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Dynamic 2.5D Surface Dosimetry Using Deformable Scintillator Array Imaging

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Purpose and Objective – Deformable scintillator array offers solution to dynamic *in vivo* dosimetry

On-patient dosimeters assist in clinical decision-making by measuring surface dose, but single-point measurements cannot monitor area-wide distributions and are misleading in high-gradient regions. This limitation is illustrated in breast radiotherapy with tangent-beam arrangements, where steep dose gradients and complex surface contours can increase contralateral breast dose and, consequently, increase the risk of secondary malignancy. **This work introduces a novel 2.5D surface dosimetry technique using a wide-area deformable scintillator array combined with Cherenkov imaging for regional dose monitoring in high-gradient areas.**

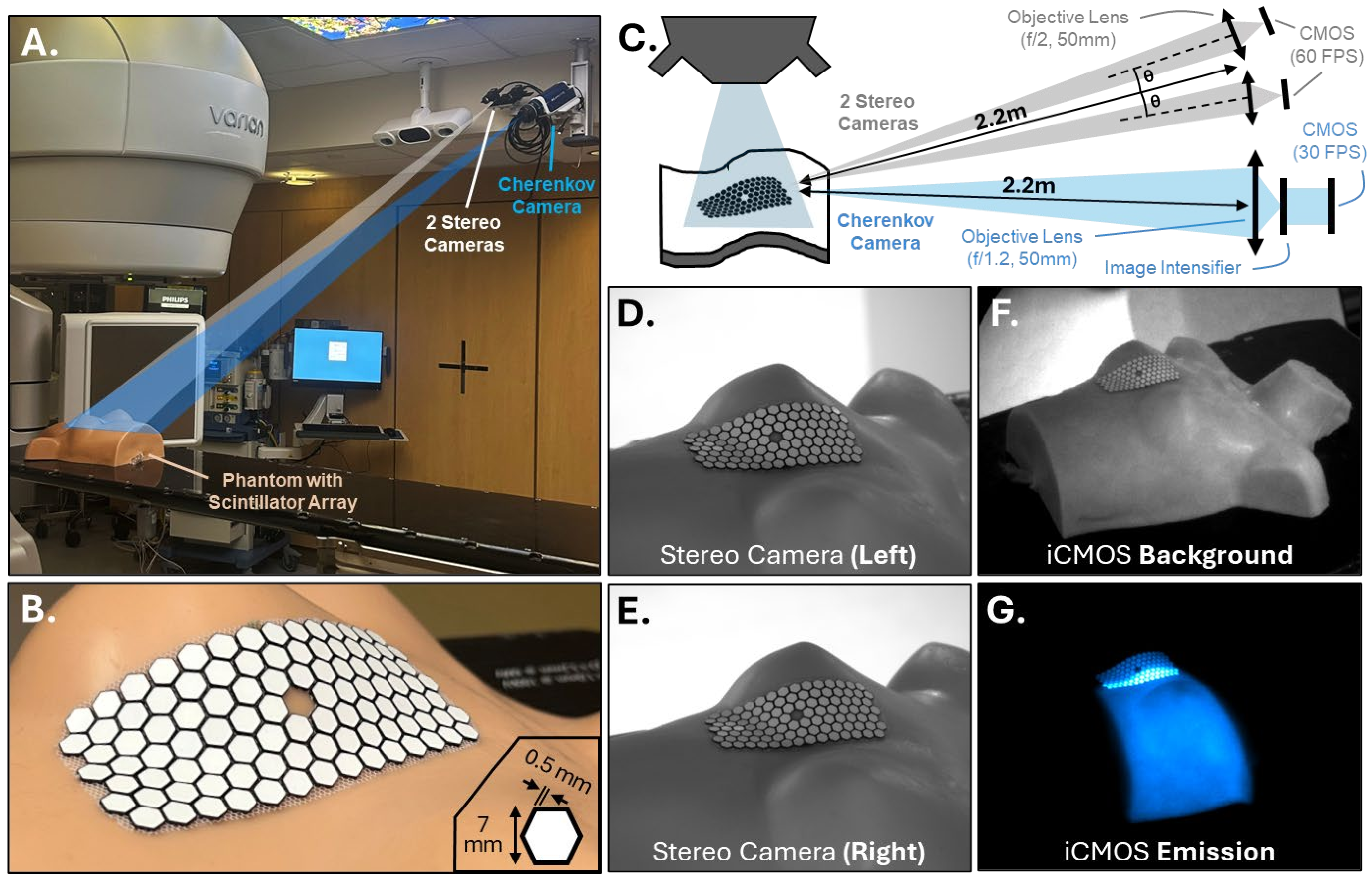

Figure 1: (a) Sample experimental setup showing a dual-stereovision system mounted adjacent to a clinical Cherenkov camera. **(b)** A detailed view of the scintillator array is shown in a sample position on an anthropomorphic chest phantom. **(c)** A reference diagram of the imaging setup is highlighted and sample image outputs from the stereovision modules **(d-e)** and Cherenkov camera **(f-g)** are shown.

Performance Analysis – Linearity with dose is shown and angular dependence is characterized

Current standard-of-care treatments leverage angular variation during delivery to optimize dose target coverage. Surface dosimetry has been shown to display significant dependence on irradiation angle, with up to 50% variation in emission compared to en-face delivery. Optical dosimeters exhibit additional dependence of emission intensity with angle to the imaging plane. **This work presents extensive characterization of scintillation emission variation with gantry angle and camera angle, linearity with dose, repetition rate, and build-up effect on the beam delivery.**

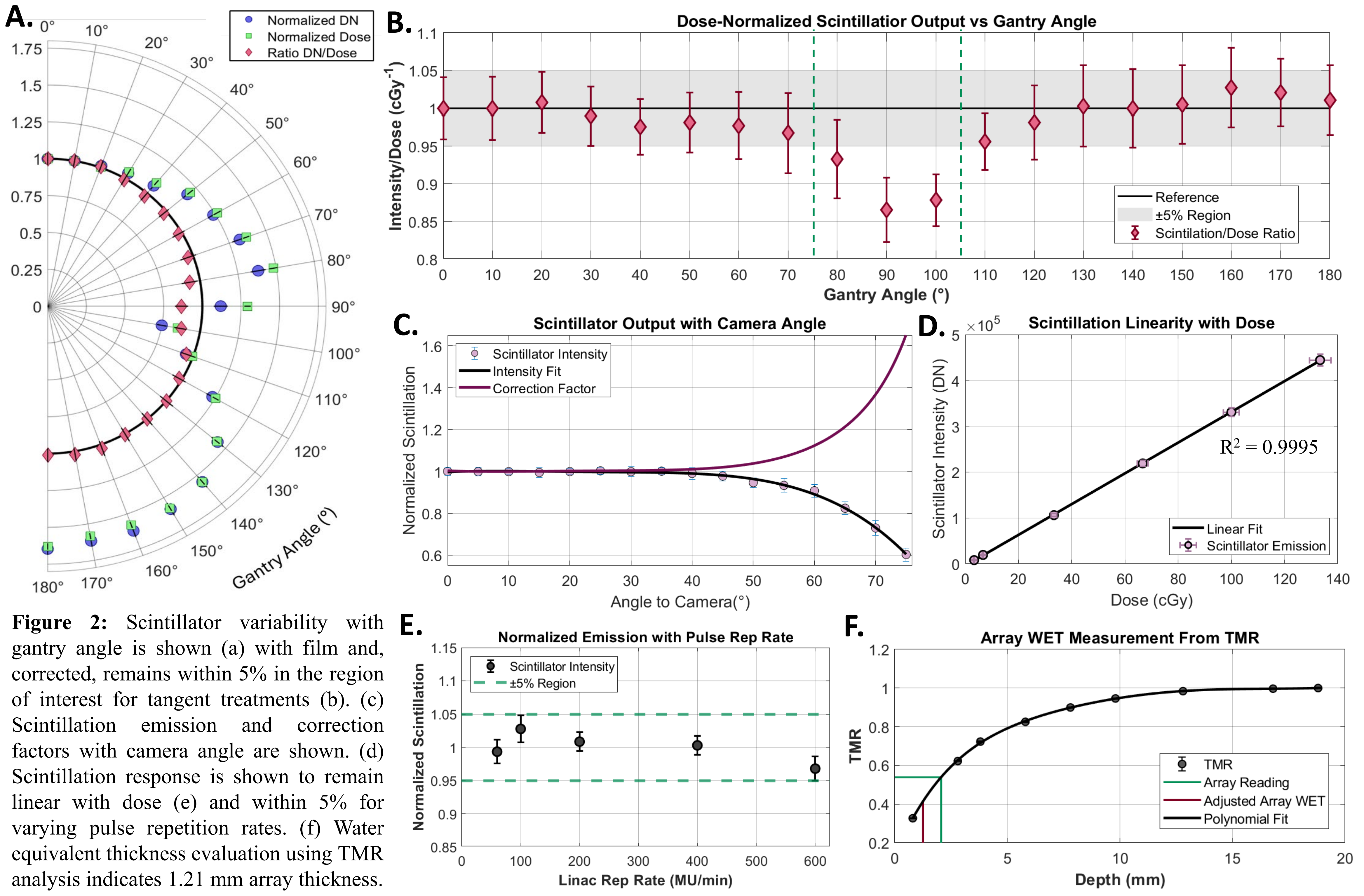

Figure 2: Scintillator variability with gantry angle is shown (a) with film and, corrected, remains within 5% in the region of interest for tangent treatments (b). (c) Scintillation emission and correction factors with camera angle are shown. (d) Scintillation response is shown to remain linear with dose (e) and within 5% for varying pulse repetition rates. (f) Water equivalent thickness evaluation using TMR analysis indicates 1.21 mm array thickness.

Pre-Clinical Testing – 3D localization and angular correction achieved via stereovision

Geometric correction is essential for maintaining linearity between scintillation and dose. Stereovision monitoring at 30 FPS enabled precise 3D localization of each array element during delivery, allowing angular correction using known gantry and camera positions. **A tangent field was delivered to an array placed over the gradient line across the contralateral breast of an anthropomorphic phantom to test feasibility with complex geometry.**

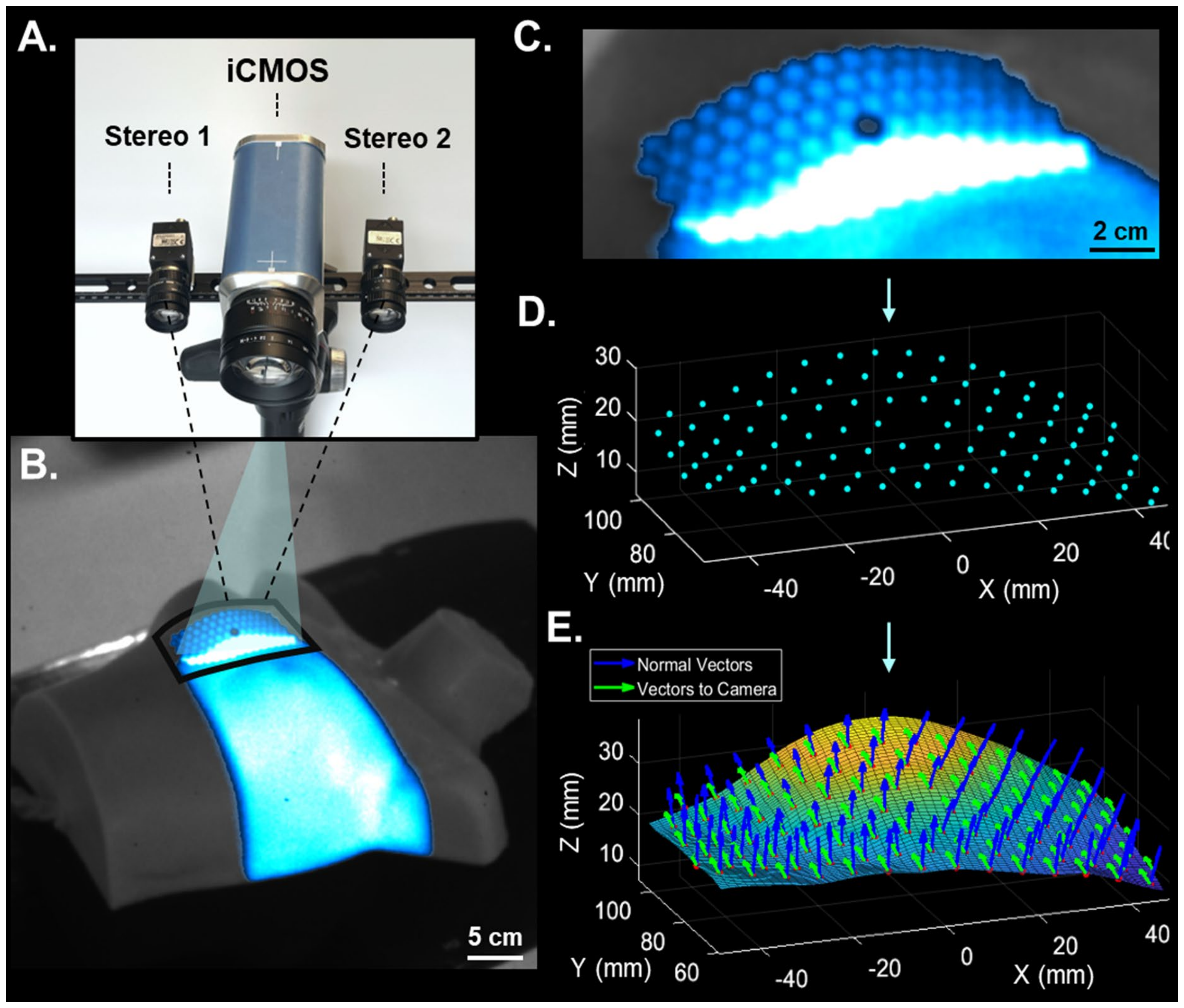

Figure 3: Cherenkov and stereovision cameras were **(a)** used to image Cherenkov and scintillator emission from anthropomorphic phantom undergoing 6MV photon irradiation **(b)**. Scintillator array **(c)** was placed over the gradient on the contralateral breast, localized in 3D **(d)** in room coordinates and interpolated to **(e)** form a surface.

Clinical Translation – Scintillator array successfully translated to monitor contralateral breast dose *in vivo* with high agreement to TLDs

The 2D surface dosimetry offered by this technique is uniquely suited for wide area gradient imaging given its high resolution and conformality. To demonstrate the efficacy of this approach, it was **translated clinically to monitor a patient treatment with suspected high contralateral breast dose in which 6 fields (medial/lateral wide tangents, supraclavicular fields with RAO/LPO) were delivered**. Dose was collected from each field, processed to isolate the surface dose profile from scintillation imaging, and the cumulative map was compared against 3 TLDs positioned along the central axis of the array.

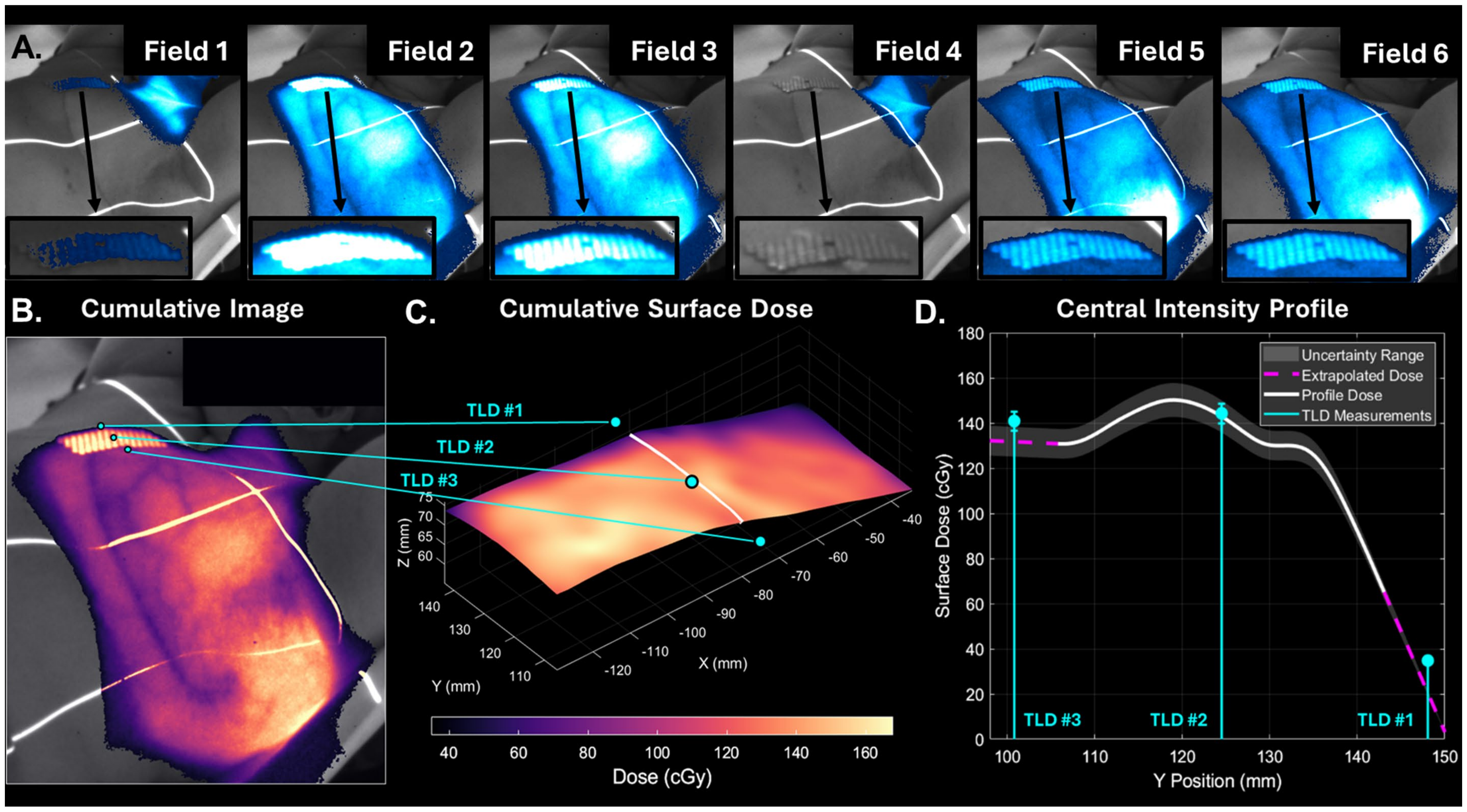

Figure 4: Scintillator array used to measure dose during a 6 field (medial/lateral wide tangents, supraclavicular fields with RAO/LPO) post-mastectomy radiotherapy treatment. **(a)** Signal from each field was isolated, localized, and corrected into a **(b)** cumulative image with 3 TLD measurements along the central axis of the array. Cumulative surface dose **(c)** was sampled along TLD path showing agreement within uncertainty **(d)**.

Results

Scintillator intensity demonstrated linearity with dose (R^2>0.999), remained within 5% for varying pulse repetition rates, and maintained minimal response deviation up to a camera angle of 50°. TLD measurements agreed within 5cGy of the scintillator-derived central dose profile. The system resolved dose gradients up to 150cGy/cm at the field edge.

Conclusions / Future Work

This work presents a time resolved 2D surface dosimetry method optimized for irregular surface geometry. This approach enables quantitative spatially-resolved dose measurements across non-uniform and high gradient treatment regions and clinical translation is ongoing.

Acknowledgments

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