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A Dual-mode Optical Fiber for Long-haul Transmission

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We are currently investigating the feasibility of dual-mode optical fibers of both matched-clad and depressed-clad, pure-silica core designs for application in missile tethers and undersea surveillance cables. The ultimate goal is to realize a fiber with a pure-silica core for the lowest spectral attenuation and dual-mode operation ($\lambda_c > 1550$ nm) for reduced bending losses. An intermediate goal has been achieved in which the dual-mode fiber performance was realized in a matched-clad design. This was done to study bending loss and modal noise and dispersion at 1550 nm. The matched-clad dual-mode fiber exhibits low bending losses that are comparable to high- Δ single-mode fibers, but with a lower Δ which is achievable in depressed-clad, pure-silica core fibers. Δ is the relative index difference between the core and cladding. Since the fiber supports two modes, we also studied the effects of modal noise and modal dispersion and found that the fiber can be designed to exhibit minimal modal noise and dispersion penalties.

The goal for the matched-clad dual-mode fiber was to duplicate the low bending losses exhibited by high- Δ fibers (Δ as large as 1%)^{1,2}, which are the lowest bending loss fibers available for long-haul applications. This was achieved by increasing the cutoff wavelength λ_c to 1630 nm and reducing Δ to 0.75% to be comparable with the largest Δ reported for a pure-silica core fiber¹. Fig. 1 shows that the bending losses in the dual-mode fiber are comparable to a high- Δ fiber with $\Delta=0.93\%$ and $\lambda_c=1259$ nm. The bending losses in both fibers also are much less than a telco fiber with $\Delta=0.34\%$ and $\lambda_c=1200$ nm. The high λ_c in the dual-mode fiber has the same effect of confining the mode field tightly to the core and reducing bending losses as the high Δ in the high- Δ fiber.

Since the dual-mode fiber supports both the fundamental LP_{01} mode and second-order LP_{11} mode, modal noise and dispersion can impact system performance. Both effects were found to be minimal for $\lambda_c=1630$ nm where the LP_{11} mode is very loosely bound to the core. Bit-error-rate tests at a data rate of 200 Mb/sec were conducted to evaluate the effects of modal noise. The modal-noise power penalty in a worse case situation where a misaligned splice was positioned near the end of the fiber was only 0.2 dB with respect to a baseline measurement. The spectral attenuations of the modes also were measured to indirectly evaluate modal dispersion since long lengths of the dual-mode fiber were not available for direct dispersion measurements. The LP_{11} mode exhibited about 300 dB/km attenuation at 1550 nm, which is three orders of magnitude greater than the attenuation of the LP_{01} mode and precludes modal dispersion.

Based on the test results, the matched-clad, dual-mode fiber is feasible for reduced bending losses in long-haul transmission. Further investigations into a pure-silica core, dual-mode fiber is recommended.

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1. Starkey, T.C., J.W. Suggs, "Reduced Mode-Field Diameter Single-Mode Fiber for Specialty

