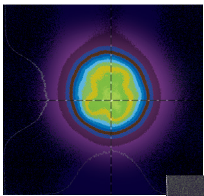
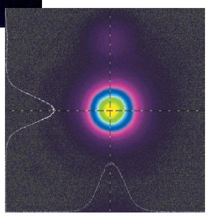
True TEM_{00} or Not?

Litron is one of the few laser manufacturers to offer Nd:YAG lasers with true TEM_{00} beam quality as standard. Some manufacturers claim to offer lasers with TEM_{00} output but a closer look will show that that is not always the case.

To generate a TEM_{00} beam requires a stable resonator and, usually, an aperture to suppress higher order modes. Litron typically employs its telescopic stable resonator as the intracavity telescope yields a TEM_{00} mode volume and hence energy that is about three times greater than a conventional stable resonator (but about four times less than the energy available from a multimode stable resonator or an unstable resonator).

Near field beam profile with stable resonator at 1064nm.





Near field beam profile of TEM_{00} at 1064nm.

Some manufacturers claim that the output from their graded reflectivity mirror, unstable resonators is in fact TEM_{00}. Litron knows that this cannot be true. It also manufactures lasers with graded reflectivity mirror unstable resonators but makes no assertions other than that the beam is a single transverse mode with an M^2 value of around 2, in common with most lasers of this design. Litron's true TEM_{00} lasers offer far better beam quality than can be obtained from any unstable laser, with typical M^2 values of around 1.15.

Quite simply, TEM_{00} is the name of the fundamental Hermite-Gaussian mode of any stable laser resonator that supports such modes. An unstable resonator cannot support Hermite-Gaussian modes and therefore cannot give a TEM_{00} output.

A TEM_{00} beam has a spatial profile that is very nearly Gaussian (>95%) and that does not change as it propagates (i.e. from when it emerges from the laser right into the far field). An unstable laser with a graded reflectivity mirror produces a beam that is only a 70-80% fit to Gaussian in the near field, which is not very close if you consider that a top hat profile is nearly 70%. It then picks up diffraction structure as it propagates until finally about 70-80% of the energy is to be found in a Gaussian spot in the far field, the remaining energy having propagated with a larger divergence angle as a result of diffraction. Therefore 20-30% of the output energy is lost by diffraction in any system using an unstable resonator when considering the far field beam energy.

A laser oscillator with a 100mm long, 6.3mm diameter Nd:YAG rod is a fairly common arrangement. With either a stable resonator or a graded reflectivity unstable resonator, about 350mJ or so can usually be Q-switched out quite easily. Running the same laser with a true TEM_{00} output, the most that can be reliably achieved is about 80-100mJ. To reach 350mJ true TEM_{00} requires the use of an amplifier, which adds considerably to the cost of the laser.

Both resonator types have their advantages. Outputs from unstable resonators offer high energy beams that have a high focussability and therefore an inherently low divergence, making them ideal for non-linear processes. However beams from such systems exhibit a large degree of structure (spatial ringing) in their outputs and it is not until the far field (i.e. at the focus of a lens) that the profile is truly Gaussian. TEM_{00} lasers have output beams that are temporally longer and smoother and spatially exhibit little structure. Beams from such lasers can be used in the near and intermediate fields as their profile is always a Gaussian and the longer smoother pulses are ideal for OPO pumping, where a longer pump pulse offers more round trips of the resonator.

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