ENGINEERING PHYSICS

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Department of Science and Humanities

- Class #39

Gain and loss in laser systems

1. Gain in a cavity
2. Laser Comb
3. Line Broadening
4. Losses in the cavity

- ***Suggested Reading***

1. Lasers: Fudamentals and Applications

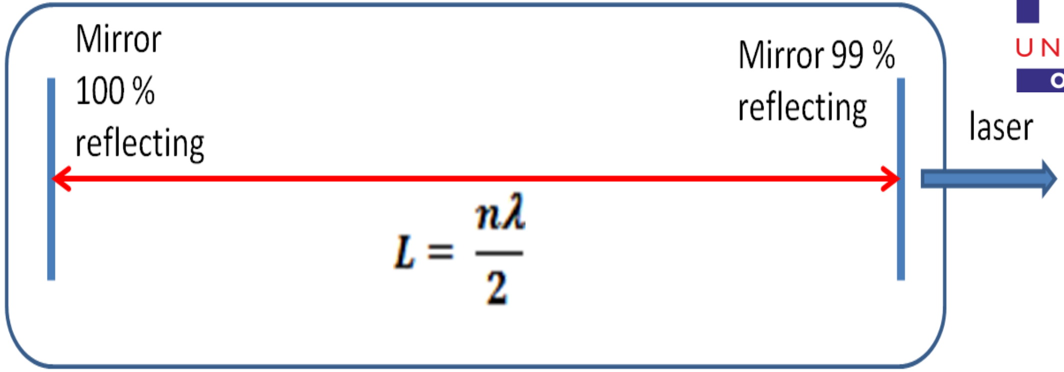
K Thyagarajan, A Ghatak

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/*](https://ocw.mit.edu/resources/res-6-005-understanding-lasers-and-fiberoptics-spring-2008/laser-fundamentals-i/)

Resonating Cavity



- Consists of two mirrors of various geometries and coatings creating standing waves

- Because of the energy amplification due to stimulated emission

- The laser comes out of the partially reflecting mirror

- Photons travelling in directions not perpendicular to the mirrors are not amplified

Resonating Cavity: Frequency Comb

$$n_1\lambda_1 = 2L$$

$$n_2\lambda_2 = 2L$$

$$n_3\lambda_3 = 2L$$

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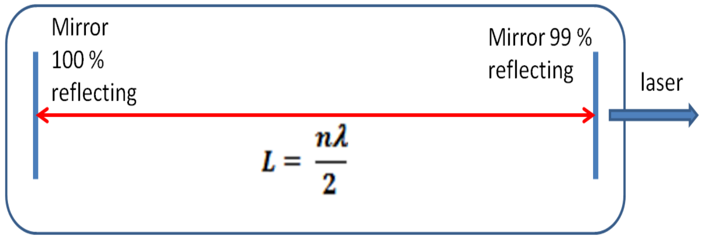
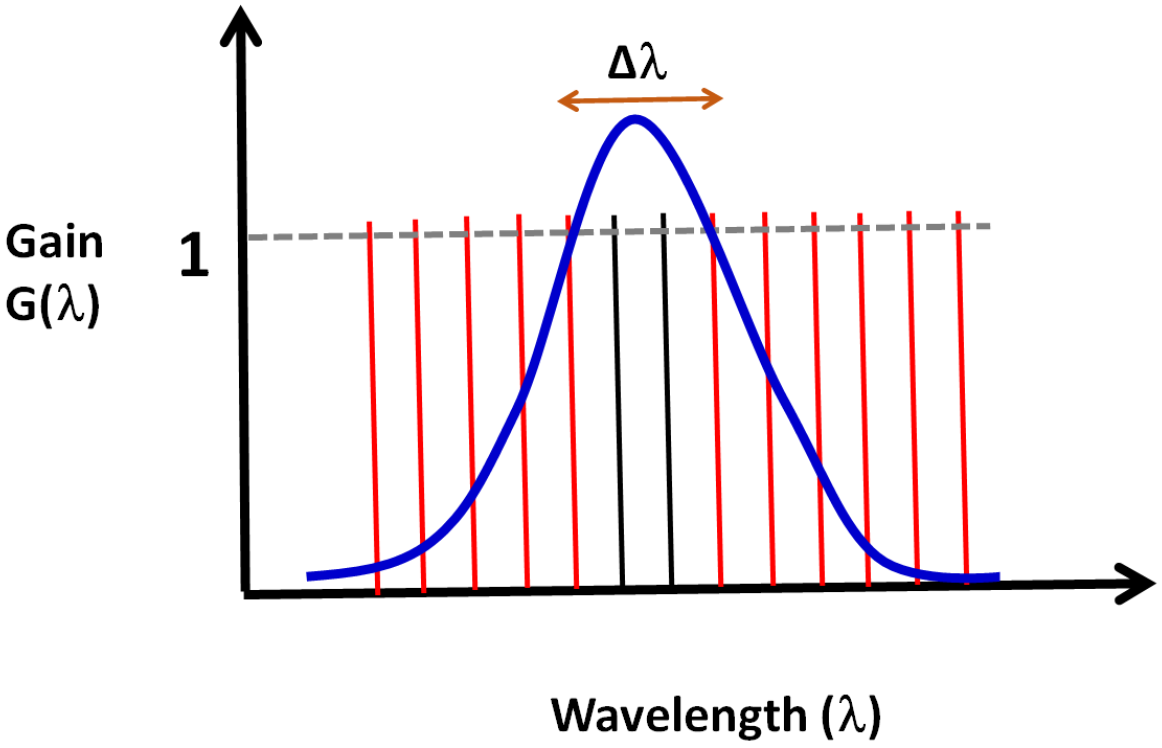




Gain is a function of wavelength

Laser Line width Broadening

1. Frequency comb and gain curve broadening
2. Doppler Broadening
3. Pressure broadening
4. Inhomogeneous broadening
5. Quantum noise
6. Design flaws

Losses in the cavity

1. Scattering(greater at shorter wavelengths)
2. Absorption in the beam path
3. Diffraction losses
4. Mirror losses

Round Trip Threshold Gain

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

where g is the gain coefficient

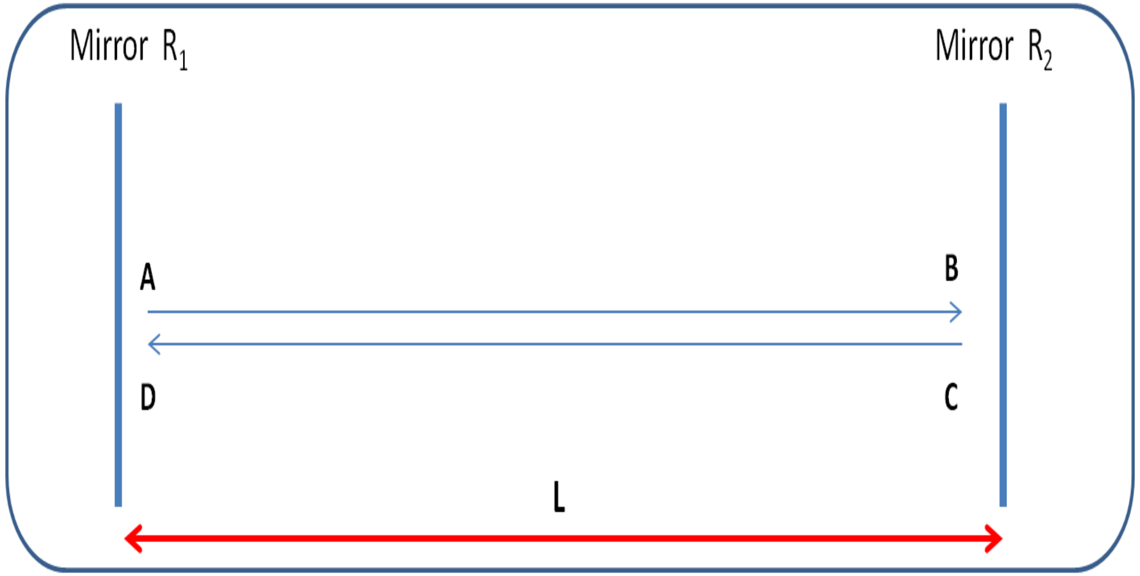
α is the loss coefficient

and l is the legth of traverse

$I_A = I_{initial}$

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

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



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 $I_{final} = R_1R_2 e^{(g-\alpha) 2l}$

$$Gain = \frac{I_{final}}{I_{Initial}} = \frac{I_{initial}R_1R_2 e^{(g-\alpha) 2l}}{I_{initial}}$$

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

Check Your Understanding (Yes/No)

1. *Line width for a good laser is very small*

2. *Doppler effect causes broadening of the line*

3. *Shape of the gain curve may affect the line width*

4. *Lasers are generally low loss systems*

THANK YOU

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