Electromagnetic wave propagation in the optical fiber with frozen-in electrical field

Optical fiber designs have experienced real revolution in the last thirty years. First optical fiber was entirely made of silica glass with the germanium dope in the core. Today fibers are made of many different materials: glasses with different dopants, multicomponent glasses, or polymers. Moreover the design of the cladding and the core of presently fabricated fibers is more sophisticated, i.e. there are inclusions of medias with specific properties, and even air channels, which are present throughout entire length of the fiber. Despite of high variety of used materials, they were always transparent and selected to be, in general, thermally compatible in fiber fabrication process.

The optical fiber guides the electromagnetic wave, which can be modulate by changing the temperature in the area of the fiber, or by inducing the tension, but the interaction of the light wave guided in the fiber with the electrical field is almost impossible, because of high isolation of the glass. What can obtain for extremely thin glass layer which isolates the light wave from the electrical field? And how it could be done in the optical fiber?

The research project is about the fabrication of an optical fibers with internal metallic electrodes, placed very closely to its core. The isolation layer will be very thin and used voltage of a few kilovolts will led to interplaying between the optical wave and electrical field. The goal of the project is to investigate the influence of the electrical field on a light wave, so on the optical fiber properties of different designs and made of different materials, like silica glasses and multicomponent glasses. Dependly on the glass type and the design of the fiber it is possible to induce electrooptic effects: linear Pockels effect and quadratic Kerr effect. The goal of the project is also stimulation of these effects in fabricated optical fibers and estimation of efficiency of light modulation. Glasses are medias in which the intrinsic second order nonlinearity is not present and the third order nonlinearity is very small, i.e. for silica glasses. It is two orders higher, in comparison to silica, for the multicomponent chalcogenide glasses. In the medias, in which the second order nonlinearity is different from zero the frequency conversion of light wave is possible – it is called second harmonic generation. The method for second order nonlinearity stimulation in the medias deprived of this nonlinearity, is the effect called thermal poling. Within this effect the frozen-in electrical field is induced by the presence of electrical field of high voltage in the fiber which is additionally heated to the 300 ^{o}C. The induced electrical field accordingly with the third order nonlinearity is directly proportional to the second order nonlinearity value. Thanks to second order nonlinearity stimulation the generation of the nonlinear processes is then possible. For the multicomponent glasses this effect could generate much higher values of second order nonlinearity, because of higher movability of different ions in comparison to silica glass and highest value of intrinsic third order nonlinearity, which is advantage in thermal poling process.

The research will lead to better understanding of the phenomenon of stimulated nonlinearity in optical fibers and broaden the knowledge on the possibility of modulation of linear and nonlinear properties of optical fibers by use of high voltage. This will lead to development of optical fibers devices.