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Diamond-Based Detection System: Design and Characterization for Advanced Dosimetry and Microdosimetry in Ion Beam Therapy

Ion beam therapy has rapidly expanded in clinical practice over recent years, while dosimetric verification has progressed more slowly, particularly in capturing the microscopic energy deposition patterns that drive radiobiological effects. Conventional dosimetry remains limited to absorbed dose, with no direct link to micro- and nanometric stochastic interactions.

To address this unmet need, we present a novel detector system based on synthetic single-crystal diamond, designed to provide both dosimetric and microdosimetric information in clinical ion beams. The detector integrates two diamond Schottky diodes on a single substrate, ensuring high sensitivity and reproducibility. Its functionality is complemented by dedicated readout electronics, currently under further development to optimize signal quality and broaden clinical adaptability. The system is housed in a compact, waterproof aluminum case for robust operation in treatment environments.

Extensive characterization campaigns at multiple ion beam facilities confirmed the detector's capability to simultaneously measure absorbed dose and lineal energy distributions at varying depths in water. Monte Carlo simulations (Geant4) closely reproduced the experimental results, validating depth-dose profiles, microdosimetric spectra, and dose-mean lineal energy values. The detector exhibited low noise (~ 0.3 keV/ μ m) and stable performance with uncertainties below 10%.

This work demonstrates how an advanced diamond-based detector, together with evolving readout electronics, can bridge the gap between dosimetry and microdosimetry for clinical applications, paving the way for more precise and reliable verification in particle therapy.

Topic

Title

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