GAIN COEFFICIENT

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Main Components

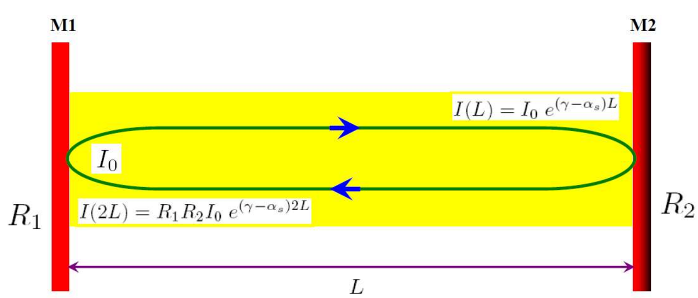
Three main components of **ANY** lasers are

(i) The active medium
(ii) The pumping source
(iii) The optical resonator

- The active medium acts as an **amplifier** for light waves
- For amplification, **medium** should be in a state of **Population inversion**
- Population inversion – **metastable levels** – lifetime is bit longer as compared to excited state
- The active medium placed inside an optical resonator – acts as an **oscillator**
- A pair of mirrors + active medium - optical resonators

Threshold condition for LASING action

- **Output of the active medium bouncing back and forth in the optical resonator.**
- **During amplification it suffers various losses**



The losses occur mainly due to

1.Transmission at the output mirror
2.Scattering, diffraction and absorption of light with in the active medium

- **Proper build up of laser oscillation:** The amplification between two constructive reflections of light from rear end mirror must balance the losses.
- Assume that the active medium of the laser fills the space between the mirrors **M1** and **M2.**
- The reflectivity of both mirrors are **R1** and **R2**
- Mirrors be separated by a distance **L**
- Let the intensity of light beam at **M1** be **I_0**
- Traveling from **M1** to **M2**, the beam intensity increases from

$$I(L) = I_0 \, e^{(\gamma - \alpha_s)L}$$

Where γ is the gain of the laser medium

α_s losses due to scattering, diffraction and absorption in the medium

After reflection at mirror **M2**, the beam intensity will be

$$I(L) = R_2 I_0 \, e^{(\gamma - \alpha_s)L}$$

After complete the round trip the final intensity will be

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

The amplification obtained during the round trip

$$G = \frac{I(2L)}{I_0} = R_1 R_2 \, e^{(\gamma - \alpha_s)2L}$$

The product **R_1R_2** represents the losses at the mirror

The losses are balanced by gain, when the amplification factor

$$G \geq 1$$

It requires that

$$R_1 R_2 \, e^{(\gamma - \alpha_s)2L} \geq 1$$

$$e^{(\gamma - \alpha_s)2L} \geq \frac{1}{R_1 R_2}$$

$$(\gamma - \alpha_s)2L \geq ln \left(\frac{1}{R_1 R_2} \right)$$

$$\gamma - \alpha_s \geq \frac{1}{2L} ln \left(\frac{1}{R_1 R_2} \right)$$

$$\gamma \geq \alpha_s + \frac{1}{2L} ln \left(\frac{1}{R_1 R_2} \right)$$

The above equation is the condition for the lasing action

This equation is determined the threshold value of pumping energy for lasing action

As the pump power is slowly increased, a value of γ_{th} called threshold value is reached and the laser starts oscillations

The threshold value γ_{th} is given by

$$\gamma_{th} = \alpha_s + \frac{1}{2L} ln \left(\frac{1}{R_1 R_2} \right)$$

Gain threshold - $\boldsymbol{\gamma_{th}}$

1. Gain required to just balance the total losses in a gain medium. The loss in gain medium may be due to three factors:
2. Absorption of photons within the gain medium
3. Scattering of photons within the gain medium
4. Transmission of photons through the reflecting mirrors
5. Lasing action begins just above the gain threshold -γ_{th}>α (loss co-eff).
6. For efficient lasing action $\frac{1}{2L} \ln(R_1 R_2) \longrightarrow 0$
7. Which means the mirrors should be highly reflecting (such that the product of their reflectances $R_1 x R_2 \approx 1$) or the optical cavity length should be infinite.
8. The losses (α) due to absorption and scattering in the gain medium cannot be controlled so for perfectly reflecting mirrors and long optical cavity, γ_{th}>α

Laser threshold condition:

- Gain balances the losses within medium
- Stimulated emission begins to dominate spontaneous emission
- Laser action begin with exponential amplification of photons due to sustained oscillations