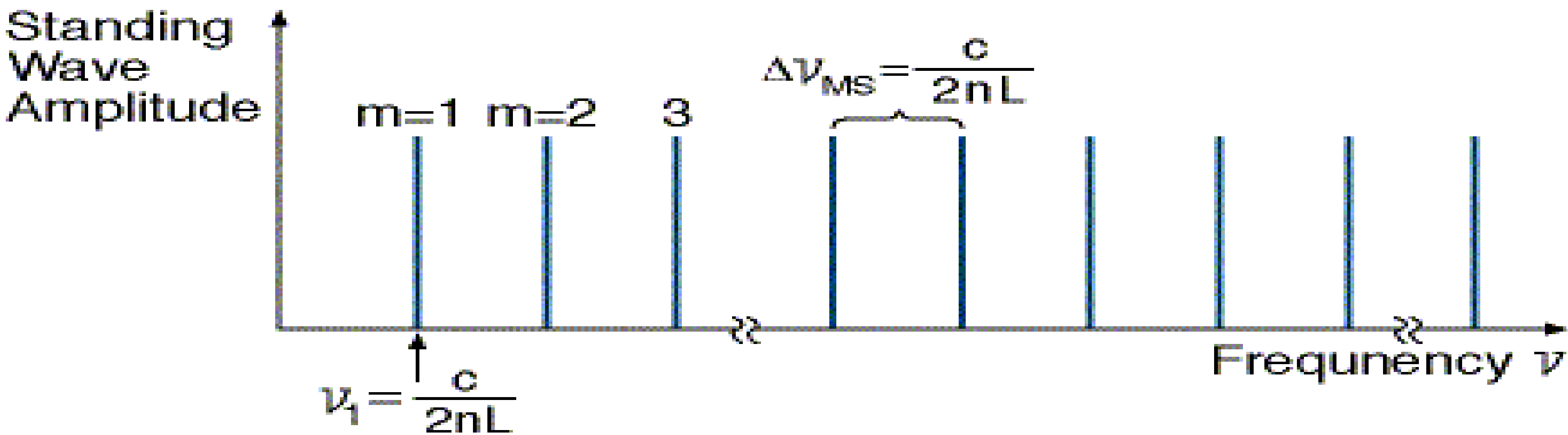
Allowed Frequencies inside a Laser Cavity



Allowed Longitudinal modes inside a Laser Cavity of length (L) and index of refraction (n).

In practice, the frequencies are not defined mathematically as single frequencies, but each have a **width of frequencies** around the possible modes,

Longitudinal modes are standing waves along the optical axis of the laser.

The **standing waves** inside a laser are created when the electromagnetic radiation is forced to move back into the cavity from the mirrors.

The allowed frequencies inside an optical cavity are determined by the length of the cavity (L) and the index of refraction of the active medium.

Only those frequencies which create **nodes at both mirrors** are allowed. Thus, the cavity length must be an integer multiplication of half their wavelengths.

The allowed frequencies are spaced at constant interval, which is equal to the basic frequency of the cavity.

The **transverse distribution of intensity**

Are modes in cross section of the beam, perpendicular to the optical axis of the laser.

These **transverse modes** are created by the width of the cavity, which enables a few diagonal modes to develop inside the laser cavity.

A little misalignment of the laser mirrors causes different path length for different rays inside the cavity.

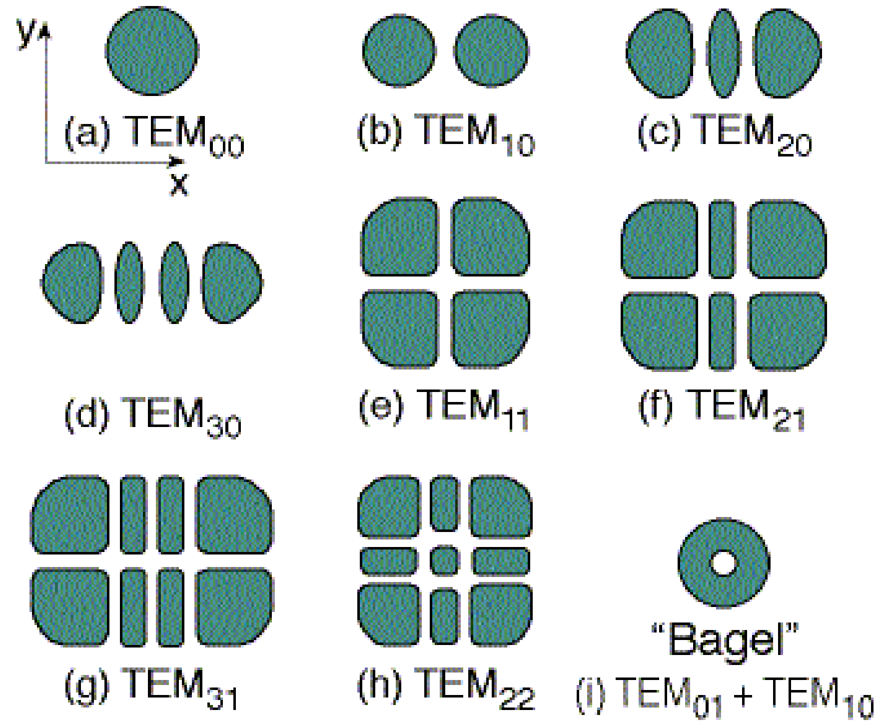
Shape of Transverse Electromagnetic Modes

Transverse Electro-Magnetic (TEM) Modes

The dark areas mark places where laser radiation hit.

When the laser output power is of the order of several

distribution of energy in the beam
cross section can be measured by
a short illumination of a stick
of wood with the laser.



Optical Cavity In every laser cavity

There are different shapes of mirrors, with different lengths between them.

A specific optical cavity is determined by the active medium used, the optical power in it, and the specific application.

The explanation here will summarize the **design principles of an optical cavity:**

Losses inside optical cavity.
Common optical cavities.
Stability criterion of laser optical cavity .

Optical Cavity - Laser Cavity - The region between the end mirrors of the laser.

Optical Axis -The imaginary line connecting the centers of the end mirrors, and perpendicular to them. **The optical axis is in the middle of the optical cavity**.

Aperture -The beam diameter limiting factor inside the laser cavity. Usually the aperture is determined by the diameter of the active medium, but in some lasers a pinhole is inserted into the laser cavity to limit the diameter of the beam. An example is the limiting aperture for achieving single mode operation of the laser

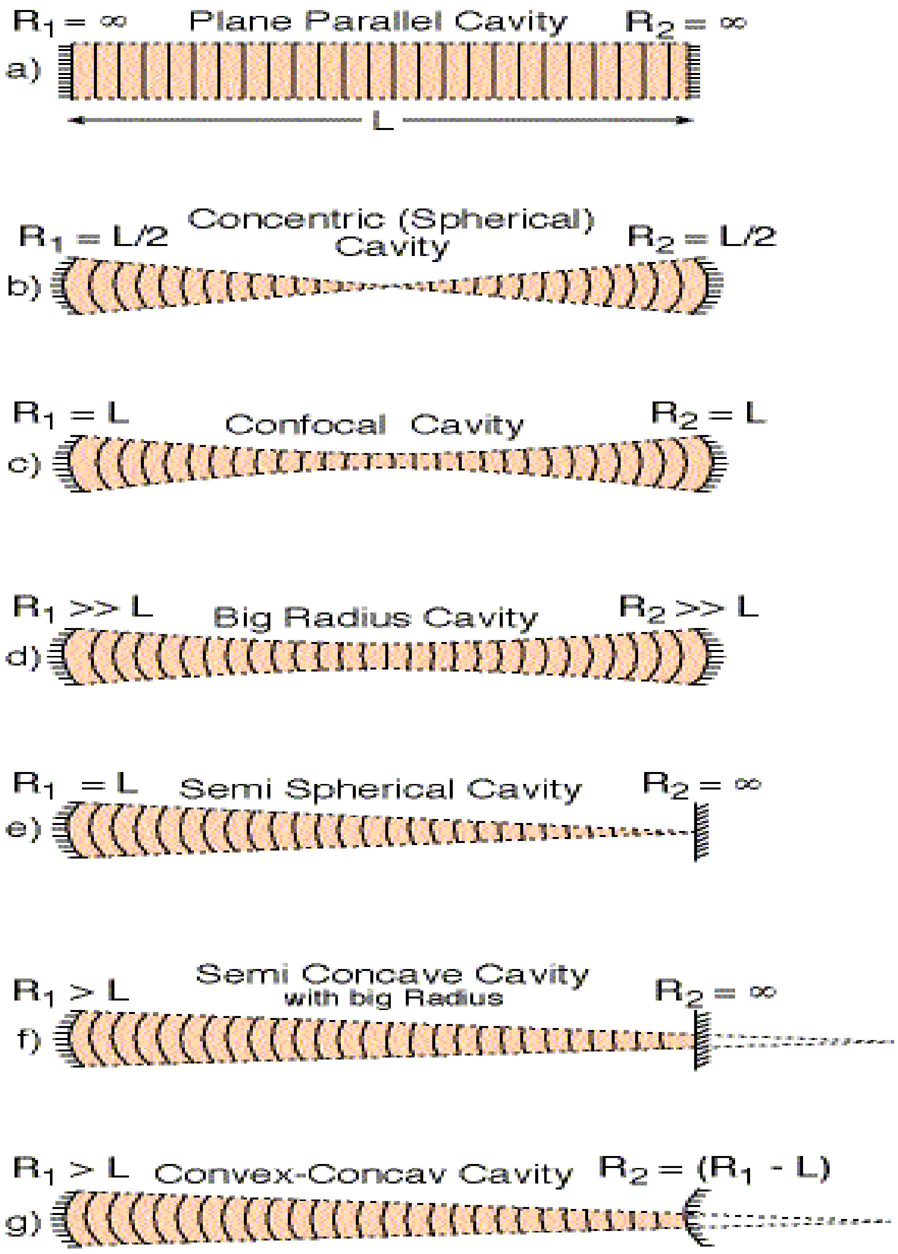
Losses inside Optical Cavity - Include **all the radiation missing from the output of the laser** (emitted through the output coupler).

The gain of the active medium must overcome these losses

Losses inside an optical cavity Misalignment of the laser mirrors –

- **The cavity mirrors are not exactly aligned perpendicular** to the laser axis, and parallel to each other (symmetric), the radiation inside the cavity will not be confined during its path between the mirrors.
- **Absorption, scattering and losses in optical elements** - Since optical elements are not ideal, each interaction with optical element inside the cavity cause some losses.
- **Diffraction Losses** - Every time a laser beam pass through a limiting aperture it diffract. It is not always possible to increase the aperture for reducing the diffraction. As an example, such increase will allow lasing in higher transverse modes which are not desired

The most common optical cavities



Stability Criterion of the cavity A stable cavity

Is a cavity in which the radiation is captured inside the cavity, creating standing waves while the beam move between the mirrors.

The geometry of the cavity determines if the cavity is stable or not.

It is possible to use **unstable resonator** only if the active medium have high gain, since the beam pass through the active medium less times than in stable cavity.

For determining stability of a cavity, a stability criterion need to be defined.

Stability Diagram of an Optical Cavity

The stability criterion for laser cavity is: **$0 < g_1 * g_2 < 1$**

$g_1 = 1 - L/R_1$ $g_2 = 1 - L/R_2$

In the stability diagram the geometric parameters of the mirrors are the axes x and y.

Figure show the **stability diagram** of all laser cavities.