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Titolo

New Dosimetric methods and devices for UHDP electron beams

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Riassunto

Radiotherapy (RT) stands as a pivotal element in cancer care, utilized by nearly 50% of patients in developed nations for both curative and palliative purposes. Recent advancements in radiotherapy techniques like Intensity Modulated Radiation Therapy (IMRT), stereotactic Radiosurgery (SRS), and Volumetric Modulated Arc Therapy (VMAT) have significantly improved dose precision to target areas while preserving healthy tissues. Despite technological advancements that have improved the precision of radiotherapy treatments, there are unavoidable limitations in treatment reproducibility on the patient arising from positioning, organ motion, and other factors. Therefore, the effectiveness of radiotherapy has reached a plateau, where the pursuit of increasingly conformal treatment methodologies has only a limited impact on its overall outcomes.

A recent biological phenomenon termed the FLASH effect has emerged in the scientific community. This effect indicates a reduction in normal tissue toxicities while maintaining comparable efficacy in tumor tissues, achieved by administering radiation at an average dose rate exceeding 40 Gy/s, in contrast to conventional rates of around 1 Gy/min. The implications of the FLASH effect are groundbreaking, as they have the potential to overturn the recent paradigm that emphasizes achieving better treatment solely through increased conformality. This offers a dual advantage: reducing the necessity for increasingly complex technology and enabling the treatment of locoregional advanced tumors situated in parallel organs.

Several in vivo studies across various tissue types have exhibited promising outcomes. However, translating these discoveries into clinical applications presents significant challenges. Primarily, these challenges encompass three main areas: technological, related to FLASH source development and monitoring, radiobiological, linked to an inadequate understanding of the underlying mechanisms of the effect, and dosimetric. The dosimetric challenges form the foundation for addressing the aforementioned issues. Precise dosimetry is fundamental in both radiobiological experiments and the characterisation and monitoring of FLASH sources, providing essential answers needed to overcome the other obstacles.

This thesis aims to describe and evaluate the use of different dosimeters for Ultra High Dose per Pulse (UHDP) electron beams and to give a perspective on their different possible employment in the context of FLASH radiotherapy experiments.

To begin, an introduction to the FLASH effect is presented, along with an examination of the beam parameters associated with it. Various sources capable of generating FLASH and their historical development are discussed. A comprehensive overview and dosimetric characterisation of the ElectronFlash, the triode-gun electron LINAC at the Centro Pisano Flash Radiotherapy (CPFR), are provided. The machine's adaptability for conducting FLASH experiments, both in dosimetric investigations and radiobiological studies, are highlighted. Specific setups are described wherein

individual beam parameters are systematically altered while keeping others constant, facilitating the isolation of different dependencies. Moreover, various dosimetric zones along the beam line are defined, each with distinct requirements specified for the detectors used.

A comprehensive description of four distinct types of flash-capable dosimetric devices is provided, encompassing their operational principles, characteristics enabling precise dosimetric data collection in FLASH beams, and an extensive array of tests and validations conducted at the ElectronFlash under extreme irradiation conditions to assess their efficacy.

Specifically, the dosimetric devices studied include a diamond detector, multiple ionization chambers, scintillation detectors, and silicon carbide semiconductors. Notably, concerning ionization chambers, the thesis explores a new theoretical model of ionization chamber, the ALLS ionization chamber, designed to measure dose per pulses up to 40 Gy/p. The work also offers insights into the technical hurdles that such a chamber must overcome for effective functionality.

Finally, the thesis presents a discussion on the most effective utilisation of each investigated detector, highlighting potential development and their application in very high-energy FLASH electron beams.