Study of the characteristics of few-mode microstructured optical fibers with 6 cores made of highly doped GeO2 silica and induced chirality

G. A. Pchelkin[1, 2], V. I. Demidov[1], A.V. Bourdine[1, 2], E.V. Ter-Nersesyants[1], A.V. Khokhlov[1], A.S. Matrosova[1,3], K.V. Dukelskii [1,2,3], M.V. Dashkov[5], A.N. Podoprigora[2], V.M. Pilipova[2], V. V. Davydov[2], V.B. Romashova[4], R.R. Kashina [4]

[1]JSC "Scientific Production Association State Optical Institute Named after Vavilov S.I.", Saint Petersburg 192171, Russia

[2]The Bonch-Bruevich Saint Petersburg State University of Telecommunications Saint-Petersburg, Russia

[3]ITMO University Saint-Petersburg, Russia

[4]JSC “LLC” Saint-Petersburg, Russia

[5]PSUTI Samara, Russia

Introduction

At present, the need to transfer large amounts of information in various communication systems is constantly increasing. Increasing requirements for speed and quality of information processing. The fiber optic communication lines are one of the most reliable ways to implement these tasks, especially in difficult conditions. For example, in the presence of a large number of electromagnetic interferences in the coverage areas of radar stations or outer space. In modern designs of single-mode optical fibers for trunk communication lines, the limit has almost been reached in terms of the possibilities for transmitting large amounts of information using various seals and compressions.

Therefore, research is constantly underway to find new solutions. One of the possible solutions to this problem is associated with the use of low-mode microstructured fibers.

This work presents fabricated twisted silica MOF with special six GeO_2-doped core geometry (6-core-MOF), an outer diameter of 125 µm, operating in a few-mode regime, and induced chirality with twisting of 1000 revolutions per minute (or e.g., under a drawing speed of ~2 m per minute, ~500 revolutions per 1 m).

Fabrication of twisted silica microstructured optical fibers

Manufacturing of chiral (twisted) silica MOF includes the following three steps. The first two are concerned with MOF stack (preform) and cane (prefiber) fabrication. These steps do not differ from any other silica MOF stack and cane forming. Here, preliminarily, by using a drawing tower, microelements (micro-rods and capillaries (micro-tubes), made of high-purity fused synthetic silica glass with a content of hydroxyl groups less than 1 ppm, are drawn.

Figure. 1. The fiber of 6-core-MOF: stack and stack inside a silica tube

The design of fabricated 6-core-MOF is presented on Figure 2. It is supposed that such geometry combined with induced chirality would improve modal stability. We prepared fiber stack (Figure 1), then redrew it into the cane with an outer diameter of 2.92 mm. After that, two types of 6-core-MOF samples with the core capillaries drawn from the preform with the customized graded-index profile and core/cladding diameters ration 0.8 (Figure 3) were fabricated. The geometry of fabricated 6-core-MOF is scaled to an outer diameter 125 µm, which is a typical cladding diameter for conventional commercially available telecommunication optical fibers, to simplify following connection to measurement/test equipment.

In order to predict waveguide properties of the MOFs with the predetermined structure, we performed a series of calculations and numerical simulations based on the commercially-available software COMSOL Multiphysics utilizing the finite-element method. We used desired geometrical parameters of the 6-core-MOF, namely diameter of the air holes 5 µm, pitch (air hole to air hole distance) 7.7 µm, giving k-parameter (air hole diameter to pitch ratio) approximately 0.65. Such k-parameter should guarantee excitation of at least 4 spatial modes at wavelength 1.55 µm.

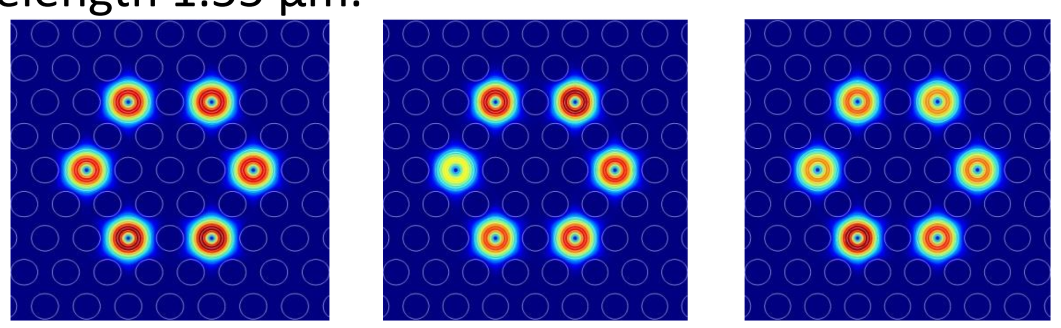

Figure 2. Calculated intensity profiles of eight guided polarization modes propagating without cutoff of the selected 6-core-MOF, LP_{11}-like

In Figure 2 shows the illustrates intensity profiles of eight guided polarization modes propagating without cutoff calculated for the selected 6-core-MOF (Δn = 0.0246 or GeO_2 concentration 16.85 at.%)

The obtained results show the presence of the necessary modes in the optical fiber.

Experimental research and discussuon

To detect quasi-annular (vortex) distributions of the optical field in low-mode microstructured optical fibers with 6 cores made of high-doped GeO2 quartz glass, a measuring bench was modified. The previously used optical scheme had large dimensions, excessive losses during radiation transmission, and increased requirements for temperature stabilization.

In Figure 4 shows the topologies of low-mode microstructured optical fibers, for which the distribution of optical radiation at the output was studied at different twisting frequencies and other parameters of the technological cycle.

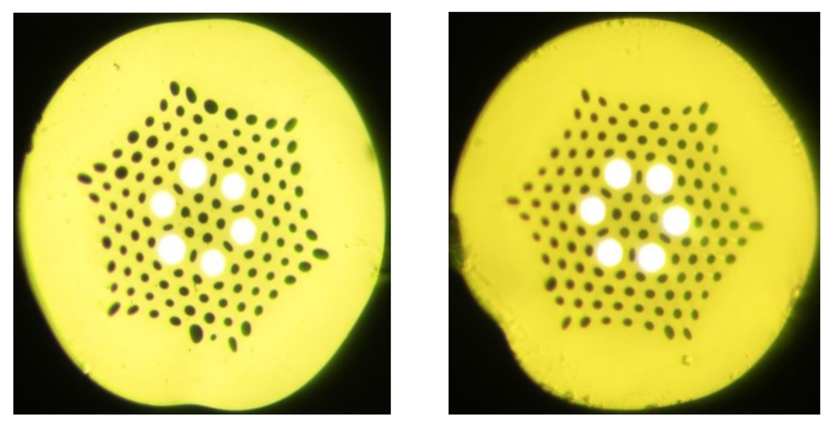

Figure 3. The fiber of 6-core-MOFs: cross-section view of the fabricated MOF with the twist of 400 rpm and 500 rpm.

In Figure 4 shows a longitudinal section of a fabricated low-mode microstructured optical fiber with 6 cores and a chirality of 100 rpm. For it, studies were carried out on the mode composition of radiation at various, from 50 to 400 rpm, twisting frequency and other parameters of the technological cycle.

Analysis of the presented data shows that the distribution of optical radiation is quasi-annular and uneven. This distribution can be controlled.

Figure 4. The fiber of 6-core-MOFs longitudinal view of the fabricated MOF with the twist of 400 rpm

In Figure 5 shows the transverse distributions of optical radiation at the output of low-mode microstructured optical fibers of the studied topology at various twisting frequencies and other technological parameters. The wavelength of radiation is 1550 nm.

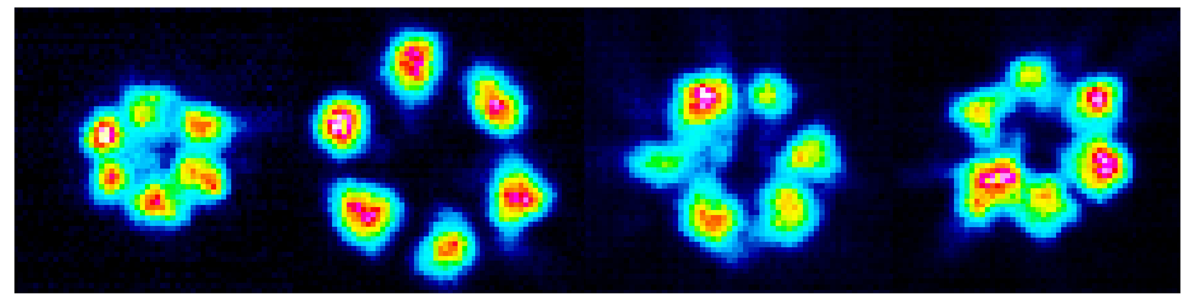

Figure 5. The fiber of 6-core-MOFs: (a) laser beam profile of an optical fiber with a degree of chirality (from left to right) are determined of revolutions per minute (rp/m): 50, 100, 400, 500

Conclusion

This work presents designed and fabricated samples of new 125-µm silica microstructured optical fiber with special six GeO_2-doped core geometry, an outer diameter of 125 µm (that corresponds to conventional commercially available telecommunication optical fibers of ratified ITU-T recommendations), operating in a few-mode regime, and induced chirality with twisting of 1000 revolutions per minute (or e.g., under a drawing speed of ~2 m per minute, ~500 revolutions per 1 m). Some technological issues and fabrication of such microstructured optical fibers are discussed. Some results of tests, performed with pilot samples of designed and manufactured microstructured optical fibers, including their geometrical parameters, basic transmission characteristics, as well as measurements of far-field laser beam profiles are represented. Detailed research of the 6-core-MOF properties underutilization in various applications in measurements/sensors or/and laser systems, telecommunications etc. require an additional series of tests and experiments in future works.