Evaluation of Plastic Scintillator Detector for In-Vivo Dosimetry

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Introduction: Tissue-equivalent, high–spatial resolution detectors are emerging as powerful clinical tools for accurate dose measurement and comprehensive quality assurance in radiation therapy. Despite this need, the availability of commercially viable in-vivo dosimeters remains limited. Existing systems often suffer from inadequate spatial resolution, are constructed from high-Z materials, or are restricted to single-point dose measurements. These limitations are particularly significant in proton therapy, where uncertainties arising from patient setup, tissue heterogeneity, and anatomical changes during treatment can lead to substantial dosimetric uncertainties. In-vivo dosimeters provide critical means to verify the delivered dose to the patient in real-time.

Motivation: The purpose of this study is to develop and characterize plastic scintillator sheets for in-vivo dosimetry to measure entrance dose distributions for therapeutic photon, electron, and proton beams.

Methods: An in-vivo dosimeter made from plastic scintillator sheets was developed and evaluated using electron and photon beams from a TrueBeam linear accelerator and proton beams from a MEVION-S250i system. The detector consisted of plastic scintillator sheet of forming an effective cross-sectional area of $30 \times 30cm^2$ and 2mm thickness. The plastic scintillation sheets were placed on the top of a phantom and the scintillation light produced by radiation was collected with multiple cameras positioned around the detector. The recorded optical projections were subsequently used to reconstruct surface entrance dose distributions obtained by the plastic scintillation sheet.

Results: The developed detector functioned as a large, water-equivalent 2D dosimeter with an effective sensitive area of $30 \times 30cm^2$ (Fig. 1a–b). Dose projections acquired from multiple viewing angles enabled reconstruction of the surface dose distributions, extending beyond the planar measurements typically obtained with conventional 2D dosimeters. When tested with therapeutic spot-scanning proton beams, the system successfully detected and tracked individual beam spots, with temporal resolution limited by the camera acquisition rate of 30 frames per second (Fig. 1c). While the plastic scintillator itself provided intrinsically high spatial resolution, the accuracy of the reconstructed dose distributions was constrained by the camera digitization resolution (0.5 mm). Detector sensitivity was influenced by optical attenuation through the scintillator slabs and sensitivity of the cameras to the blue scintillation light and background from ambient light in the room (Fig. 1d).

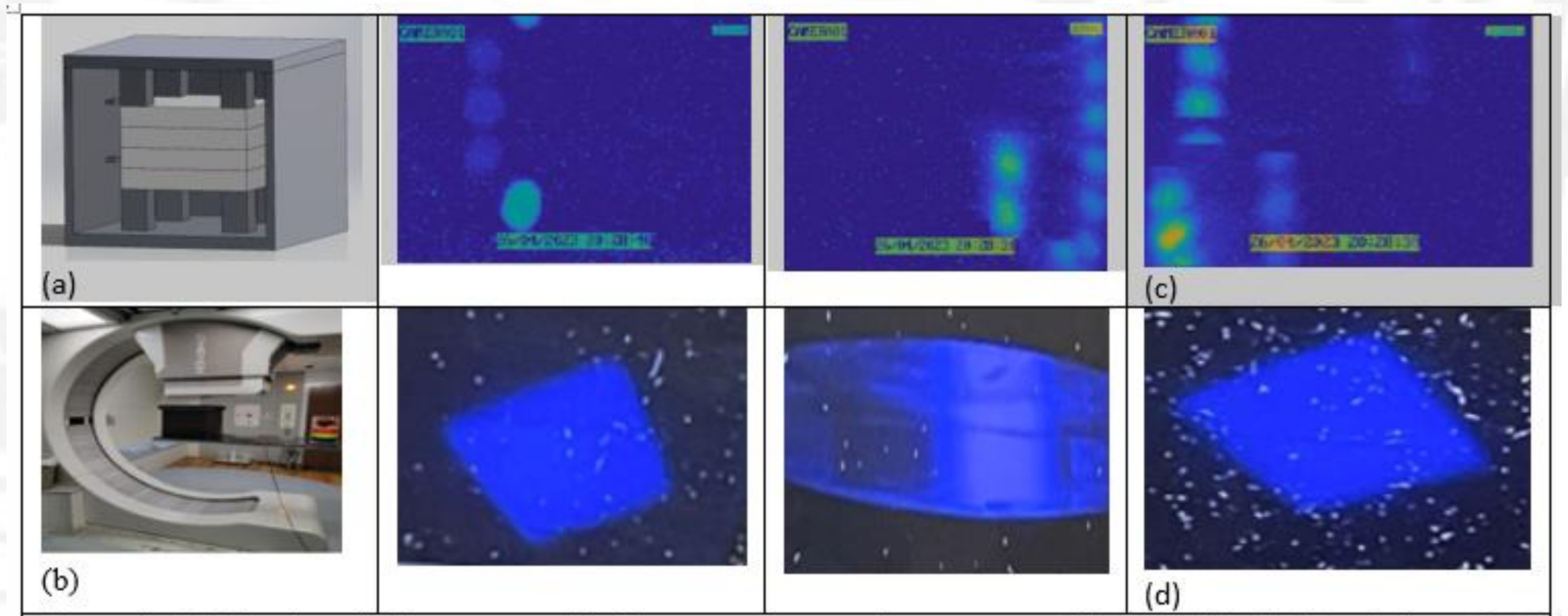

Figure 1: (a) Plastic scintillator setup. (b) Detector setup on the proton machine. (c) Scintillation light emitted during exposure of the plastic scintillation block to 227 MeV spot scanning proton beam, and (d) 6 MV photon beam

Conclusion: This plastic scintillator–based 2D-dosimeter provides a tissue-equivalent detector with a large effective area and high spatial resolution, offering a novel detector for in-vivo dosimetry. This detector system has strong potential for broad clinical application in quality assurance procedures for therapeutic electron, photon, and proton beams.

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