The influence of temperature on the fluorescence of lithium fluoride crystals

With the rapid development of technology, ionizing radiation becomes more and more prevalent in human life. It gives a motivation to introduce new and to improve already existing methods of detecting, measuring, and imaging of ionizing radiation that could be used in various areas e.g. medicine, radiation protection, industry, research, and many others. Fluorescent Nuclear Track Detection method (FNTD) is one of the most revolutionary techniques developed over the last years in the field of radiation dosimetry.

FNTD technique exploits photoluminescence (PL) of radiation-induced crystal lattice defects called color centers (CC). Such centers, when excited by light of an appropriate wavelength, emit photons which make it possible to see the track of a particle while using a fluorescence microscope. First and for a long time, the only material used as Florescent Nuclear Track Detector was aluminum oxide doped with carbon and magnesium impurities (Al_2O_3:C,Mg). Only recently, the work of the team at IFJ PAN in Kraków succeeded in obtaining high-quality fluorescent tracks with lithium fluoride (LiF) crystals. Thanks to LiF nuclear track detectors it is possible to image tracks of heavy ions such as helium, carbon, neon, silicon, and iron. They can also be used to detect and measure neutron doses or to establish the energy of the alpha particles interacting with the crystal. LiF crystals were also exploited to register tracks of cosmic radiation at the Earth orbit.

While it is apparent that this technique has great potential it, unfortunately, suffers due to the low signal-to-noise ratio. Even for the brightest tracks, e.g. these of stopping iron ions, the background noise is about 20% of the maximum track intensity. The enhancement of signal-to-noise ratio and photoluminescence intensity is extremely important as it could allow imaging tracks not visible now and open new directions of applications. For example, at the moment it is impossible to image tracks of high-energy protons as in their case energy deposited per unit volume is too small to produce a sufficient amount of photoluminescence to be registered. This is a serious problem, as such protons (with energy 60-250 MeV) are used for radiotherapy of cancer and this seems to be potentially the most important application of FNTDs. The thermal treatment of LiF crystals seems to be the most feasible way to improve the signal-to-noise ratio.

Although LiF is a very well-known luminescent and optical material studied for several decades there are still some gaps in our knowledge about it. One of them is the influence of thermal treatment on color centers and their photoluminescence. Concentrations of various color centers in LiF and their photoluminescence spectra were found to be significantly influenced by temperature. Under thermal treatment, some centers begin to disintegrate, while others interact with each other creating new species. All these have an impact on PL spectrum shape and intensity. While it is known that such dependencies exist, the reported data are often contradictory or incomplete. Our goal is therefore to gather missing information on this subject.

Within the project, we plan to investigate the temperature effects at each part of the stage of the process (before irradiation, during irradiation, after irradiation and during PL measurement). We intend to measure absorption spectra, PL emission spectra, and PL excitation spectra as well as to register and analyze microscopic images of nuclear tracks in various spectral windows. In all experiments, not only temperature, but also the duration of treatment, as well as heating and cooling rates will be varied. We also intend to check if observed effects are universal or are dependent on specific properties of crystals. To establish that, we plan on using in our experiments crystals grown with different methods, with different growth parameters, starting materials, etc.

The main output of the proposed project will be a better understanding of the physics of color centers in LiF. We believe that performing a systematic and comprehensive study on this subject will be providing truly novel information and in this way filling the gaps in the current knowledge about color centers in LiF. As our main motivation to undertake these investigations is the further development of LiF track detectors we hope that the obtained results will lead to the optimization of LiF crystals properties in the perspective of their use for detection and imaging of ionizing radiation.