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“Colorful” solid-core Bragg fibers guiding in the visible

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Abstract: We report on the fabrication and characterization of intensely colored solid core all-polymer Bragg fibers. By modifying the reflector layer thickness we illustrate that bandgap position can be adjusted at will in the visible.

OCIS codes: 060.2280 Fiber design and fabrication; 060.2270 Fiber characterization; 999.9999 Solid core Bragg fibers

Microstructured plastic optical fibers have recently been applied to various important problems including data communication over short distances [1, 2]; non-linear optics; light amplification; bio-molecular sensors [3]; mid-IR and THz guiding; as well as biocompatible and biodegradable fibers for in-vivo light delivery and sensing.

In this paper, we present fabrication and optical characterization of a solid-core photonic crystal all-polymer Bragg fiber for guiding in the visible range. The fiber is designed in a view of its potential applications in plasmonic fiber-based sensors, high bandwidth datacom links [2], as well as in color-selective illumination. The fibers detailed in this letter consist of a large polymethyl methacrylate (PMMA) core surrounded with a 50-layer PMMA/PS(polystyrene) Bragg reflector, having a refractive index contrast $\sim 1.49/1.59$. A co-rolling process [4] was used to make the fiber preform. Large bandgaps, having a spectral width of up to $\sim 25\%$ of a bandgap center wavelength, were predicted [5] for this material combination. Fibers with distinct realizations of photonic bandgaps were fabricated by drawing the same preform into fibers of various outside diameters.

Details of the fabrication process are as follows. The fiber preform (Fig. 1(a)) was prepared using commercial plastic rods and films. Particularly, PMMA film was purchased from the Degussa company; PS film was purchased from the Dow Chemical Company; PMMA rods were purchased from McMaster Carr Canada. The core consisted of a 1.27 cm diameter PMMA rod which was degassed and annealed in an oven at 90°C for 48 hours prior to use. PS and PMMA films, both of 50 μm thickness, were then co-rolled around a PMMA core rod to create 50 alternating PS/PMMA layers (Bragg reflector). The fiber preform was consolidated in an oven at 130°C for 4 hours. The preform was then mounted in a draw tower and preheated at 150°C for 2 hours. The fiber was subsequently drawn at 180°C at a speed of 1000 mm/min. Figure 1(b) shows a microscope image of the fiber cross-section with Bragg reflector layers clearly visible.

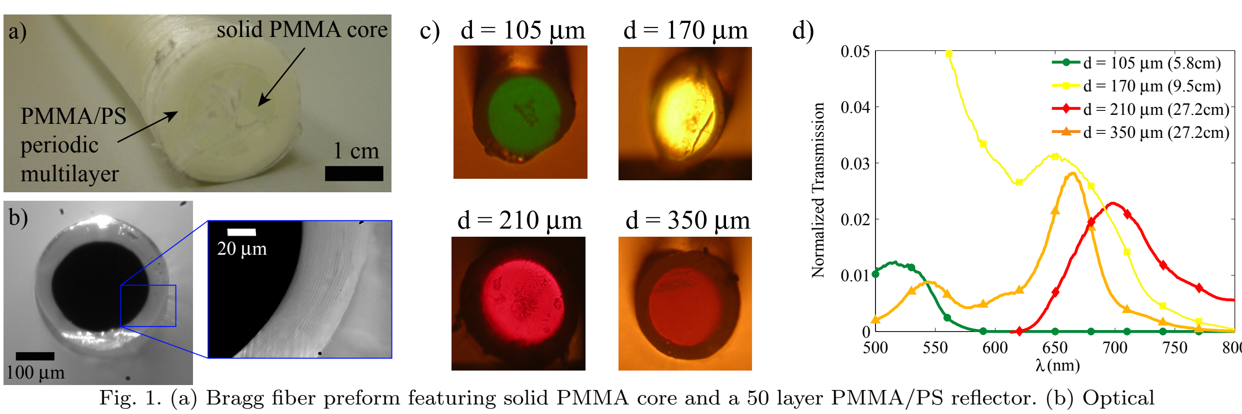

Fig. 1. (a) Bragg fiber preform featuring solid PMMA core and a 50 layer PMMA/PS reflector. (b) Optical micrograph of the drawn fiber cross-section. (c) Photographs of the transmitted light for fibers of different diameters. A white light beam from a supercontinuum source was focused by an objective and launched into the fiber center. In order of decreasing diameter, the output of the fibers appear orange, red, yellow, and green respectively. (d) Visible spectra. The diameter and the length of the fibers are indicated in the legend.

The fiber was drawn from the same preform down to several different diameters, ranging from 100 to 350 μm, with an aim of varying the spectral position of the photonic bandgap. Transmission through $\sim$20 cm of such fibers was then studied using a supercontinuum white-light source focused by an objective into the fiber center. Observation of the fibers revealed that upon launching white light, all the spectral components not guided by the reflector bandgap were irradiated in the first 1-3 cm along the fiber length. Subsequently, only a particular color guided by the bandgap was propagated to the fiber end. Moreover, due to imperfections, side-scattering loss in such fibers is substantial, thus leading to coloring of the whole fiber by the guided color.

The fiber photonic bandgaps were then independently observed by recording the fiber transmission spectra with the aid of a monochromator. Fig. 1(d) presents the fiber transmission spectra in the visible region normalized by the power spectrum of a supercontinuum source. Fiber segments having outside/core diameters of 350/250, 210/145, 170/103, 105/77 μm respectively guide reddish-orange, red, yellow and green light. The corresponding fiber lengths studied were respectively 27.2, 27.2, 9.5, and 5.8 cm. It is worth noting that the human perception of color is quite complex. Thus, for example, while the spectral transmission peak of the 350 μm diameter fiber is at red (660 nm), the actual color perceived by the eye is orange due to the presence of a second peak in the green (540 nm). Overestimate of the solid-core Bragg fiber losses from the corresponding normalized spectra give 0.6-4 dB/cm fiber loss depending on the sample. The main contribution to such loss in the near-IR is the PMMA absorption loss, while in the visible it is scattering off the fiber imperfections, which, in principle, can be greatly reduced through perfecting the preform fabrication process. Simulations of the fiber transmission properties revealed that all the fibers are guiding by the higher order photonic bandgaps.

Interpretation of the spectra in Fig. 1(d) is not trivial [6] as several loss mechanisms are contributing simultaneously. A careful comparison to a reference fiber made entirely of PMMA [6] reveals that PMMA absorption and Rayleigh scattering are insufficient to explain all the structural features of the Bragg fiber transmission spectra in the visible.

In conclusion, we demonstrated bandgap guidance in solid-core Bragg fibers operating in a visible range. The bandgap position was adjusted by drawing fibers of different outside diameters, and various colors coming out of the fibers were recorded when excited with a white light source. Fiber losses in the near-IR are dominated by the PMMA material loss, while in the visible they are dominated by scattering off reflector imperfections.

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3. References

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