Introductory Lecture

First, What are **standing waves.**
•What are the conditions for creating standing waves.
•How standing waves in a laser cavity are determined by the laser design.
Second, the properties of the optical signal which is amplified while passing back and force through the active medium are discussed.
Third, **longitudinal modes a**re created in the laser cavity.
Their importance and methods for controlling them.
Forth, the distribution of energy along the cross section of the beam, which determine the **transverse modes.**
At the end describing the **common optical cavities**
and the way to test their stability.

Two waves of the same frequency and amplitude are moving in opposite directions, which is the **condition for creating a standing wave**.

Remember that the electromagnetic waves inside the laser cavity are 3 dimensional, and are moving along the optical axis of the laser.

Create A Standing Wave

- The optical path from one mirror to the other and back must an **integer multiplication of the wavelength**.
- The wave must start with the same phase at the mirror
- The Length between the mirrors is constant (L), the suitable wavelengths, which create standing waves, must fulfill the condition: l_m **= 2L/m**

L = Length of the optical cavity.

m = Number of the mode, which is equal to the number wavelengths inside the optical cavity

l_m = Wavelength of mode m inside the laser cavity.

Wavelength in matter **(**l_m**)** is equal to: $l_m = l_0/n$

l_0 = Wavelength of light in vacuum.

n = **Index of refraction** of the active medium.

c = Velocity of light in vacuum.

Wavelength in matter **(λ_m)** is equal to: $\lambda_m = \lambda_0/\mathbf{n}$

Since: $\mathbf{c} = \lambda_0 \nu = \mathbf{n}\lambda_m \nu_m$

The **frequency** of the longitudinal mode

$$\nu_m = \frac{c}{n\lambda_m}$$

Inserting λ_m into the last equation:

$$\nu_m = m \cdot \left(\frac{c}{2 \cdot n \cdot L} \right)$$

The **first mode of oscillation** : $\nu_1 = \dfrac{c}{2 \cdot n \cdot L}$

This mode is called **basic longitudinal mode**, and it has the **basic frequency of the optical cavity**.

Basic Longitudinal

frequency of longitudinal modes is:

$$\nu_m = m \cdot \left(\frac{c}{2 \cdot n \cdot L} \right)$$

The mathematical expression in parenthesis is the **first mode of oscillation** available for this

$$\nu_1 = \frac{c}{2 \cdot n \cdot L}$$

This mode is called **basic longitudinal mode**, and it have the basic frequency of the optical cavity.

Conclusion:

The frequency of each laser mode is equal to integer (mode number m) times the frequency of the basic longitudinal mode.

From this conclusion it is immediately seen that

The difference between frequencies of adjacent modes (mode spacing) is equal to the basic frequency of the cavity: $(\Delta n) = c/(2nL)$

Attention !

Until now it was assumed that the index of refraction (n) is constant along the optical cavity.

This assumption means that the length of the active medium is equal to the length of the optical cavity.

There are lasers in which the mirrors are not at the ends the active medium, so L_1 is not equal to the length of the cavity (L).

In such case each section of the cavity is calculated separately, with its own index of refraction:

MS = Mode Spacing.

$$\Delta\nu_{MS} = \frac{c}{2 \cdot n_1 \cdot L_1 + 2 \cdot n_2 \cdot L_2}$$