NOVEL MODE FILTER FOR USE WITH CLADDED-GLASS AND LIQUID-CORE OPTICAL WAVEGUIDES

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Two methods of filtering off high-order modes in multimode fibres are proposed. One uses a periodic sequence of apertures and the other involves continuous coupling. In this way, it may be possible to achieve bandwidths approaching 100 MHz over kilometre lengths.

Until recently, research on fibre waveguides for optical communications has centred on the cladded-glass single-mode version, where the core diameter is about 3 μm, in order that an adequate bandwidth may be achieved. Interest was heightened a year or so ago by the advent[1] of a single-mode fibre having an attenuation of less than 20 dB/km. Unfortunately, the material used was silica, which is not easy to process and long lengths of this silica fibre have not become available. Launching from semiconductor lasers, and jointing between adjacent sections, are further difficulties which have not yet been solved for single-mode fibres. Multimode fibres were not thought to be suitable for long-distance links, because existing attenuations were high and the dispersion was expected to be large, owing to mode-conversion effects.

However, two recent developments have produced greatly increased interest in multimode fibres. First, liquid-core fibres* have been produced in kilometre lengths with attenuations of less than 20 dB/km. Secondly, pulse dispersions in cladded-glass and liquid-core fibres as low as 3 ps/m have been obtained[2] in lengths of 43 and 100 m, respectively. If these dispersions can be maintained over distances of a kilometre, bandwidths of about 100 Mbit/s may be possible. These measurements have also shown that a ray model gives a good description of propagation in cladded-glass fibres in particular, but that a small amount of additional scattering occurs.

We postulate, therefore, that it should be possible to maintain a low dispersion over long lengths of fibre by a mode filter which removes high-angle rays (i.e. high-order modes) as they are formed. To investigate whether such a technique might be feasible, we have placed an aperture at the output end of a length of fibre of 55 μm core diameter, and thereby obtained a reduction in dispersion from 7 to 4 ps/m. Measurements of the angular distribution of light in fibres drawn in our laboratories show that there is little change over the first 50 m, but a measurable change over 100 m. A mode filter might thus be made by introducing suitable apertures, in the form of constrictions, at intervals of about 100 m along the fibre. These would be of such a shape and length that high-angle rays were coupled out into the cladding, so that they would ultimately be lost in a third lossy layer. The apertures can be introduced by a programmed change in pulling speed during the manufacture of the cladded fibre, or of the fibre tube for a liquid-core fibre. The cross-section of our fibres can be maintained to better than 1 μm, and there should be little difficulty in forming a precise profile of the required dimensions.

* OGILVY, G. J.: Comments made at Institute of Physics meeting on fibre-optical communications, London, 28th March 1972

An alternative method is to achieve continuous mode filtering by an appropriate choice of the refractive-index difference Δn between the core and cladding. Rays scattered into angles relative to the axis of greater than $\cos^{-1}(1-\Delta n/n)$, where n is the refractive index of the core, are again coupled out. Using the ray-propagation model, the dispersion to be expected from beams of different angular widths has been calculated, and a lower limit can be placed on the bandwidth to be expected with different refractive-index ratios. Thus, for a Δn of 1%, a dispersion of less than 18 ps/m, corresponding to a bandwidth of greater than 30 Mbit/s, should be maintained over long distances. That such mode filtering does, in fact, occur is suggested by the increase in spatial coherence observed[3] when thermal light propagates along narrow tubes.

Measurements on the amount of scattering in our fibres gives a value about 10 dB/km at a wavelength of 850 nm, and, while the angular spreading of transmitted beams may also be due to additional causes, the attenuation introduced by the above mode filtering techniques will be small. Multimode fibres are easier to make than single-mode fibres, and the problems of beam launching and cable jointing are much more easily overcome. Efficient launching from lasers[4] (96%) and light-emitting diodes is possible, and multimode fibres must thus be considered as serious contenders for future optical-communications systems.

W. A. GAMBLING
J. P. DAKIN
D. N. PAYNE
H. R. D. SUNAK

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Department of Electronics
University of Southampton
Southampton SO9 5NH, England

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