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DARTMOUTH ENGINEERING

Development of a Methodology for Clinical in vivo Optical Dosimetry and Uncertainty Analysis

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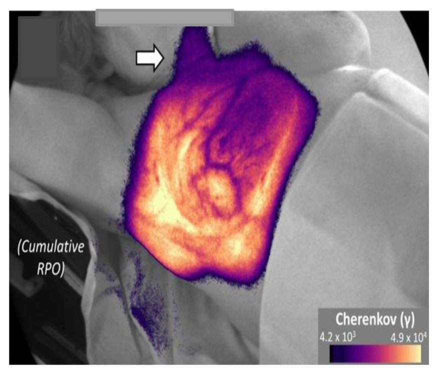
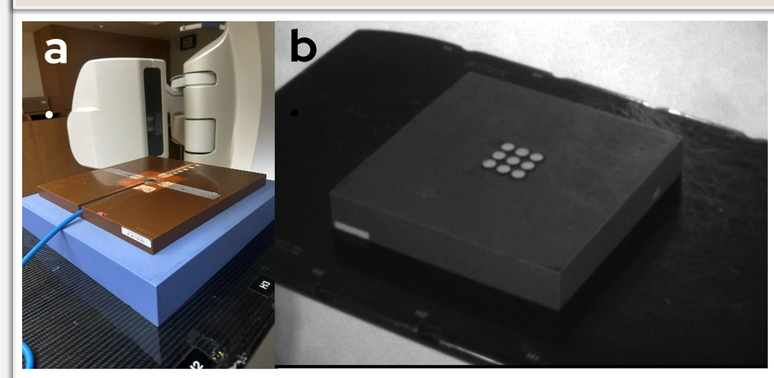
Motivation & Background

Cherenkov light is produced in tissue from high energy electrons that are released during the dose delivery process of radiation therapy. This light can be used to visualize the radiotherapy beam and detect medical incidents. The Cherenkov images are captured through time-sequenced intensifier gating of the camera to the linac pulses [1]. Cherenkov imaging produces a spatial map of dose; however, this map is not quantitative.



Cherenkov output is dependent on the tissue optical properties of the patient and not just the dose itself. For this reason, real time calibrated scintillating dosimeters that can be measured by the camera system are being developed.

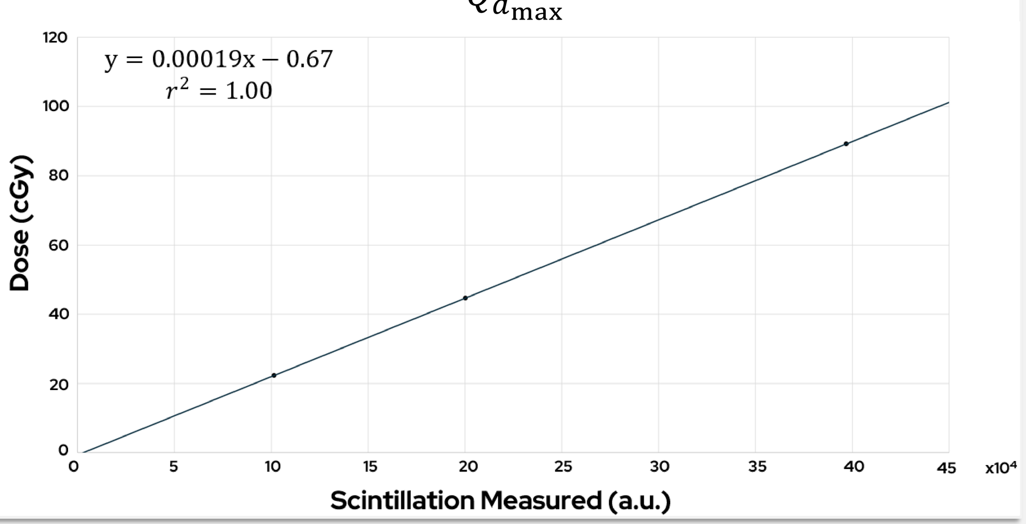
Calibration and Measurement



a. Calibration setup with the advanced Markus chamber b. 10x10 field irradiation of 9 scintillating dots to correlate to dose.

The scintillation output observed by the camera must be calibrated to a known dose. Ideally, a known dose is determined as close to the surface as possible to best represent the dose delivered to the dots. This can be done using an Advanced Markus chamber (PTW Friedberg Germany) by measuring the ratio of charge collected at a depth of 1.2mm (the buildup cap thickness) to a depth at d_{max} using the same beam parameters as TG-51. Assuming the Dose in cGy at d_{max} is identical to the linac output in monitor units, we can calculate the dose at the surface.

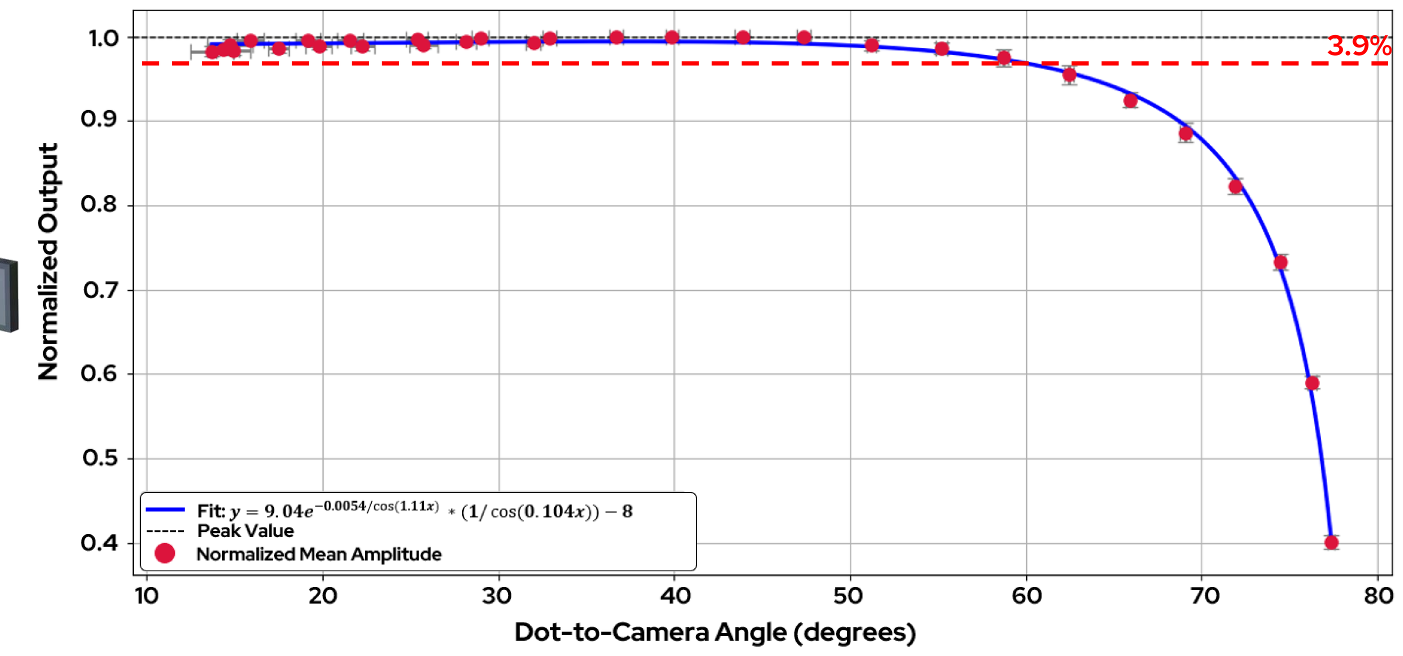
$$D_{1.2\text{mm}} = \frac{Q_{1.2\text{mm}}}{Q_{d_{\max}}} \times D_{d_{\max}}$$



Experiments

1 Angle-to-camera

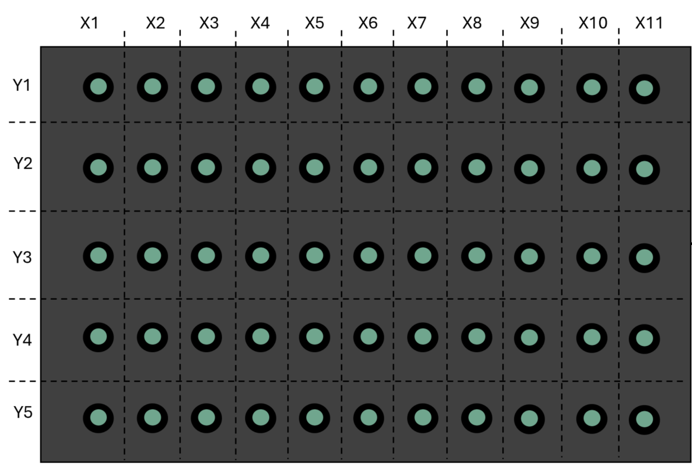
Several parameters effect the measured scintillation output of the scintillating discs. One of these is the angle from the dot to the camera. This angle is measured using the major and minor axis lengths of an ellipse fit to the dot. The scintillation output is stable until drastically dropping past 60 degrees.



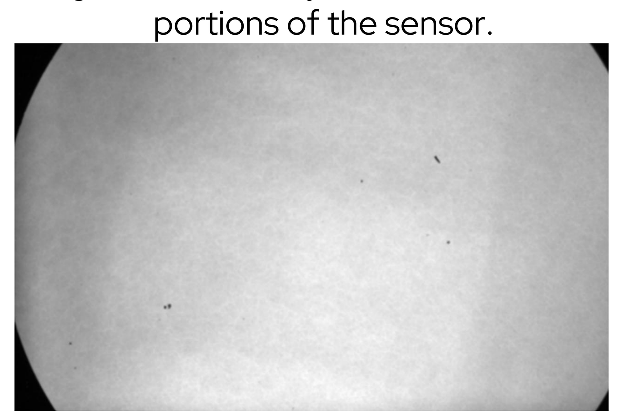
The scintillation output of a disc placed at isocenter and rotated relative to the camera. The output rises very slightly up until 40 degrees and then drops significantly past 60 degrees.

2 Flat-Field Variation

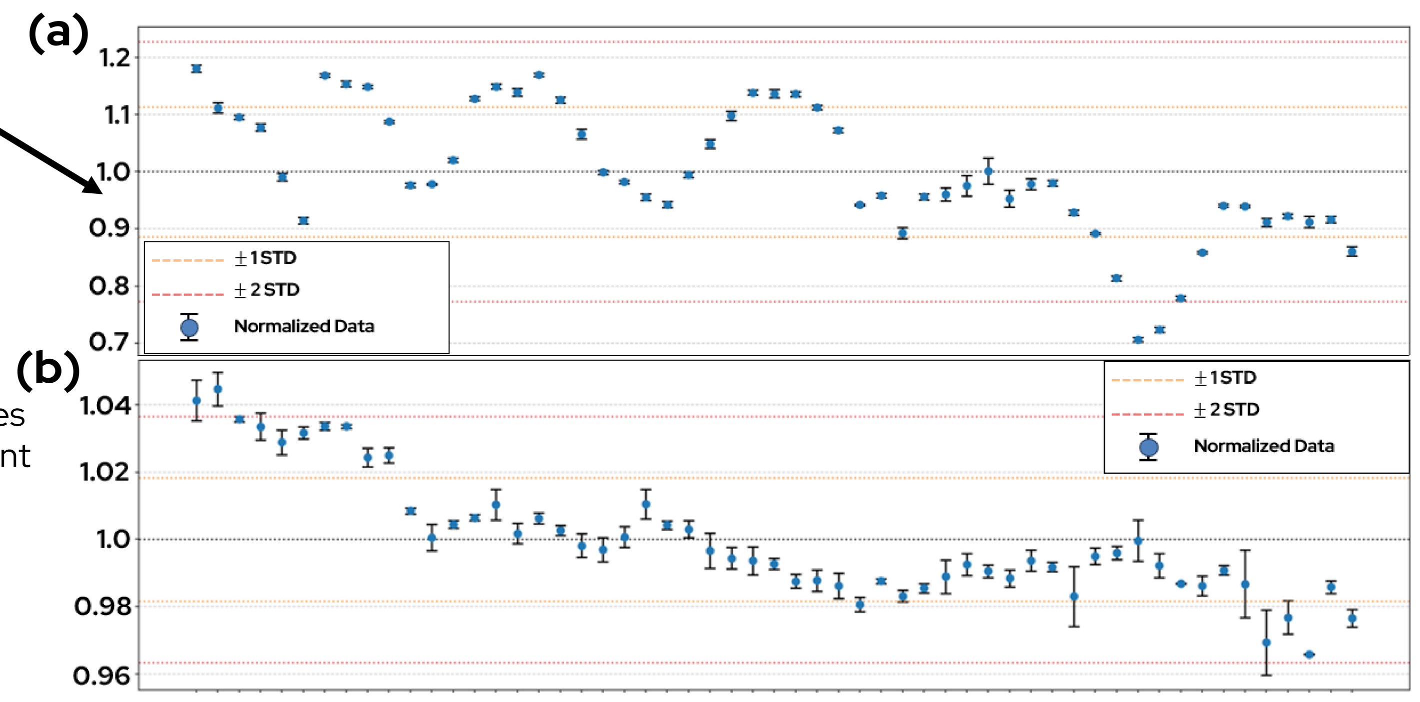
Due to lens vignetting, coupling between the sensor and the camera's image intensifier, as well as image burn in, the spatial response of the camera is not perfectly flat. This is corrected by imaging a flat, diffuse light source panel held up to the camera. Images are divided by this flat-field image along with background subtraction and normalization to produce the corrected image. To verify the results, a stationary scintillating disc was measured with the camera translated to deposit the light on different sections of the sensor as demonstrated



The camera placed on the linac couch was translated by adjusting the couch coordinates to image the stationary scintillator on different portions of the sensor.

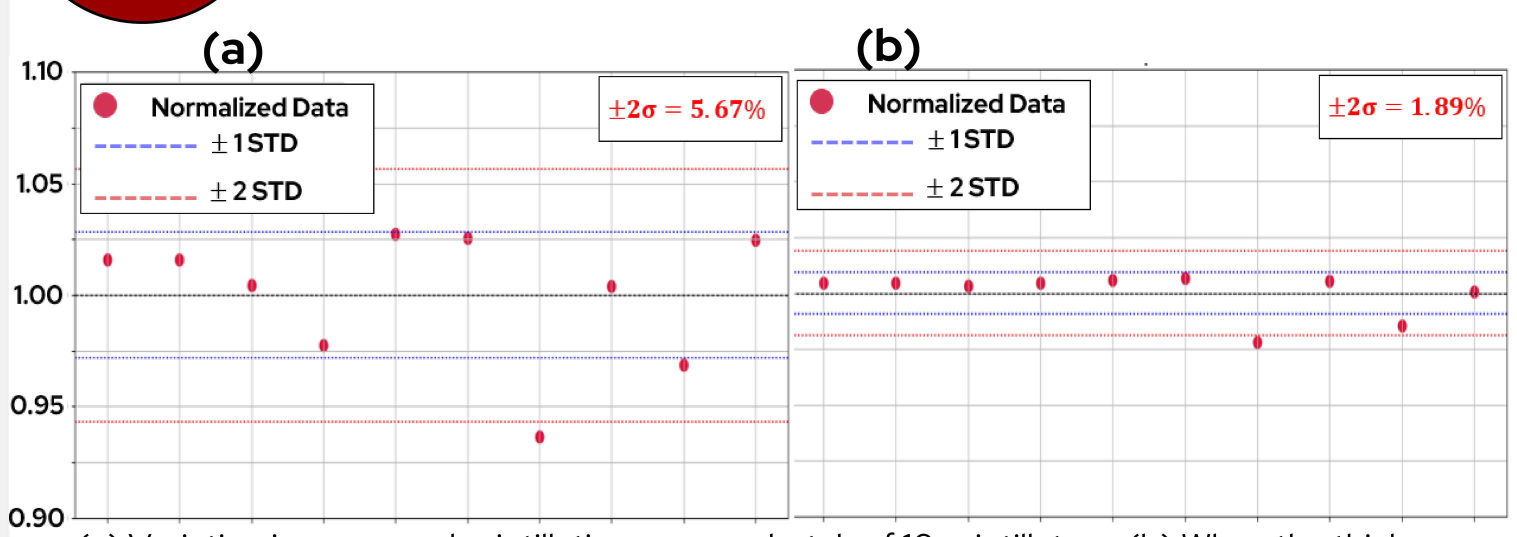


Example of a flatfield image where the light intensity imaged by the sensor falls off at the periphery



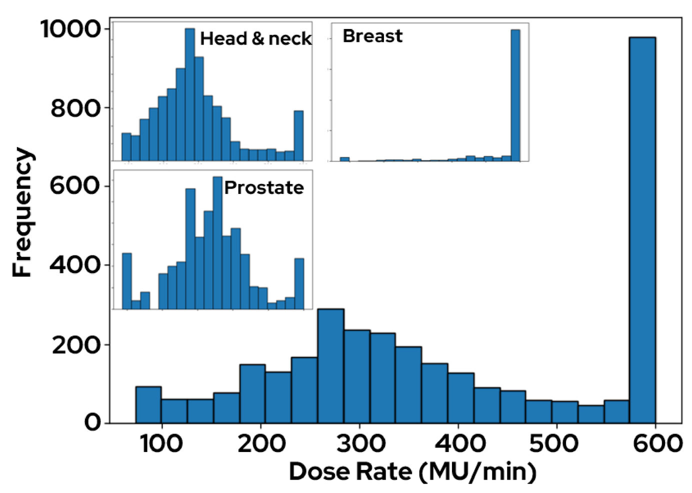
(a) Spread of scintillation data across the sensor before flat-fielding, (b) and after flat-fielding. There is a drastic reduction in variation across all measured points of the sensor when the flat-field correction is applied

3 Variation within a batch

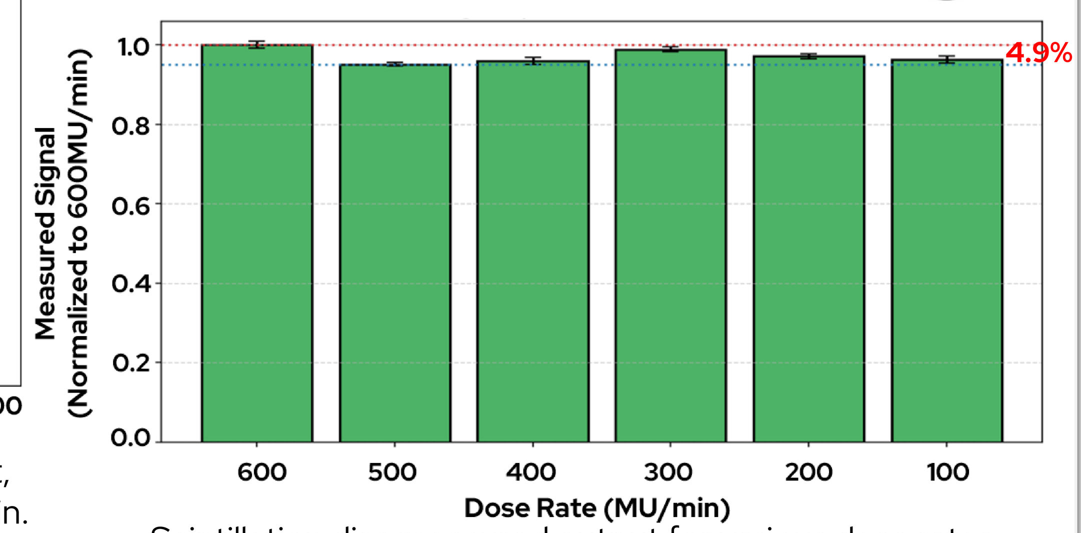


(a) Variation in measured scintillation across a batch of 10 scintillators. (b) When the thickness of the scintillating material for each individual disc is accounted for, the normalized output becomes more stable across all measured discs

4 Dose Rate



For a typical static or VMAT treatment, dose rates rarely drop below 100MU/min. Therefore, this study focused on measured scintillation output for 100-600MU/min.

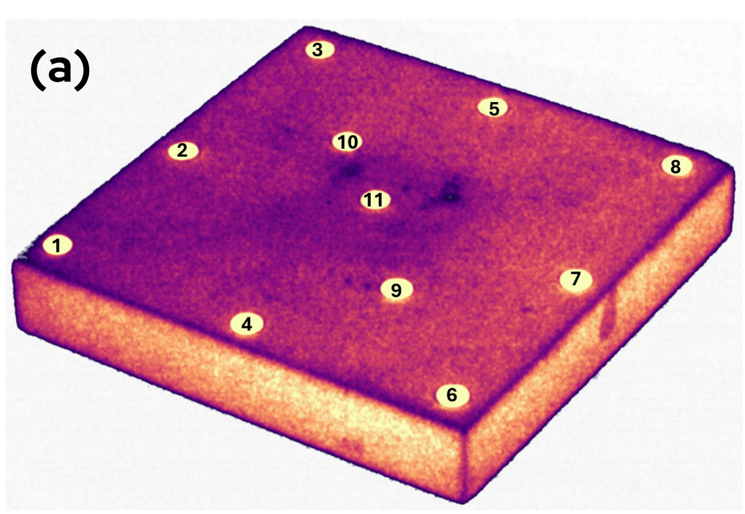


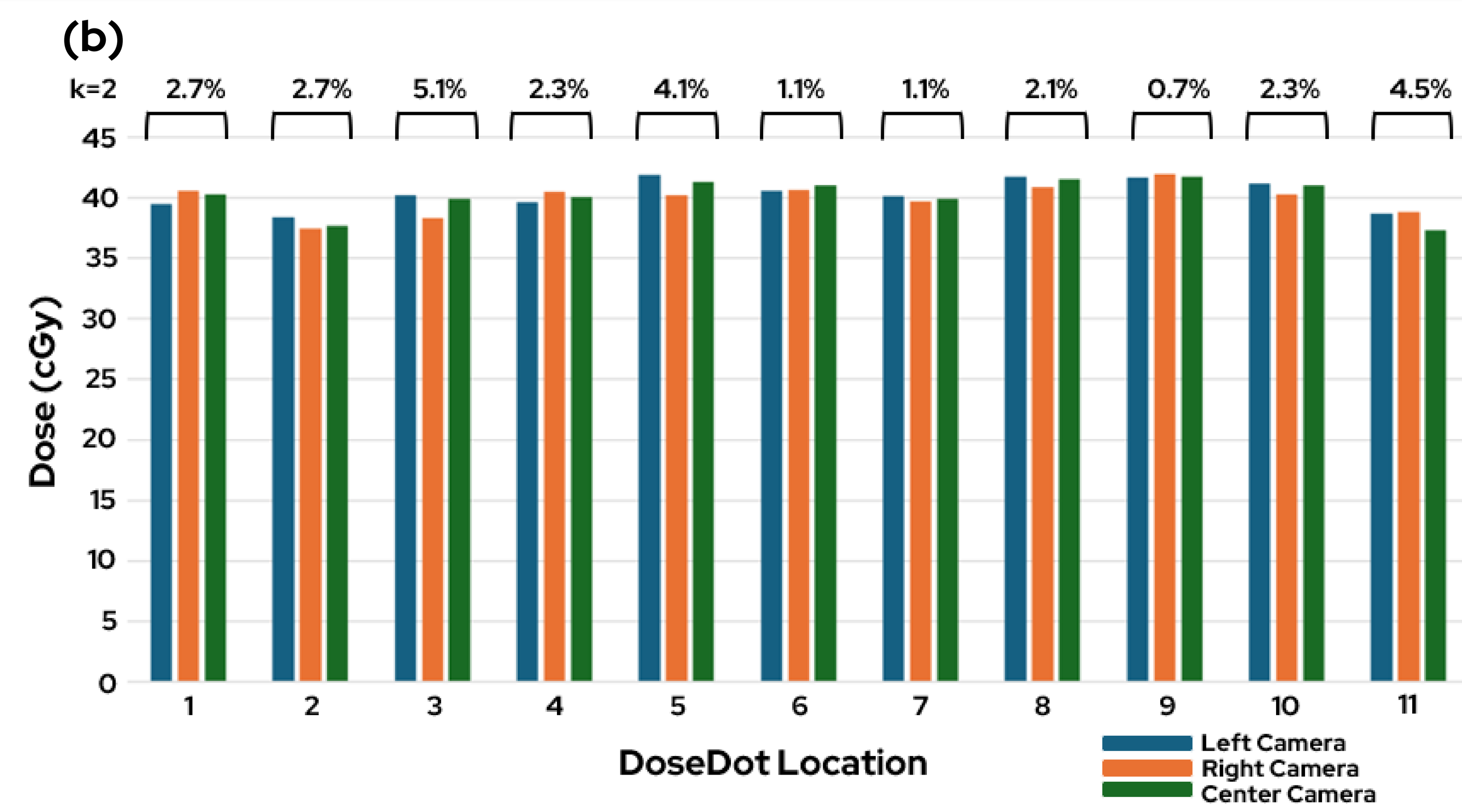
Scintillation disc measured output for various dose rates.

Validation Across Three Cameras

Discs were image with 3 cameras simultaneously to verify that they each measured the same dose.

(a) Image of a 35x35 beam incident on a solid water slab with scintillating discs spread throughout the surface. (b) Comparison of measured doses from 3 cameras imaging from different positions simultaneously.





Conclusions & Future Work

- Given imaging conditions within the appropriate camera-to-scintillator angle range along with the flat fielding correction, real time dose monitoring can be accomplished with minimal variation in the dose measurement between cameras (≤ 5% variation)
- Assess individual uncertainty sources and calculate a composite dose uncertainty value
- Refine correction methods and scintillator design to further minimize dose error

References

[1] Parks, A., Hallett, J., et al., *Review of Cherenkov Imaging technology advances in radiotherapy: single-photon-level imaging in high ambient light and radiation backgrounds.* Biophotonics Discovery, 2024.

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