• Characteristics, Structure, Safety, Common Types

Note: Due to the amount of material, information on specific commercial solid state lasers has moved to its own chapter: Commercial SS Lasers.

1 Introduction to Solid State Lasers

The Solid State (SS) Laser uses a solid crystalline material as the lasing medium and is usually optically pumped. SS lasers should not be confused with semiconductor or diode lasers which are also 'solid state' but are almost always electrically pumped (though in principle, optical pumping may be possible with some). For information on these, see the chapter: Diode Lasers.

The original laser invented in 1960 was a solid state laser. It used a synthetic ruby rod (chromium doped aluminum oxide) with mirrors on both ends (one semitransparent) pumped with a helical xenon flashlamp surrounding the rod. The lamp was similar to what is used for indoor and high speed photography. The intense flash of blue-white light raised some of the chromium atoms in the matrix (the aluminum oxide is just for structure and is inert as far as the laser process is concerned) to an upper energy state from which they could participate in stimulated emissions (see the chapter: What is a Laser and How Does It Work? for a brief explanation if this isn't familiar to you. The result was an intense pulse of coherent red light at 694.3 nm - the first ever laser light in the world. Gas and semiconductor lasers followed closely behind but only the SS laser can claim to be first.

It was found early on that these lasers could burst balloons and blow holes in razor blades and someone even attempted to coin a new measure of laser energy to be measured in 'Gillettes' based on how many razor blades could be holed at once. :) And, the popular notion that hand-held death ray weapons would soon follow are based on these sorts of demos of solid state lasers, not on whimpy gas lasers (though the carbon dioxide laser is actually a much more likely candidate being the classic heat-ray of science fiction)!

SS lasers are used in all sorts of applications including materials processing (cutting, drilling, welding, marking, heat treating, etc.), semiconductor fabrication (wafer cutting, IC trimming), the graphic arts (high-end printing and copying), medical and surgical, rangefinders and other types of measurement, scientific research, entertainment, and many others where high peak power and/or high continuous power are required. A high energy pulsed YAG laser has even been used in rocket propulsion experiments (well, at least to send an ounce or so aluminum projectile a few feet into the air using just the pressure of photons!). The largest lasers (with the highest peak power) in the World are solid state lasers. Many of the laser projectors for light shows and for other laser displays use solid state rather than gas lasers like argon or krypton ion. And, that green laser pointer is a Diode Pumped Solid State (DPSS) laser.

Common Types

Modern solid state lasers are not all that much different from that original prototype. However, while ruby crystals have and continue to have their place, the majority of modern solid state lasers use neodymium (Nd) doped materials such as Nd:YAG (Yttrium Aluminum Garnet which is $Y_3Al_5O_{12}$), Nd:YVO_4, Nd:Glass, and others. These have a much lower lasing threshold than ruby as well as other desirable physical and optical properties. The strongest output wavelength of neodymium doped lasers is around 1,064 nm – near-IR and totally invisible.

The exact wavelength of the strongest lasing lines depends on the actual host material but usually doesn't vary that much. In addition to Nd:YAG and Nd:YVO_4 at 1,064 nm, examples that lase at slightly shorter wavelengths include Nd:LSB at 1,062 nm, Nd:Glass at 1,060 nm and Nd:YLF at 1,053 nm. However, the lasing wavelengths of some like Nd:$LiNbO_3$ (niodymium doped lithium niobate, 1,084 nm and 1,092 nm) are longer and further away.

Other materials include holmium doped YAG (Ho:YAG) or Ho:YLF. These lase at around 2,060 and 2,100 nm respectively. In the fiberoptic arena, erbium doped glass (Er:Glass) may be used in optical repeaters and amplifiers at around 1,540 nm. Er:YAG lases at 2,840 nm.

Beyond these, there are not that many examples of widely used commercial solid state lasers though many other materials are capable of the population inversion needed for laser action. The workhorse by far is still Nd:YAG with Nd:YVO_4 becoming increasingly important for low to medium power (up to a few watts) 1,064 nm and frequency doubled 532 nm (green) diode pumped solid state lasers.