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Accurate evaluation of the far field error of the semiconductor laser

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ABSTRACT

For practical application, it is of importance to provide a precise description of the far field error on the basis of the source error. The "relative error volume", instead of the local error, of the source is put forward to give the maximum error range of the far field error. In order to determine the off-center source error, the "critical point" of the far field phase error is obtained, dealt with and raised. Numerical results given are used to check up this method. It is indicated that the "off-center distance" together with the "relative error volume" should be used in describing the source error and analyzing the far field error, and the "critical points" is a useful parameter to analyze the source error for the inverse problem.

1. Introduction

The radiation field is computed from the source distribution in numerous fields of optics. According to the source error, estimating the far field error is of great importance [1–6]. For instance, with the assessment of the far field distribution of the semiconductor laser [7,8], one can gain the boundary value from the theoretical analysis or measurement data. A great deal of previous researches deal with the relationship between the far field and the source distribution according to the paraxial theory [9–11], or beyond the paraxial approximation [12–15]. Zeng et al. took a novel measure to display the far field error of the off-axis Gaussian wave [16].

On the basis of the asymptotic solutions to the Helmholtz equation [10], a further study of the relationship of the far field error according to the source error is given. It is shown that the "off-center distance" should be used in analyzing the far field errors and describing the source errors accurately. The source distribution can be represented by a relative simple even function and an off-center error function. The "critical point" of the far field phase error is obtained, analyzed and discussed to depict the far field phase errors. Therefore, it is very important and useful to study the relationship between the far field and the source errors with the numerical results.

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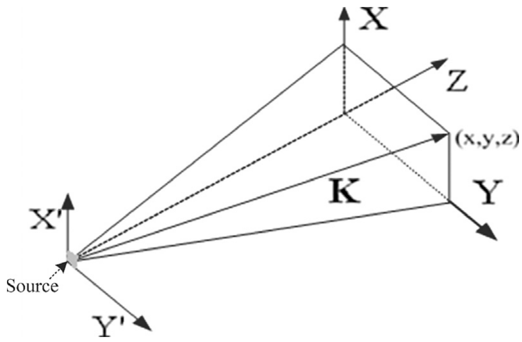

Fig. 1. Coordinate system.

2. Far field distribution

In this study, our research is limited to monochromatic radiation. According to [17] the far field distribution is described as

$$E(x,y,z) = \frac{iz}{\lambda r}\frac{\exp(ikr)}{r}\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} u_s\left(x',y'\right)\exp\left[-\frac{ik}{r}\left(xx'+yy'\right)\right]dx'dy' \quad (1)$$

where $r = \left(x^2+y^2+z^2\right)^{1/2}$, $k = 2\pi/\lambda$, and $u_s(x',y')$ is the distribution of the planar source.

The source function $u_s(x',y')$ is equal to a product of two functions, which depend only on one of the two abscissas (x' or y'), i.e., $u_s(x',y') = u_s(x')u_s(y')$ [11]. For convenience sake, we only discuss a two-dimensional case here, in other words, the far field is on the plane y = 0. Therefore, Eq. (1) can be rewritten as

$$E(x,0,z) = A\frac{iz}{\lambda r}\frac{\exp(ikr)}{r}\int_{-\infty}^{+\infty} u_s\left(x'\right)\exp\left(-\frac{ik}{r}xx'\right)dx', \quad (2)$$

where $A = \int_{-\infty}^{+\infty} u_s(y')\,dy'$, and $r = \sqrt{x^2+z^2}$.

As shown in Fig. 1, we define a rectangular coordinate system (x,y,z), whose origin locates on the plane of the source. The source only radiates in the half-space, z > 0. First, we study the case that the source plane is parallel with the observation plane, and then define the spatial frequencies μ, ν, ω as

$$\mu = \frac{k_x}{\lambda} = \frac{x}{\lambda r}, \nu = \frac{k_y}{\lambda} = \frac{y}{\lambda r}, \omega = \frac{k_z}{\lambda} = \frac{z}{\lambda r}, \quad (3)$$

where $r = \sqrt{x^2+y^2+z^2}$. For each point on the observation surface, a corresponding spatial frequency exists. Substituting Eq. (3) into Eq. (2), we can obtain

$$E(x,0,z) = iMF(\mu)\exp(ikr), \quad (4)$$

where $M = \frac{Az}{\lambda r^2}$, $F(\mu) = \int_{-\infty}^{+\infty} u_s(x')\exp(-i2\pi\mu x')\,dx'$.

3. Far field errors

To determine the effects of source error on far field distribution, we only consider the relative errors. Suppose that $u_s = f_1(x')$ and $u_{s0} = f_1(x') + f_2(x'-b)$ are two planar sources as shown in Fig. 2 and their difference is not large, where b is the off-center distance. According to Eq. (4), the two sources' far field distributions could be written as

$$E_s = iMF_1(\mu)\exp(ikr), \quad (5)$$

$$E_{s0} = iM\left[F_1(\mu) + F_2(\mu)\exp(-i2\pi b\mu)\right]\exp(ikr), \quad (6)$$