AL- Mustaqpal University
Science College
Dep. Medical physics

Medical physics
Third Stage

Lec 10

Optical cavity and laser gain

م . م علي سـلمان حمادي

Optical Cavities (Resonator)

For some people, the expression **spot size of a laser beam** means its smallest diameter at the focal plane when focused by a lens, whereas for other people they mean the laser beam's diameter when it exits the laser, or at any other place where they need to measure it.

It is important to make a distinction between the two cases because the approach to measurement is different.

Round trip Gain (G)

Figure below show the round trip path of the radiation through the laser cavity. The path is divided to sections numbered by 1-5, while point "5" is the same point as "1".

Round trip gain, determines if the output power of the laser will increase, decrease, or remain constant. It includes all the losses and amplifications that the beam has in a complete round trip through the laser.

By definition, Round trip Gain is given by:

$$G = I_5 / I_1$$

G = Round trip Gain.

I_1 = Intensity of radiation at the beginning of the loop.

I_5 = Intensity of radiation at the end of the loop.

OPTICAL RESONATORS AND EIGENMODES

Important Concepts

- Stability
- Resonance (Eigen modes)
- Photon Lifetime

Optical cavities

The optical cavities (also known as optical resonators) are made to amplify the light within the cavity, so the mirrors used are highly reflective. Essentially, light enters the cavity through one mirror, reflects off the opposite mirror, and returns to the first mirror, while some of it is transmitted (exits the cavity) through each mirror. This light transmitted through the first mirror in each arm is the light that interferes at the beam splitter to form the signal.

Various types of optical resonators The cavity is designed so that the beam will remain entirely within the cavity's mirrors. These are referred to as follows where $\mathbf{R_1}$ and $\mathbf{R_2}$ are the radii of curvature of the mirrors and L is the distance between the mirrors:

a) plane-parallel $R1=R2=\infty$

b) concentric (spherical) $R1+R2=L$

c) confocal $R1+R2=2L$

d) hemispherical $R1=L, R2=\infty$

e) concave-convex $R1>>L, R2=L-R1$

There are five different types of stable two-mirror optical cavities, as shown in Figure 1. These types of resonators differ in their focal lengths of the mirrors (governed by the mirror's radius of curvature) and in their distance between the mirrors (cavity length). As you can see from Figure 1, some beams have different shapes within the cavity and are thus chosen for different purposes.

There are simple mathematical formulae that indicate whether or not a cavity is stable. In its simplest form, the rule can be stated as follows: Given a cavity made of two spherical mirrors (of radii of curvature R1 and R2) separated by a distance L, the cavity is stable .

Threshold Gain Coefficient: To sustain laser oscillations the gain coefficient must be at least large enough to overcome the losses in the laser system. The sources of loss include the following:

1. Transmission, absorption and scattering by the mirrors.

2. Diffraction around the boundary of the mirrors.

3. Absorption and scattering in the laser active medium.

The minimum or threshold gain coefficient kth required from the condition that the round trip gain G in the irradiance of the beam must be at least unity. If G < unity then the oscillations would die out, and G > unity then the oscillations would grow. In traveling from M1 to M2 in the laser resonator cavity, the beam irradiance increases from $\mathbf{I_o}$ to $\mathbf{I}$

The spot size of a laser beam cutter ranges from 15 µm to 170 µm (0.003 to 0.007 inches), depending on the lens you are mounting. The shorter the focal length of the lens, the smaller the spot, which allows for the engraving of finer details. However, smaller spots are not suitable for working with thick materials.

Discussion

1. What does the term "spot size" of a laser beam typically refer to?

A. The smallest diameter of the beam at the focal plane

B. The diameter of the beam as it exits the laser

C. The beam's diameter at any measurement point

D. All of the above, depending on context

E. None of the above

Correct Answer: D

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2. What is the formula for Round Trip Gain (G)?

A. $G=I_1/I_5$

B. $G=I_5/I_1$

C. $G=I_1 \times I_5$

D. $G=I_5-I_1$

E. $G=I_1+I_5$

Correct Answer: B

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3. What happens to the laser's output power when the Round Trip Gain GG is less than unity?

A. The output power increases

B. The output power decreases

C. The output power remains constant

D. The beam splits into multiple paths

E. The gain reaches threshold

Correct Answer: B

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4. What is the primary purpose of optical cavities?

A. To scatter light outside the cavity

B. To amplify light within the cavity

C. To increase the wavelength of light

D. To focus light into a single point

E. To block incoming light

Correct Answer: B

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5. In which type of optical resonator are the radii of curvature of the mirrors infinite?

A. Plane-parallel

B. Concentric

C. Confocal

D. Hemispherical

E. Concave-convex

Correct Answer: A

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6. Which of the following is NOT a source of loss in a laser system?

A. Scattering in the laser active medium

B. Transmission by the mirrors

C. Light reflection within the cavity

D. Diffraction around the boundary of mirrors

E. Absorption by the mirrors

Correct Answer: C

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7. For a stable two-mirror cavity, which relationship must be satisfied?

A. R1+R2=0

B. R1+R2≥L

C. R1+R2≤2L

D. R1+R2=∞

E. None of the above

Correct Answer: C

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8. Which type of optical resonator has R1=L and R2=∞ ?

A. Plane-parallel

B. Concentric

C. Confocal

D. Hemispherical

E. Concave-convex

Correct Answer: D

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9. What determines whether laser oscillations will grow or die out?

A. Spot size

B. Photon lifetime

C. Threshold gain coefficient

D. Resonance frequency

E. Laser power supply

Correct Answer: C

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10. What is the typical spot size range for a laser beam cutter?

A. 1 μm to 10 μm

B. 10 μm to 100 μm

C. 15 μm to 170 μm

D. 100 μm to 300 μm

E. None of the above

Correct Answer: C