Technology Brief 15: Lasers

Lasers are used in CD and DVD players, bar-code readers, eye surgery, and multitudes of other systems and applications (Fig. T15-1). A laser—acronym for ***L***ight ***A***mplification by ***S***timulated ***E***mission of ***R***adiation—is a source of ***monochromatic*** (single wavelength), ***coherent*** (uniform wavefront), narrow-beam light, in contrast with other sources of light (such as the sun or a light bulb) which usually encompass waves of many different wavelengths with random phase (incoherent). A laser source generating microwaves is called a ***maser***. The first maser was built in 1953 by Charles Townes and the first laser was constructed in 1960 by Theodore Maiman.

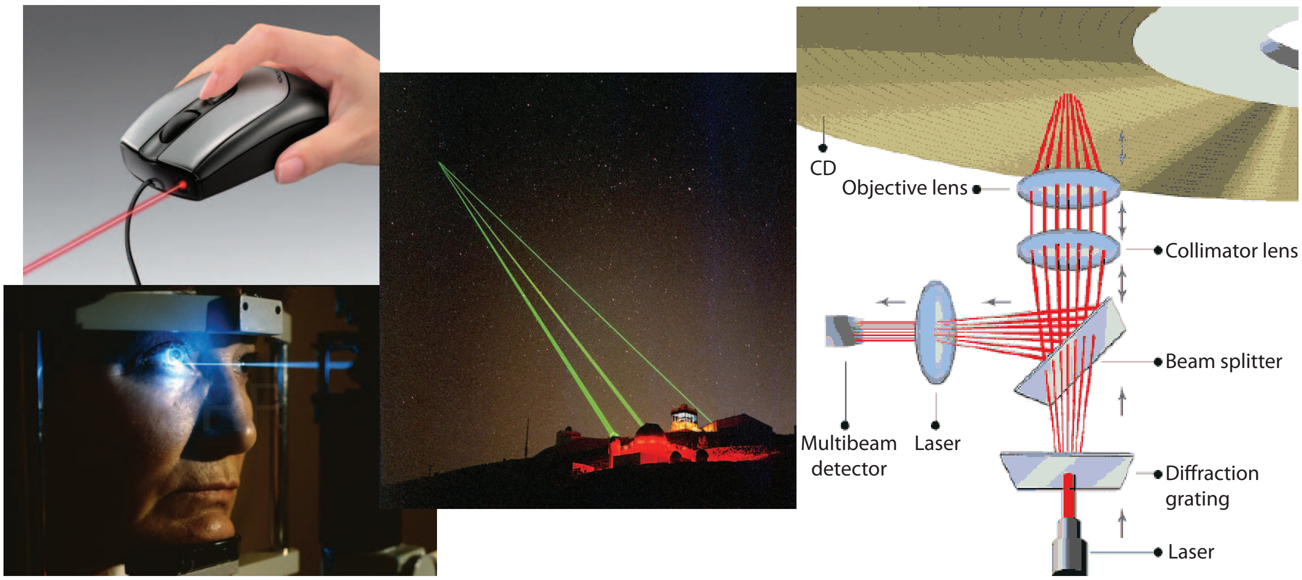

Figure TF15-1: A few examples of laser applications.

Basic Principles

Despite its complex quantum-mechanical structure, an atom can be conveniently modeled as a nucleus (containing protons and neutrons) surrounded by a cloud of electrons. Associated with the atom or molecule of any given material is a specific set of ***quantized*** (discrete) ***energy states*** (orbits) that the electrons can occupy. Supply of energy (in the form of heat, exposure to intense light, or other means) by an external source can cause an electron to move from a lower energy state to a higher energy (***excited***) state. Exciting the atoms is called ***pumping*** because it leads to increasing the population of electrons in higher states [Fig. T15-2(a)]. ***Spontaneous emission*** of a photon (light energy) occurs when the electron in the excited state moves to a lower state [Fig. T15-2(b)], and ***stimulated emission*** [Fig. T15-2(c)] happens when an emitted photon "entices" an electron in an excited state of another atom to move to a lower state, thereby emitting a second photon of identical energy, wavelength, and wavefront (phase).

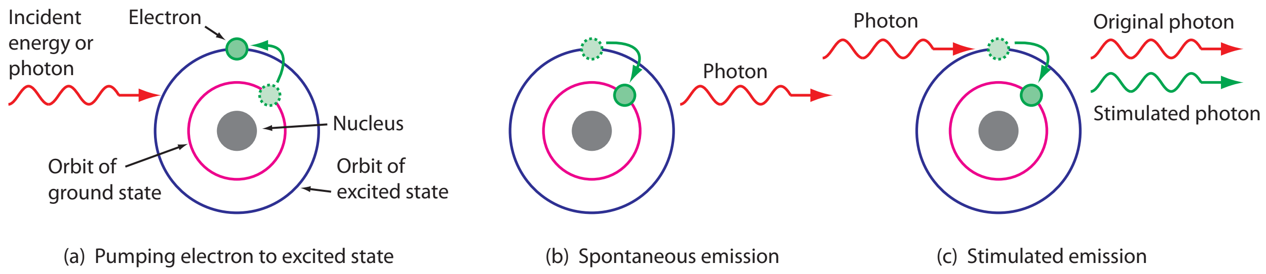

Figure TF15-2: Electron excitation and photon emission.

Principle of Operation

Highly amplified stimulated emission is called ***lasing***. The lasing medium can be solid, liquid, or gas. Laser operation is illustrated in Fig. T15-3 for a ruby crystal surrounded by a flash tube (similar to a camera flash). A perfectly reflecting mirror is placed on one end of the crystal and a partially reflecting mirror on the other end. Light from the flash tube excites the atoms; some undergo spontaneous emission, generating photons that cause others to undergo stimulated emission; photons moving along the axis of the crystal will bounce back and forth between the mirrors, causing additional stimulated emission (i.e., amplification), with only a fraction of the photons exiting through the partially reflecting mirror. Because all of the stimulated photons are identical, the light wave generated by the laser is of a single wavelength.

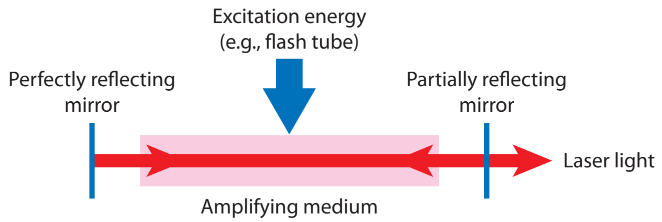

Figure TF15-3: Laser schematic.

Wavelength (Color) of Emitted Light

The atom of any given material has unique energy states. The difference in energy between the excited high energy state and the stable lower energy state determines the wavelength of the emitted photons (EM wave). Through proper choice of lasing material, monochromatic waves can be generated with wavelengths in the ultraviolet, visible, infrared or microwave bands.