University of Mosul
College of science
Department of Physics
Third Stage
Lecture 5

Laser

2024-2025

Lecture 5: The Resonator

Preparation
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2. The Resonator:

To make an oscillator from an amplifier, it is necessary to introduce suitable positive feedback. In the case of lasers, the feedback is obtained by placing the active material between two highly reflecting mirrors (e.g., plane parallel mirrors).

In this case; a plane e.m. wave traveling in the direction perpendicular to the mirrors will bounce back and forth between two mirrors and be amplified on each passage through the active material. If one of the two mirrors is made partially transparent, a useful output beam is obtained from this mirror. It is important, to realize that certain **threshold condition** must be reached.

Threshold condition → for instances the oscillation will start when the gain of the active material compensates the losses in the laser.

If a plane wave with a photon flux F is travelling along the z direction, the elemental change, df, of the flux along the elemental length dz of the material is given as:

$dF = \sigma_{21} F[N_2 - N_1]dz$ the gain per pass in the active material

$\frac{dF}{F} = \sigma_{21} F[N_2 - N_1]dz$ i.e., the ratio between the output and input photon flux

Taking the integration of last equation, and for simplicity $\sigma_{21} = \sigma_{12} = \sigma$ and L is the length of the active material, the flux is:

$F\exp(\sigma (N_2 - N_1)L)$ …………………. 11

If R_1 and R_2 → power reflectivity of the two mirrors

L_i → internal loss per pass in the laser cavity.

F → the photon flux in the cavity, leaving mirror 1 and toward mirrors2.

F' → photon Flux again leaving mirror 1 after one round trip

$F' = F \exp\sigma\{(N_2 - N_1)L\} \times R_2 - F \exp\sigma\{(N_2 - N_1)L\} \times R_2 L_i \times F\exp\sigma\{(N_2 - N_1)L\} \times R_1 - F \exp\sigma\{(N_2 - N_1)L\} \times R_1 L_i$ ………..12

$F' = F \exp\sigma \{(N_2\text{-}N_1) L\} x (1\text{- }L_i) R_2 \text{ x } \exp \{\sigma(N_2\text{-}N_1) L\} x(1\text{-}L_i) R_1$ …. 12.a

at threshold $F' = F$

Therefor:

$$R_1R_2 (1\text{-}L_i)^2\exp\{2\sigma(N_2 - N_1)L\} = 1 \qquad \text{……….. 13}$$

This equation shows that threshold is reached when the population inversion, *N* or N_c reaches a critical value, known as the **critical inversion**:

$N_C = N_2 - N_1$

$$\therefore \quad N_C = - [\ln R_1R_{2+} 2\ln(1\text{-}Li)] / 2\sigma L \qquad \text{..………14}$$

once the critical inversion is reached, oscillation will build up from spontaneous emission. the photons that are spontaneously emitted along the cavity axis will, in fact initiate the amplification process. this is the basic of a laser oscillator or laser.

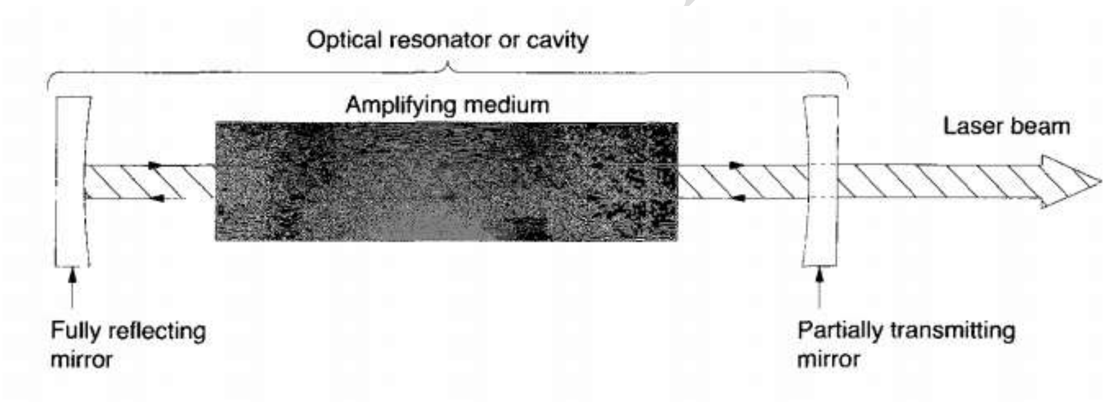

Figure (3): simple concept of resonator

The word laser, now commonly applied to any device emitting stimulated radiation, whether in the far or near infrared, ultraviolet, or even in the x-ray region.

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