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Orbital angular momentum modes by twisting of a hollow core antiresonant fiber

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Generation and use of orbital angular momentum (OAM) of light is finding more and more interest in a wide variety of fields of photonics: communications, optical trapping, quantum optics, and many more [1]. In the investigation of such behavior, twisting of photonic crystal fibers shows interesting physical phenomena [2]. We previously reported the ability to create helical hollow fibers by mechanically twisting a tube lattice fiber made of polyurethane, the twist of which can be adjusted and reversed [3]. In this work we report how such deformation induces a mode transformation to an OAM mode, allowing a simple and tunable way to generate OAM modes. We take advantage of THz time domain spectroscopy to obtain information on both intensity and field components, and to be able to investigate how they change both in time and with frequency.

The fiber here reported is 10 cm long, has a core diameter of 3 mm, it is twisted with twist rates between 0 and 62 rad/m and it is designed for frequencies 0.2 to 1.5 THz. A microscope image of the fiber is shown as inset of Fig. 1(a). The transmission spectrum of the fiber when straight and twisted was measured and is shown in Fig. 1(a). Above and below, the measured near-field images of the untwisted and twisted fiber output, respectively, are plotted for some selected frequencies in the different transmission bands. The twisted fiber in the transmission band centered at 750 GHz has a mode with a central minimum. The effect of twist on this fiber's modes is investigated by finite-element (COMSOL) simulations by using a helical coordinate transformation [2] (Fig. 1(b)). A small amount of twist is not sufficient to perturb the guided mode. However, when sufficient twist is applied, the mode shows a singularity at its center. Increasing the twist further compromises guidance and the mode leaks into the cladding. Comparison between measurements and simulations for both mode intensity and x component of the electric field (Fig. 1(c)) confirms agreement between the two. Moreover, from the electric field it is possible to infer that the mode observed is radially polarized as the measured x-component of the output mode has a zero of electric field occurring along y. To ensure this mode possesses orbital angular momentum (which is expected because of the helicity of the fiber), the temporal evolution of the mode is examined: as the input is not a continuous wave, but a pulse, an OAM mode will have a temporal spiraling evolution. Snapshots of the temporal evolution of the mode are shown is Fig. 1(d). The mode starts from the lower-right corner and spirals to the top-left confirming the mode carries an orbital angular momentum.

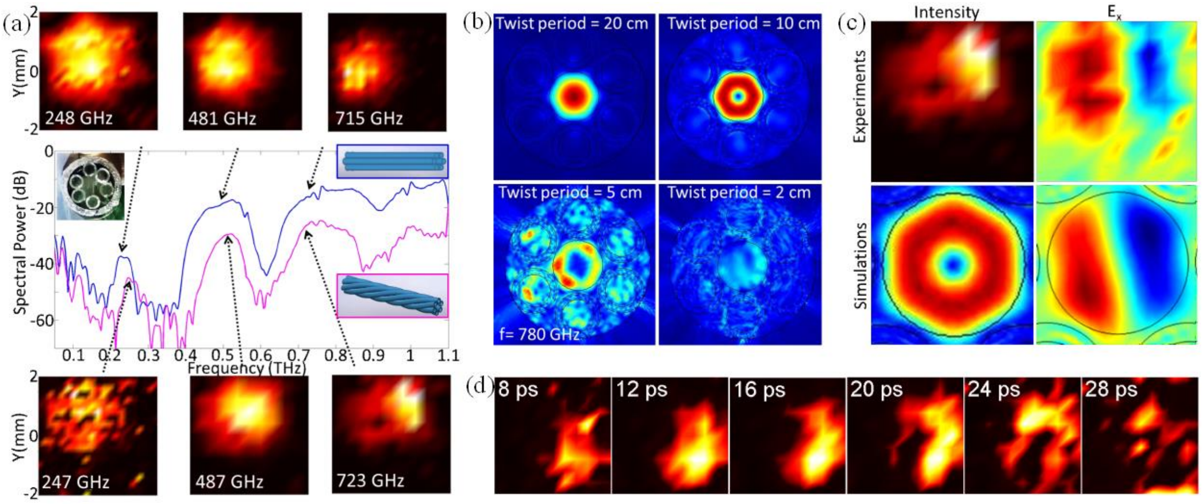

Fig. 1 (a) Normalized transmission of the straight and twisted fiber. Top and bottom: near-field mode profiles at selected frequencies. Insets: microscope image of the fiber end-faced and sketches of the straight and twisted fiber. (b) Intensity profiles of the simulated modes as function of twist. (c) Comparison between experimental and simulated mode intensity and x-component of the electric field. (d) Time snapshots of the measured mode.

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