Condition For Steady State Oscillation

The light amplification implies a continuous and marked increase in amplitude of light wave. To achieve proper amplification, the wave making round trip should maintain both phase and amplitude conditions. It is necessary that the wave returning to some point in the medium must have same phase as that of original wave with any number of reflections within the cavity.

It ~~must~~ implies that the phase delay must be some multiple of "2π" i.e optical path length travelled by wave between two consecutive reflections at the same end mirror should be integral multiple of ~~(x)~~ 'λ' wavelength.

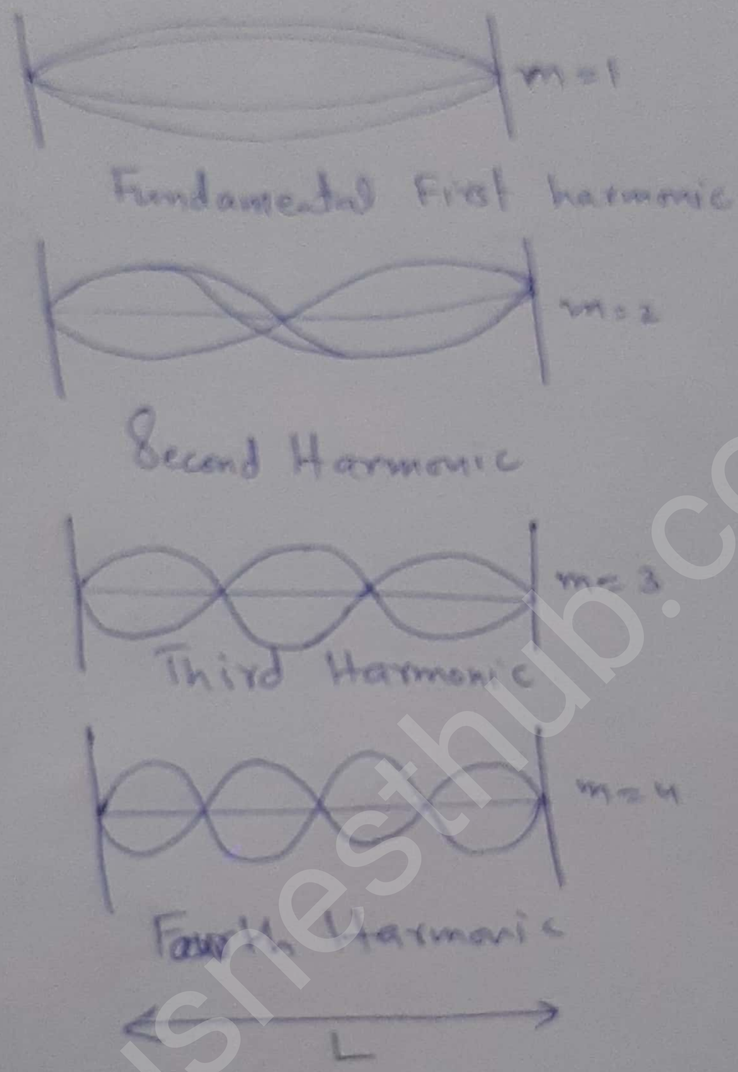
This ~~imposes~~ imposes a certain condition on the relationship b/w the wavelength 'λ' and the length of the laser rod 'L' given by

$$2nL = m\lambda \quad (1)$$

'n' is refractive index of active medium

The cavity length therefore, puts the restriction that only those light waves which satisfy the above condition, the integral multiple of 'λ' within twice the cavity length are amplified strongly and other wavelengths are attenuated

Thus, the cavity of length 'L' should accomodate integral number of standing waves



From Eq (1)

$$2nL = m\lambda$$

$$\boxed{L = \frac{m\lambda}{2n}} \quad (2)$$

Cavity Resonance Frequencies

The cavity will be resonant for those waves which fit an integral multiple of half the wavelength

$$\lambda_m = \frac{2nL}{m} \qquad (1)$$

In terms of frequency.

$$\nu_m = \frac{mc}{2nL} \qquad (2)$$

Theoretically, the cavity resonants at very large frequency as shown in example:

If $L = 0.5\,m$, $\lambda = 500\,nm$, $n = 1.5$

then $\nu_m = 3 \times 10^6$ frequencies.

The spacing between any two neighboring frequencies may be given as:

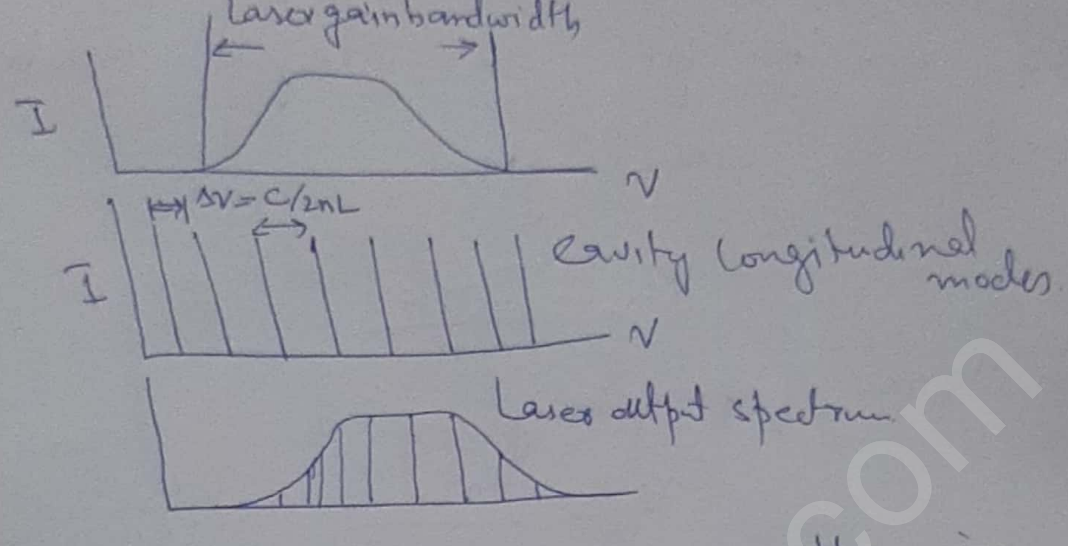
$$\Delta\nu' = \nu_{m+1} - \nu_m = \frac{c}{2nL} \qquad (3)$$

. $\Delta\nu$ is linewidth of radiation, the number of resonant frequencies within the cavity is

$$N = \frac{\Delta\nu}{\Delta\nu'} = \frac{2nL\Delta\nu}{c} \qquad (4)$$

number of resonant frequencies

The resonator therefore, transform a gain line into a set of narrow lines



Equation (3) can also be written in terms of 'λ'

$$\Delta\lambda = \lambda \frac{\Delta\nu}{\nu} = \lambda^2 \frac{\Delta\nu}{c} \quad \left(\text{using } \frac{\Delta\nu}{\nu} = \frac{\Delta\lambda}{\lambda} \text{ and } \nu = \frac{c}{\lambda}\right)$$

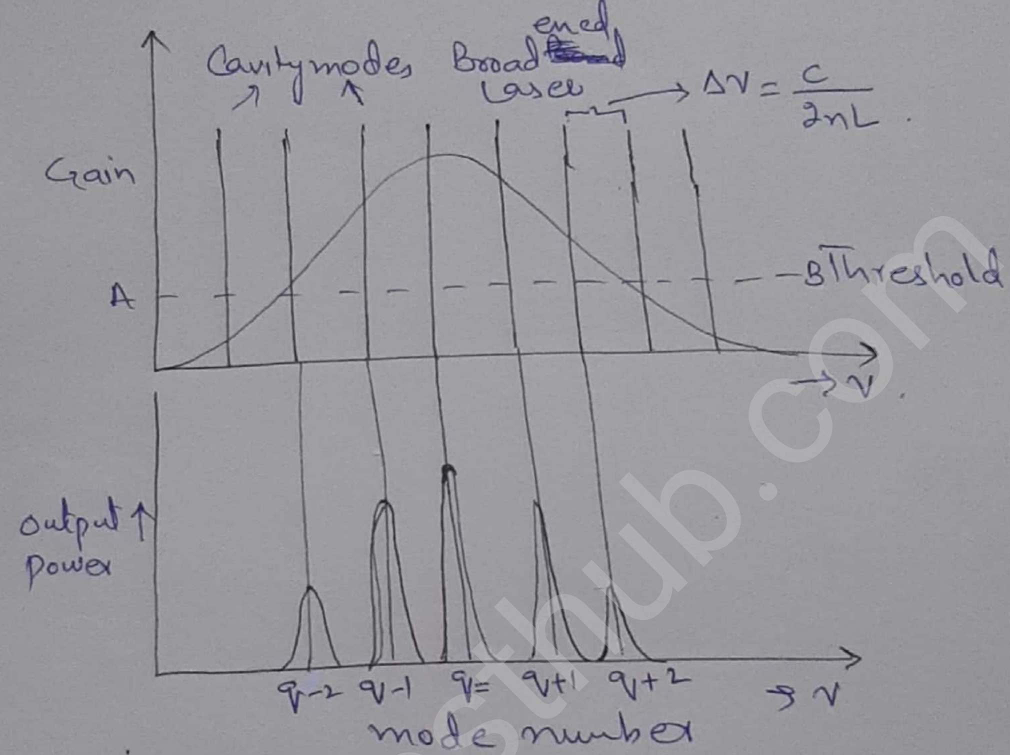
$$\Delta\lambda = \lambda^2 \left(\frac{c}{2nL}\right)\frac{1}{c}$$

$$\boxed{\Delta\lambda = \frac{\lambda^2}{2nL}} \quad (5)$$

Cavity Gain Bandwidth

Ideally a group of same frequencies radiate within the cavity by stimulated emission. However due to line broadening mechanism, there is a small spread of frequencies about the central wavelength called bandwidth

The limitted range of frequencies over which stimulated emission can provide sufficient gain is called emission bandwidth. This is also Known as gain profile.



Line AB = cavity loss level.

The curve above line AB include the area of the net gain for the laser.

The gain bandwidth ΔV is measured at at the cavity loss level. Thus, ΔV constit the range of frequencies for which the gain exceeds the cavity losses.