circular case. We believe this is because for the 8 tubes case, the AR tubes are smaller compared to the 6 tubes case. Therefore for small bend radius, 6 AR tubes have coupling between the core modes and tube modes due to the larger AR tubes whereas the coupling is reduced in 8 AR tubes because of the smaller AR tubes. Figure 6 also shows contour plots of the fundamental modes for 10 cm bending radius in which for 6 AR tubes there is a coupling between the core modes and tube modes whereas for 8 AR tubes there is no coupling between the core modes and tube modes. Therefore, choosing 6 or 8 tubes would have to be a compromise in terms of whether loss bandwidth, HOMER or bend loss is the most important feature.

We also considered introducing the ellipticity from the optimized circular design (10.2 μm AR tube radius), but instead of squeezing the ellipse azimuthally, it was elongated radially (i.e. extending the major axis) while keeping the core size fixed. This implies that the outer capillary expands its size as the ellipticity drops, which results in an improved loss performance compared to shrinking the minor axis (the case we have discussed so far). However, our calculations showed that the HOMER could not reach the same high values as found in Fig. 5(a). This implies that it is harder to reduce the phase-mismatch between the core HOMs and the cladding modes when extending the major axis.

## 3. Conclusion

In summary, a novel hollow-core anti-resonant fiber design has been proposed, in which the anti-resonant elements in the cladding are anisotropic in shape, in contrast to the conventional isotropic circular shape. Numerical simulations using an elliptical shape as the anisotropic cladding element showed loss performances and effective single-mode guidance that could not be achieved with isotropic (circular) cladding elements. In both cases the guiding of light in the core is based on the anti-resonances of the struts in the cladding and the inhibited coupling mechanism. However, the anisotropic shape has improved performance because it simultaneously offers: (a) strong negative curvature in the core, (b) node-free (non-touching) anti-resonant elements, and (c) larger distance from the core to the outer capillary for a given core curvature. This gives a design degree-of-freedom essential for enhancing the performance, e.g. by fixing the size of the core and outer capillary while tuning the ellipticity to minimize loss. We studied a specific case, where a silica-based fiber was optimized for the Yb-laser wavelength of 1.06 μm. The HOM extinction ratio was over 1000 in the range $\lambda$ = 1.0-1.75 μm with FM loss <5 dB/km at 1.06 μm and <15 dB/km for $\lambda$ = 1.0-1.65 μm, which relied on increasing HOM loss by reducing the phase-mismatch between them and the cladding modes, while still maintaining a large phase-mismatch between the FM and the cladding modes. These properties are extremely promising for ultra-fast extreme nonlinear optics applications exploiting fiber-based light-matter interaction [3]. The proposed design is generic, irrespective of glass composition and target wavelength, and we expect it to improve almost any type of hollow-core fiber design exploiting the anti-resonant effect.

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