Air-Guided Air-Silica Bragg Fibers With Nanostructured Cladding

T. Sørensen, Y. Xu, G. Vienne, C. Jakobsen, H. J. Deyerl, J. B. Jensen, T. P. Hansen, Y. Huang, M. Terrel, R. K. Lee, N. A. Mortensen, J. Broeng, H. Simonsen, A. Bjarklev and A. Yariv

A new class of hollow-core Bragg fibers[1] composed of concentric cylindrical silica rings separated by nanoscale support bridges is presented.[2, 3] These fibers are believed to be especially useful for high-power delivery of light within a broad wavelength range or at multiple wavelength bands. We experimentally observe theoretically predicted hollow-core confinement over an octave frequency range. The bandwidth of bandgap guiding in this type of Bragg fiber far exceeds that of other hollow-core fibers reported in the literature. With the record-low number of three rings of silica cladding layers, these Bragg fibers achieve a propagation loss of the order of 1 dB/m. The concept of hollow-core Bragg fibers, in which the fiber cladding is composed of cylindrical dielectric layers with alternating refractive indices, was first proposed in 1978.[1] Cregan et al. demonstrated another class of hollow-core fibers, namely, photonic crystal fibers, in which the cladding structure is formed by creating a two-dimensional array of airholes in a high-index material, typically silica.[4]

In general, the transmission coefficient through a planar Bragg reflector, which translates to a leakage coefficient of the Bragg fiber, depends exponentially on the number of layers.[5, 6] We consider a specific Bragg fiber with a hollow-core radius of 10 μm. The fiber cladding is formed by three layers with a refractive index of 1.45 and average thickness of 370 nm, separated by 4.10-μm-thick air layers. In practice, support bridges must be introduced to separate the adjacent silica rings. Assuming mass conservation throughout the fiber pulling process, we estimate the support bridge thickness to be in the area of 45 nm, which is in reasonable agreement with the results obtained with scanning electron microscopes.

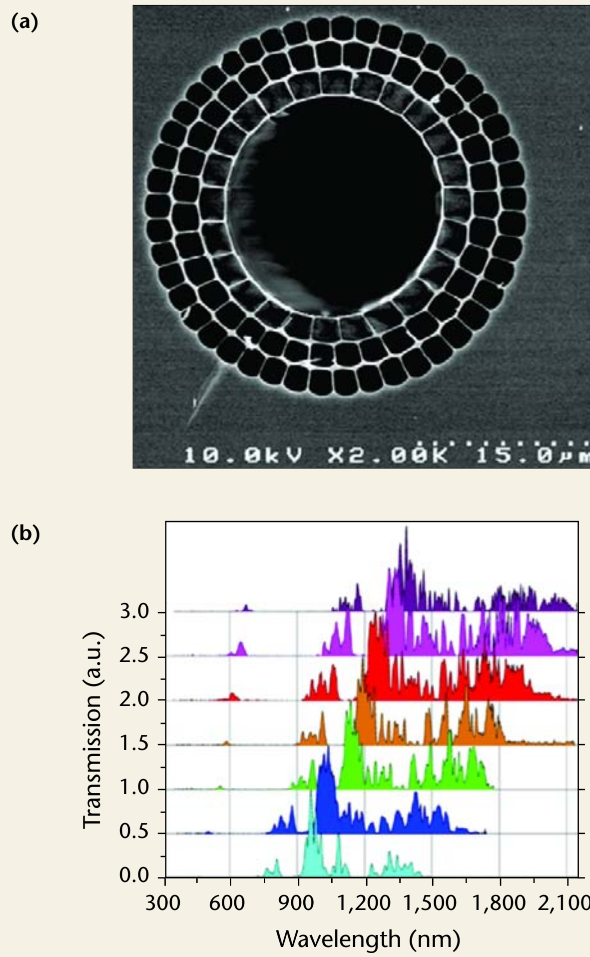

Figure 1. Scanning electron micrograph of a Bragg fiber with an outer diameter of 90 μm and transmission spectra of similar fibers with different scalings.

Because the support bridges are much smaller than the wavelength of interest, we can, to a good approximation, neglect the presence of these support bridges and regard the region between the high-index silica layers as composed entirely of air. An interesting feature that will further inspire the development of this type of fiber is that, with only four silica layers, theoretical considerations predict that the fiber leakage loss can be reduced to less than 0.1dB/km. Also, the Bragg fiber supports low-loss modes (less than 1dB/m) in the 0.82–2.86-μm wavelength range, which is almost two octaves in frequency range, and also in a wavelength interval in which material losses are so high that one could indeed benefit from an air core of the fiber.

T. Sørensen (thors@ com.dtu.dk), J. B. Jensen, T. P. Hansen and A. Bjarklev are with Research Center COM, Technical University of Denmark, Lyngby, Denmark. H. J. Deyerl is with the Abteilung für Ionenphysik, Technische Universität Chemnitz, Germany. Y. Xu, Y. Huang, M. Terrel, R. K. Lee and A. Yariv are with the California Institute of Technology, Pasadena, Calif. G. Vienne is with the Center for Advanced Research in Photonics, Chinese University of Hong Kong, Shatin, Hong Kong. C. Jakobsen, T. P. Hansen, J. Broeng and H. Simonsen are with Crystal Fibre A/S, Birkerød, Denmark. N. A. Mortensen is with the Department of Micro and Nanotechnology, Technical University of Denmark, Lyngby, Denmark.

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