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Core modal spatial-structuring in inhibited-coupling hollow-core fibers

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A profound knowledge of the cladding mode properties and their interaction with the core modes is decisive for successfully designing inhibited-coupling (IC) guiding hollow-core photonic-crystal fibers (HC-PCFs). In IC fibers, the core and cladding modes coupling is robustly minimized due to a strong mismatch between their transverse phases and a small overlap between their fields. In the latest years, great attention has been given to IC fibers, especially since the introduction of the hypocycloid core contour concept [3], which entailed a dramatic loss reduction and preceded the development of single-ring tubular-lattice (SR-TL) HC-PCFs [4]. The interest on SR-TL HC-PCFs is due to their noteworthy properties such as geometric simplicity and the absence of connecting nodes in the fiber cladding, which favors IC guidance. Efforts on SR-TL HC-PCFs development entailed the accomplishment of ultra-low loss and broad transmission bandwidth [5]. Here, we show that the alteration of the lattice-tubes azimuthal position in SR-TL HC-PCFs causes modifications in the mode loss hierarchy and can be used to select the propagation of specific higher order modes (HOMs). It can be done by conveniently enlarging the spacing between the cladding tubes and by providing additional leakage to the fundamental mode while keeping low impact in the confinement loss (CL) of specific HOMs. It allows obtaining uncommon intensity profiles and polarization properties at the fiber output allowing it to act as a mode shaper.

Fig. 1a shows three fiber designs (FD) and their simulated CL spectra for the LP₀₁ and selected HOMs. FD#1 is a 10-tubes lattice fiber and has the LP₀₁ mode as the lowest loss one (3.6 dB/km at 1000 nm). In FD#2, by creating two larger gaps between the lattice tubes (at 180°), the LP₀₁ mode CL increases by two orders of magnitude while keeping low impact on the LP_{11,a} mode CL (modes profiles in Fig. 1a). It causes the latter to be the lowest loss one. In FD#3, the cladding structure has four larger gaps (at 90°) and favors LP₂₁ mode propagation. Poynting vector plots (p_r) in Fig. 1a maps the mode leaking channels for the different modes in the different FDs. Two fibers (F#1 and F#2) were fabricated and the losses of selected HOM were measured (Fig. 1b). The losses were measured for the situations in which LP₁₁- and LP₂₁-like profiles were seen at the fiber output. Finally, mode transformations in F#1 and F#2 were tested. Fig. 1c presents the uncommon fiber output profiles obtained for different input polarization angles. The unusual profiles observed in Fig. 1c arises from mode superpositions in F#1 and F#2 and are achievable by convenient light coupling. In particular, the lobes in the LP₁₁-like profile in F#1 have orthogonal polarization states, which is remarkable and very particular. We believe this novel concept will find applications in atom optics, atom-surface physics, sensing and nonlinear optics. Further details can be found in [6].

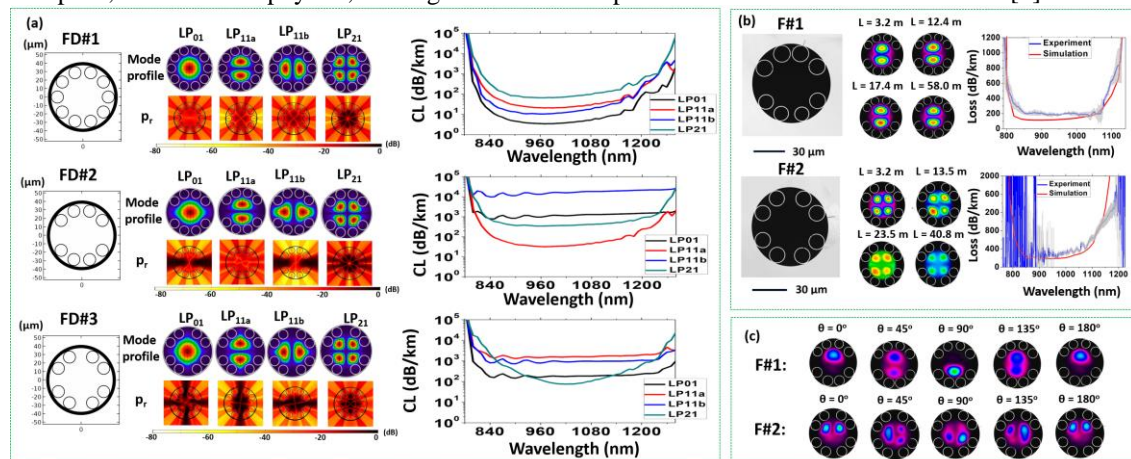


Fig. 1 (a) Fiber designs, mode profiles, Poynting vector map (p_r) and simulated CL. (b) Fabricated fibers, output near-field profiles and loss measurement of HOMs. (c) F#1 and F#2 output for different input polarization angles.

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References

- [1] T. A. Birks *et al.* "Full 2-D photonic bandgaps in silica/air structures," *Electronics Letters* **31**, 1941-1943 (1995).
- [2] F. Couny *et al.* "Generation and photonic guidance of multi-octave optical frequency combs," *Science* **318**, 1118-1121 (2007).
- [3] Y. Wang *et al.* "Low loss broadband transmission in optimized core-shape Kagome hollow core PCF. In *CLEO* (2010), paper CPDB4.
- [4] A. D. Pryamikov *et al.* "Demonstration of a waveguide regime for a silica hollow-core microstructured optical fiber with a negative curvature of the core boundary in the spectral region $> 3.5 \mu\text{m}$," *Optics Express* **19**, 1441-1448 (2011).
- [5] B. Debord *et al.* "Ultra-low transmission loss in inhibited-coupling guiding hollow fibers," *Optica* **4**, 209-217 (2017).
- [6] J. H. Osório *et al.* "Tailoring modal properties of inhibited-coupling guiding fibers by cladding modification" *Scientific Reports* (accepted, 2019).