

Near-infrared scintillation of lead halide perovskite nanocrystals for ultra-high dose rate dosimetry

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FLASH radiotherapy (RT) is an innovative cancer treatment technique based on the delivery of ionizing radiation within extremely short irradiation times (typically under 100 -200 ms) resulting in ultra-high dose rates (UHDR, > 40 Gy/s). Compared to conventional radiotherapy, FLASH RT has shown the potential to reduce damage to healthy tissues while preserving antitumor efficacy, although the biological mechanisms responsible for the so-called FLASH effect are still under investigation [1]. The extreme irradiation conditions of FLASH RT introduce significant technological challenges, particularly for real-time dosimetry, as conventional dosimeters often suffer from saturation effects under UHDR conditions. Fiber-coupled dosimeters employing scintillating materials represent a promising approach for FLASH RT dosimetry due to their high temporal resolution, passive operation, and capability for remote signal transmission [2]. However, their accuracy is limited by spurious signals such as Cherenkov radiation and intrinsic fluorescence of passive optical fibers, mainly in the UV-VIS spectral range, which are responsible for the undesired stem effect. The use of near-infrared (NIR) emitting scintillators provides an effective strategy to spectrally separate the dosimetric signal from these spurious contributions [3].

In this study, cesium lead iodide (CsPbI₃) perovskite nanocrystals embedded in a polymethyl methacrylate (PMMA) matrix are being investigated as potential NIR scintillators for fiber-based dosimetry in ultra-high dose rate conditions. Polymer encapsulation is shown to enhance the environmental stability of the perovskite nanocrystals while enabling straightforward handling and efficient coupling with optical fibers. Structural and optical characterizations indicate a uniform nanocrystal distribution in the nanocomposite and a strong, spectrally narrow emission centered at ~1.8 eV, not overlapping with fiber-related spurious signals which, therefore, can be filtered out. Time-resolved photoluminescence measurements reveal decay times in the ns to sub-ns time scale, suggesting that the material is well suited to resolving the ultra-short radiation pulses (~ 4 μs) typical of eFLASH RT. Cathodoluminescence experiments on drop casted nanocrystals from toluene solution further indicate that the emission remains intense and spectrally stable under electron beam excitation. Radioluminescence measurements show a linear dependence of signal intensity on dose rate within the investigated range of values, and radiation hardness tests demonstrate stable optical performance up to accumulated doses exceeding 300 Gy, with no evidence of radiation-induced absorption in the emission region. These results indicate that CsPbI₃ perovskite-PMMA nanocomposites are a promising platform for fast, stable NIR-emitting scintillators in fiber-optic dosimetry for FLASH radiotherapy.

1. V.Favaudon et al, "Ultrahigh dose-rate FLASH irradiation increases the differential response between normal and tumor tissue in mice," *Transl. Med*, **6** (2014).
2. I.Veronese et al, "Infrared luminescence for real time ionizing radiation detection," *Appl. Phys. Lett*, **105** (2014).
3. F.Cova et al, "Stem effect-free (Y,Yb)AG-based detectors for ultra-high dose rate electron beam dosimetry," *Sensors Actuators: A. Physical*, **390** (2025)