Mid-infrared antiresonant hollow core fibers made from heavy metal oxide and fluoride glasses

In recent years there is great progress in photonics, especially in optical fibers and novel photonic materials. Many of their applications are focused, i.e., on the mid-infrared spectral range for the detection of simple gas molecules like methane and nitrous oxides, where the absorption bands are localized. One of the recent photonics achievement is the new type of optical fibers, which are antiresonant fibers. They are often called revolver fibers because of their internal structure composed of the few (5-8) non-touching capillaries inside the hollow cladding, which is similar to the revolver drum. In conventional fibers used in telecommunications, light guidance is based on the total internal reflection phenomena through the core made from the glass with a higher refractive index than the cladding. In the antiresonant fibers, the light propagates in the hollow core, and the guidance is achieved through the transmission windows between resonance bands, which are characteristic for the given fiber structure. The value of the frequencies and fiber attenuation depends on the fiber material, thickness of the capillaries walls, and symmetry of the internal structure. Antiresonant fibers have very low attenuation, and theoretically, it can be even lower than the conventional telecom fibers. The guiding light inside the hollow core also has many advantages, including low dispersion, low attenuation, low nonlinearity, and the ability to transmit high power pulses. Additionally, the possibility to fill the hollow core with any gaseous medium allows building very sensitive fiber gas sensors.

Currently, antiresonant fibers are fabricated mainly from the high silica content– fused silica glasses. Aside from the very low absorption and excellent mechanical properties, this material is non-transparent above 4μm range. For this reason, the fibers made from fused silica cannot be effectively used in longer wavelengths. Multicomponent glasses are used as an alternative material for fabricating optical fibers due to properties greatly exceeding high silica glasses, including the ability to incorporate a high concentration of rare-earth dopants for lasing applications, nonlinear optical effects generation and great transmission in mid-infrared.

Within the project, the fabrication of the antiresonant fibers made from multicomponent glasses is planned. The glasses used for research will be heavy metal oxide glasses (HMO) and fluoride glasses, which has excellent transmission in mid-infrared, reaching even 8μm. The research part focused on HMO glasses will include the development of the new chemical compositions of the glasses and their optical and thermal characterization. In the case of fluoride glasses, the research will focus on the improvement of the synthesis process. In both materials, the aim will be to improve the transmission in the mid-infrared range and thermal properties affecting the fiber fabricating process.

The antiresonant fibers will be made by utilizing the stack and draw and extrusion techniques. The stack and draw method in the case of antiresonant fibers is based on the build of the initial fiber design on a large scale using the glass capillaries. The most challenging part is to obtain capillaries with thin walls, which will be realized by the extrusion technique by the direct ejection of the elements above the glass softening point. Joining these two methods will allow obtaining a highly precise fiber structure with excellent symmetry, which should have a positive effect on the optical properties of the fibers. The fiber design will be developed by applying numerical calculations. The aim will be to achieve broadest transmission windows in the 4-8μm range with maintaining minimal attenuation. Fabricated fibers will be characterized for optical properties, and the results will be verified by the numerical calculations comparing experimental data with the theoretical for ideal and real fiber structure properties.

The goals of the project are the development of the new multicomponent glasses, which have a broad transmission window in the mid-infrared, and the fabrication of the antiresonant fibers made from them. Obtained knowledge during the synthesis and characterization of new glass chemical compositions, will extend the state of the art about multicomponent glasses, especially heavy metal oxide glasses. Obtained antiresonant fibers could be used in the future for the advanced applications in the mid-infrared range, including high power delivery and all-fiber gas sensing applications.