DARTMOUTH ENGINEERING

Conformal Scintillator Array Imaging Allows for Dynamic 2D In Vivo Dosimetry of Wide-Area and High-Gradient Fields

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Purpose and Objective – scintillator array solution to dynamic IVD

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. In breast radiotherapy, steep dose gradients and complex surface contours can increase contralateral breast dose and, consequently, increase the risk of secondary malignancy. **This work introduces a 2.5D surface dosimetry technique using a wide-area deformable scintillator array combined with Cherenkov imaging for regional dose monitoring in high-gradient areas.**

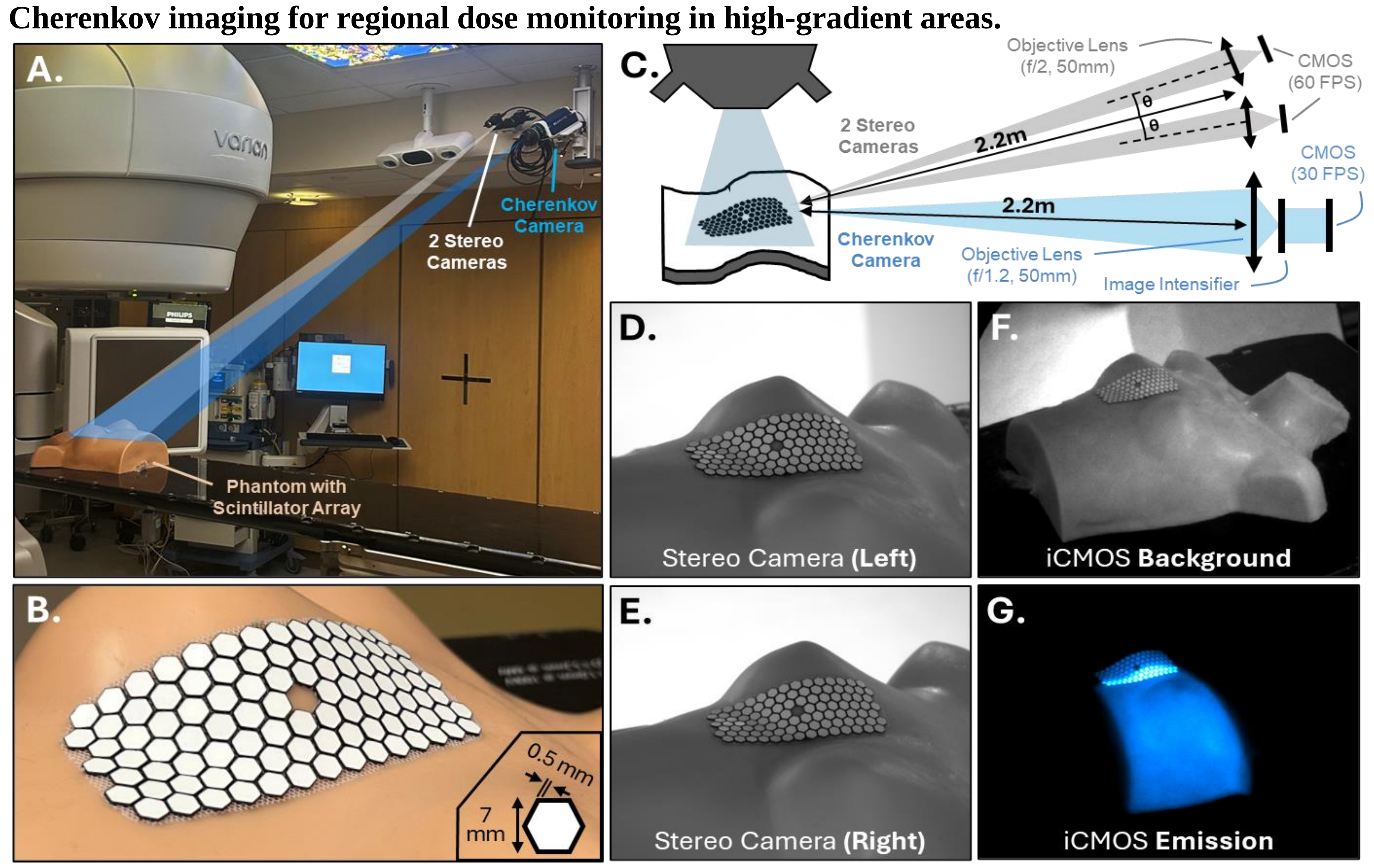

Figure 1: (a) Dual-stereovision system setup mounted adjacent to clinical Cherenkov camera. **(b)** A detailed view of the scintillator array on an anthropomorphic phantom. **(c)** A diagram of the imaging setup is highlighted and sample image outputs from the stereovision modules **(d-e)** and Cherenkov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

Method – 3D localization and angular correction via stereovision

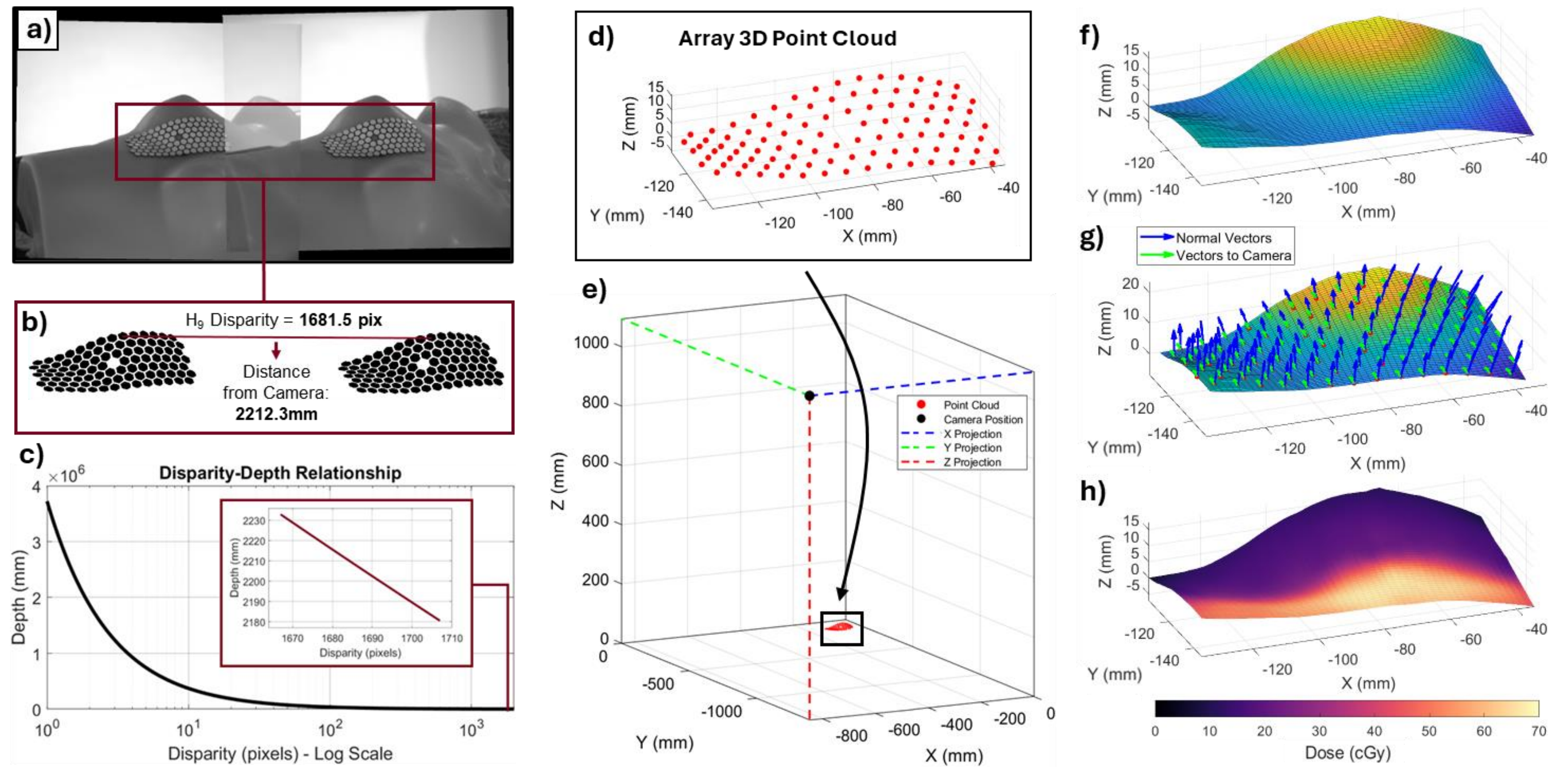

Figure 2: (a) Rectified image pair, **(b)** sample disparity definition using masked array profiles, **(c)** analytically derived relationship between disparity and depth, **(d)** sample array point cloud oriented in **(e)** the bunker environment with respect to the isocenter and the camera. **(f)** Interpolated surface with **(g)** normal and camera directional vectors, and a **(h)** sample dose map following angular correction and interpolation.

Clinical Translation – Scintillator array used to monitor contralateral breast dose *in vivo*

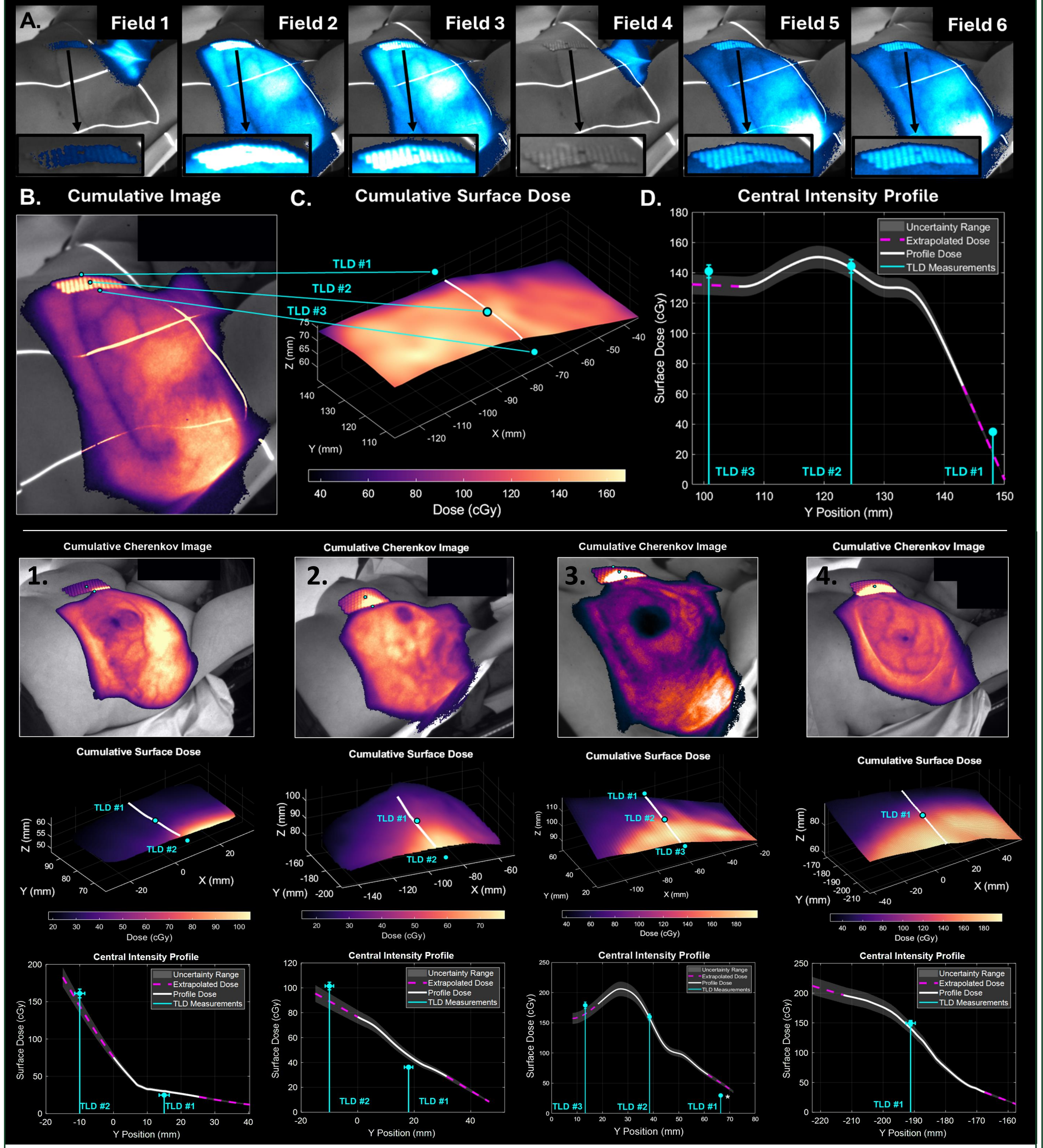

Figure 3: Single full process is highlighted (top) - scintillator array used to measure dose during a 6 field post-mastectomy radiotherapy treatment. **(a)** Signal from each field was isolated, localized, and corrected into a **(b)** cumulative image with 3 TLD measurements along the central axis of the array. Cumulative surface dose **(c)** was sampled along TLD path showing agreement within uncertainty **(d)**. Resulting data from 4 additional patients is shown **(1-4)** highlighting cumulative Cherenkov, surface dose map, and central intensity comparison to TLDs.

Performance Analysis – Dose Linearity, Angular Characterization, Beam Impact

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.**

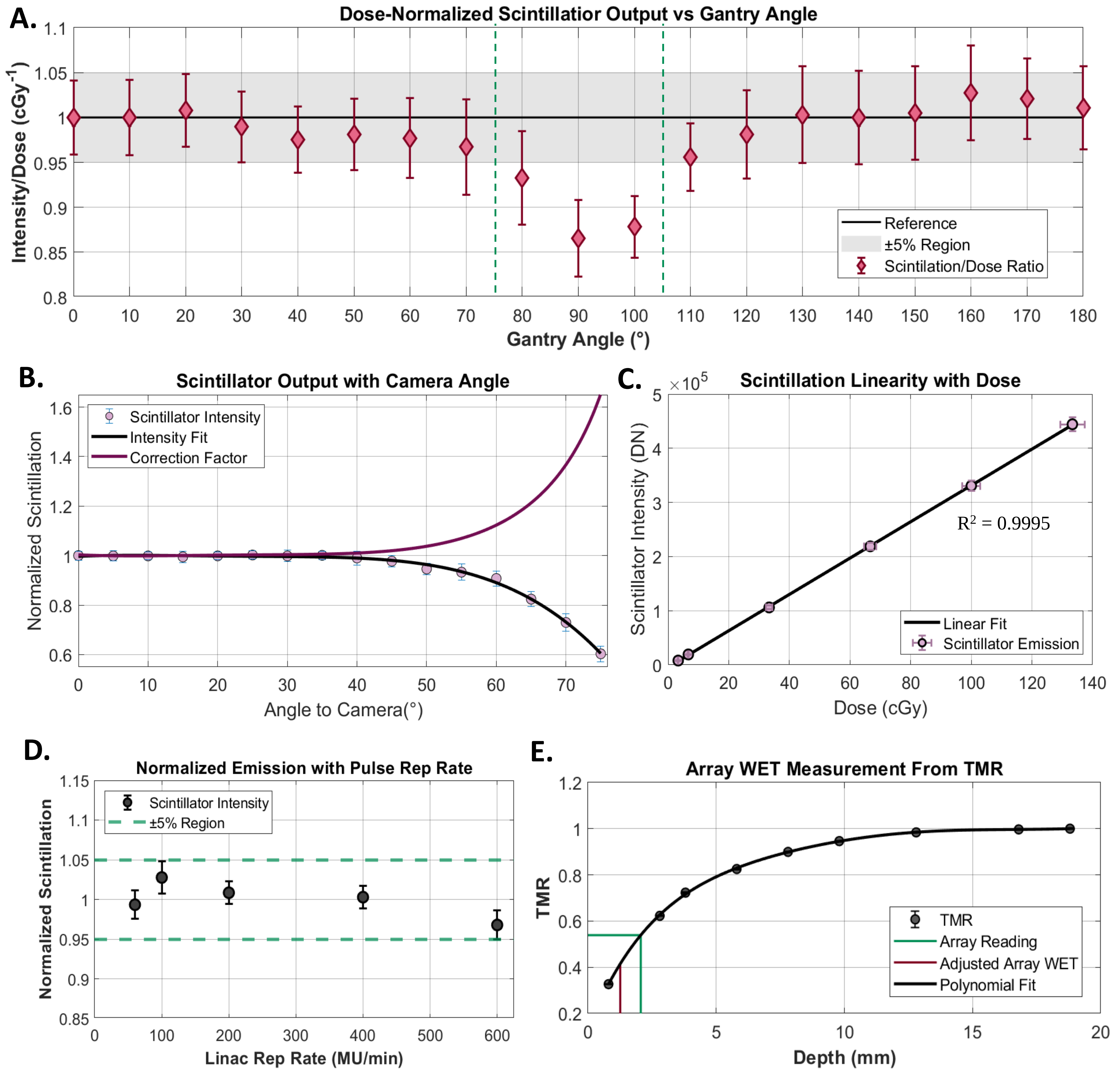

Figure 4: Scintillator variability with gantry angle is dose corrected and shown to remain within 5% in the region of interest for tangent treatments **(a)**. **(b)** Scintillation emission and correction factors with camera angle are shown. **(c)** Scintillation response remains linear with dose (R^2 = 0.9995) for the range of interest **(d)** and remains within 5% deviation for varying pulse repetition rates. **(e)** Water equivalent thickness evaluation using TMR analysis indicates 1.1 mm array thickness.

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°. Stereovision positioning localized the 3D target surface in patient coordinates with 0.5mm accuracy. The system resolved continuous dose gradients up to 150cGy/cm at the field edge and captured real-time in vivo surface dose distributions during treatment revealing contralateral breast dose ranging from 230 cGy to 40 cGy. Across all deliveries, central TLDs agreed within 1% (1.5 cGy) of the interpolated dose map. Edge TLD deviations were higher due to extrapolation but still agreed within 20 cGy and 2 mm.

Conclusions / Future Work

This work presents a time resolved 2.5D 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.

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