Higher Order Modes in Anti-Resonant Hollow Core Fibers

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Abstract: Using spatially and spectrally resolved imaging, the higher order mode content in two designs of anti-resonant hollow core fiber is investigated. The length and bending dependence of the mode content is measured for both fibers.
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1. Introduction

Anti-resonant hollow core fibers (ARHCF) have recently been generating a lot of interest, due to their various potential applications [1]. The low attenuation and dispersion, broad transmission bandwidth, and relatively low design complexity make these fibers attractive for high power and short pulse delivery, midIR transmission, and fiber gas lasers [2,3]. While many aspects of these fibers have been studied, the mode content of the core has not been investigated in detail experimentally. Spatially and spectrally resolved imaging (S^2 imaging) allows for the measurement of the mode content in optical fibers using Fourier analysis of the multimode interference in both the spatial and the spectral domain [4].

2. Results and Discussion

Two fiber designs were measured with S^2 imaging, the first being an ARHCF with eight non-touching rings, a core diameter of 70 µm, and a ring thickness of 1.2 µm (Fig. 1 (a)), and the second with eight touching rings forming ice cream cone shapes, a core diameter of 48 µm, and a ring thickness of 0.77 µm (Fig. 1 (b)). Both fibers had their modal content measured as a function of fiber length in a cut back measurement and as a function of their bending diameter. The non-touching ring fiber was measured in the spectral region of 1400-1600 nm, the touching ring 1100-1300 nm, in order to avoid the resonant wavelength locations. The Fourier transforms from the cut back measurements are shown in Fig. 1 (c) and (d), for the non-touching and touching designs, respectively. The non-touching ring fiber was shown to have three higher order modes present, while the touching design only supported one higher order mode. The cut back measurements allowed for the calculation of the loss of each of the higher order modes, which enables understanding of how long the ARHCF needs to be in order to effectively operate in a "single mode" regime. Investigating the dependence of the higher order modes on bending, it was found that, in general, bending the ARHCF did increase the higher order mode attenuation considerably.

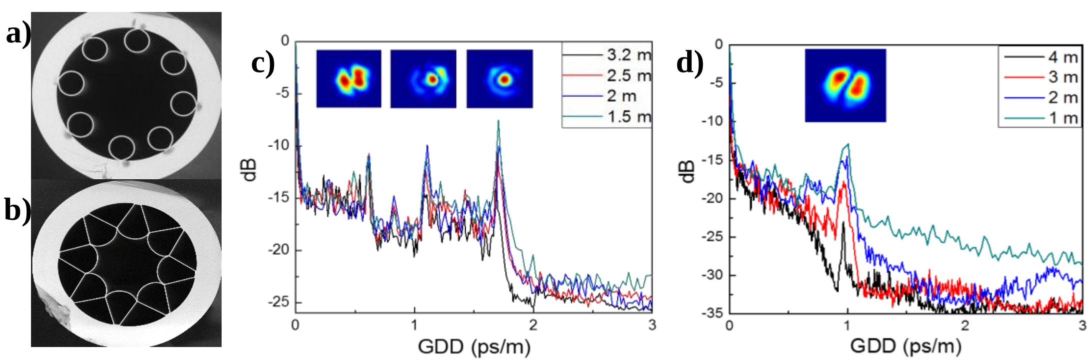

Fig. 1 (a) SEM image of non-touching ring ARHCF, (b) SEM image of ice cream cone ARHCF, Fourier transforms from S^2 cut back of (c) non-touching ring ARHCF and (d) ice cream cone ARHCF, with the reconstructed images of the associated higher order modes above the peaks.

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3. References

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