DESCRIPTION FOR THE GENERAL PUBLIC

The principal goal of this project will be a full understanding of new wave phenomena arising as a result of helical twist of microstructured fibers of different types. The project combines two, until now almost independent, areas of research. The first one is related to microstructured fibers which have been investigated for almost 15 years, while the second one is connected with helical core fibers investigated since recently. The project goal will be achieved by proper combination of advanced numerical simulations based on the newly developed numerical methods, new technological solutions enabling the fabrication of helical microstructured fibers with predefined sensing and transmission characteristics, and experimental investigations finally confirming novel functionalities of the helical microstrcutured fibers and allowing to select the best structures for future practical applications.

The general research hypothesis is that properly designed microstructure in fiber cladding and/or fiber core, in combination with helical twist, provides an additional degree of freedom in engineering the waveguide properties and gives rise to new phenomena not observed before. Examples of such phenomena are: exotic polarization of core modes guided in helical microstructured core (vortex modes with different orbital angular momentum), a possibility of obtaining high circular birefringence (of the order of 10-2), propagation of only one circularly polarized core modes (single polarization propagation), broadening of single mode operation range in helically twisted fibers through proper microstructuring of the core neighborhood, a possibility of coupling between the core modes and predefined cladding modes controlled by proper microstructure of the cladding, and novel sensing applications of helical structures.

Investigations of microstructured helical fibers are in early stage of development. Until recently, understanding of optical phenomena arising in such structures was not possible because of lack of numerical methods allowing for rigorous modeling of twisted waveguides. Approximate methods based on perturbation approaches have limited applicability and with these methods more complex helical structures could not be modeled at all. In last years, a novel numerical method based on transformation optics formalism has been proposed, which allows for rigorous simulations of helical waveguides. This created an interest in and allowed for fundamental studies of helical waveguides of more complex structure. The topic of helically twisted microstructured fibers is therefore very promising and will certainly bring in upcoming years many valuable publications and patents.

In this context, a wide research program planned within this project, which combines numerical, technological and experimental investigations, seems to be very promising. Realization of the project will bring a full understanding of new wave phenomena arising in helically twisted microstructured fibers. It is expected that the project results will prompt further advances in the field of optical communications and metrology thus giving rise to development in future novel optoelectronic devices and components (as for example new fibers for multichannel transmission based on vortex modes, lasers employing active helical microstructured fibers, passive optical components used in optical communications like couplers and filters, and sensors based on helical microstructured fibers) with improved characteristics.

An important part of this project will be numerical simulations of transmission and sensing properties of microstructured helically twisted fibers and numerical investigations of new wave phenomena arising in such structures. It is expected that most of the electromagnetic simulations will be carried on using a newly developed approach based on transformation optics formalism, in which a 3-D problem of helically twisted structures is reduced to 2-D problem by proper transformation of the electric permittivity and magnetic permeability tensors. Sensing properties of twisted fibers will be modeled with the methods used in structural mechanics simulations. The Finite Element Method will be used in both electromagnetic and structural mechanics calculations, as it allows for straightforward analysis of the effect of stress/deformations on fiber optical characteristics.

Within the experimental part of the project it is planned to develop three methods of fiber twisting assuring different twist period Λ, i.e., twisting over practically unlimited distance during the fiber drawing process ($\Lambda \approx 100 \div 1$ cm), local fiber twisting over a few centimeters distance in the flame of hydrogen torches ($\Lambda \approx 1 \div 0.1$ cm) and local twisting over a distance of tens of centimeters with the use of CO2 laser, ($\Lambda \approx 0.1 \div 0.01$ cm). Preforms for fibers with specially designed microstructure of the core and/or cladding will be manufactured by stacking capillaries and rods of proper purity obtained using MCVD or FCVD technologies. An experimental characterization of helical microstructured fibers or components based on such fibers will be carried on using standard procedures with necessary modifications related to exotic polarization of guided modes.