Special highly birefringent multicore fibers for simultaneous multiparameter optical sensing

Fiber optic sensors utilizing classic optical fibers have many advantages over their electrical counterparts and have been applied successfully for many years. The small size allows their use in a variety of conditions while maintaining low installation and maintenance costs. The dielectric properties of silica glass, which is usually used for the production of optical fibers, allow the application of fiber optic sensors in the area of electromagnetic interferences and high voltages, in dusty conditions and at high pressures, temperature, and vibrations. The advantage of fiber optic sensors is also the ability to transmit measurement results over a long distance, even for tens of kilometers. It is used, among others, in stress and vibration monitoring of large building structures such as bridges, tunnels, dams, and track conditions in the railway industry. A multitude of areas in which optical fibers can be applied as an active measuring medium is very extensive. It includes measurements of mechanical parameters (pressure, strain), temperature measurements, measurements of chemical composition, the concentration of impurities, and measurements of electrical and magnetic quantities. Optical fibers also show their universality in the measurement techniques, in particular in the range, or area, from which they can collect information. Point sensors, e.g., fiber optic Bragg gratings or various types of fiber interferometers, provide measurement data from one selected point. Pseudo-distributed sensors are composed of multiple point sensors and can measure the response to changes of a selected external factor in many places. Harnessing the Brillouin, Raman, or Rayleigh scattering phenomena in optical fibers allows performing measurements with such excellent spatial resolution, that from the point of view of monitoring, it can be regarded as continuous measurement, also called distributed sensing.

Thanks to the unique light properties, it is possible to transfer a lot of information at once. It is useful while designing multiparameter fiber optic sensors that can simultaneously detect several parameters using one medium (in this case, optical fiber). Unlike arrays or sets of sensors, real multiparameter sensors measure the parameters of interest in the same place. The ability to measure the temperature and any other parameter at the same time is crucial because temperature changes are very difficult to eliminate from the environment. Most of the proposed devices offered on the market are dedicated to the measurement of a single parameter only, assuming that the sensor head is separated from the influence of the other external stimulus. Unfortunately, in many applications, such as monitoring and supervision of the technical condition of the engineering structure, it is problematic or even impossible. For example, while detecting the deformation of the structure exposed to the impact of climate change, it is not possible to completely separate the sensor head from temperature fluctuations, which produces spurious results of the measurement. A conventional way to overcome this problem is to use two physically separated measurement fibers. For instance, one of the fiber monitors only temperature changes, while the other fiber monitors changes in both parameters, temperature, and strain at the same time. It permits to compensate for the temperature and to determine the deformation itself only. The use of such a solution in practice, however, can be complicated and does not provide satisfactory results, mainly due to the need for placing both fibers in some distance apart, to separate the effect of strain on one of the optical fibers. It makes the temperature impact on both fibers uneven. **Therefore, within the project, we plan to create a solution based on fiber-optic technology, which will enable simultaneous measurements of temperature and other external parameters with the use of the single optical fiber only.**

The crucial goal of this project is the development of specialty multicore fibers with high birefringence. By placing an appropriate microstructure in the cladding, in combination with their twisting along the fiber length, we will obtain a sufficiently large differentiation of sensitivity to temperature and pressure, temperature and elongation or all three parameters. We expect that the developed new fibers structures will enable simultaneous measurements of two or three parameters with a high resolution. Fibers developed within this project will have significantly different sensitivities to the parameters mentioned above. They will be the universal solution in the context of distributed sensing, responses of Bragg, or polarization gratings inscribed in the fiber as well as measurements based on couplings between different polarizing core modes. This project, in large part, is devoted to basic research with potential implications for application in optical metrology.

Achieving this goal will be possible through a proficient combination of knowledge and experience covering various fields of science. Simulation research using advanced numerical methods will enable to design the unique fibers' construction. The new technological solutions will allow for twisting the fiber during the drawing as well as the manufacturing of microstructured fibers with special internal structures and earlier unavailable optical properties. Carried out experimental research will validate the transmission and metrological properties and facilitate the selection of the most promising fiber optic constructions for future practical applications.