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Gaussian Beam Optics

Gaussian Beam Propagation

For virtually all optical laser cavities, the propagation of an electromagnetic field, $E^{(0)}$ through one round trip in an optical resonator can be described mathematically by a propagation integral which has the general form

$$E^{(1)}(x, y) = e^{-jkp} \iint_{\text{Input Plane}} K(x, y, x_0, y_0) E^{(0)}(x_0, y_0) dx_0 dy_0$$

where K is the propagation constant at the carrier frequency of the optical signal, p is the length of one period or round trip, and the integral is over the transverse coordinates at the reference or input plane. The function K is commonly called the propagation kernel, since the field $E^{(1)}(x, y)$ after one propagation step can be obtained from the initial field $E^{(0)}(x_0, y_0)$ through the operation of the linear kernel or "propagator" $K(x, y, x_0, y_0)$.

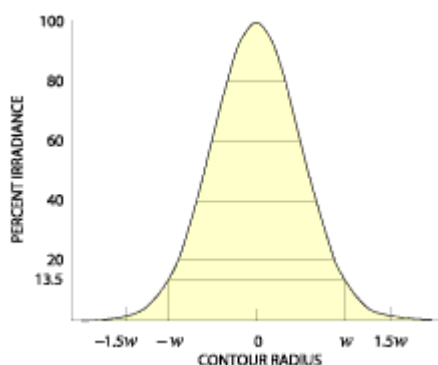
By setting the condition that the field, after one period, will have exactly the same transverse form, both in phase and profile (amplitude variation across the field), we get the equation

$$\gamma_{nm} E_{nm}(x, y) \equiv \iint_{\text{Input Plane}} K(x, y, x_0, y_0) E_{nm}(x_0, y_0) dx_0 dy_0$$

where E_{nm} represents a set of mathematical eigenmodes, and γ_{nm} a corresponding set of eigenvalues. The eigenmodes are referred to as transverse cavity modes, and, for stable resonators, are closely approximated by Hermite-gaussian functions, denoted by TEM_{nm} .

The lowest order, or "fundamental" transverse mode, TEM_{00} has a gaussian intensity profile, shown in the figure below, which has the form

$$I(x, y) \propto e^{-k(x^2+y^2)}$$



Gaussian beam intensity profile

In this section we will identify the propagation characteristics of this lowest order solution to the propagation equation. In the next section, *Real-World Beams* we will discuss the propagation

characteristics of higher-order modes, as well as beams that have been distorted by diffraction, or various anisotropic phenomena.

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