PhD thesis

Engineering the transmission and sensing properties of optical fibers by twisting

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ABSTRACT

The dissertation analyzed the impact of continuous or local twisting of optical fibers on their transmission and sensing properties. The research conducted within the dissertation aimed to prove three theses formulated as follows:

(1) The local twisting of the birefringent fiber enables intermodal conversion in the first-order mode group, particularly the generation of vortex modes.
(2) A local change in the twist period of a helical-core optical fiber improves the light coupling efficiency.
(3) Twisting the side-hole optical fiber along its entire length during the drawing process allows its sensitivity to hydrostatic pressure to be engineered.

Proving the first thesis, two methods of local twisting of optical fibers were proposed and the possibility of using them for mode conversion in the group of first-order modes was presented. Firstly, it was experimentally shown that twisting a PANDA fiber over a length of several centimeters with a variable period enables the adiabatic conversion of LP_{11} modes to vortex modes with total angular momentum of ±2 or 0. As one of the many possible applications of the developed mode converter, a fiber-based source of vortex beams, operating in broadband or tunable mode, was investigated. The developed source is based on the combination of a specially designed microstructured optical fiber, enabling the generation of supercontinuum or tunable solitons in first-order modes, and a commercial PANDA-type optical fiber with a gradually twisted output end, allowing the conversion of LP_{11} modes to vortex modes.

The second locally twisted structure was rocking-filter grating for resonant coupling between different pairs of LP_{11} modes. Such gratings were produced using a CO_2 splicer, by periodic, pointwise twisting of PANDA-type optical fiber over a length of several centimeters. The performed simulations and experiments showed that effective conversion can be achieved both between LP_{11} modes with orthogonal polarizations and the same spatial distribution of amplitude and between modes with the same polarizations and orthogonal spatial distributions of amplitude. The generation of vector beams, including beams with azimuthal or radial polarization distribution, was proposed and experimentally confirmed as an attractive application of the produced gratings.

To prove the second thesis of the dissertation, the possibility of increasing the efficiency of light coupling between a helical core fiber (HCF) and a standard fiber, by partially unscrewing the HCF fiber over a section of several millimeters using a hydrogen torch, was examined. The proposed method allowed for an increase in the efficiency of light coupling between such fibers by ten times, as well as for increasing the efficiency of light coupling into the HCF fiber from free space.

The subject of the research conducted to prove the third thesis was the polarimetric sensitivity of twisted side-hole fibers to pressure and their distributed sensitivity, examined separately for each polarization mode using OFDR based on Rayleigh scattering. It has been experimentally shown that the polarimetric sensitivity to pressure in the tested fibers decreases with the shortening of the twisting period. Distributed pressure sensitivity measurements of side-hole twisted fibers showed that for one polarization mode a decrease in sensitivity as a function of the increasing degree of twist was observed. In contrast, for the other polarization mode, there was a visible increase in sensitivity.

The results obtained within the dissertation were partially published in five articles and presented at five national or international conferences. The topics discussed in the dissertation align with current research trends, and the obtained results open new possibilities for the applications of twisted fibers.