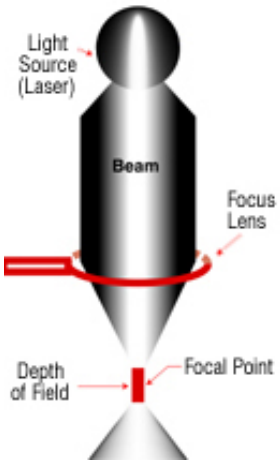
GRAVOGRAPH
NEW HERMES

Laser Theory

1. Like many inventions of recent times, lasers were first conceived in a laboratory. It was in the early 1960's when scientists first discovered, that they could create a light source, focus the energy and have a tool powerful enough to affect certain materials.

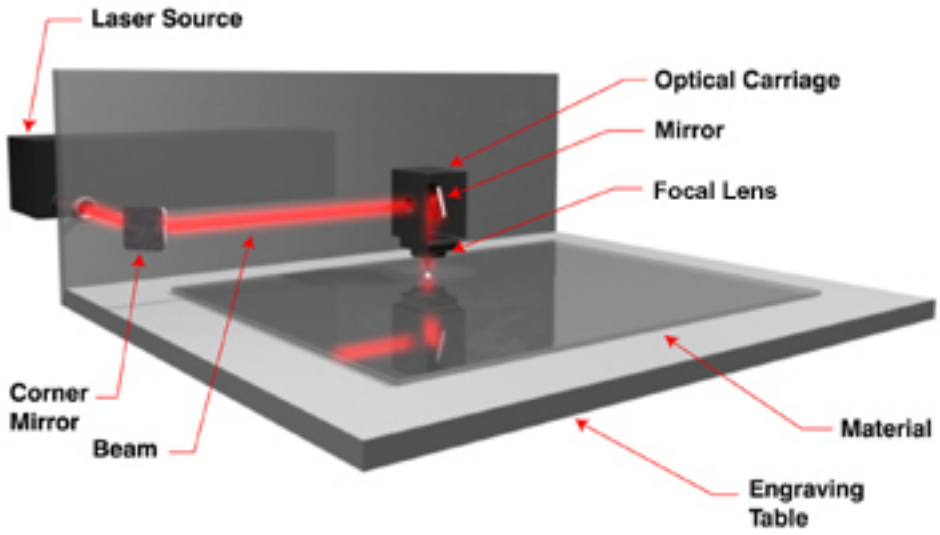
2. They named these first light sources LASER, an acronym for **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation.

3. Think of a laser as a light source similar to a light bulb. A light bulb will emit energy out all around it. A laser puts energy out of a tube, usually 1/2" diameter. The energy is collected from a larger area and focused onto a fine spot size, where the energy is denser. This is like adjusting the beam of a flashlight down to a small dot of light. It is also is similar to using a magnifying glass in the sun. Move the magnifying glass up and down and you lose concentration of the energy. Just like the sun through a magnifying glass can be powerful enough to burn through paper, a leaf, or other material, so can a laser.



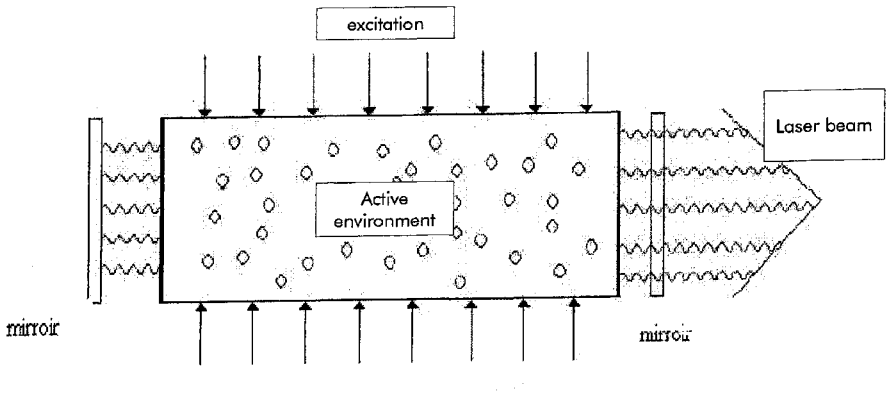
4. Similarly to light bulbs, lasers are rated by wattage. Simply put, the higher the wattage, the more powerful the tool. Engraving lasers generally range in power from 10 - 100 watts.

5. Laser engraving, cutting and marking is a viable and versatile technology that is being by many engravers to improve productivity, add more services to their customers and increase profits. Engraving with a laser is actually a fairly simple process. A laser is merely a tool. Like most tools it help to understand how the tool works. The laser emits the beam of light. The beam goes though a corner block and is turned by a mirror and out to a focusing assembly which focuses the beam down to the material, where it actually vaporizes the material. Moving the beam on the X and Y axis is how the letters and graphics are created.



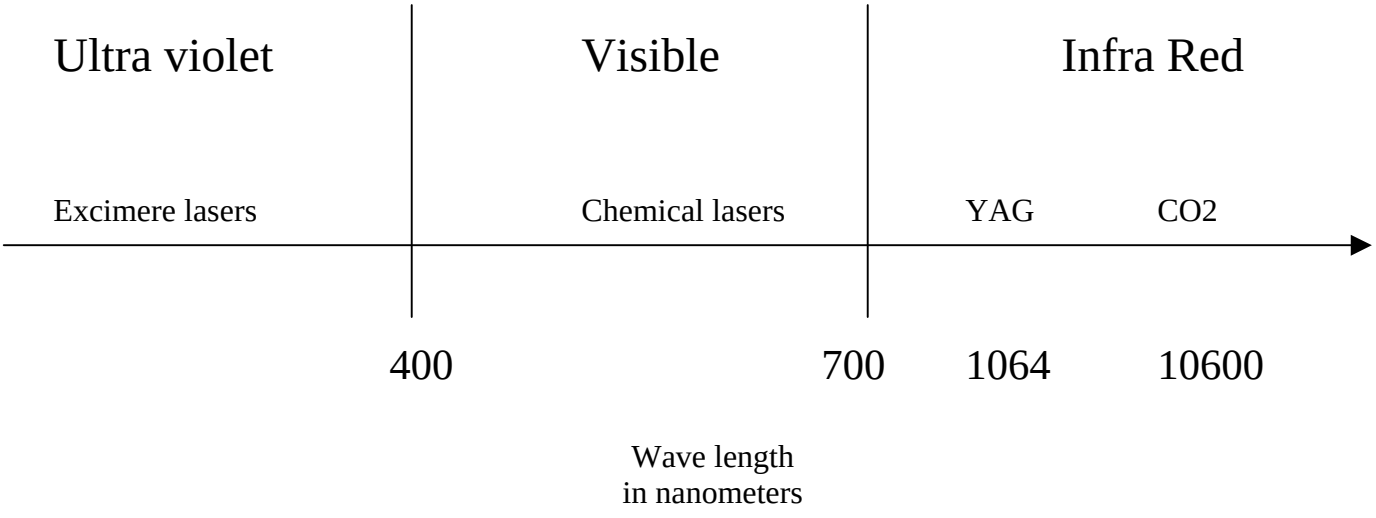
6. There are a variety of advantages to using a laser over other methods of engraving. First of all, because the tool is a beam of light, there is no product contact, which translates into less chance of product damage or deformation. Tooling does not wear out, or need to be replaced as in other methods of engraving. Additionally, a laser will provide more versatility in material and product choices. Laser can engrave most materials. The most popular in the engraving fields are coated metals, wood, acrylic, glass, leather, marble, plastic, and host of synthetic materials made specifically for lasers. Additionally, the same machine that engraves can also cut through thin materials, providing even more versatility for an engraver. Lasers are also faster engraving up to 80”/second. (depending on machine, material choice, artwork and desired effect) There are no consumables so operating costs are minimal, and the laser system, if properly exhausted, runs clean, so that costly cleanup or by product disposal is unnecessary.

7. It didn't take long for the engraving industry to notice lasers and soon lasers were being used for a wide variety of industrial applications including welding, heat-treating, etching and engraving. There were early experiments with several types of methods to generate the light source, thus creating several types of lasers.

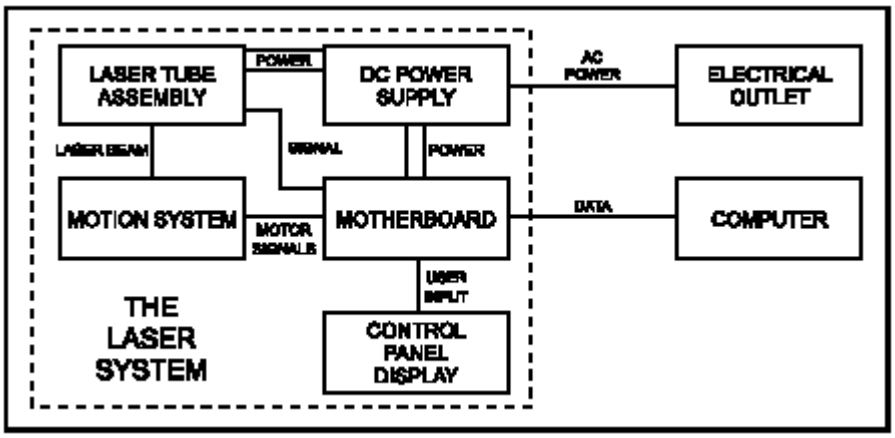


For the engraving industry, CO2 lasers, named for the gasses used to create the light source, are the tools of choice. The CO2 laser uses a mix of CO2 and Helium gases to excite the beam of light. The CO2 Laser is very inexpensive and efficient at marking on materials that are not good conductors of heat and electricity. It also uses a plotter beam technology and can cover a large engraving area. The CO2 lasers operate at a wavelength of 10.6 microns.

8. The more costly laser is the Nd YAG that operates at 1.06 microns. This laser uses a solid crystal made of Yttrium Aluminium Garnet with a small amount of Neodynium. YAG lasers operate more repeatable than gas lasers because they are not affected by day-to-day variations in gas mixture. Mechanical vibration is all but eliminated because the YAG crystal requires no circulation blower (like those needed for CO2 lasers). These lasers are used more for marking on bare metal. They are not suited for vector cutting because they normally use the steered beam or beam deviation technology. A restricted engraving area is also a considerable drawback.



9. There are five (5) basic components that make up the laser system, the control panel, the motherboard, the DC power supply, the laser tube assembly, and the motion system.



A. DC Power Supply
The DC power supply converts the incoming AC electricity to DC voltage. This is used to power both the laser tube assembly and the motherboard.

B. Motherboard
The motherboard is the "brains" of the system and controls everything. Located on the motherboard are standard computer memory SIMMS. This is where incoming files, from the computer, are stored while the power is on. The motherboard gets input from the computer and the control panel. It outputs precisely timed signals to fire the laser beam and to move the motion system simultaneously.

C. Control Panel
This is where the operator controls the laser system. It is composed of push buttons, indicator lights and a LCD display. From this panel, the operator can position the motion system, move around through the menu system in the LCD display, and run the laser system.

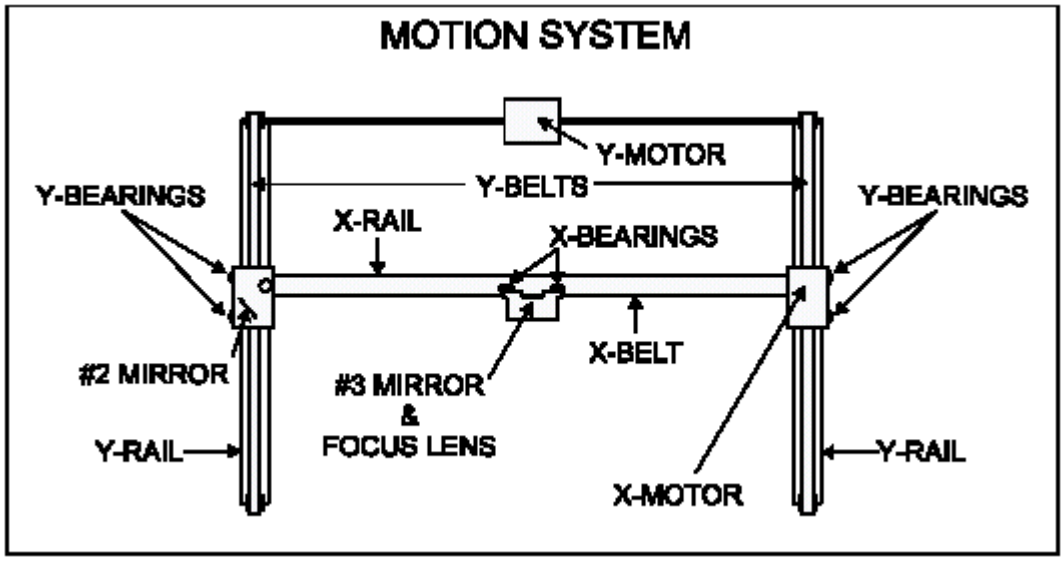
D. Laser Tube Assembly
The laser tube assembly is a very sophisticated device. It is composed of a plasma tube filled with a special mixture of CO2 and other gases, and RF (radio frequency) electronics. The function of the entire assembly is to turn electrical energy into concentrated light energy.

It receives power from the DC power supply and its "trigger signal" from the motherboard. When the laser system is powered ON and the trigger signal comes from the motherboard, the RF electronics produce a high frequency AC signal across the electrodes located inside the plasma tube. This causes spontaneous photon emissions from the gas mixture that produces an invisible, infrared light beam at a frequency of 10.6 microns. The laser beam exits the laser tube through its output optics, bounces off the #1 mirror, passes through the beam window, bounces off the #2 and #3 mirror, and finally passes through the focus lens. The width of the laser beam as it exits the tube, called the "Beam Diameter", is about 4 mm. The focus lens focuses the beam into a very small spot who's "Spot Size" is dependent on the "Focal Length" of the lens. The "Focal Length" is the distance from

about the center of the lens to the point where it converges the beam into the smallest spot possible. Using a standard 2 inch focal length lens, the spot size produced is approximately .005 inches. The “Focal Range” of the lens, where the beam is considered to be “in focus”, is equivalent to +/- 5% above and below the focus point. Shorter lenses produce a smaller spot size but also have a very narrow focal range. This means that it would only be useful for engraving very flat objects. The longer lenses have a much wider range of focus but also produce a larger spot size that would prohibit the engraving of fine detail. This can be related to trying to write small text with a wide, felt tip marker. There are pros and cons to the different lenses that are available for different applications. “Wattage” signifies the amount of heat energy that the laser light is producing over a period of time. Laser energy is measured with a laser power meter. Do not confuse the electrical wattage rating of a light bulb or a hair dryer with the wattage rating of the laser system. They are two different types of measurements.

E. Motion System

The motion system consists of the mechanically moving parts of the laser system. It is made up of rails, motors, bearings, belts, mirrors, a lens, and other parts. There are two directions of motion, left and right is called the “X” direction and front to back is called the “Y” direction.



The motherboard controls the movement of the motors, which moves the mirrors and focus lens across the engraving area and over the material. At the same time, it is synchronizing the laser pulses with the position of the focus lens. It is this precise positioning and timing of the laser pulses that produces the highest quality and fastest speed of engraving. In summary, the five (5) components work together to take the graphic image that is downloaded to the laser system from your computer and burn it into the material located on the engraving table inside of the laser system.

10. Laser Terms:

absorb
to transform radiant energy into a different form, with a resultant rise in temperature

absorption
transformation of radiant energy to a different form of energy by the interaction of matter, depending on temperature and wavelength

accessible emission limit (AEL)
the magnitude of accessible laser (or collateral) radiation of a specific wavelength or emission duration at a particular point as measured by appropriate methods and devices. Also means radiation to which human access is possible in accordance with the definitions of the laser's hazard classification

accessible radiation
laser radiation that can expose human eye or skin in normal usage

argon
a gas used as a laser medium. It emits blue-green light primarily at 448 and 515 nm

aperture
the opening through which laser radiation can pass

attenuation
the decrease in energy (or power) as a beam passes through an absorbing or scattering medium

average power
total energy of an exposure divided by the duration of the exposure

aversion response
action, such as closing of the eye or movement of the head, to avoid exposure to laser light

beam diameter
the distance between diametrically opposed points in the cross section of a circular beam where the intensity is reduced by a factor of e=1(0.368) of the peak level (for safety standards). The value is normally chosen at e=2(0.135) of the peak level for manufacturing specifications

beam divergence
angle of beam spread measured in radians or milliradians (1 milliradian = 3.4 minutes of arc or approximately 1 mil). For small angles where the cord is approximately equal to the arc, the beam divergence can be closely approximated by the ratio of the cord length (beam diameter) divided by the distance (range) from the laser aperture

brightness
the visual sensation of the luminous intensity of a light source. The brightness of a laser beam is most closely associated with the radio-metric concept of radiance.

continuous wave (CW) laser
a laser which with a continuous output that is greater than or equal to 0.25 watts

carbon dioxide
molecule used as a laser medium. Emits far energy at 10,600 nm (10.6 µm)

closed installation
any location where lasers are used which will be closed to unprotected personnel during laser operation

CO2 laser
a widely used laser in which the primary lasing medium is carbon dioxide gas. The output wavelength is 10.6 µm (10600 nm) in the far infrared spectrum. It can be operated in either CW or pulsed

coherence
a term describing light as waves which are in phase in both time and space. Monochromaticity and low divergence are two properties of coherent light

collimated light
light rays that are parallel. Collimated light is emitted by many lasers. Diverging light may be collimated by a lens or other device

collimation
ability of the laser beam to not spread significantly (low divergence) with distance

continuous mode
the duration of laser exposure is controlled by the user (by foot or hand switch)

continuous wave (CW)
constant, steady-state delivery of laser power

controlled area
any locale where the activity of those within are subject to control and supervision for the purpose of laser radiation hazard protection

diffuse reflection
takes place when different parts of a beam incident on a surface are reflected over a wide range of angles in accordance with Lambert's Law. The intensity will fall off as the inverse of the square of the distance away from the surface and also obey a Cosine Law of reflection

divergence
the increase in the diameter of the laser beam with distance from the exit aperture. The value gives the full angle at the point where the laser radiant exposure or irradiance

embedded laser
a laser with an assigned class number higher than the inherent capability of the laser system in which it is incorporated, where the system's lower classification is appropriate to the engineering features limiting accessible emission

emission
act of giving off radiant energy by an atom or molecule

enclosed laser device
any laser or laser system located within an enclosure which does not permit hazardous optical radiation emission from the enclosure. The laser inside is termed an "embedded laser"

energy (Q)
the capacity for doing work. Energy is commonly used to express the output from pulsed lasers and it is generally measured in Joules (J). The product of power (watts) and duration (seconds). One watt second = one Joule

excimer "Excited Dimer"
a gas mixture used as the active medium in a family of lasers emitting ultraviolet light

fail-safe interlock
an interlock where the failure of a single mechanical or electrical component of the interlock will cause the system to go into, or remain in, a safe mode

gas discharge laser
a laser containing a gaseous lasing medium in a glass tube in which a constant flow of gas replenishes the molecules depleted by the electricity or chemicals used for excitation

gas laser
a type of laser in which the laser action takes place in a gas medium

helium-neon (HeNe) l**aser**
a laser in which the active medium is a mixture of helium and neon. Its wavelength is usually in the visible range. Used widely for alignment, recording, printing, and measuring

infrared radiation
invisible electromagnetic radiation with wavelengths which lie within the range of 0.70 to 1000 µm. These wavelengths are often broken up into regions: IR-A (0.7-1.4 µm), IR-B (1.4-3.0 µm) and IR-C (3.0-1000 µm)

intrabeam viewing
the viewing condition whereby the eye is exposed to all or part of a direct laser beam or a specular reflection

irradiance
power per unit area, expressed in watts per square centimeter

laser accessories
the hardware and options available for lasers, such as secondary gases, Brewster windows, Q-switches and electronic shutters

laser device
either a laser or a laser system

laser medium (Active Medium)
material used to emit the laser light and for which the laser is named

laser rod
a solid-state, rod-shaped lasing medium in which ion excitation is caused by a source of intense light, such as a flash lamp. Various materials are used for the rod, the earliest of which was synthetic ruby crystal

laser system
an assembly of electrical, mechanical and optical components which includes a laser. Under the Federal Standard, a laser in combination with its power supply (energy source)

lens
a curved piece of optically transparent material which, depending on its shape, is used to either converge or diverge light

light
the range of electromagnetic radiation frequencies detected by the eye, or the wavelength range from about 400 to 760 nm. The term is sometimes used loosely to include radiation beyond visible limits

laser
acronym for Light Amplification by Stimulated Emission of Radiation. A laser is a cavity with mirrors at the ends, filled with material such as crystal, glass, liquid, gas or dye. It produces an intense beam of light with the unique properties of coherency, collimation, and monochromaticity

laser safety officer
one who has authority to monitor and enforce measures to control laser hazards and effect the knowledgeable evaluation and control of laser hazards

limiting aperture
the maximum circular area over which radiance and radiant exposure can be averaged when determining safety hazards

maintenance
performance of those adjustments or procedures specified in user information provided by the manufacturer with the laser or laser system, which are to be performed by the user to ensure the intended performance of the product. It does not include operation or service as defined in this glossary

maximum permissible exposure (MPE)
the maximum level of laser radiation to which a human can be exposed without adverse biological effects to the eye or skin

Nd:Glass laser
a solid-state laser of neodymium:glass offering high power in short pulses. A Nd-doped glass rod used as a laser medium to produce 1064 nm light

Nd:YAG laser
Neodymium:Yttrium Aluminum Garnet. A synthetic crystal used as a laser medium to produce 1064 nm light

Neodymium (Nd)
the rare earth element that is the active element in Nd:YAG laser and Nd:Glass lasers.

nominal hazard zone (NHZ)
the nominal hazard zone describes the space within which the level of the direct, reflected or scattered radiation during normal operation exceeds the applicable MPE. Exposure levels beyond the boundary of the NHZ are below the appropriate MPE level.

nominal ocular hazard distance (NOHD)
distance along the axis of the direct laser beam to the human eye beyond which the MPE of the laser is not exceeded

optical cavity (Resonator)
space between the laser mirrors where lasing action occurs

optical density
a logarithmic expression for the attenuation produced by an attenuating medium, such as an eye protection filter

optical fiber
a filament of quartz or other optical material capable of transmitting light along its length by multiple internal reflection and emitting it at the end

optical pumping
the excitation of the lasing medium by the application of light rather than electrical discharge

optical radiation
ultraviolet, visible, and infrared radiation (0.35-1.4 μm) that falls in the region of transmittance of the human eye

output power
the energy per second measured in watts emitted from the laser in the form of coherent light

power
the rate of energy delivery expressed in watts (Joules per second). Thus: 1 Watt = 1 Joule × 1 Sec

protective housing
a protective housing is a device designed to prevent access to radiant power or energy

pulse
a discontinuous burst of laser, light or energy, as opposed to a continuous beam. A true pulse achieves higher peak powers than that attainable in a CW output

pulse duration
the "on" time of a pulsed laser, it may be measured in terms of milliseconds, microseconds, or nanoseconds as defined by half-peak-power points on the leading and trailing edges of the pulse

pulsed laser
laser which delivers energy in the form of a single or train of pulses

pump
to excite the lasing medium

pumped medium
energized laser medium

pumping
addition of energy (thermal, electrical, or optical) into the atomic population of the laser medium, necessary to produce a state of population inversion

pulsed laser
laser which delivers energy in single or multiple pulses which are less than or equal to 0.25 watts in duration

radiant energy (Q)
energy in the form of electromagnetic waves usually expressed in units of Joules (watt-seconds)

radiant exposure (H)
the total energy per unit area incident upon a given surface. It is used to express exposure to pulsed laser radiation in units of J/cm2

radiant power
laser power emitted, expressed in watts (W)

reflection
the return of radiant energy (incident light) by a surface, with no change in wavelength

refraction
the change of direction of propagation of any wave, such as an electromagnetic wave, when it passes from one medium to another in which the wave velocity is different. The bending of incident rays as they pass from one medium to another (e.g., air to glass)

repetitively pulsed laser
laser with multiple pulses with a pulse repetition frequency greater than or equal to 1 Hz

resonator
the mirrors (or reflectors) making up the laser cavity including the laser rod or tube. The mirrors reflect light back and forth to build up amplification

ruby
the first laser type; a crystal of sapphire (aluminum oxide) containing trace amounts of chromium oxide

scanning laser
a laser having a time-varying direction, origin or pattern of propagation with respect to a stationary frame of reference

secured enclosure
an enclosure to which casual access is impeded by an appropriate means (e.g., door secured by lock, magnetically or electrically operated latch, or by screws)

semiconductor laser
a type of laser which produces its output from semiconductor materials such as GaAs

service
performance of adjustments, repair or procedures on a non-routine basis, required to return the equipment to its intended state

source
the term source means either laser or laser-illuminated reflecting surface, i.e., source of light

specular reflection
mirror-like reflection

tunable laser
a laser system that can be "tuned" to emit laser light over a continuous range of wavelengths or frequencies

tunable dye laser
a laser whose active medium is a liquid dye, pumped by another laser or flash lamps, to produce various colors of light. The color of light may be tuned by adjusting optical tuning elements and/or changing the dye used

radiant energy
laser energy emitted, expressed in joules (J) **ultraviolet radiation**
electromagnetic radiation with wavelengths from180-400 nm

visible radiation
electromagnetic radiation which is visible to the human eye; wave lengths from 400-700 nm

ultraviolet (UV) **radiation**
electromagnetic radiation with wavelengths between soft X-rays and visible violet light, often broken down into UV-A (315-400 nm), UV-B (280-315 nm), and UV-C (100-280 nm)

visible radiation (light)
electromagnetic radiation which can be detected by the human eye. It is commonly used to describe wavelengths in the range between 400 nm and 700-780 nm

wavelength
the length of the light wave, usually measured from crest to crest, which determines its color. Common units of measurement are the micrometer (micron), the nanometer, and (earlier) the Angstrom unit

YAG
Yttrium Aluminum Garnet, a widely used solid-state crystal composed of yttrium and aluminum oxides and a small amount of the rare earth neodymium