



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

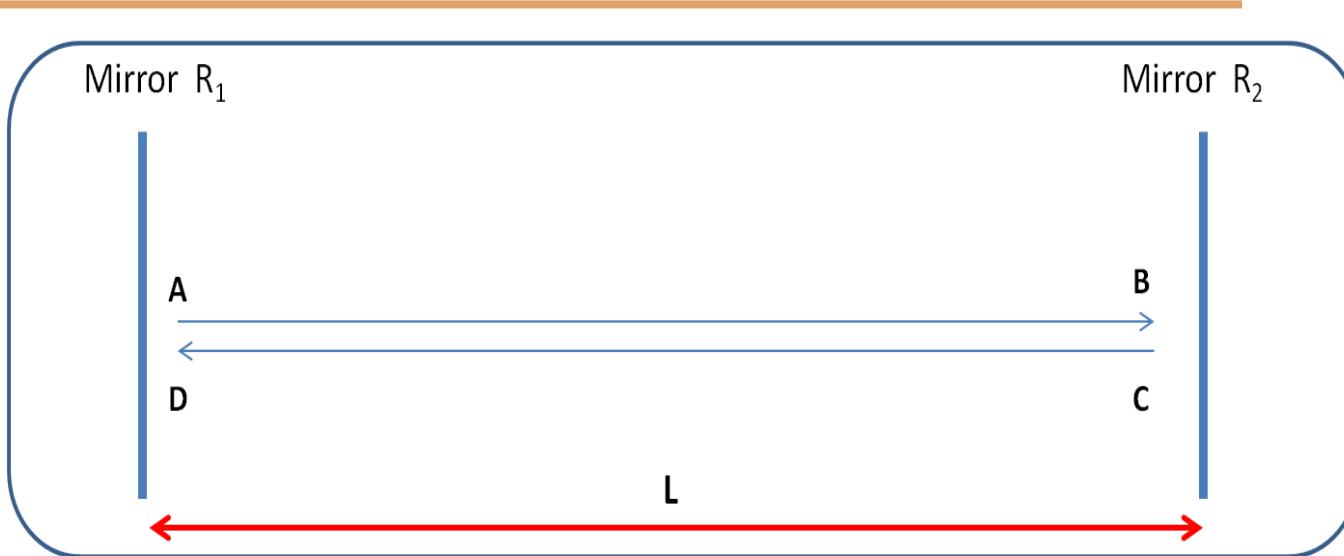
2. Course material developed by the Department

➤ *Reference Videos*

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

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Round Trip Gain



- 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

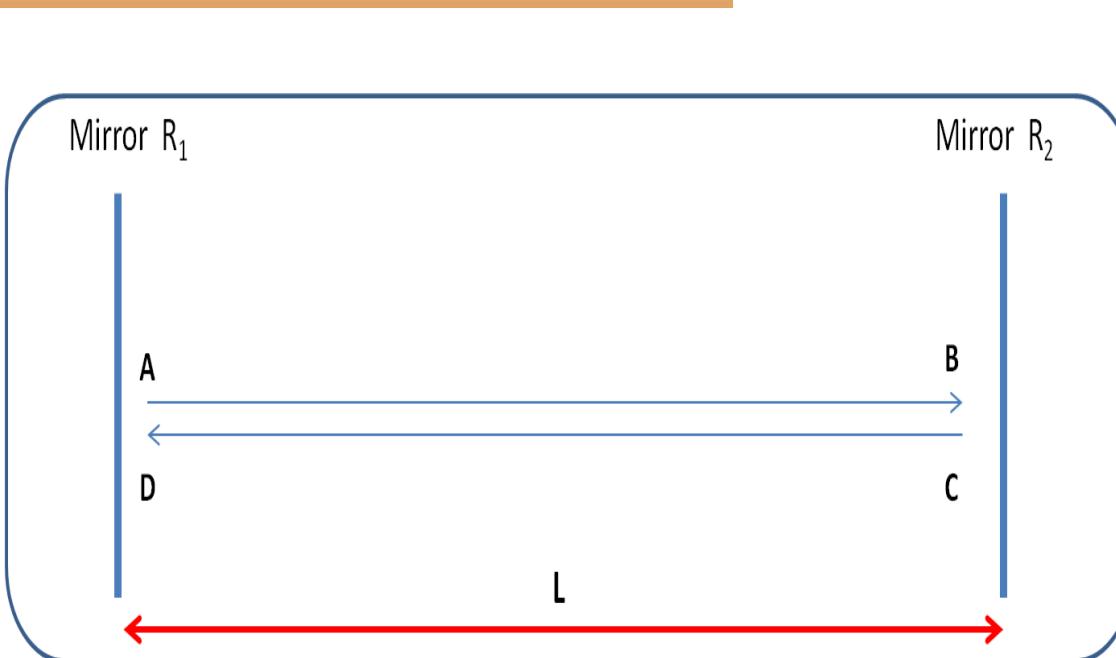
$$I_A = I_{\text{initial}}$$

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

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

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

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



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Round trip Threshold Gain

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

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

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

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

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

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

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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