2nd ProtoTera PhD Students Workshop

Development of Microdosimetric Detectors for Radiobiology in Hadron Therapy Facilities

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Understanding the intricate effects of radiation at the microscale is pivotal for advancing cancer treatment strategies. The groundbreaking nature of ultra-high dose radiation (FLASH) therapy requires new developments in dosimetry to access a more detailed description of energy distribution inside the cells and the contribution from the different secondary particles. This is particularly interesting concerning proton FLASH, where the secondary components of the radiation field should be quite different as compared to other methods, such as Pencil Beam Scanning (PBS) or Broad Beam Scattering (BBS). New developments are necessary to achieve a detailed description of the energy distribution. This study is focused on the development of materials able to achieve microscale sensitivity, namely, micrometric scintillating plastic optical fibers (mSPOF) and aluminum oxide (Al_2O_3) crystals.

Since their discovery in 1965, SPOFs have been used as radiation detectors in nuclear and high energy physics research. Multiple methods for the production of mSPOFs were investigated, namely electrospinning, melt-electrospinning and fiber drawing. Polystyrene-based mSPOFs with a diameter of 10ths micrometers have been successfully produced via fiber drawing, using a customized setup. Scintillating organic compounds (TPB, POPOP, BBOT) will be used to dope the mSPOFs.

Corundum (Al_2O_3) single crystals were grown isothermally by the flux method, with a Li_2O–MoO_3 flux system. MoO_3 with 99.5% and 99.0% purity were used to investigate flux purity influence on crystal growth. Li_2O concentration ranged from 2% to 15% mol of the total flux. To achieve the standard composition for the commercial detectors, C and C,Mg doped Al_2O_3 were grown. Alternative dopants, namely carbon co-doping with Zn, Ti(IV) and Mn(II), were also explored. Optically stimulated luminescence in continuous wave mode (CW-OSL) measurements were performed, to evaluate the crystals' luminescence efficiency. Flux composition and process optimizations led to the successful growth of high-quality 5 mm size Al_2O_3 crystals. Flux purity was shown to significantly affect the material OSL potential, with higher purity reagents resulting in better shaped OSL curves. C,Ti co-doped Al_2O_3 may be a promising material for OSL dosimetry.