With the advance of the civilization, one can observe a growing presence of ionizing radiation in various fields of human activity. This entails increasing needs for better measuring methods – for detection, dosimetry and imaging of ionizing radiation, in such diverse areas as: medicine (radiotherapy and radiodiagnostics), industry, radiation protection, research, homeland security etc. Among the most important measuring techniques are these based on luminescence phenomena. This concerns specially so called passive methods – for example, the great majority of many millions of workers professionally exposed to radiation all over the world, wear dosimeters using phenomena of thermoluminescence (TL), optically stimulated luminescence (OSL) and radio-photoluminescence (RPL).
Photoluminescence (PL), i.e. emission of light by some substances due to excitation with light of a shorter wavelength, may occur within defects generated in crystals by ionizing radiation (electrons, protons, alpha particles, etc.). If the defects are stable, then illuminating the crystal with the light of a given wavelength, may cause their excitations and places where interaction of radiation with atoms of the crystal occurred, will begin to emit light themselves. Therefore observing the crystal with a fluorescence microscope, would in principle allow to see tracks left by the ionizing particles. This idea was recently realized for the first time (and so far the only one) by US scientists for crystals of aluminum oxide doped with carbon and magnesium, raising a great interest in the scientific community and opening perspectives of numerous applications for radiation dosimetry. In this project we propose to carry out the studies on another material exhibiting a stable photoluminescence – lithium fluoride (LiF). The performed initial investigations revealed that it might be successfully used for micro-imaging of ionizing radiation tracks.
The main problems in using fluorescence of crystals for micro-imaging are a low intensity of PL emitted by a single particle track and an always present quite strong not-radiation induced background. Our investigations will be therefore aimed on gaining the new and in-depth knowledge on LiF photoluminescence, which will allow to optimize LiF crystal properties and to develop the optimum measuring method, leading in consequence to obtaining microscopic fluorescence images of radiation dose distribution, with the maximum intensity, contrast and resolution.
The main part of the project will consist of growth of LiF single crystals in various conditions. The team is equipped with a unique facility for crystal growing with the micro-pulling-down technique, as well as with the classic Czochralski method. The micro-pulling-down is a new method of crystal growth, developed in 1990s. It is a technique allowing a very fast growth of small crystals in form of thin rods. It is therefore perfectly suited for material research purposes, e.g. for optimizing material content. Much attention will be paid to investigations of the influence of doping on LiF photoluminescence. So far very little is known on this issue, while our initial studies show that this influence is very significant. The basic examinations of the manufactured crystalline samples will include measurements of photoluminescence emission and excitation spectra, absorption spectra, total photoluminescence yield, for irradiations with different doses and modalities of radiation. Further, the microscopic fluorescence images will be registered for different spectral ranges of excitation and emission light, as well as for different temperatures. Irradiations will be realized among others with the proton beams at the accelerators working at the IFJ PAN and also alpha particles and neutrons from radioisotope sources.
The gathered experimental data will broaden knowledge of physics of color centers and will allow for better understanding of the luminescence mechanisms occurring in LiF. It is expected among others that the role of dopants in PL mechanism in LiF will be recognized and photoluminescence phenomenon on the microscopic scale will be characterized. Basing on this knowledge it should be possible to obtain images of single particle tracks. Moreover, LiF, thanks to the presence of ^{6}Li isotope (7.5% in the natural lithium), which has a very high cross-section for nuclear reaction with thermal neutron, creates a unique possibility for neutron detection with very high effectiveness. So far there is no passive detector of similar features available for neutron dosimetry. The realization of the project will therefore lead to the development of a measuring system unique on a worldwide scale, based on an original technology. It may find future applications in measurements of radiotherapy particle beams, neutron dosimetry, cosmic radiation measurements and others. Beside this main application for detection of particle tracks, the results of the project will be also important for microradiography – a technique of X-ray imaging of microscopic objects. The expected increase of PL intensity should allow for reduction of X-ray doses, which may extend range of applications of this method. In this context one should also mention a potentially very interesting possibility of exploiting LiF crystals for neutron radiography (thanks to ^{6}Li content).