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A Fibre-Optic Dosimeter for Real-Time Tracking of HDR Brachytherapy Source

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Precise source localisation is vital for safe HDR brachytherapy. This study examines a fibre-optic dosimeter for real-time tracking of a ^{192}Ir source, using a new calibration approach that incorporates fluorescence and Cherenkov contributions alongside scintillation signals. Unlike conventional stem-effect correction methods, which rely on hardware modifications or spectral separation, this technique offers a more integrated and streamlined solution for reliable signal correction and source tracking. A real-time source tracking system for HDR brachytherapy was developed using a fibre-optic dosimeter. The phantom consisted of multiple PMMA slabs, each 90 mm wide and 10 or 5 mm thick, with drilled slabs for detector and source placement. A high-yield CsI(Tl) scintillation detector measured the radial dose function (1–5 cm) and anisotropy function (15° – 155°). These data supported source characterisation and the development of a calibration model, enabling accurate source localisation. Tracking was assessed with 5 mm and 3 mm step sizes and a 5-second dwell time. Real-time source tracking was successfully demonstrated for both step sizes. Using the reference dataset, large deviations occurred at the beginning of the plan, where the source travelled perpendicular to the detector. In this region, the signal was strongly influenced by the stem effect, as contributions originated from both the scintillator and optical fibre. As the source passed the central region, the signal became dominated by scintillation, leading to improved agreement. Overall, deviations reached 5 mm (3 mm step plan) and up to 6 mm (5 mm step plan) using the reference calibration model. With the new calibration model, deviations were reduced to within ± 1.2 mm for both plans. This study demonstrates the feasibility of a fibre-optic dosimeter for real-time HDR brachytherapy source tracking, achieving improved accuracy through an integrated calibration approach. The results indicate strong potential for clinical implementation, offering enhanced precision in source localisation and treatment delivery.

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