Suspended core polymer fibers with isolated mode for terahertz guiding

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Abstract: The fabrication and characterization of polymer suspended core fibers (porous and non-porous cores) for terahertz guiding is demonstrated for the first time. These novel fibers enable strong mode isolation from perturbations in the surrounding environment.

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1. Introduction

The design and fabrication of low-loss terahertz waveguides is currently the subject of active research. Dielectric subwavelength fibers have demonstrated single-mode propagation losses below 0.02 cm^{-1}. It was also shown that introducing significant porosity, in the otherwise solid core, makes it possible to shift the peak transmission of a subwavelength fiber to higher terahertz frequencies [1]. However, because of the highly delocalized fields, subwavelength fibers suffer from a high sensitivity to the surrounding environment and are difficult to manipulate or hold in place without disrupting the propagating terahertz signal.

In this paper, we propose a novel type of terahertz waveguide to address this problem: the dielectric suspended core fiber. Two different kinds of polymer suspended core fibers (one solid core and one porous core) are fabricated for the first time, and their modal and transmission properties are characterized by a combination of THz near-field microscopy and THz spectroscopy [2]. We demonstrate the ability of these highly flexible fibers for low-loss guiding of terahertz radiation in isolation from most external disturbances. Our results suggest that dielectric suspended core fibers are excellent candidates to provide signal delivery in THz imaging/microscopy applications that require a certain stand-off distance [3].

2. Fabrication and microstructure of polymer suspended core fibers

All fibers in this work were fabricated using commercial rods of low density polyethylene (LDPE) known to be one of the lowest loss material in the terahertz range. Both of the two suspended core preforms were made using a combination of drilling and stacking techniques. Following pressure-controlled drawing, a suspended *solid core* fiber of 5 mm outside diameter with a small 150 µm core diameter, and a suspended *porous core* fiber of 3 mm outside diameter with a relatively large 900 µm core diameter were obtained. The cross-sections of both fibers are presented in Figures 1(a) and 1(c), with corresponding detailed views of the suspended core in Fig. 1(b) and Fig. 1(d).

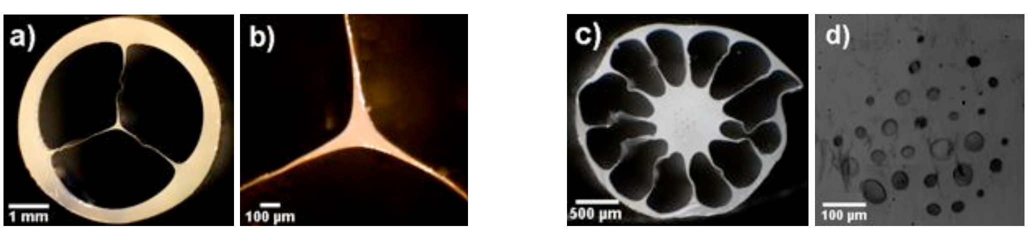

Fig. 1. (a) Cross section of the suspended core fiber Φ_{fiber} = 5 mm, and (b) close-up view of the suspended core region (Φ_{core}= 150µm). (c) Cross section of the porous core fiber Φ_{fiber} = 3 mm, and (d) close-up view of the suspended porous core (Φ_{core}= 900µm)

3. Terahertz transmission and near-field imaging of suspended core fibers

Figure 2 presents the transmission spectra of the two suspended core fibers. The solid core fiber, of maximal length 11.4 cm, was shown to guide in a relatively wide band of frequencies between 0.25 and 0.55 THz. On the other hand, the porous core fiber guides at lower frequencies between 0.05 and 0.30THz for an 11.9 cm long fiber. The attenuation α (cm^{-1}) of each fiber was evaluated via cut-back measurements and we report losses as low as 0.02 cm^{-1} within the peak transmission regions.

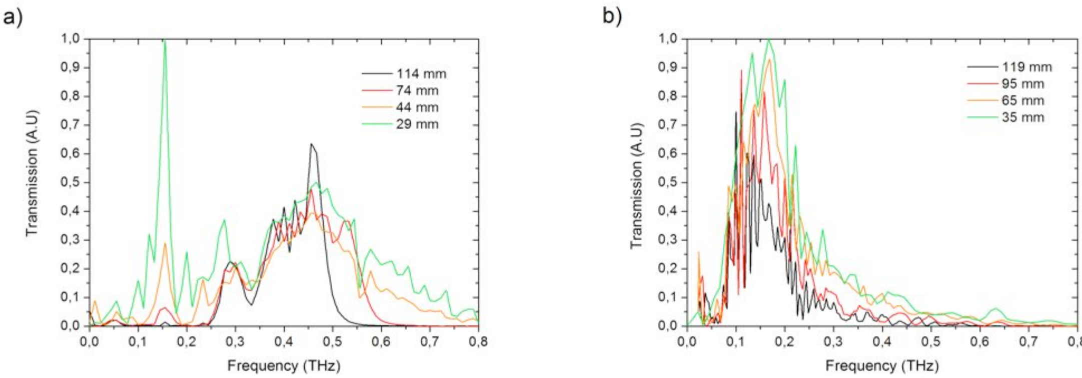

Fig. 2. Normalized transmission as a function of frequency between 0.01 and 0.80 THz for (a) the suspended solid core fiber, and (b) the suspended porous core fiber.

The near field images of the fiber output |E| profiles are also reported in Figure 3. Both fibers support a quasi-single mode regime inside their transmission window. The large fraction of air between the polyethylene core and the tube cladding creates a high-index contrast that enables strong confinement of the guided power in the core. As observed in Fig. 3, the fundamental guided mode becomes more and more confined inside the core as the frequency increases. Moreover, the tubular cladding effectively shields the core, and the propagating signal it supports, from perturbations in the surrounding environment thus allowing convenient hand manipulation and positioning via holders.

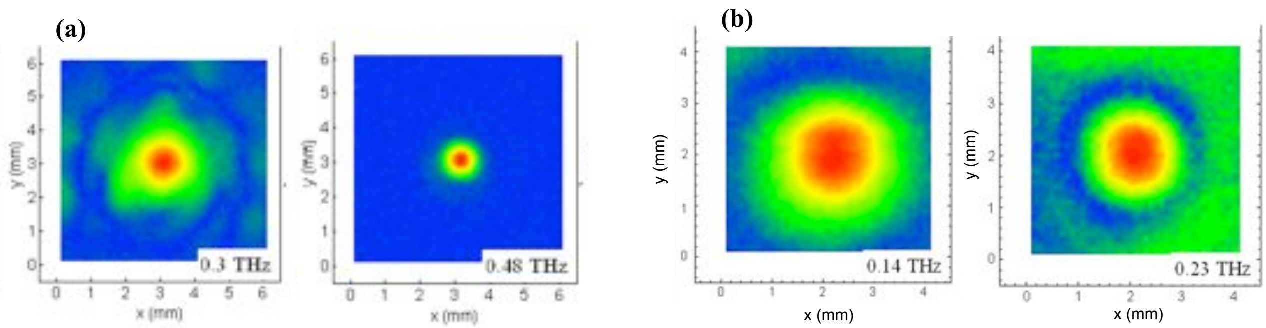

Fig. 3. Near field imaging of the output field profile of (a) suspended solid core fiber at 0.30 and 0.48 THz, and (b) suspended porous core fiber at 0.14 and 0.23 THz.

4. Summary

We demonstrate for the first time in this work, the fabrication and near-field characterization of suspended core polymer fibers. The proposed fibers allow a quasi-single mode propagation regime over a 0.20 THz bandwidth with losses as low as 0.02 cm^{-1}. Experimental results were confirmed in full-vector finite-element simulations. Contrary to bare subwavelength fibers, the guided mode in suspended core fibers largely remains confined within the core and isolated from external disturbances by the tubular cladding. This last feature makes these suspended core fibers very good candidates to enable efficient and perturbation-free signal delivery for THz near-field imaging/microscopy setups [3]. Moreover, thanks to the highly porous structure, one might envisage to use polymer suspended core fibers in THz sensing and spectroscopy applications [4,5].

5. References

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