6.2 OPTICAL DIELECTRIC WAVEGUIDES*

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By cladding a high index of refraction glass core of sufficiently small cross-section with another glass of lower refractive index, dielectric waveguides have been made with one or a few modes of propagation in the visible region of the spectrum.

Except for the cylindrially symmetric TE_{om} and TN_{om} modes, which are similar to those in the metallic waveguide, the modes have z-components for both the electric and magnetic fields. There are two sets of hybrid modes, designated HE_{nm} and EH_{nm} ($n\geq 1$). The axial components of the field for these modes are given by

$$(E_z, \ H_z) \quad \alpha \quad J_n(ur/a) \ \cos n\theta \ \exp[i(hz - \omega t)], \tag{1}$$

where J_n is the n'th order Bessel function, a the radius of the core, and h and u are parameters found from the boundary conditions. The distinction between HE and EH modes is in the transverse components of the field. For the case of a small difference in the indices of refraction of the core and cladding, the radial dependence of the transverse components of the field is $J_{n-1}(ur/a)$ for the HE_{nm} mode and $J_{n+1}(ur/a)$ for the EH_{nm} mode.

The lowest order mode, the HE_{11} hybrid mode, does not have a cutoff. The cutoff parameters for the modes designated TE_{om}, TM_{om}, HE_{1m} and EH_{nm} are given by the roots of

$$J_n(u_{nm}) = 0, \tag{2}$$

and for the HE_{nm} ($n\geq 2$) modes it is the solution of

$$\frac{J_{n-2}(u_{nm})}{u_{nm}J_{n-1}(u_{nm})} = -(n-1)\frac{n_1^2 - n_2^2}{n_2^2} \tag{3}$$

The cutoff parameters are in turn related to the properties of the guide by

$$u_{nm} = 2\pi(a/\lambda)(n_1^2 - n_2^2)^{1/2}, \tag{4}$$

where n_1 and n_2 are the indices of refraction of core and cladding and λ the free space wavelength.

For small values of the quantity (n_1 - n_2) the right side of Equation (3) is close to zero and the cutoff parameter for an HE_{nm} ($n\geq 2$) mode is approximately the m'th root of $J_{n-2} = 0$, which applies for the $EH_{n-2,m}$ mode. Furthermore, the tranverse components of the field have the same radial dependence for these two modes. The interesting effects resulting from the coherent excitation of such pairs of modes will be discussed.

Two methods of selectively exciting a mode or combination of modes have been used. The simpler one consists of illuminating the entire end of the fiber with a relatively narrow cone of light of approximately 1^{o} to 5^{o}. By varying the angle of incidence with respect to the guide axis different modes can be excited. In the second method, a demagnified image of a pinhole is projected onto or near a portion of the end of the core with an oil immersion microscope. The fiber receives light in a wide cone, but selective excitation is achieved by illuminating different portions of the fiber.

By focusing a microscope on the exit end of the fiber the direct image or near field for the mode excited can be obtained. The radiation pattern can be observed by use of a telescopic eyepiece to view the back focal plane of the microscope objective.

The fibers studied had core indices of refraction ranging from 1.48 to 1.80 and cladding indices from 1.47 to 1.52. Single modes have been observed in fibers with diameters down to 0.1 micron, in which only the HE_{11} mode propagates, and with diameters as large as 25 microns, where modes such as the $HE_{14,11}$ propagates.

Crosstalk between two closely spaced cores in a common cladding has been investigated both theoretically and experimentally. Each mode crosstalks independently of the others with coherence preserved in the transferred light.

Some experiments with mode filtering by use of absorbing filaments down the center of the core will be presented.

The use of glass fibers to simulate microwave dielectric endfire antennas, some possible device applications, and the possible role of waveguide effects in color vision will be discussed.

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*This work supported in part by the U. S. Air Force Cambridge Research Center.