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Published in:
Proceedings, OTST

Publication date:
2009

Document Version
Publisher's PDF, also known as Version of record

Citation (APA):
Nielsen, K., Rasmussen, H. K., Adam, A. J. L., Planken, P. C. M., Bang, O., & Jepsen, P. U. (2009). Dispersion-tailored, low-loss photonic crystal fibers for the THz range. In *Proceedings, OTST*

Dispersion-tailored, low-loss photonic crystal fibers for the THz range

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Abstract: We have fabricated a new type of photonic crystal fibers based on a cyclic olefin copolymer, transparent in the THz range. We characterize the propagation loss, dispersion, and spatial beam profile in fibers designed for low and high dispersion.

Result: In this paper we demonstrate propagation of broadband THz pulses through microstructured polymer optical fibers designed with different dispersion characteristics. By using a cyclic olefin copolymer (COC) with the lowest known material loss and dispersion [1] in the THz range we can design photonic crystal fibers with favorable propagation characteristics, similar to photonic crystal fibers at telecommunication wavelengths but scaled to the much longer wavelength in the THz range. Here we demonstrate this design freedom with two structures that have zero group velocity dispersion (GVD) at 0.6 THz, and that utilize a small mode area (SMA) and a large mode area (LMA) to obtain high and low dispersion on the low- and high-frequency side of the zero-GVD point, respectively.

Our fibers are produced using a polymer drawing tower and is made by drilling holes in a solid COC cylindrical perform drawn down to dimensions suitable for THz frequency propagation. The fibers presented here have several advantages compared to fibers produced by the stacking method; they are more robust, they are easily cut, they can easily be shaped into sharp bends, and the periodicity of the structure is much more homogeneous along the fiber length.

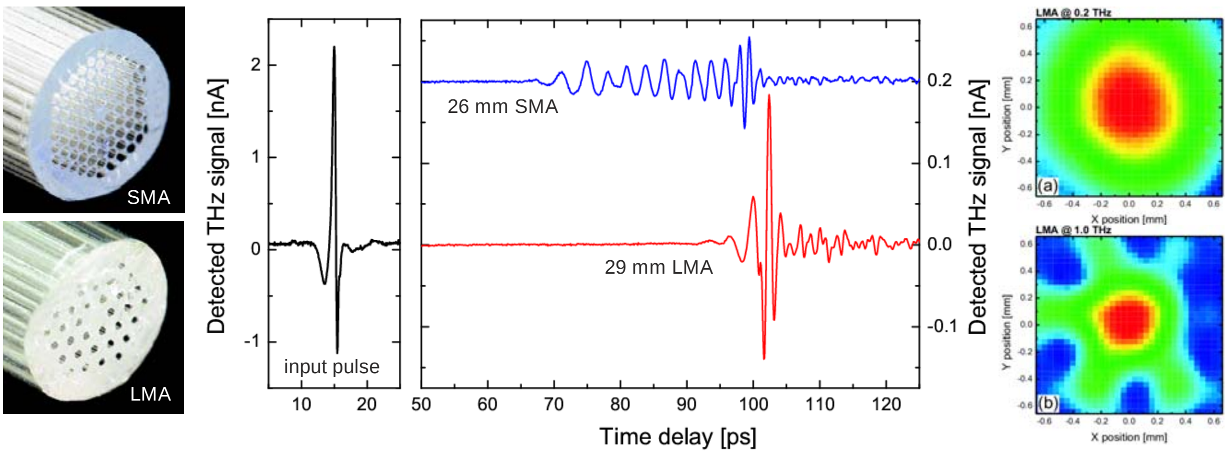

Figure 1: (left) photographs of the end facets of two PCF fibers, designed with a small mode area (SMA) and a large mode area (LMA). (center) transmitted THz pulses through the two fiber types, and (right) the measured mode profile of the LMA fiber at 0.2 THz and 1.0 THz.

The propagation loss of the fibers is characterized by standard THz time-domain spectroscopy, and reveals a record-low loss of 0.3 dB/cm at 0.6 THz, and an average loss <0.5 dB/cm in the 0.1-1.5 THz range. Dispersion measurements show that the fibers display normal dispersion at low frequencies, zero dispersion at 0.6 THz, and anormalous dispersion above 0.6 THz, in good agreement with numerical predictions. The SMA fiber displays strong dispersion, and the LMA fiber displays weak dispersion. The dispersion properties of the two fibers are illustrated by the pulse forms propagated through the two fiber types shown in the central part of Fig. 1.

The spatial mode profile of the propagating beam inside the two photonic crystal fibers has been characterized by near-field electro-optic sampling [2] of the electric field at the end facet of the fibers. Experimental results for the LMA fiber are shown for two frequencies (0.2 THz and 1.0 THz) in the right section of Fig. 1. These images demonstrate, here for the first time experimentally, the transition from theoretically predicted low-frequency propagation in a porous, microstructured fiber environment [3], where the air holes in the fiber form a sub-wavelength-sized modulation of the refractive index of the core of the fiber, to the situation at higher frequencies where the core and the cladding regions are well-defined separate entities and propagation is tightly confined to the core region. The sixfold rotational symmetry observed in the mode profile at 1.0 THz corresponds to the hexagonal lattice of the air holes.

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