atoms.

Application of $\text{CO}_2 - \text{N}_2 - \text{He}$ laser.

This laser is mainly used for Surgery work. Efficiency of this laser is about 45% and which is more than Ruby and He-Ne laser.



19640 Å

Nd: YAGI LASER \rightarrow Solid state
Ruby laser \rightarrow Solid state laser

Energy band

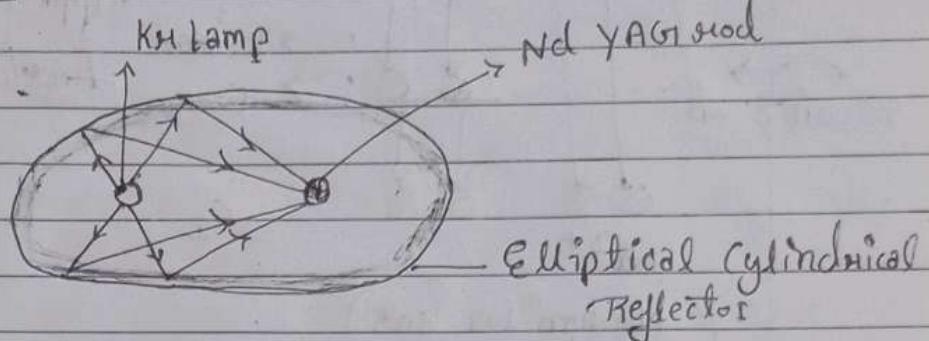
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Nd: YAGI LASER

Crystalline Laser

Construction

Diagram



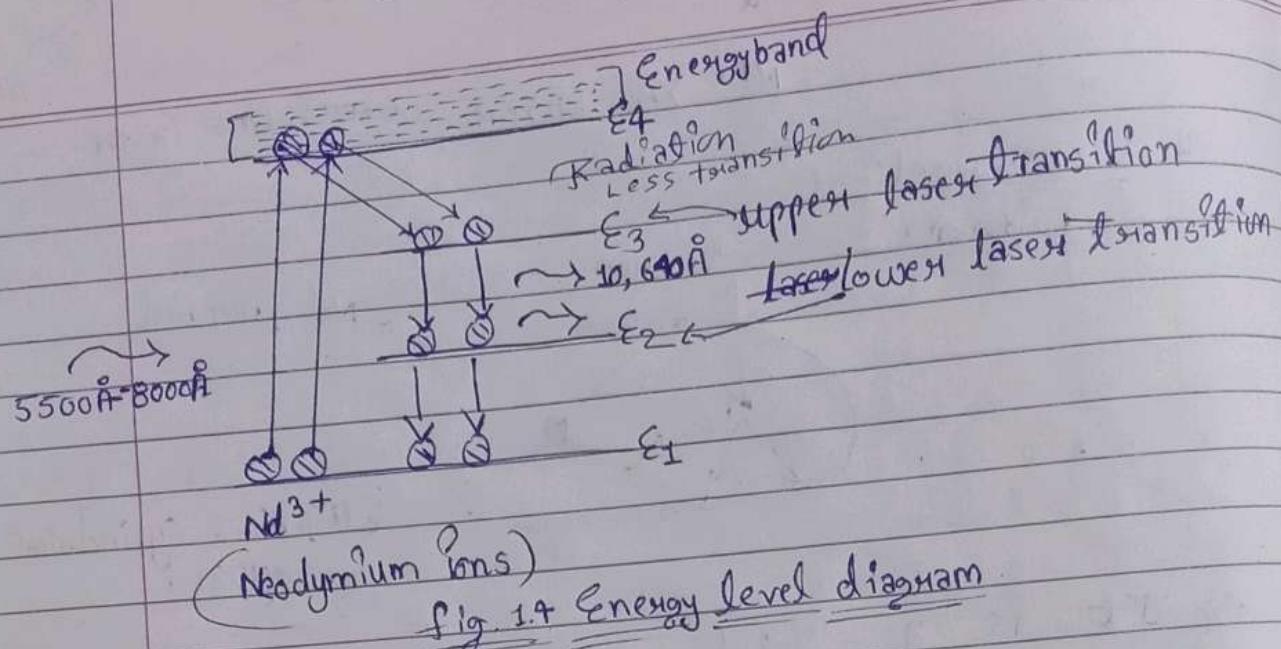
- ⇒ It is a solid state laser where Nd stands for neodimium Neodymium. YAGI stands for Yttrium aluminum garnet
- ⇒ It is consist of an elliptical cylindrical reflector
- ⇒ Krypton (Kr) lamp is used to provide optical pumping
- ⇒ Krypton (Kr) lamp is fixed at one focus and Nd:YAGI Rod on the other focus of the elliptical cylindrical reflector
- ⇒ It is four energy level laser, Having Energy band b. at the Excited state

Working:-

Infrared radiation to come from E_3 to E_2 (and E_4 to E_3 is radiation less)

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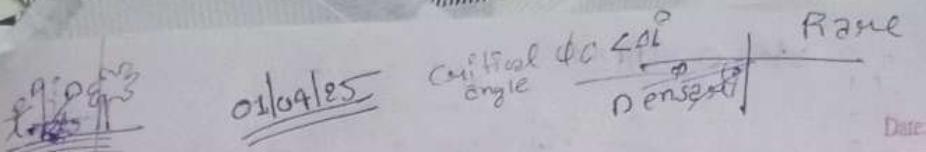


Working

- ① When we flash krypton lamp neodymium ions (Nd^{3+}) absorbed radiation of wavelength $5500 \text{ \AA} - 8000 \text{ \AA}$ and raise to the excited state.
- ② From E_4 energy state Nd^{3+} ions execute radiation less transition and comedown to E_3 energy level.
- ③ Laser transition takes place between E_3 and E_2 energy level by the infrared emission of wavelength $10,640 \text{ \AA}$.
- ④ From E_2 energy level Nd^{3+} ions are comedown to the ground state by transferring their energy to the ground state ions.

Application

- # This laser is mainly use in medical field for cosmetic surgery work, like skin lightening, unwanted hair removal & tattoo removal.



~~total removal~~ Based on Principle of total internal reflection
Optical fibre

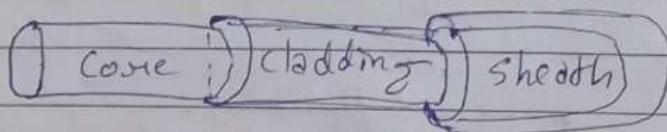
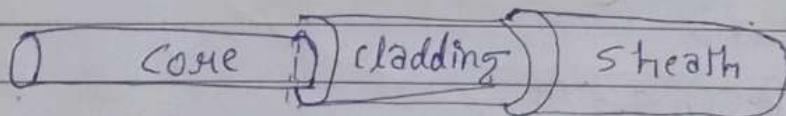
Total Internal Reflection (TIR)

There are two Conditions required to execute (TIR)

- # Light should be travel from dense medium to rare medium.
- # Angle of incidence should be more than critical angle

Optical fibres

- # It is made by glass ~~or~~ plastic pipe.
- # It is very thin like a human hair.
- # It is based on the Principle (TIR)



- # Optical Fibre has three sections.
- I Core
- II Cladding
- III Sheath

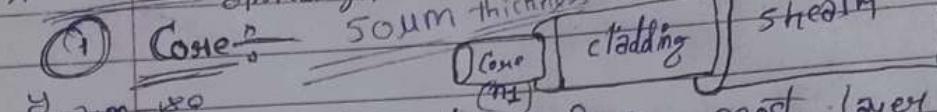
$$H_2O = 1.5$$

$$\sin i = \frac{1}{\sqrt{n}} \quad n = \sin i / \sin r$$

UNIT - 4
Optics
C.C Interference

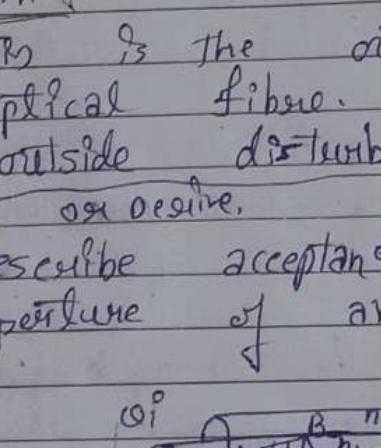
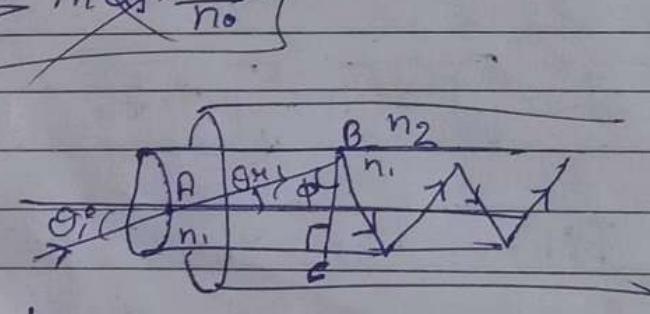
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Describe structure of optical fibre & its principle



(1) Core: n_1 n_2 n_3 n_4 n_5 n_6 n_7 n_8 n_9 n_{10} n_{11} n_{12} n_{13} n_{14} n_{15} n_{16} n_{17} n_{18} n_{19} n_{20} n_{21} n_{22} n_{23} n_{24} n_{25} n_{26} n_{27} n_{28} n_{29} n_{30} n_{31} n_{32} n_{33} n_{34} n_{35} n_{36} n_{37} n_{38} n_{39} n_{40} n_{41} n_{42} n_{43} n_{44} n_{45} n_{46} n_{47} n_{48} n_{49} n_{50} n_{51} n_{52} n_{53} n_{54} n_{55} n_{56} n_{57} n_{58} n_{59} n_{60} n_{61} n_{62} n_{63} n_{64} n_{65} n_{66} n_{67} n_{68} n_{69} n_{70} n_{71} n_{72} n_{73} n_{74} n_{75} n_{76} n_{77} n_{78} n_{79} n_{80} n_{81} n_{82} n_{83} n_{84} n_{85} n_{86} n_{87} n_{88} n_{89} n_{90} n_{91} n_{92} n_{93} n_{94} n_{95} n_{96} n_{97} n_{98} n_{99} n_{100} n_{101} n_{102} n_{103} n_{104} n_{105} n_{106} n_{107} n_{108} n_{109} n_{110} n_{111} n_{112} n_{113} n_{114} n_{115} n_{116} n_{117} n_{118} n_{119} n_{120} n_{121} n_{122} n_{123} n_{124} n_{125} n_{126} n_{127} n_{128} n_{129} n_{130} n_{131} n_{132} n_{133} n_{134} n_{135} n_{136} n_{137} n_{138} n_{139} 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Q.1 * Describe acceptance angle and Numerical aperture of an optical fibre.



$$n_1^2 + n_2^2 - 1 = 0 \quad \text{Solve} \quad \text{Snell's law } \mu_2 = \frac{\sin i}{\sin r} = \frac{n_2}{n_1}$$

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Let n_0, n_1, n_2 be the refractive index of outside medium, core, cladding respectively. Then by applying Snell's law at point A.

$$\frac{\sin \theta_i}{\sin \theta_r} = \frac{n_1}{n_0}$$

$$\sin \theta_i = \frac{n_1}{n_0} \sin \theta_r \quad \text{--- (1)}$$

$$\text{By } \triangle ABC \quad \theta_r + \phi + 90^\circ = 180^\circ$$

$$(\theta_r = 90^\circ - \phi)$$

By placing this value in Eqn (1)

$$\sin \theta_i = \frac{n_1}{n_0} \sin(90^\circ - \phi)$$

$$\sin \theta_i = \frac{n_1}{n_0} \cos \phi \quad \text{--- (2)}$$

when $\theta_i = \theta_{\max}$ then $\phi = \phi_c$ c is critical angle

$$\sin \theta_{\max} = \frac{n_1}{n_0} \cos \phi_c \quad \text{--- (3)}$$

At point B by applying Snell's law

$$\frac{\sin \phi_c}{\sin \theta_0} = \frac{n_2}{n_1}$$

$$\sin \theta_0 = 1$$

$$\sin \phi_c = \frac{n_2}{n_1}$$

$$\cos \phi_c = \sqrt{1 - \frac{n_2^2}{n_1^2}}$$

$$(\cos \phi_c = \frac{\sqrt{n_1^2 - n_2^2}}{n_1})$$

By placing this value in Eqn (3)

$$\sin \theta_{\max} = \frac{n_1}{n_0} \cdot \frac{\sqrt{n_1^2 - n_2^2}}{n_1}$$

$$\sin \theta_{\max} = \frac{\sqrt{n_1^2 - n_2^2}}{n_0}$$

If first medium is

By placing this value in Eqn(3)

$$\sin \theta_{\max} = n_1 \cdot \frac{\sqrt{n_1^2 - n_2^2}}{n_0}$$

$$\sin \theta_{\max} = \frac{\sqrt{n_1^2 - n_2^2}}{n_0}$$

If first medium is air $n_0 = 1$

$$\left(\sin \theta_{\max} = \sqrt{n_1^2 - n_2^2} \right) \rightarrow \text{Numerical aperture}$$

$$\theta_{\max} = \sin^{-1} \sqrt{n_1^2 - n_2^2}$$

acceptance angle

Q&A 125

V-number → It is a count quantity that characterise an optical fibre as single mode or multimode. If V-number is less than 2.405 then optical fibre is Single mode.

V-Number $< 2.405 \rightarrow$ Single Mode

V-Number $> 2.405 \rightarrow$ Multimode

where,

2.405 is called cut off value.

$$\left(V = \frac{2\pi a}{\lambda} \cdot \sqrt{n_1^2 - n_2^2} \right) \rightarrow$$

$\lambda \rightarrow$ wavelength
 $n_1 \rightarrow$ Refractive Index
 $n_2 \rightarrow$ Refractive Index of cladding

where,

$a \rightarrow$ Radius of the core.

- Q) Calculate the numerical aperture, acceptance angle and v-number of an optical fibre.
- Given that refractive Index of core = 1.45
- (n₂) Refractive Index of cladding = 1.40
- (n₃) wavelength of light = 6000 Å = 6000×10^{-10} m
- (a) Core radius = 2 mm = 2×10^{-3} m

$$n.A = \sqrt{n_1^2 - n_2^2}$$

$$n.A = \sqrt{(1.45)^2 - (1.40)^2}$$

$$n.A = \sqrt{(0.05)(2.85)}$$

$$n.A = 0.37$$

Acceptance

$$\text{Angle} \Rightarrow \theta = \sin^{-1} \sqrt{n_1^2 - n_2^2}$$

$$\theta = \sin^{-1}(0.37)$$

$$\theta = 21.71^\circ$$

$$V = \frac{2\pi a}{\lambda} \sqrt{n_1^2 - n_2^2}$$

$$V = \frac{2\pi a}{\lambda}$$

$$V = \frac{2 \times 22}{7} \times 2 \times 10^{-3} \times 0.37$$

$$= \frac{2}{6000 \times 10^{-10}}$$

$$V = 2$$

Wave optics — Light — wave
quantum mechanics — Light — dual nature & particle

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Unit - Quantum mechanics

Dual nature of light :-

Light shows wave nature as well as particle nature. This phenomenon is known as dual nature of light.

Energy of light is concentrated to small regions which is known as photon. So photons are energy particle.

Louis-de Broglie Hypothesis :-

According to the de Broglie every moving particle is surrounded by a wave and wavelength of this wave depends on the mass and velocity of the particle and the relation is given by

$$\lambda = \frac{h}{mv}$$

$$h = 6.63 \times 10^{-34} \text{ Js}$$

where, $h \rightarrow$ Planck's constant

$m \rightarrow$ mass of particle

$v \rightarrow$ velocity of particle

$$\lambda = \frac{h}{P}$$

$$P = mv = \text{momentum}$$

moving particle - electron

this wave is called ~~metal~~ matter wave.

~~Imp~~ Properties of matter wave ↪

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Charge oscillating particle Electromagnetic wave

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- ① Wavelength of heavier particle is less
- ② Wavelength of a matter wave for having particle is less as compared to lighter particle.
- ③ Wavelength of faster moving particle is less as compared to slower moving particle
- ④ If the particle is at least rest then the wave does not exist
- ⑤ Matter wave is independent of charge and every moving particle produces matter wave.
- ⑥ These waves are not electromagnetic waves.

Displacement Eqn $y = A \sin(\omega t - kx)$

ω → angular velocity
 k → wave no.
 $\frac{2\pi}{\lambda}$ → λ wavelength

Max^m displa - A
Two crest trough

$y = A \cos(\omega t - kx)$

$(\omega t - kx)$ → phase angle
 y - displacement on y -axis
 t - time
 A → Amplitude
 x - displacement on x -axis

In ~~on~~ Quantum mechanics wave eqn is given by

$$y = A \sin(\omega t - kx)$$
$$y = A \cos(\omega t - kx)$$

where y = displacement on y -axis
 A - Amplitude
 $\omega t - kx \rightarrow$ phase

$$K = \frac{mv}{\lambda}$$

$$T \rightarrow v \Rightarrow \frac{h}{mv} \rightarrow \frac{h}{p} \Rightarrow$$

$$y = A \sin(\omega t - Kx)$$

$$y = A \cos(\omega t - Kx)$$

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wave packet

Every moving particle is surrounded by group of wave that forms a packet of which is known as wave packet.

Notes:

Quantum mechanics

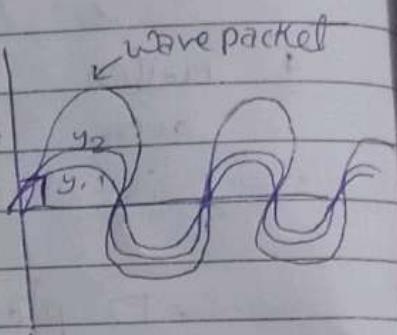
Wave Eqn

$$y = A \cos(\omega t - Kx)$$

or

$$y = A \sin(\omega t - Kx)$$

$y \rightarrow$ Displacement on y -axis
 $(\omega t - Kx) \rightarrow$ Phase



$$K \rightarrow \text{wave no.} = \frac{2\pi}{\lambda}$$

$x \rightarrow$ Displacement on x -axis.

wave packet

Every moving Particle is surrounded by group of wave that forms a packet which is known as wave packet.

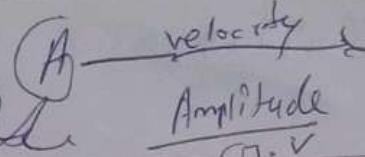
~~Q1~~ ~~PYQ~~

Group velocity & Phase velocity & acceleration b/w them.

Group velocity is velocity of the wave packet is called Group velocity

$$\cos A + \cos B$$

$$= 2 \cos \frac{A+B}{2} \cos \frac{A-B}{2}$$

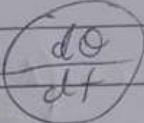


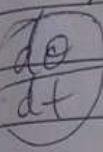
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G.V. → Average
Phase → C.V.
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Second definition

(G.V.)

→ Velocity of the overall amplitude of resultant wave is called group velocity.

* Phase velocity 

→ The rate at which the phase of wave changes with time. It is known 

→ Let a moving particle is surrounded by two waves and their displacement Eqn's are given by y_1 & y_2

$$y_1 = A \cos(\omega_1 t - k_1 x)$$

$$y_2 = A \cos(\omega_2 t - k_2 x)$$

After superposition displacement eqn of resultant wave

$$\bar{y} = \bar{y}_1 + \bar{y}_2$$

$$y = A [\cos(\omega_1 t - k_1 x) + \cos(\omega_2 t - k_2 x)]$$

$$(\cos A + \cos B = 2 \cos \frac{A+B}{2} \cos \frac{A-B}{2})$$

$$y = 2A \left[\cos \left(\frac{(\omega_1 + \omega_2)t}{2} - \frac{(k_1 + k_2)x}{2} \right) \cdot \cos \left(\frac{(\omega_1 - \omega_2)t}{2} - \frac{(k_1 - k_2)x}{2} \right) \right]$$

$$\omega_1 + \omega_2 = \omega$$

①

$$\text{let } \frac{\omega_1 + \omega_2}{2} = \omega \quad , \quad \frac{k_1 + k_2}{2} = K$$

$$\omega_1 - \omega_2 = \Delta\omega, \quad K_1 - K_2 = \Delta K$$

By placing values in Eq. ①

$$y = 2A \cos(\omega t - kx) \cdot \cos\left(\frac{\Delta \omega t}{2} - \frac{\Delta k x}{2}\right) = \textcircled{2}$$

y By rearranging the eqn displacement Eqn of resultant wave. is given by

$$y = A \cos\left(\frac{\Delta \omega t}{2} - \frac{\Delta K x}{2}\right) \cdot \cos(\omega t - Kx) \quad (3)$$

Amplitude (Average) Phase.

Group Velocity

$$\frac{\Delta w t}{2} - \frac{\Delta K_{xc}}{2} = \text{Constant}$$

Differentiate with respect to t

$$\frac{A\omega}{2} - \frac{\Delta K}{2} \frac{dx}{dt} = 0$$

$$\frac{\Delta Q}{2} = \frac{\Delta K}{2} \frac{dc}{dt}$$

$$\frac{dx}{dt} = \frac{\Delta v}{\Delta k}$$

$$V_g = \frac{\Delta \omega}{\Delta K} \quad (4)$$

Phase velocity

$$\omega t - \kappa x = \text{constant}$$

diff. w.r.t

$$\dot{W} - \frac{Kd\sigma}{dt} = 0$$

$$\omega = \frac{kd\varphi}{dt}$$

$$\frac{d\theta}{dt} = \omega$$

$$V_P = \frac{V_0}{R}$$

K (5) phase velocity

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$$V_g = V_p - \lambda \frac{dV_p}{dx}$$

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for small change in wavelength
relation b/w V_g & V_p

from Eqn ④ ~~(4)~~

$$V_g = \frac{\Delta w}{\Delta K} - ④, \quad V_p = \cancel{w} - ⑤$$

$$V_g = \frac{\Delta w}{\Delta K} \approx \frac{dw}{dK}$$

from Eqn ⑤

$$V_g = \frac{d}{dK} (KV_p)$$

$$V_g = V_p + K \frac{dV_p}{dK}$$

we know that $K = \frac{2\pi}{\lambda}$

$$V_g = V_p + K \frac{dV_p}{d\lambda} \frac{d\lambda}{dK}$$

$$V_g = V_p + K \frac{dV_p}{d\lambda} \cdot \frac{d(2\pi/K)}{dK}$$

$$V_g = V_p + K \frac{dV_p}{d\lambda} \left(-\frac{2\pi}{K^2} \right)$$

$$V_g = V_p - \frac{2\pi}{K} \cdot \frac{dV_p}{d\lambda}$$

$$\boxed{V_g = V_p - \lambda \frac{dV_p}{d\lambda}}$$