26/05/22 Vidhi Shah E2 + TE2

Page No.
Date: / /

# Physics Assignment

Q1 Explain the principle, working, energy level diagram and application of He-Ne LASER.

He-Ne LASER is a type of gas laser which consists of a mixture of Helium and Neon gases in the ratio 10:1. Gases are filled in a narrow quartz tube.

→ **Principle:**

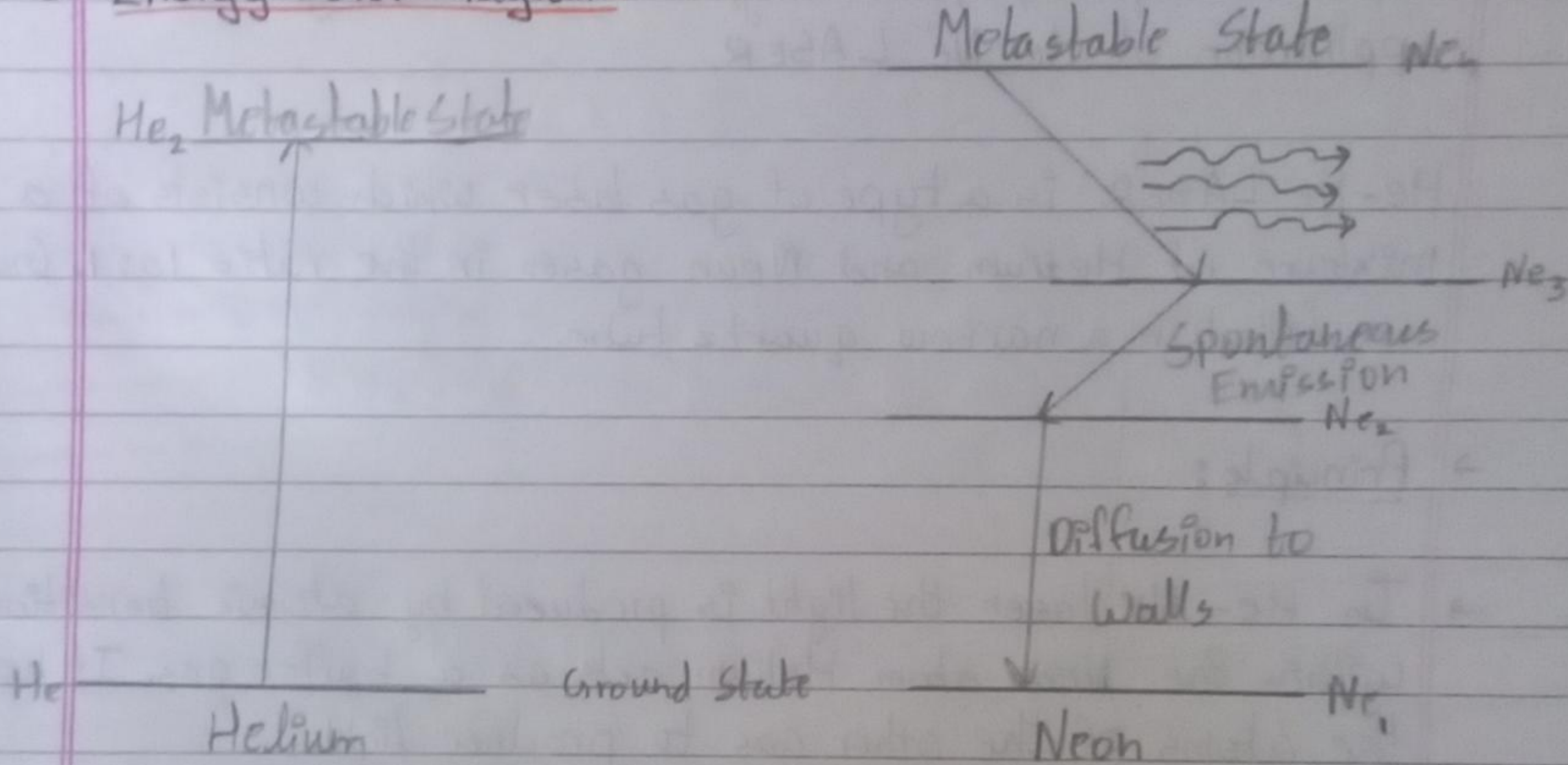
→ In He-Ne laser the light is produced by atomic transitions within the Neon atom. Helium acts as a buffer gas. It helps the atoms of the other gas to produce light

→ Ne atoms act as active centers and He atoms help in the excitation process.

→ **Working:**

- It is a four energy level laser system
- Electrons produced from electric discharge collide with He and Ne atoms and excite them to higher energy levels ($He_2$ and $Ne_3$)
- Since these levels are very close to each other some of the He atoms at He2 state may transfer their energy to ground state Ne atoms and excite them.
- The kinetic energy of atoms provide the additional energy
- Some of the Ne atoms decay spontaneously emitting photons

→ Energy Level Diagram:




→ Applications:

He-Ne laser is used in commercial and industrial applications such as Barcode Scanners, holography. It is commonly used in laboratory demonstrations of optics.

Q2 i) How is LASER light different from a conventional light source?

| LASER Light | Ordinary Light |
| --- | --- |
| → Monochrome, directional, and highly consistent, focused beam in which all photons move with same wavelength | → Mixture of EM waves of different wavelengths, non-directional and non-consistent. |
| → Light Amplification by Simulated Emission of Radiation, Induced emission | → Natural light |
| → Energy is concentrated in a very narrow area | → Intensity decreases rapidly with distance |
| eg:- Used in metal cutting machines, laser printers | eg:- Used in illumination |

Q.iii) In what way the Einstein's work on probability of absorption and emission of an atom is related to LASER?

According to Einstein, interaction of radiation with matter consists of 3 processes: Stimulated absorption, spontaneous emission and stimulated emission.

LASER is an acronym for Light Amplification by Stimulated Emission of Radiation.

- Einstein coefficient for Stimulated Absorption ($B_{12}$):
  ↳ Probability of absorption radiation

Let $R_1$ be the rate of absorption of light by $E_1 \to E_2$ transitions by the process of Stimulate Absorption

$R_1 \propto N_1 E$ , $N_1 \to$ No. of atoms per unit volume in ground state

$\Rightarrow \boxed{R_1 = B_{12} N_1 E}$ — ① $E \to$ Energy density of radiations

↳ Einstein's coeff. of stimulate absorption

- Einstein coefficient for Spontaneous Emission ($A_{21}$):
  ↳ Probability of spontaneous emission

Rate, $R_2$, of spontaneous emission, $E_2 \to E_1$, is independent of energy density, E, of the radiation field.

$R_2 \propto N_2$

$\boxed{R_2 = A_{21} N_2}$ — ②

$N_2 \to$ No. of atoms in excited state $E_2$

↳ Einstein's coeff. for spontaneous emission

- Einstein Coefficient for Stimulated Emission ($B_{21}$):

↳ Probability of Stimulated Emission

$$E_2 - E_1 = h\nu$$

$$R_3 \propto N_2 E$$

$$\Rightarrow \boxed{R_3 = \underbrace{B_{21}}_{\text{Einstein coeff. for stimulated Emission}} N_2} \quad - (3)$$

In steady state, the 2 emission rates must balance the rate of absorption

$$R_1 = R_2 + R_3$$

$$\Rightarrow N_1 B_{12} E = N_2 A_{21} + N_2 B_{21} E$$

$$\Rightarrow (N_1 B_{12} - N_2 B_{21}) E = N_2 A_{21}$$

$$\Rightarrow E = \frac{N_2 A_{21}}{N_1 B_{12} - N_2 B_{21}}$$

$$\Rightarrow E = \frac{\cancel{N_2} A_{21}}{\cancel{N_2} B_{21}\left[\frac{N_1 B_{12}}{N_2 B_{21}} - 1\right]}$$

$$\Rightarrow E = \frac{A_{21}}{B_{21}}\left[\frac{1}{\frac{N_1}{N_2}\frac{B_{12}}{B_{21}} - 1}\right]$$

According to Einstein probability of stimulate absorption is equal to probability of stimulated emission $\Rightarrow B_{12} = B_{21}$

$$\Rightarrow E = \frac{A_{21}}{B_{21}} \left[ \frac{1}{\frac{N_1}{N_2} - 1} \right] \quad -(4)$$

From Boltzmann's distribution law,

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

$$\Rightarrow \frac{N_1}{N_2} = e^{h\nu/KT} \quad -(5)$$

$K \rightarrow$ Boltzmann constant
$h \rightarrow$ Planck's constant

From (4) and (5)

$$\Rightarrow E = \frac{A_{21}}{B_{21}} \left[ \frac{1}{e^{h\nu/KT} - 1} \right] \quad -(6)$$

According to planck's radiation law,

$$E = \frac{8\pi h\nu^3}{c^3} \left[ \frac{1}{e^{h\nu/KT} - 1} \right] \quad -(7)$$

From (6) and (7)

$$\boxed{\frac{A_{21}}{B_{21}} = \frac{8\pi h\nu^3}{c^3}}$$

$\hookrightarrow$ Relation between Einstein's coefficient in LASER

→ This shows that coefficient of stimulated emission of radiation is proportional to the cube of frequency ($\nu^3$)

→ This means that probability of spontaneous emission increase rapidly with the energy difference in 2 states and thus its application in LASER.