ME2 Update on polarization-maintaining fibers

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There is widespread interest in fibers which can hold a given state of polarization despite bends, kinks, and environmental changes. Applications at present are primarily in fiber sensors with the fiber gyroscope[1] the most immediate. However, the attainment[2] of low loss with good polarization holding in lengths up to 8 km is an indication of the potential for coherent communication systems.

Conventional single-mode fibers propagate *x*- and *y*-polarized versions of the HE_{11} mode (HE_x and HE_y). Sustained transmission of linear polarization requires only one mode to be present. This can be achieved in two ways:

(1) The fiber birefringence is made large[3] so that the propagation constants of the *x*- and *y*-polarized modes differ greatly, thus ensuring that the modes remain independent, i.e., do not couple. Typical perturbations experienced by the fiber require a modal birefringence $B > 10^{-4}$ to prevent significant power transfer to the unwanted mode and degradation of the extinction ratio. A modal birefringence as high as $B = 1.2 \times 10^{-3}$ has been reported.[4] Such fibers are polarization-maintaining.

(2) A better solution is to ensure that the mode with the unwanted polarization is attenuated, being either leaky or below cutoff. The fiber then acts as a polarizer and is known as a polarizing or single-linear-polarization (SLP) fiber.

Both schemes require the birefringence to be as large as possible. Asymmetric waveguide geometry (elliptical,[5] sit-pit[6]) can be employed but requires larger index differences than current low-loss fabrication technology is able to provide easily. Thermal stress on the other hand can give large values of material anisotropy. Several designs have emerged (elliptical jacket,[7] PANDA,[2] Bow-Tie[8]) aimed at maximizing stress birefringence, although none yet approaches the theoretical maximum set by the intrinsic fracture strength of the glass. An analytic solution for thermal stress birefringence is now available and allows optimization of the disposition of the stress-inducing high-expansion regions.

The most recent advances have been in the development of polarizing (SLP) fibers.[10,11] Although polarizing performance can be achieved by means of an asymmetric geometry alone,[12] a combination of stress birefringence to split the HE_x and HE_y modes and a waveguide structure which provides differential mode leakage is currently more successful. Long lengths of low-loss Bow-Tie fiber have been reported[10] in which the unwanted mode is attenuated by >55 dB/km. The mode leakage mechanism whereby the LP_y mode is differentially attenuated is considerably enhanced by fiber bends,[11,13] although it is found that some designs have good performance when straight. Analysis of the leakage mechanism is made more complex by the asymmetry of the waveguiding structure which gives bend losses which differ with bend orientation.[13] However, in simplest terms the preferential leakage can be understood by noting that the stress-induced anisotropy of core and cladding combine to give a more weakly guiding index profile for one polarization than for the other. It has been found that, when used as a high-performance polarizer, extinction ratios can be limited by reexcitation of the leaky mode at bends and twists.

Advances in optimizing the fiber structure to give a wide operating wavelength window and high-extinction ratios will be reviewed.

(Invited paper, 12 min)

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