Laser Beam Expander Theory

Diffraction

Perfect Gaussian Laser beams are often characterized by a parameter known as beam divergence. Divergence is the angular spreading of light waves as they propagate through space. Even a perfect unaberrated ray of light will experience some beam divergence due to diffraction effects. Diffraction is the effective bending of light rays caused by truncation from an opaque object such as a knife edge. The spreading arises from secondary wavefronts emitted from the edge of truncations. These secondary waves interfere with the primary wave, and also themselves, sometimes forming quite complicated diffraction patterns. Diffraction makes it impossible to perfectly collimate light, or to focus it to an infinitely small spot size. Fortunately diffraction effects can be calculated. Consequently theory exists which predicts the degree of collimation and spot size for any diffraction limited lens.

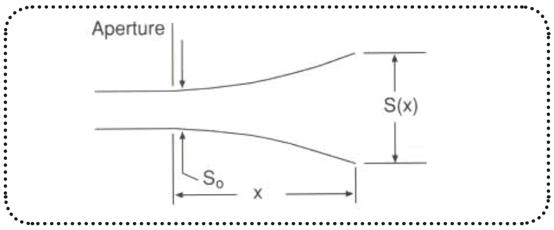

Fig. 1

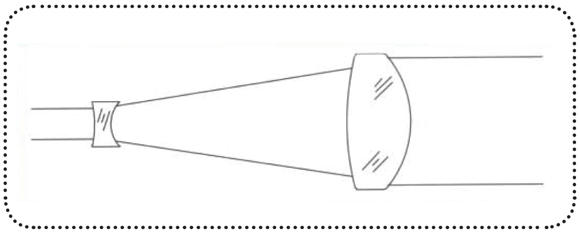

Fig. 2

Improving Divergence

The far field beam divergence defines the best collimation for a given beam diameter. It also illustrates that zero beam divergence or perfect collimation can never be achieved, because doing so would require and infinite beam diameter. However this equation does suggest a means of improving divergence.

Consider a collimated beam of light with a beam divergence of θ and a beam diameter of S_0. Clearly, if the beam diameter were to be increased, the far field divergence would be decreased by the inverse proportion i.e. by 1/< where M is the expansion ration. This is precisely the advantage of expanding laser beams. In addition, lower divergence allows for better focusing of Gaussian beams (see Bestform Laser Lenses). With this improvement in mind we now describe several ways of expanding collimated light.

Galilean Beam Expanders

The most common type of beam expander is derived from the Galilean telescope (figure 2) which usually has one negative input lens and one positive output lens. The input lens presents a virtual beam focus at the output. For lens expansion ratios (1.3x-20x) the Galilean telescope is most often employed due to its simplicity, small package size and low cost. Designs can usually be obtained having minimal spherical aberration, low wavefront distortion and achromaticity. Limitations are that it cannot accommodate spatial filtering or larger expansion ratios.

Keplerian Beam Expanders

In cases where larger expansion ratios or spatial filtering is required, Keplerian design telescopes are employed. The Keplerian telescope has a positive input element presenting a real beam focus to the output elements. In addition, spatial filtering can be instituted by placing a pinhole at the focus of the first lens.

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