플라스틱 광결정 섬유 안에서 테라헤르츠 펄스의 전파
THz Pulse Propagation in Plastic Photonic Crystal Fibers

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The recent progress in terahertz (THz) technology has generated much interest in low loss THz waveguides which are essential for the construction of compact THz devices and measurement systems. Photonic crystal fibers (PCF) has engendered growing interest over the past few years since they offer the opportunity to create new means of THz waveguiding, compared to the conventional optical fibers, such as broadband single-mode operation(1) and air guiding(2). In this talk, we experimentally demonstrate for the first time the low loss single-mode propagation of THz pulses in plastic PCFs.

The PCF was fabricated by using high density polyethylene (HDPE) tubes. The HDPE tubes were stacked to form a two-dimensional triangular photonic crystal, and then thermally fused. The lattice constant is 500 μm, and the tube thickness is 50 μm. At the center of the triangular lattice structure, a single HDPE filament was inserted to create a high refractive index defect. Shown in Fig. 1 are the optical micrograph of a photonic crystal (a) and the theoretical field distribution of the guided mode at 1 THz (b). The experimental setup for THz wave transmission through plastic PCFs is similar to that used for other THz waveguides(3-5). The THz pulse was generated via optical rectification by using a (111) GaAs substrate, and detected by a photoconductive antenna on a low-temperature grown GaAs. The PCF is placed at the THz beam waist between two off-axis parabolic mirrors.

The THz pulse transmitted through a 2 cm-long PCF is shown in Fig. 2. The theoretical curve has been obtained by using a frequency-independent refractive index of 1.5 for HDPE, and shows good agreement with experiments. The incident THz pulse is stretched to ~30 ps after transmission through the PCF. The THz pulse dispersion is mainly due to the PCF waveguide dispersion. The leading parts of the transmitted pulses show a positive chirp where the low frequencies arrive earlier in time. After the main peaks, small oscillations are seen at ~40 ps due to the multiple reflections at air gaps between the PCF and silicon lenses.

Shown in Fig. 3(a) are the amplitude spectra of the THz pulses after propagating through a 2 cm-long plastic PCF. The small ripples in the transmission spectra are due to the small air gaps between the PCF and silicon lenses. The loss in the transmitted THz signal is mainly due to mode-mismatch and reflection losses at the entrance and exit faces of the PCF. The estimated power attenuation coefficient of the plastic PCF is less than 1 cm^{-1} over the measured spectrum. The measured spectrum below 0.2 THz is found to be significantly reduced. This is due to the large mode-mismatch between the focused Guassian beam and the PCF guided mode at low frequencies. It is noted that there is no sharp low frequency cutoff characteristics for dielectric waveguides such as PCFs with high index defects.

The effective and group indices of plastic PCFs are shown in Fig. 3(b). It is seen that at the high frequency limit, both effective and group indices approach to the refractive index of the HDPE core while at the low frequency limit they approach to that of the cladding, the average refractive index of air and HDPE. This is simply because the field confinement in the high index core gets stronger as the frequency increases. In the low frequency part of the spectrum below 0.4 THz, the group velocity dispersion (GVD) is large, and the group velocity decreases as the frequency increases, resulting in the positive chirp in the time domain.

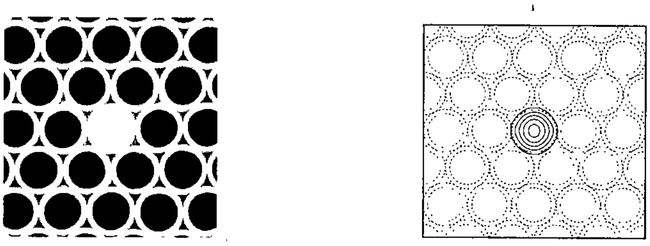

FIG. 1 (a) Optical micrograph of a triangular photonic crystal fiber with a high index defect, and (b) calculated field distribution of a fundamental guided mode at 1 THz.]

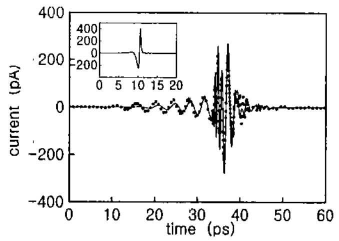

FIG. 2. Measured (dots) and calculated (solid line) pulses after propagating through a 2 cm-long plastic photonic crystal fiber. The inset shows the measured reference signal.

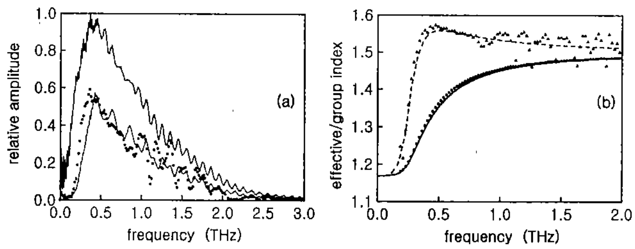

FIG. 3. (a) Amplitude spectra of measured (dots) and calculated (solid line) pulses pulses after propagating through a 2 cm-long plastic photonic crystal fiber. The dashed line shows the reference spectrum. (b) Measured effective (dots) and group (triangles) indices. The solid and dashed lines show the theoretical values.

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