DECIPHERING LASER SPECIFICATIONS

When shopping for a laser, you may run across some facts and figures that may seem baffling at first but quite simple, after learning the jargon.

Lasing Medium: The material that lases, falling into the broad categories of the basic forms of matter, solid state, liquid, gas, or semiconductor.

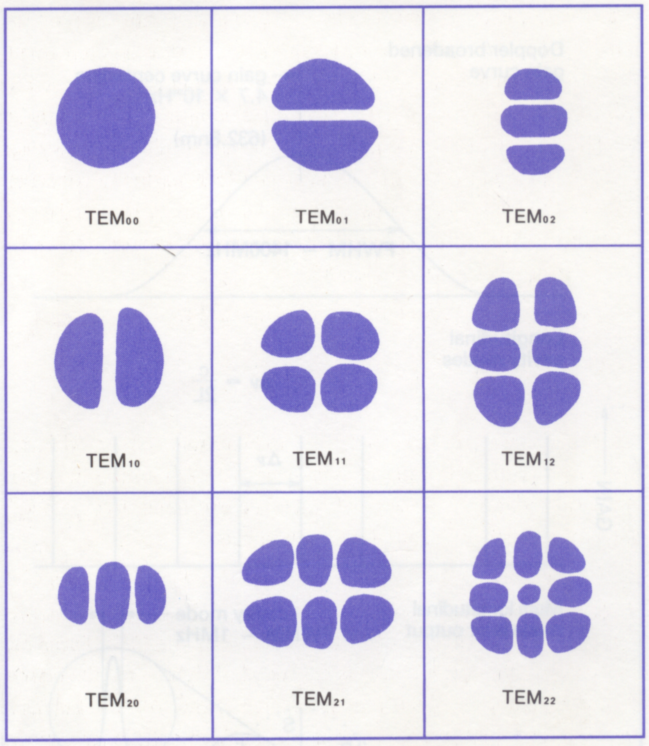
Wavelength: The color of emission, almost always given in nanometers. The most popular wavelengths arre in the visible, but some lasers emit in the infrared (Nd:Glass, YAG, or YLF; certain dyes; CO2; semiconductors) or ultraviolet (Nitrogen, some Argon or Krypton lines). Most lasers emit at one particular line (for example, the ubiquitous He-Ne lambda of 633nm), or emit a series of lines, (like the major Argon lines of 458, 476, 488, 496, 502, 515 and 528), either individually or simultaneously. Some media are tunable over a certain continuous range (Alexandrite, Ti:Sapphire and most dyes). Frequency doubling or tripling, also called first or second harmonic generation, is applicable to some instruments, by halving or thirding the fundamental laser line, as in converting the fundamental infrared 1.064 micron line of the Nd:YAG into a nice green @ 532nm.

CW or Pulsed: Whether the laser emits a Continuous Wavetrain and is on indefinitely like a lightbulb, or emits light in short blasts in finite units of time. The ability to do either mode depends on the intrinsic energy storage capability of the medium, and/or intracavity devices like mode lockers, cavity dumpers, or Q-switches. Pulses can be emitted as a gigantic one, (Q-Switched) or a series of dribbles (free-lasing). Solid state lasers operating in the free-lasing mode (also called free-running or open mode) emit a pulse as soon as they reach threshold (population inversion) in a random bunch of pulse widths of varying energies intermittently while they are being optically pumped. But mode-lockers inside the laser cavity order the pulses to be the same in duration, delivered regularly with respect to time, and consistent in energy. The duration or pulsewidth is measured in fractions of a second, the delivery rate or frequency is in Hertz (remember that anything higher than about 16 Hz will look continuous to our eyes). A typical mode-locked Nd:YAG laser will emit 10 picosecond pulses 60 times a second with energies of 100 microJoules with a peak power of tens of milliJoules.

CW Power: Is measured either in full Watts (W) or milliWatts (mW, thousandths of a Watt). The range of power in the visible ranges from .5 mW of the gentle Helium-Neon to the 25-30 Watts of a fire-breathing Argon.

Pulsed Energy: Is measure either in full Joules (J) or milliJoules, (mJ, thousandths of a Joule), a Joule being one Watt of light emitted over a period of a second. (a Watt-second) The shorter the pulsewidth, the higher the peak power for a given energy. One Joule delivered in 1 microsecond means a MegaWatt* of peak power; in one nanosecond means that the peak power reached a GigaWatt; and in a picosecond, one TeraWatt.

TEM Mode: This is a map of the <u>Transverse **E**lectromagnetic **M**odes</u> of the laser, a picture of the beam's cross-section. The subscript numbers tell how many gaps there are across the beam first in the **x** (<u>horizontal</u>) direction then in the **y** (<u>vertical</u>). A **01** mode looks like two semi-circles on top of each other, while a **10** mode looks like two of them side by side. See figure from M-G. For cylindrical lasers the orientation is a moot point. **TEM00** mode is called the <u>fundamental</u>, <u>lowest order</u>, or <u>Gaussian</u> mode, and all the rest are called higher order or multi-modes. Another common laser mode is the **<u>donut mode</u>**, a round beam with a black center.



TRANSVERSE ELECTRIC AND MAGNETIC MODES of a laser cavity.

The modes are created by interference effects inside or outside the cavity. If the diameter of the beam is big enough, and the divergence caused by the non-flat optics in a confocal or hemispherical resonator form a geometry which causes parts of the beam to be out of phase with each other in certain locations, causing dark zones of destructive interference. This effect is especially troublesome in high gain media like Ruby or Argon. The black lines or spots appear, and the energy that should be there is shifted into the bright areas, because constructive interference effects occur there.

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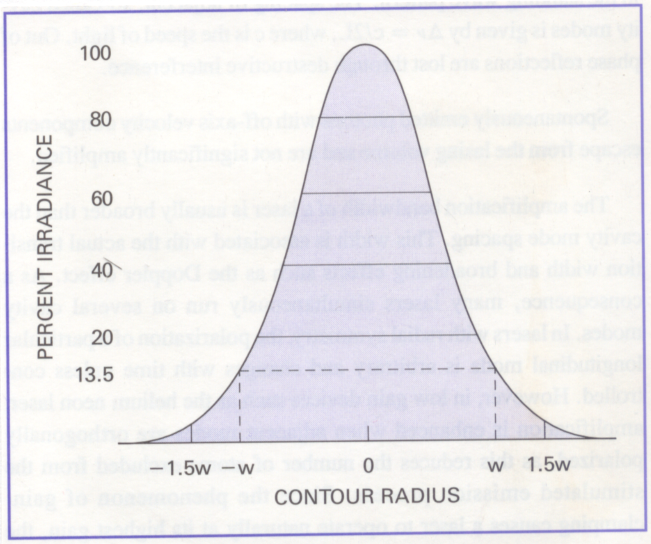
*. Know your metric prefixes! **Mega** = million, **Giga** = billion, **Tera** = trillion.

Apertures, either holes drilled in metal or variable irises, to decrease the working diameter of the bore of the lasing tube can remedy this situation. Of course this decreases the output power, but what is left can be put to use much more effectively. To decrease the price per milliWatt ratio, some He-Ne manufacturers offer the same length tube but equipped with a bigger bore capillary tube to use more gain medium, for higher, albeit multi-moded, output.

For holography, the fundamental mode, or TEM 00, is preferred, as well as for any application requiring the focussing of a beam to a small spot. Any other type of beam profile, without a pair of 0's, is useful for things where a simple beam is necessary, like laser light shows or pointers, where the audience never gets to see the beam standing in one place for long.



GAUSSIAN IRRADIANCE PROFILE for TEM_{00} mode, showing definitions of beam radius w.

This fundamental mode has an intensity distribution that when plotted across its diameter has a distribution that follows the classical bellshaped curve of Gauss. Once in a while a laser pops up that has an even distribution of energy from the center out to a certain point; this is called a flat-top intensity distribution.

DIVERGENCE: The beam of a laser is rarely perfectly parallel. They do diverge because of the typical confocal mirrror configuration, which has a concave mirror at one end of the resonator. Plus the wave-like nature of light dictates that the beam is constantly diffracting; spreading out to the side.

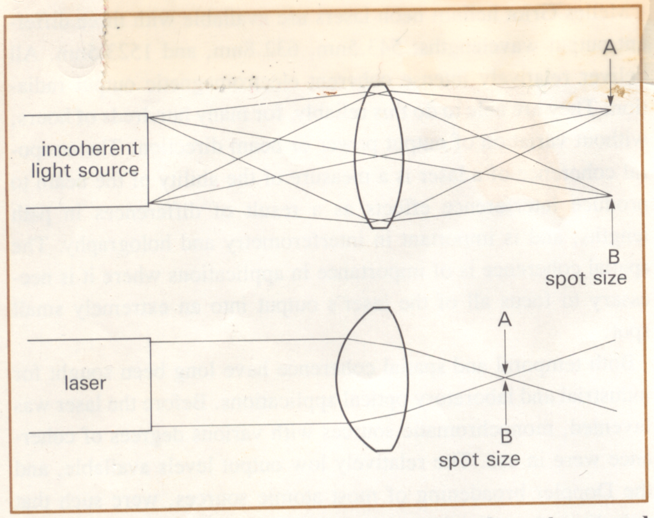
The units of divergence should be degrees, but the beam spreads so slowly that a smaller, more precise angular measure is used, the milliradian. An example of a milliradian is the angle at the tip of an isoceles triangle that is formed by a pair of meter sides with a base of one millimeter.

A typical He-Ne has a divergence between .8 to 2.0 milliradians; diode lasers have typically have divergences between 12 and 30 degrees, or 200 to 500 milliradians!

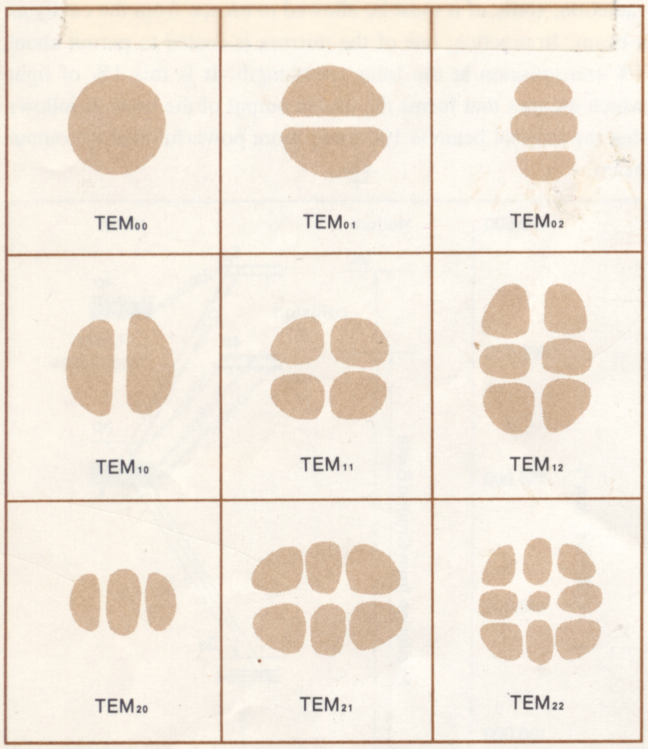
LONGITUDINAL MODE-SPACING: This is a measure of coherence length, the maximum allowable path-length difference where interference can occur. Typically it is a figure given in frequency units.

The mode-spaced frequency is figured from the round-trip cavity length and wavelength. But because of the gain of the tube, not all the modes predicted by the formula may lase.

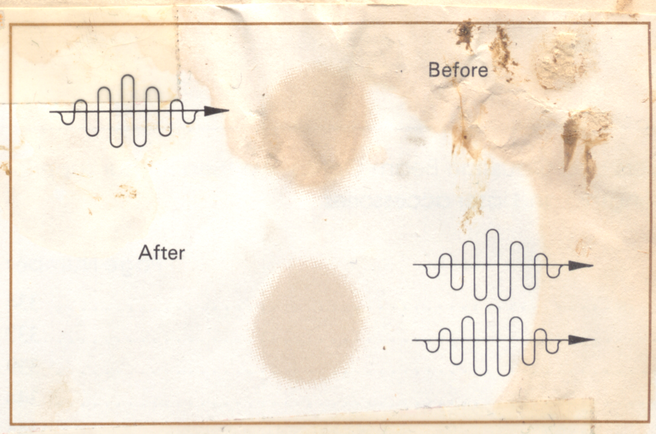
The smaller the number, the better. A Melles Griot LHP-171 lists a longitudinal mode-spacing of 373 MHz; practical tests show that 4 decimeters is the actual working coherence length.



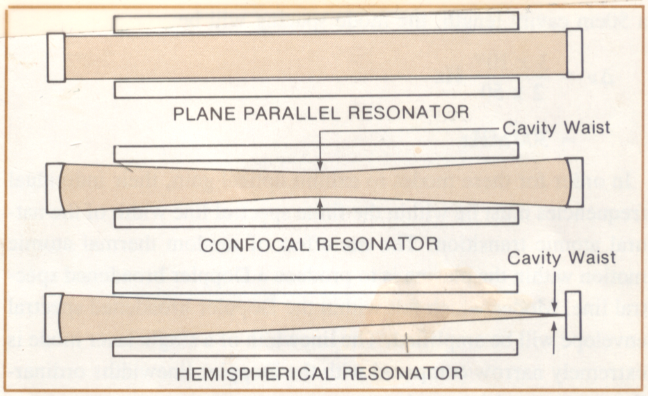
FOCUSABILITY COMPARISON for light from laser and conventional sources. Extended sources have extended images. The laser is the functional equivalent of a true point source situated at the corner of the cavity waist.



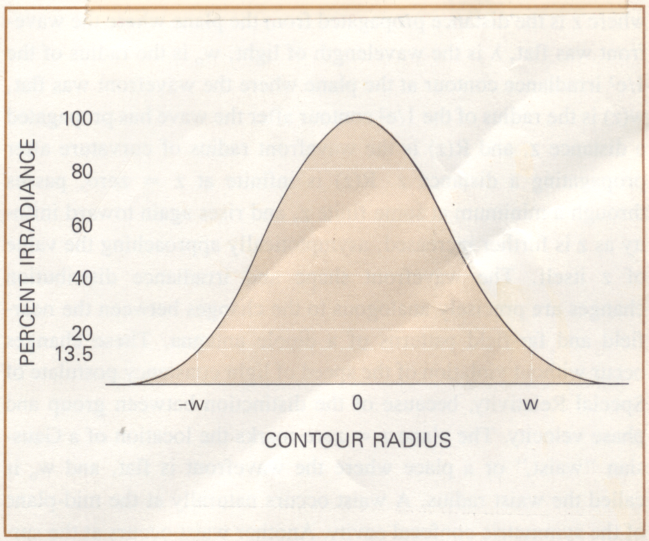
TRANSVERSE ELECTRIC AND MAGNETIC MODES of a laser cavity.



STIMULATED EMISSION, an artist's conception.



LASER CAVITY TYPES, showing the shape and size of the active plasma volume.



GAUSSIAN IRRADIANCE PROFILE for TEM$_{00}$ mode, showing definition of beam radius w.

BEAM DIVERGENCE