In situ electron beam dose measurements in FLASH Radiotherapy using fiber-optic scintillation sensors based on Al_2O_3:Ce and GAGG:Ce Crystals

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FLASH radiotherapy (FLASH-RT) is an emerging radiation treatment modality designed to reduce damage to healthy tissues while maintaining effective tumor control. This technique employs ultra-high dose rates (UHDRs) exceeding 40 Gy/s, which are several orders of magnitude higher than those used in conventional radiotherapy. From a radiation dosimetry perspective, accurate real-time monitoring of such ultra-high-dose-rate radiation beams remains a significant challenge.

Conventional ionization chambers (ICs), which are widely used as reference detectors in radiotherapy dosimetry, exhibit a dose-per-pulse (DPP) dependence caused by ion recombination effects. As a result, measurements obtained with ICs require correction procedures when the DPP exceeds approximately 0.01 Gy per pulse [1]. Radiochromic films may also be employed for FLASH-RT dosimetry; however, these detectors are inherently unsuitable for real-time dose measurements due to the need for post-irradiation analysis [2].

In this study, we developed a fiber-optic dosimeter consisting of an optical fiber coupled to a scintillation crystal positioned at its distal end. Two scintillation materials, Al_2O_3:Ce and GAGG:Ce, were investigated as sensing elements for dose measurements of electron beams used in FLASH radiotherapy. To evaluate the linearity of the detector response, absorbed doses ranging from 1.5 Gy to 30 Gy were delivered and measured.

The experimental results demonstrated a highly linear response of the developed sensor over the investigated dose range. Furthermore, the study confirmed that ultra-high-dose electron beams employed in FLASH radiotherapy can be measured accurately and in real time using the proposed fiber-optic scintillation detector. These findings highlight the potential of the developed dosimetric system as a promising tool for online monitoring and quality assurance in FLASH radiotherapy applications.

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