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Optical Waveguides With Very Low Losses

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Low-loss optical fibers may be necessary for economical optical transmission systems. We have developed fibers that exhibit losses of less than 2 dB/km, at 1.06 μm. The fibers were made by a chemical vapor deposition (CVD) technique that employs simultaneous reaction and fusion to a clear glassy core material.

Two fiber compositions have been used. In the first fiber, a GeO_2-doped fused-silica core is deposited inside a fused-quartz tube that acts as the cladding after the tube is collapsed into a rod and pulled into a fiber.

Figure 1 shows the loss spectrum of a fiber made in this manner. The fiber is 723 m long and has a core approximately 35 μm in diameter. The numerical aperture is 0.235. The loss decreases by approximately λ^{-4}, the expected Rayleigh scattering dependence, to a minimum just under 2 dB/km at 1.06 μm. Hydroxyl-ion-related absorptions at 0.72, 0.88, and 0.95 μm are low, amounting to less than 10 dB/km at 0.95 μm. We believe that the OH impurities causing these absorptions are due to siloxane present in the $SiCl_4$ starting material. This can be removed by fractional distillation, and loss peaks due to the hydroxyl-ion-related absorptions as low as 2 dB/km above background at 0.95 μm have been observed in similar fibers. This process has been used to produce GeO_2-doped fibers with numerical apertures as high as 0.35,

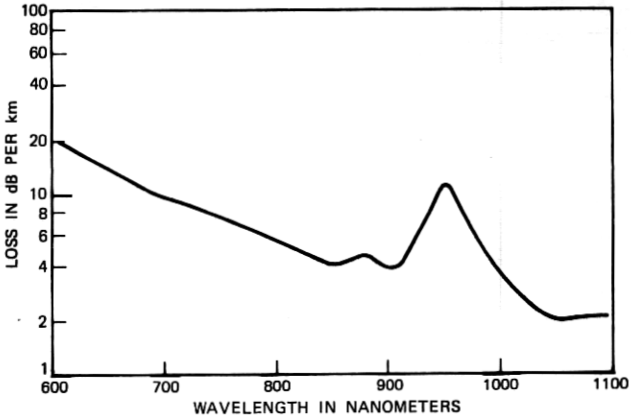

Fig. 1—Loss spectrum of a fiber waveguide with a GeO_2–SiO_2 core and a SiO_2 cladding.

and lengths up to 1.2 km. The length is presently limited by the available fiber-drawing facilities.

Figure 2 illustrates the loss spectrum of a second type of fiber consisting of a pure fused-silica core and borosilicate cladding. In this

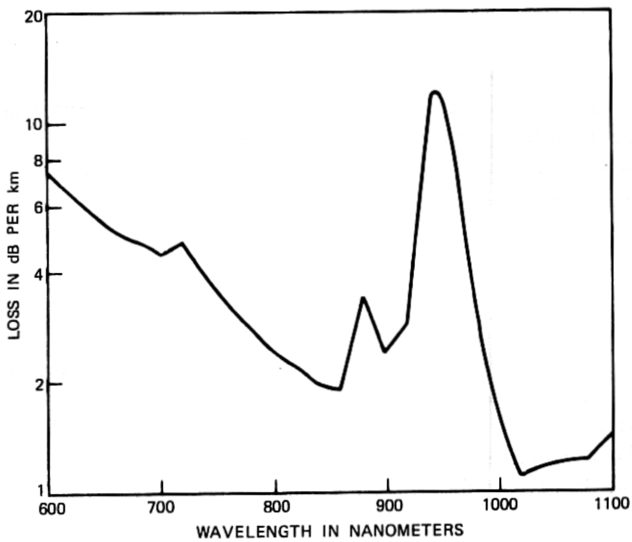

Fig. 2—Loss spectrum of a fiber waveguide with a SiO_2 core and B_2O_3–SiO_2 cladding.

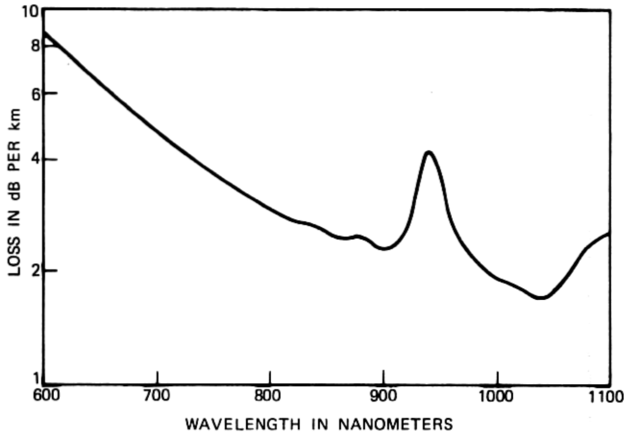

Fig. 3—Loss spectrum of a fiber waveguide with a graded-refractive-index core (B_2O_3–SiO_2) and borosilicate cladding.

case, both core and cladding were formed by CVD with simultaneous fusion inside a fused-quartz tube, which will be described in an article to be published in the near future. This fiber was over 0.5 km long and was characterized by an 18-μm-diameter core, a 15-μm cladding thickness, a 100-μm overall diameter, and a numerical aperture of 0.17. Loss minima occurred at 0.86, 0.90, and 1.02 μm. The average losses at these wavelengths were 1.9, 2.4, and 1.1 dB/km, respectively. The loss at 1.06 μm was 1.2 dB/km.

In addition to low loss, optical waveguides should exhibit low pulse dispersion so that high data rates can be achieved. One way to accomplish this is through the use of graded-refractive-index cores.[1] By gradually changing the concentration of reactive gases as the film thickness is built up, graded-refractive-index profiles can be achieved. This has been accomplished in the GeO_2-doped-core system by varying the concentration of $GeCl_4$ in the gas stream and in the silica-core, borosilicate-clad system by varying the concentration of BCl_3 during the deposition. The loss spectrum of a fiber in which the B_2O_3 concentration gradually changes from 0 at the center to about 20 percent at the core-cladding interface is presented in Fig. 3. This fiber had a 22-μm core diameter, a 15-μm cladding thickness, and a 0.17 numerical aperture. Minima occur in the loss spectrum at 0.90 and 1.04 μm. The losses at these wavelengths were 2.3 and 1.7 dB/km, respectively.

ACKNOWLEDGMENTS

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