



ENGINEERING PHYSICS

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ENGINEERING PHYSICS

Unit IV : Application of Quantum Mechanics to Optical Waves: LASERS



Class #40

Round Trip Threshold Gain

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LASERS: Threshold Gain



➤ *Suggested Reading*

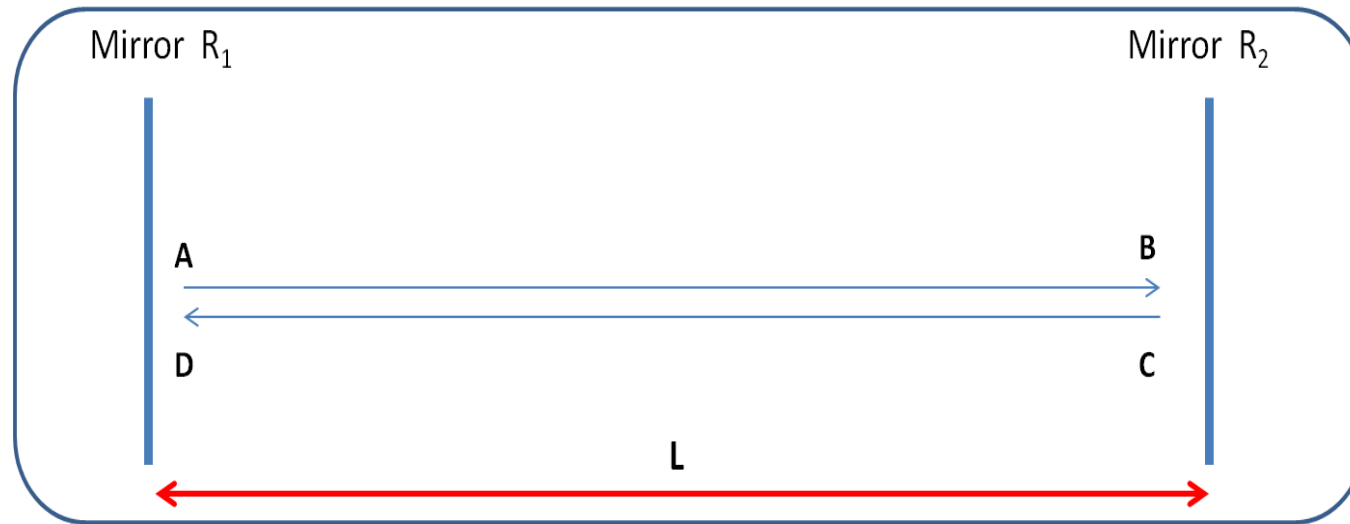
1. Lasers: Fundamentals and Applications

K Thyagarajan, A Ghatak

2. Course material developed by the Department

➤ *Reference Videos*

<https://ocw.mit.edu/resources/res-6-005-understanding-lasers-and-fiberoptics-spring-2008/laser-fundamentals-i/>



- Let R_1 and R_2 be the reflective coefficients of the mirrors
- L , the distance between the mirrors
- Let I_A be the initial intensity of the beam at point A at the first mirror
- As the beam travels its intensity is proportional to

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Round Trip Threshold Gain

$$I \propto e^{(g-\alpha)l}$$

where g is the gain coefficient

α is the loss coefficient

and l is the length of traverse

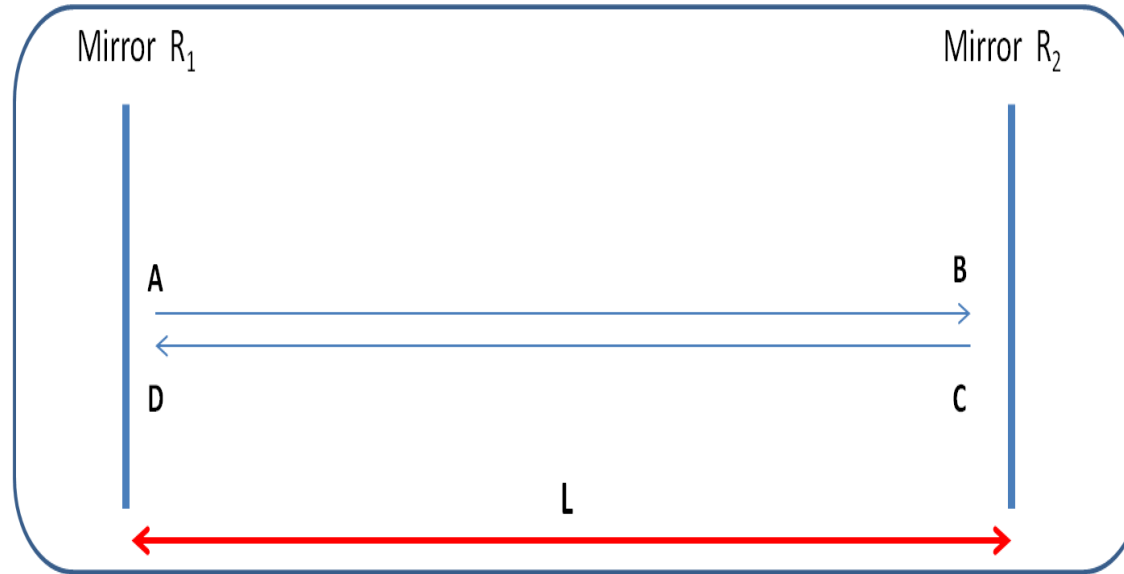
$$I_A = I_{\text{initial}}$$

$$I_B = I_{\text{initial}} e^{(g-\alpha)l}$$

$$I_C = R_2 I_B = R_2 I_{\text{initial}} e^{(g-\alpha)l}$$

$$I_D = R_2 I_{\text{initial}} e^{(g-\alpha)2l}$$

$$I_{\text{final}} = I_{\text{initial}} R_1 R_2 e^{(g-\alpha)2l}$$



So we started with an intensity of $I_{initial}$

and after a traverse of length $2l$

and two reflections the final intensity is $I_{final} = R_1 R_2 e^{(g-\alpha) 2l}$

$$Gain = \frac{I_{final}}{I_{Initial}} = \frac{I_{initial} R_1 R_2 e^{(g-\alpha) 2l}}{I_{initial}}$$

*In a round trip, even if we achieve
a marginal gain compared to the loss,
over billions of such trips,
the total gain would be significant*

*We define the threshold gain coefficient g_{th}
such that over a round trip the Gain is 1*

$$1 = \frac{I_{initial} R_1 R_2 e^{(g_{th} - \alpha) 2l}}{I_{initial}} \quad 1 = R_1 R_2 e^{(g_{th} - \alpha) 2l}$$

$$e^{(g_{th} - \alpha) 2l} = \frac{1}{R_1 R_2} \quad (g_{th} - \alpha) 2l = \ln \left(\frac{1}{R_1 R_2} \right)$$

$$(g_{th} - \alpha) = \frac{1}{2l} \ln \left(\frac{1}{R_1 R_2} \right)$$

Threshold Gain Coefficient

$$g_{th} = \alpha + \frac{1}{2l} \ln \left(\frac{1}{R_1 R_2} \right)$$

Check Your Understanding (Yes/No)

- 1. Over one round trip, the gain should be much greater than 1.*
- 2. Threshold gain depends on the quality of the mirrors.*
- 3. The loss coefficient is generally very small*
- 4. The intensity is exponentially dependent on length traversed by the beam*



THANK YOU

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