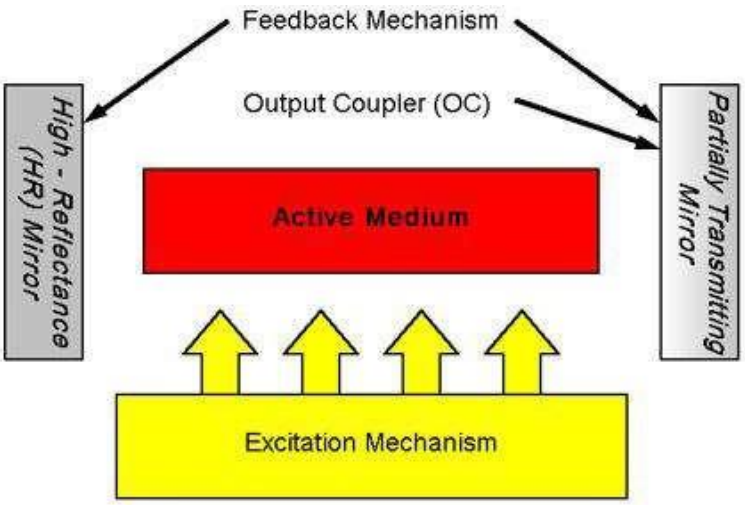
Lecture (6)

ELEMENTS OF A LASER

Four functional elements are necessary in lasers to produce coherent light by stimulated emission of radiation.(Figure 1)illustrates these four functional elements



)Figure 1 Elements of a laser)

ACTIVE MEDIUM

The active medium is a collection of atoms or molecules that can be excited to a state of inverted population; that is, where more atoms or molecules are in an excited state than in some lower energy state. The two states chosen for the lasing transition must possess certain characteristics. First, atoms must remain in the upper lasing level for a relatively long time to provide more emitted photons by stimulated emission than by spontaneous emission. Second, there must be an effective method of "pumping" atoms from the highly-populated ground

state into the upper lasing state in order to increase the population of the higher energy level over the population in the lower energy level. An increase in population of the lower energy level to a number above that in the high energy level will negate the population inversion and thereby prevent the amplifications of emitted light by stimulated emission. In other words, as atoms move from the upper energy level to the lower energy level, more photons will be lost by spontaneous emission-giving off randomly directed, out-of-phase light-than gained due to the process of stimulated emission

The active medium of a laser can be thought of as an optical amplifier. A beam of coherent light entering one end of the active medium is amplified through stimulated emission until a coherent beam of increased intensity leaves the other end of the active medium. Thus, the active medium provides optical gain in the laser.

The active medium may be a gas, a liquid, a solid material, or a junction between two slabs of semiconductor materials

A ruby crystal was the active medium of the first laser, invented by Dr. Theodore Maiman at the Hughes Laboratories in 1960. Liquid active media in tunable dye lasers consist of certain dyes dissolved in ethyl or methyl alcohol. Other active media include many types of gases and mixtures of gases. Lasers that contain a mixture of helium and neon gases or carbon dioxide gas are

common examples of a gaseous active medium. A pn semiconductor junction, composed of gallium arsenide or gallium phosphide, is an example of yet another type of active medium.

Excitation Mechanism

The excitation mechanism is a source of energy that excites, or "pumps," the atoms in the active medium from a lower to a higher energy state in order to create a population inversion. In gas lasers and semiconductor lasers, the excitation mechanism usually consists of an electrical-current flow through the active medium. Solid and liquid lasers most often employ optical pumps; for example, in a ruby laser, the chromium atoms inside the ruby crystal may be pumped into an excited state by means of a powerful burst of light from a flashlamp containing xenon gas.

FEEDBACK MECHANISM

The feedback mechanism returns a portion of the coherent light originally produced in the active medium back to the active medium for further amplification by stimulated emission. The amount of coherent light produced by stimulated emission depends upon both the degree of population inversion and the strength of the stimulating signal. The feedback mechanism usually consists of two mirrors--one at each end of the active

medium--aligned in such a manner that they reflect the coherent light back and forth through the active medium.

OUTPUT COUPLER

The output coupler allows a portion of the laser light contained between the two mirrors to leave the laser in the form of a beam. One of the mirrors of the feedback mechanism allows some light to be transmitted through it at the laser wavelength. The fraction of the coherent light allowed to escape varies greatly from one laser to another--from less than one percent for some helium-neon lasers to more than 80 percent for many solid-state lasers.

LASING ACTION

When the excitation mechanism of a laser is activated, energy flows into the active medium, causing atoms to move from the ground state to certain excited states. In this way, population inversion is created. Some of the atoms in the upper lasing level drop to the lower lasing level spontaneously, emitting incoherent photons at the laser wavelength and in random directions. Most of these photons escape from the active medium, but those that travel along the axis of the active medium produce stimulated emission, as indicated in Figure 13. The beam produced is reflected back through the active medium by the mirrors. A portion of the light that strikes the output coupler leaves the laser as the output beam.