In Vivo Cherenkov Imaging Monitors FLASH RT

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OBJECTIVE

- **Develop a fast-imaging technique** for the **first *in vivo* Cherenkov emission imaging** for ultra-high dose rate (UHDR) electron beam characterization and real time monitoring during delivery.

INTRODUCTION

- Ultra-high dose rate beam (>40 Gy/s) induces normal tissue sparing with equivalent tumor control (FLASH effect)[1]
- *In vivo* models could predict the effect on humans, but some studies indicate lack of FLASH effect potentially due to dosimetry of delivery:
  - **Spatial Distribution**
  - **Temporal Structure**
- **Dosimetry Uncertainties** can affect reproducibility and translation of the new modality

METHODS

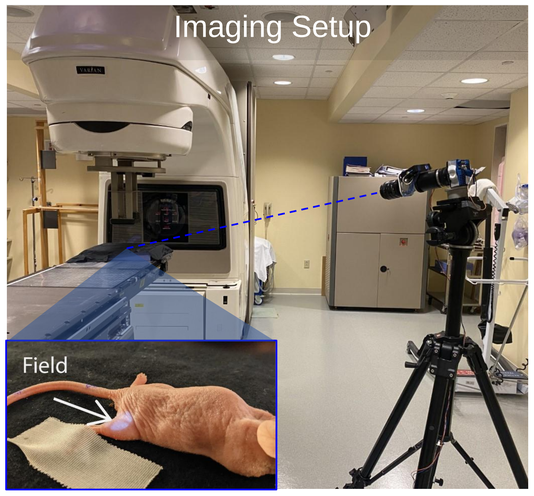


Figure 1. Experimental setup of Imaging acquisition of mice irradiated with electron FLASH beam.

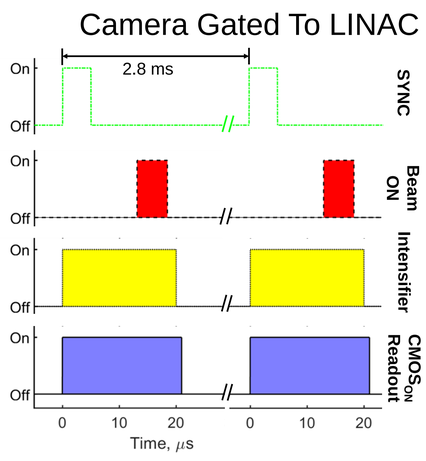


Figure 2. Sketched timing Diagram of Camera acquisition with respect to SYNC signal from LINAC and beam on time. The acquisitions occurred at 360 Hz to match the repetition rate of the LINAC. CMOS and the Intensifier were triggered off the rising edge of the SYNC signal.

A HIGH FRAME RATE CAMERA WITH AN INTENSIFIER CAN MONITOR UHDR TEMPORAL STRUCTURE AND SPATIAL BEAM UNCERTAINTIES *IN VIVO* VIA CHERENKOV EMISSION IMAGING.

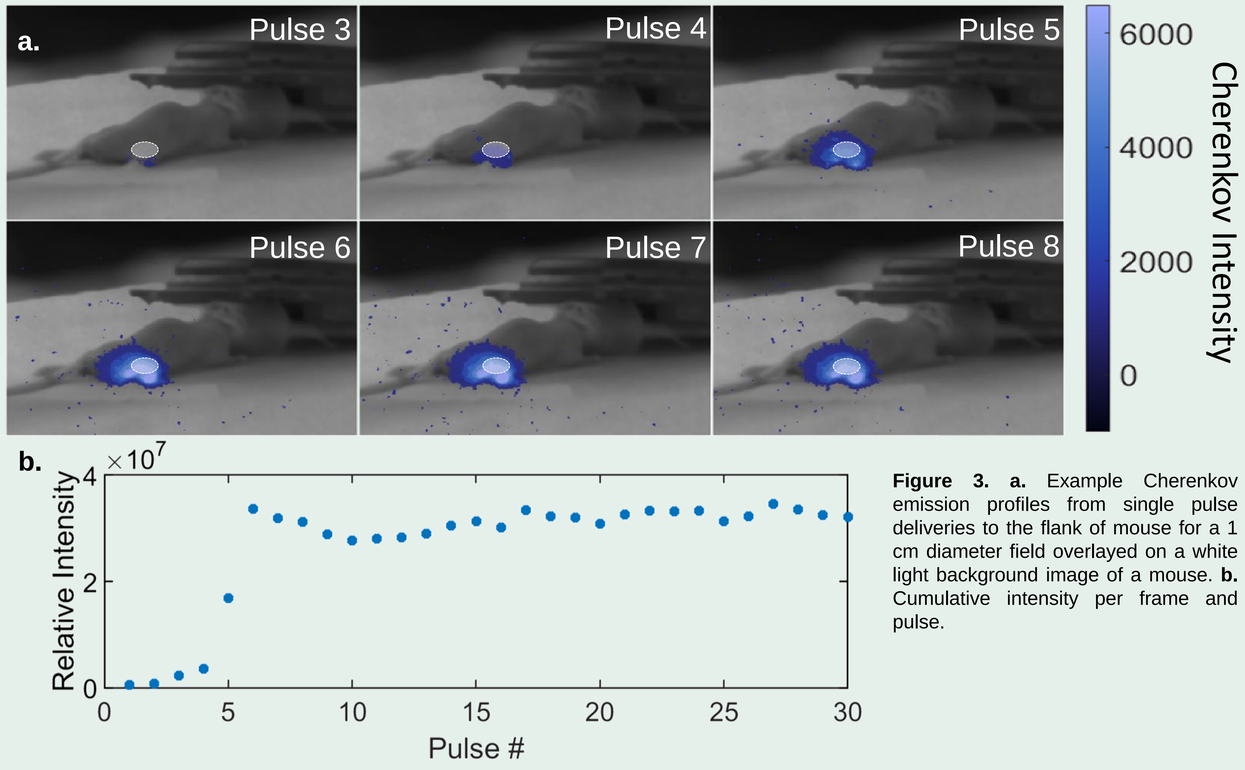


Figure 3. a. Example Cherenkov emission profiles from single pulse deliveries to the flank of mouse for a 1 cm diameter field overlayed on a white light background image of a mouse. **b.** Cumulative intensity per frame and pulse.

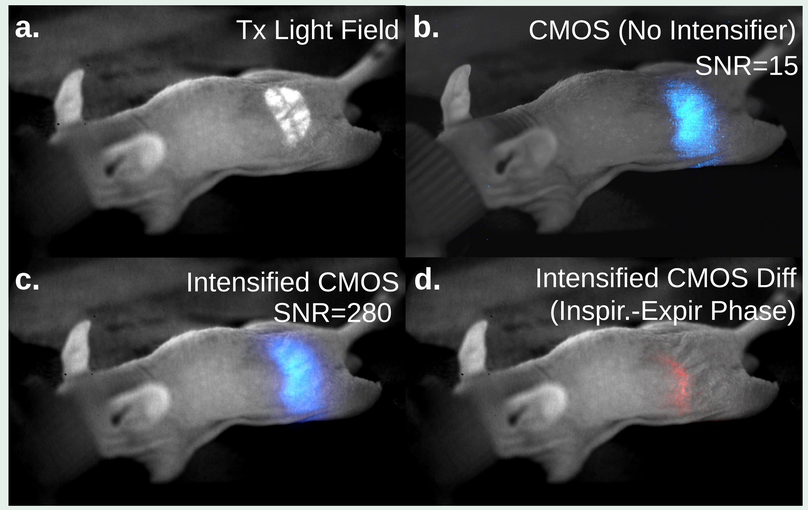
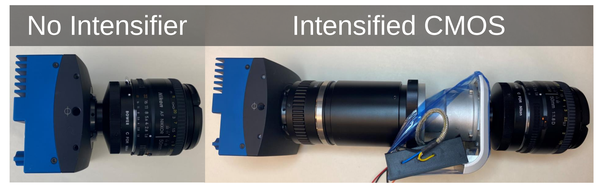


Figure 4. a. Light field of mouse treated with a 2 cm diameter field **b.** Cherenkov emission profile of a single pulse with no intensifier **c.** Cherenkov emission profile of a single pulse with an intensifier **d.** Difference in Cherenkov emission profile while the mouse breathed during delivery

CAMERA CHARACTERIZATION



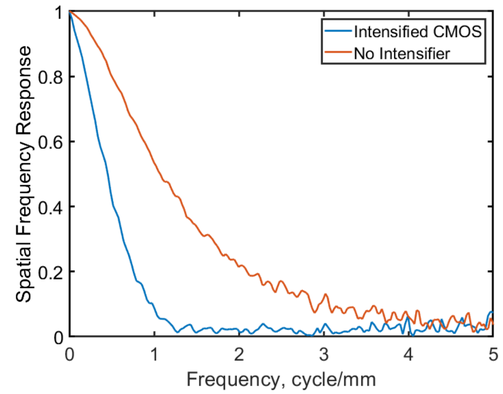


Figure 5. Spatial frequency response to compare spatial resolution of the camera with and without the intensifier

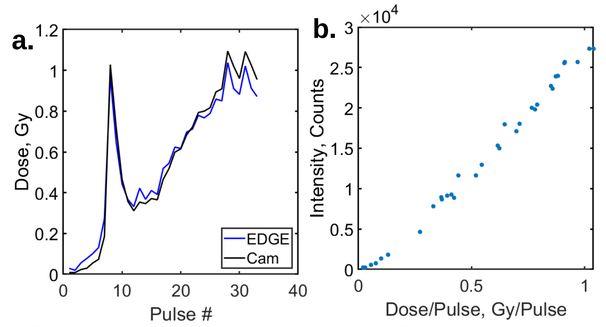


Figure 6. Camera response with an intensifier in comparison to a dose rate independent EDGE diode detector in the UHDR regime[2]. **a.** Output per pulse from a delivery **b.** Camera response per dose within the pulse.

CONCLUSION

- **Real time independent imaging system** of delivery under FLASH conditions
  - **Single pulse *in vivo* Cherenkov profile** imaging
  - Demonstrated at **360 frames per second** and at least **millimeter resolution**.
- The **intensifier improved the signal to noise ratio** with reduced spatial resolution in comparison to imaging without an intensifier
- Future Work
  - **Document delivery and temporal beam structure** of animal and patient treatments
  - Explore imaging proton pencil beam scanning systems delivering UHDR beams.
  - Quantify camera response at >1 Gy/pulse.

References

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