Suspended Core Subwavelength Plastic Fibers for THz Guidance

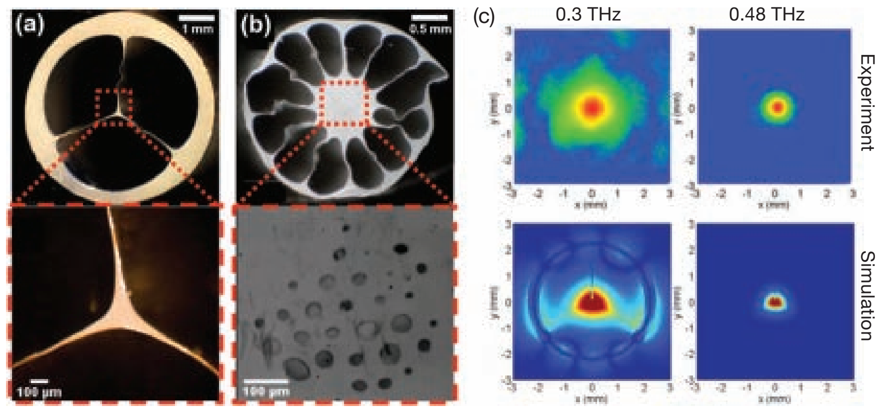
Bora Ung, Mathieu Rozé, Anna Mazhorova, Markus Walther and Maksim Skorobogatiy

The past decade has shown significant progress in the generation and detection of terahertz (THz) signals. The first generation of fully integrated THz imaging and spectroscopy systems are being commercialized for industrial and scientific applications. These systems are often based on expensive and bulky free-space optical components that require careful alignment. In order for THz systems to become more practical, their footprint must be reduced while their ease of operation and working standoff distance must be increased. This is why researchers have emphasized the development of THz waveguides for flexible, low-loss light delivery. We report on the design and realization of a practical, single-mode, fully encapsulated low-loss THz fiber.

It is well known that most materials in the THz exhibit high absorption losses (>0.1-20 dB/cm) that complicate the design of waveguides. Most current dielectric-based THz fibers are made of plastics since they are relatively low loss and low cost, and they offer low-temperature thermoforming and a wide array of chemical formulations.[1]

The most successful designs of dielectric THz waveguides allow mode confinement to be predominantly inside the low-loss and low-dispersion gaseous regions, thus alleviating the large material losses and chromatic dispersion experienced in the THz spectrum.

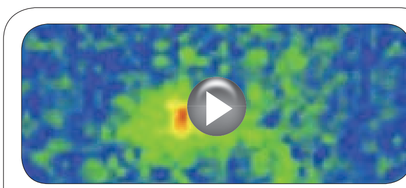
Specifically, subwavelength-size polymer fibers—featuring either a plain or porous core—have demonstrated single-mode guidance and attenuation losses in the 0.01 cm^{-1} range.[2] However, the guided mode of a subwavelength fiber features the strong presence of the fields in the cladding region, which prevents direct fiber handling due to the strong field overlap between the THz signal and the environment. This limitation represents a serious impediment to the deployment of fiber-based THz devices such as fiber endoscopes.



Examples of a suspended solid core subwavelength fiber (a) and suspended porous core subwavelength fiber (b). (c) Output near-field distribution of the suspended fiber in (a).

To solve this problem, we fabricated a polyethylene microstructured fiber featuring a subwavelength-size core suspended by very thin bridges in the middle of an air-filled tubular jacket.[3,4] Two types of fibers were successfully fabricated—one with a solid core (a) and the other with a porous core (b).

Near-field THz microscopy measurements[5] of the fiber output facet (c, top) indicate that, in the frequency range 0.28-0.48 THz, the core-guided mode of a suspended core fiber remains well confined within the tubular fiber jacket, and thus it is efficiently shielded from the environment. The experimental modal field distributions were also well reproduced by the finite-element simulations (c, bottom)—which also confirmed the effectively single-mode guidance in this frequency range.



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Moreover, the hollow region in the immediate vicinity of the core can be used as a micro-enclosure purged with dry gases, thus allowing us to forgo the cumbersome purging cages typically used in THz setups. Cutback measurements performed on the 50-cm-long fiber established low-loss guidance with signal attenuation below 0.02 cm^{-1} in the range of 0.28-0.48 THz.

In summary, this work shows that all-polymer suspended core fibers enable low-loss guidance, convenient handling and mode isolation from external perturbations. Moreover, the sealed tube cladding can also be used as a purging micro-enclosure. These crucial features make polymer suspended core fibers excellent candidates for practical THz signal delivery in next-generation THz imaging and spectroscopy setups. ▲

Bora Ung (boraung@gmail.com) Mathieu Rozé, Anna Mazhorova and Maksim Skorobogatiy are with the Ecole Polytechnique de Montreal, Canada. Markus Walther is with the University of Freiburg, Germany.

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