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Abstract

The dissertation concerns optical properties of selected hollow core photonic crystal fibers (PCF), where the core was infiltrated with a broad selection of liquids. The research work includes supercontinuum generation (SCG) in PCFs infiltrated with high nonlinear liquids and studies on transmission windows for antiresonant (AR) fibers filled with low-index liquids for application in bio-lasers and bio-sensing.

The work contains three main parts. The first part includes design, fabrication, and characterization of linear properties of liquid core PCFs. A thermal method based on a conventional fusion splicer has been used to obtain selective filling of the core with liquids. Dispersion characteristics of liquid core PCFs with different structures were simulated numerically and later experimentally verified using March-Zehnder interferometer. This part of the work verifies if liquid core PCFs make possible to obtain all-normal and flat dispersion in the near-infrared spectral range.

The second part of the work includes measurements of SCG using PCFs infiltrated with high-refractive index liquids such as toluene and carbon tetrachloride (CCl_4). When a commercial femtosecond laser was used as a pump source, the liquid core fibers offered supercontinuum (SC) spectrum in the near-infrared region and showed potential for coherence. This part also discusses dynamics of SC formation in liquid-core PCFs, including self-phase modulation following by optical wave breaking for spectral broadening in all-normal dispersion regime, and soliton dynamics for anomalous dispersion SCG. Due to the design flexibility of the PCFs and the high nonlinearity of liquid, the liquid core PCFs may offer broad SC spectrum with low peak power of input pulses. Therefore, the liquid core PCFs, when supported by commercially available high power laser sources, can be used as components for all-fiber SCG systems. Such systems allow for manufacturing of low-cost coherent SC sources for various applications such as e.g., frequency comb generation, sensing, and medical imaging. Moreover, in order to couple the liquid core PCF with a single mode fiber when all-fiber SCG system is considered, within this work a large mode area (LMA) silica PCF was additionally designed and fabricated. Proposed LMA PCF show low nonlinear properties, low bending loss and it can offer high coupling efficiency with the liquid core PCFs.

The last part of the work focus on the properties of AR fibers infiltrated with low-index liquids, e.g., water and ethanol. In this case, the fibers were filled and other than total internal reflection guiding was implemented. The aim of this part was to verify if the AR fiber with liquid infiltration could offer a broad transmission window. The experiments have proven that the transmission windows of AR fiber experience blue-shift when the fiber is filled with low-index liquids. The shift depends on the refractive index of the liquid and thickness of the capillary in the cladding region of the fiber. Due to the broad transmission window, the AR fiber infiltrated with low-index liquid may become a promising approach for optofluidic applications. Thus, in this part, optical properties of commercially available liquids used for biological experiments were also measured over storage time. The biologically-active structures, such as bacteria or cells, require specific life-supporting aqueous solutions called as buffers or cell culture media. Refractive index, transmission spectra and scattering for all the considered liquids are presented and compared with those of pure water. Moreover, influence of aging on the investigated properties has also been discussed. Finally, AR fibers infiltrated with these solutions containing the microorganisms for application in the optofluidic system were discussed.