

ABSTRACT OF DOCTORAL THESIS

Title: „Infrared supercontinuum generation in soft glass photonic crystal fibers”

Photonic crystal fibers have been of interest for over twenty years. The flexibility of dispersive properties engineering through the structure selection and high optical power density in the core make them very useful in nonlinear optics. It has been quickly noticed, that optical pumping in anomalous dispersion range with high energy pulses can create the optical solitons and next their break up. In the presence of other nonlinear phenomena the pulse spectrum broadens significantly, which is called supercontinuum generation. Supercontinuum spectrum can extend to the infrared range, becoming a very convenient light source for a multitude of applications in science. The most commonly used fused silica glass has limited transmission in the infrared up to 2.4 μm . Therefore, many works are focused on the synthesis of glasses with improved transmission at the infrared wavelengths and with high nonlinear index of refraction, which are additionally not susceptible to crystallization during thermal processing.

In my work I prove, that photonic crystal fibers made of novel heavy metal oxide glasses enable supercontinuum generation in the near and, when pumping in anomalous dispersion regime. Furthermore, I show that optical pumping can be realized with the relatively low-cost and low-complex fiber lasers operating in the third telecom window (about 1.55 μm). In my thesis, two different approaches to dispersion tailoring in the fibers are proposed. The first, typical method is based on air-glass structure modification of the photonic cladding. The new concept is subwavelength structuring of the core area itself, which is surrounded by a solid glass cladding.

In this thesis, the linear optical properties of the selected photonic crystal fibers made of lead-bismuth-gallate glass and tellurite glass were investigated. The supercontinuum spectrum broad over one octave was generated and its features were discussed. Promising results encouraged to perform the dispersion optimization process. As a consequence of this optimization, the fiber structure with three different filling factors was developed and further successfully fabricated and investigated. Obtained flat dispersion profile and high nonlinearity of the fiber enabled to generate supercontinuum in spectral range from 0.8 μm to 2.4 μm when pumping at a wavelength of 1.56 μm with 400 fs pulses. I also present results on the fiber made of tellurite glass with regular, hexagonal structure of cladding, which fabrication process was a technological challenge. Such a construction provides more efficient heat dissipation from the core in comparison to typical tellurite fibers with suspended core. In the examined fiber, supercontinuum spectrum in the infrared was limited to 2.5 μm due to high and broad absorption peak of OH^- ions contained in the glass.

This dissertation also includes extensive analysis of the highly birefringent fiber ($B \sim 10^{-3}$), in which the artificial anisotropy was obtained by subwavelength structure of the core. Investigated fiber was fabricated with two different thermally matched glasses characterized by higher nonlinear refractive index than in fused silica glass. Additionally, small size of the core (about $7 \times 3 \mu\text{m}$) increases nonlinear coefficient. This unique fiber construction results in flat dispersion and birefringence characteristics, which was not observed in another types of highly birefringent fibers. Due to very similar dispersion profiles for the orthogonal polarized modes, with zero dispersion wavelength around 1.5 μm , obtained supercontinuum spectra are almost the same for both polarization modes.

The use of high energy pulse laser for pumping of the nonlinear fibers, which are usually characterized by high attenuation at the level of a few dB/m, is associated with dissipation of energy into heat. It causes temperature rise inside the fiber, which can change the optical properties and affect the generation of nonlinear effects. In this work I propose a method of dispersion measurement as a temperature function in range of 20°C - 420°C. Next, two types of fibers for nonlinear application were investigated. For the silicate fiber, the zero dispersion wavelength was shifted by +8 nm for temperature change of 400 °C, but for the fiber made of heavy metal oxide glass the shift was more significant and reached +18 nm. However, thermal influence on dispersion characteristics is too low to have an impact on the process of supercontinuum generation.