Highly nonlinear non-silica glass microstructured optical fibers with near-zero dispersion and dispersion slope for 1.55μm applications

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Microstructured optical fiber (MOF) technology has generated several new opportunities for the implementation of optical fibers with novel properties and functions [1]. The novel optical properties of MOFs arise from the combination of wavelength-scale features in the fiber cross-section with the large index-contrast of the materials comprising the microstructured cladding. Due to the higher linear (n) and nonlinear refractive index (n_2) of non-silica glasses as compared to silica, it has been demonstrated that the effective nonlinearity (γ) of a non-silica glass MOF can be between 2-4 orders of magnitudes higher than that of the conventional silica fiber ($\gamma \sim 1W^{-1}km^{-1}$), thus enabling the realisation of compact nonlinear devices operating at practical power levels. However, for such applications as wavelength-conversion, optical parametric amplification, supercontinuum generation etc, apart from a high γ value, it is equally desirable that the nonlinear fiber also exhibits near-zero dispersion and dispersion slope at the operating wavelengths. We report here our recent advances on the fabrication of single-mode highly nonlinear lead-silicate MOFs with low dispersion and dispersion slope values at 1.55 μm.

The key in engineering the dispersion properties of small-core fibers is to achieve a suitable refractive index contrast between the core and cladding, while maintaining single mode guidance and a suitably high γ value. We discuss here two approaches to achieving this: (a) a solid MOF utilising two soft glasses with compatible thermal properties, and (b) a single-material holey fiber (HF) with a precisely engineered microstructure. Fig.1(a)&(b) shows the SEM images of fibers we have fabricated using these two respective approaches. Fiber #1 is a one-dimensional (1D) MOF. A high-index core with the diameter of 3.7μm is surrounded by low and high index rings. The high-index core and rings are made of Schott SF6 glass (n = 1.76 at 1.55μm) and the low-index rings are made of LLF1 glass (n= 1.53 at 1.55μm). Fiber #2 is a single-material HF, made of SF57 glass (n=1.80 at 1.55μm). A hexagonal core element comprising graded-sized holes is surrounded by six large holes to restrict the fiber confinement loss. The core element has a hole spacing Λ of 1.60μm and the hole-to-spacing ratio d/Λ varies between 0.35-0.50, while the side six large holes have an average hole-to-spacing ratio d_s/Λ_s of 0.85. For both types of fibers, the structured preforms are made using the glass extrusion method, as described in detail elsewhere [2,3]. Effectively single-mode guidance has been observed in both fibers at 1.55μm. The γ values of Fibers #1 and #2 have been respectively measured as $120W^{-1}km^{-1}$ and $270W^{-1}km^{-1}$ at 1.55μm, using the Boskovic method, whereas their respective propagation losses are 0.8±0.2dB/m and 3.0±0.1dB/m at 1.55μm. Note that 0.8dB/m is the lowest reported loss value at 1.55μm amongst all non-silica glass MOFs so far, and is largely limited by the material loss. Numerical calculations of the dispersion curves of the two fibers based on their SEM images are shown in Fig.1(c). Measurements at 1.55μm have confirmed dispersion values of +12.5ps/nm/km and -17ps/nm/km respectively (see marked symbols in Fig.1c). The dispersion slope of Fiber #2 of +0.10 ps/nm^2/km at 1.55μm is also the lowest reported value for non-silica glass fibers [4].

In conclusion, we have presented two techniques for the implementation of high nonlinearity non-silica fibers with tailored dispersion properties. We show that even though both techniques present their own challenges and benefits, all-solid MOFs can achieve similar optical properties to complex HF structures, while providing a more straight-forward route to alleviating excess waveguide losses. This work is funded by FP7-22457 PHASORS.

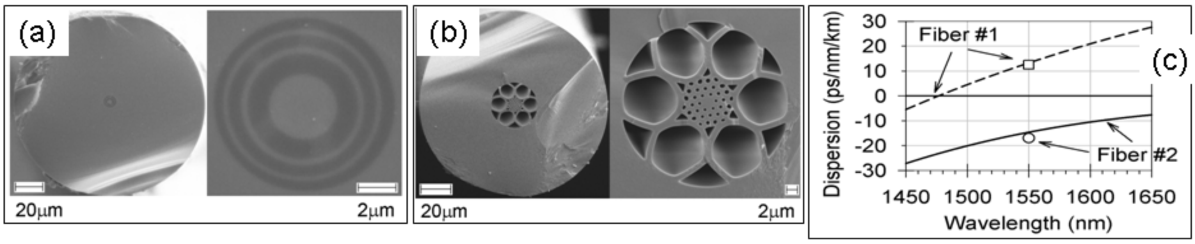

Fig. 1 SEM photos of (a) Fiber #1 and (b) Fiber #2; (c) calculated dispersion curves of Fiber #1 and Fiber #2 with measured dispersion (square: Fiber #1; circle: Fiber #2) at 1550nm

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