Highly birefringent, low loss and low dispersion THz waveguides with sub-wavelength porous structure

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Summary

We demonstrate ultra high birefringence ($\Delta n \approx 0.026$) in a new type of porous THz waveguide that has rectangular and slot-shaped air-holes in the core. We also demonstrate low loss (0.01 cm^{-1}) and low dispersion ($\upsilon_g/c > 0.85$) for these porous fibers, which makes them suitable for THz field propagation.

Introduction

Bulk optics used to transport THz radiation in almost all terahertz spectroscopy and imaging systems. However, this is a limitation when it comes to integrating THz systems with infrared and optical techniques. Although terahertz waveguides promise a means of overcoming these hurdles, results to date have been limited by signal loss and dispersion.

Recently, a novel class of porous fibers for THz was suggested independently by two research groups [1,2]. Porous fibers are air-clad fibers with a pattern of sub-wavelength air-holes in the core. Such fibers allow low loss THz propagation and a better confinement of the field relative to solid core sub-wavelength fibers [3] (called THz microwire [4]). We have also recently demonstrated that porous fibers have less signal degradation, effective material loss and waveguide dispersion, compared to those of microwires [5].

Here we develop a new design of sub-wavelength air-holes in porous fibers that leads to ultra high birefringence in addition to low loss and dispersion characteristics of porous fibers [5]. This makes these fibers good substitutes for free space THz propagation for which the polarization state of the THz beam is always preserved.

Results, discussion and conclusion

Enhancement of the electric field in the sub-wavelength air-holes have been demonstrated in [2] and the references therein. The enhancement of the normal component of electric field at the interface of the sub-wavelength discontinuities in porous fibers depends on the refractive index contrast between the two media. Thus to maximize the overall enhancement of the electric field of one polarization with respect to the other, we choose rectangular and slot-shaped sub-wavelength air-holes with the long sides of rectangles perpendicular to one of the polarizations. The best arrangement for achieving high porosity values for rectangular and slot shaped air-holes are shown in Fig.1 (a) and Fig 1(b), respectively. Figures 1(c) and 1(d), the plot of normalized z-component of the Poynting vector, at 0.4 THz, show the intensity enhancement within

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the sub-wavelength holes. Cyclic olefin copolymer, TOPAS, is considered as the host material for all of the fibers, where its THz properties (refractive index and absorption coefficient) have been measured by THz time-domain spectroscopy [6].

Figure 2(a) shows the modal birefringence, $|n_x - n_y|$ i.e. the difference between the effective indices of the *x*-polarized and *y*-polarized fundamental modes. The porous fibers with slot and rectangular shaped air-holes provide a birefringence of 0.026 and 0.015, respectively, while the birefringence for porous fibers with circular air-holes and microwire is zero. These values are comparable to recently achieved high birefringence ≈ 0.025 in photonic crystals fibers [7].

The effective material loss (Fig. 2.(d)) and dispersion (Fig. 2.(c)) of these new porous fiber designs are comparable to the porous fibers with circular air-holes and much lower compared to microwire. Maintaining the polarization of the propagating field in THz waveguides is a step toward expanding their applications in polarization preserving systems. More details of the results will be presented and discussed.

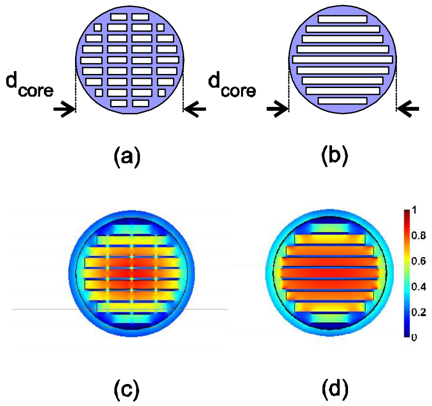

Fig. 1. Cross-section of porous fibers with (a) rectangular, and (b) slot shaped air-holes. The 2D view of normalized S_z for (c) rectangular and (d) slot shaped air-holes, at 0.4 THz.

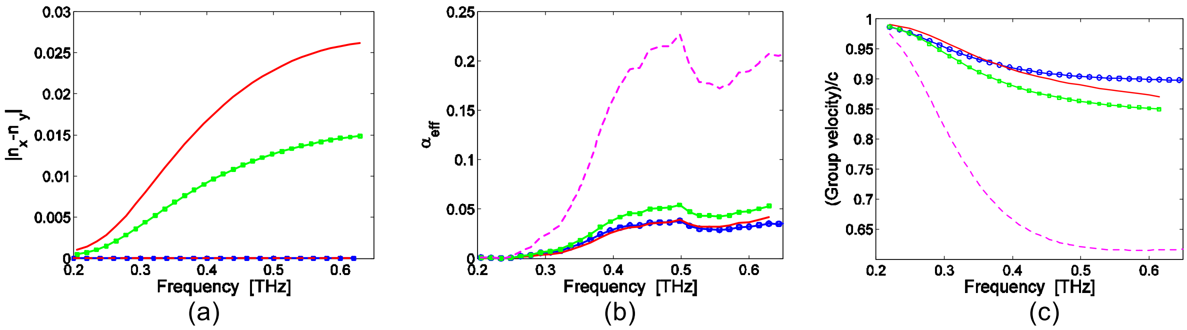

Fig. 2. (a) Modal birefringence, (b) effective material loss and (c) waveguide dispersion of porous fibers. ——— proous fiber with rectangular shaped air-holes and 57% porosity, —□— slot shaped air-holes and 61% porosity, —○— circular shaped air-holes and 74% porosity and - - - the microwire .

References

[1] A. Hassani, A. Dupuis, and M. Skorobogatiy, *Opt. Exp.* **16**, 6340–6351, 2008.
[2] S. Atakaramians, S. Afshar V., B. M. Fischer, D. Abbott, and T. M. Monro, *Opt. Exp.* **16**, 8845-8854, 2008.
[3] L.-J. Chen, H.-W. Chen, T.-F. Kao, J.-Y. Lu, and C.-K. Sun, *Opt. Lett.* **31**, 308–310 (2006).
[4] S. Afahar Vahid, S. Atakaramians, B.M. Fischer, H. Ebendorff-Heidepriem, T.M. Monro, and D. Abbott, *CLEO/QELS*, art. no. JWA105, Baltimore, Maryland, 2007.
[5] S. Atakaramians, S. Afshar Vahid, B. M. Fischer, D. Abbott, and T. M. Monro, *IRMMW/THz 2008*, California, US, accepted.
[6] B. M. Fischer, *PhD thesis*, University of Freiburg, 2005.
[7] X. Chen, M.-J. Li, N. Venkataraman, M. T. Gallagher, W. A. Wood, A. M. Crowley, J. P. Carberry, L. A. Zenteno and K. W. Koch, *Opt. Exp.* **12**, 3888-3893, 2004.