Near-Field Optical Diffraction from a Subwavelength Aperture

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Due to the emergence of scanning near-field optical microscopes, near-field optics and optical resonators have been developed recently. [1-3] The central concept of near-field optics is involving evanescent electromagnetic waves. Taking evanescent waves into account makes it difficult to use any simple approximation in Maxwell's equations. The optical system considered is an infinite thin plate with a subwavelength aperture embedded. Owing to the small thickness of the thin plate, a reasonable assumption [4] was adopted that the magnetic field component H_3 in z direction is equal along the thickness, and the other components in x and y directions are $H_1 = z\,\partial H_3/\partial y$ and $H_2 = -z\,\partial H_3/\partial x$, respectively. Based on the power flow theorem, the governing equation for the magnetic field distribution in the thin plate, due to the incident electric field, can be further obtained as

$$\nabla^4 H_3 - k_n{}^4 H_3 = \frac{-3i\omega\varepsilon}{h^2}\left[\left.\frac{\partial E_{30}}{\partial z}\right|_{z=h/2} + \left.\frac{\partial E_{32}}{\partial z}\right|_{z=-h/2}\right], \tag{1}$$

where $\nabla^4 = \partial^4/\partial x^4 + 2\partial^4/(\partial x^2 \partial y^2) + \partial^4/\partial y^4$, h is the thickness of the plate, ε is the permittivity of the plate material, ω is the circular frequency, $E_{30}(x,y,z)$ and $E_{32}(x,y,z)$ are the electric fields in the z direction on the both sides of the plate, and k_n is the eigenfrequency of the thin plate with a circular aperture of radius $r = a$, which can be obtained from the frequency equation

$$\det\begin{vmatrix} \mathrm{H}_n^{(1)}(k_n a) & \mathrm{K}_n(k_n a) \\ \mathrm{H}_n^{(1)\prime}(k_n a) & \mathrm{K}_n'(k_n a) \end{vmatrix} = 0, \tag{2}$$

where the prime denotes the derivative, $\mathrm{H}_n^{(1)}$ is the Hankel function of the first kind and K_n is the modified Bessel function of the second kind. Figure 1 shows the first 3 resonant modes in the near field diffracted from the aperture. Furthermore, the diffracted electric field and magnetic field can be figured out by using the Kirchhoff formula.

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[3] J. H. Wu, and A. Q. Liu, ***Opt. Lett*. 31**, 1720 (2006).
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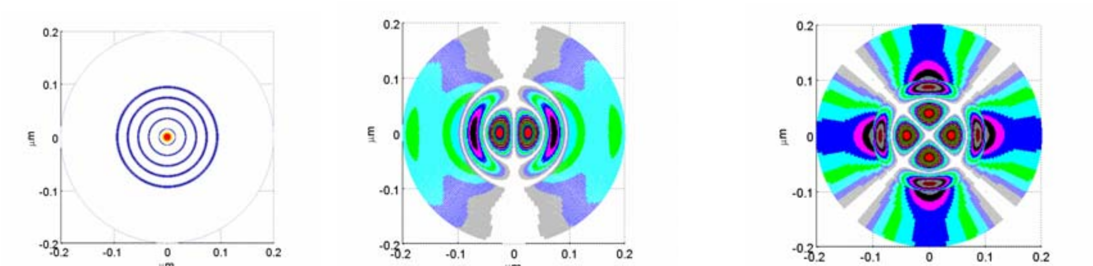

(a) 1st order mode (b) 2nd order mode (c) 3rd order mode

Fig.1 The resonant modes in the near field diffracted from the aperture embedded in the thin plate