Charge accumulation in liquid water under electron FLASH irradiation

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PURPOSE

Accurate absorbed dose estimation is essential for radiotherapy and research. In ultra-high dose-rate (FLASH) beams, ~Gy doses are delivered in a few pulses, so single pulse perturbations can bias monitoring. Beam current transformers (BCTs) are widely used for FLASH beam monitoring, but charge accumulation in insulating materials can perturb BCT signals. Because reference dosimetry is performed in water (whose resistivity varies widely and is often contained in an insulating tank), the impact of liquid water on BCT-based monitoring varies. This work quantified the influence of charge accumulation in liquid water phantoms on BCT signals in ultra-high dose-per-pulse (DPP) electron beams and evaluated mitigation strategies.

MATERIAL & METHODS

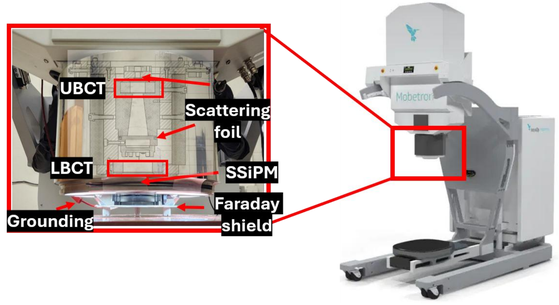

Figure 1. Installation of BCTs and scintillator coupled to a SiPM (SSiPM) in the Mobetron head for beam monitoring.

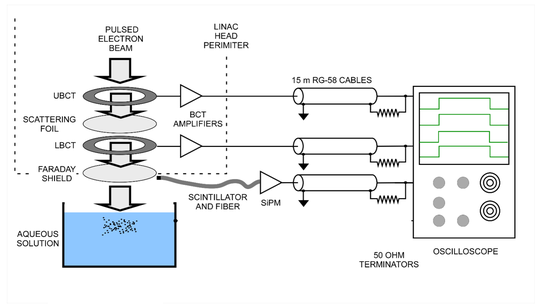

Figure 2. Diagram describing connection of the detectors to an oscilloscope for pulse visualization.

RESULTS

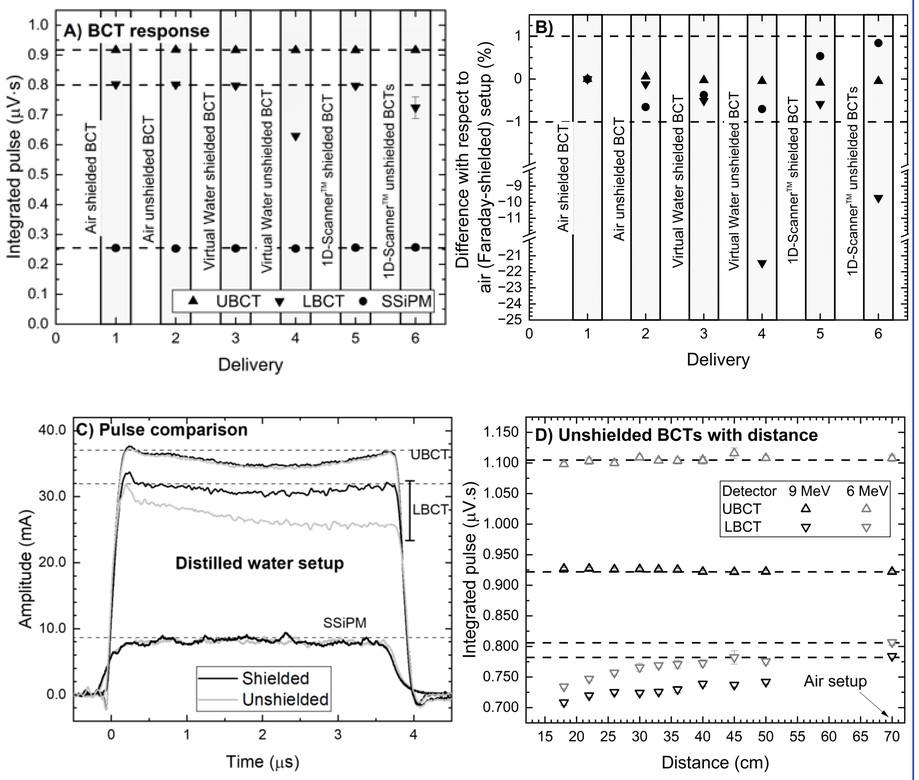

Figure 3. A) Charge accumulation effect observed in the upper and lower BCT signals, and SSiPM using air, Virtual Water, and Distilled water below the linac head. **B)** Percent differences between the setups with respect to air. **C)** Pulse shapes observed with and without the Faraday shield using the 1D-Scanner Water Tank (distilled water). **D)** Unshielded BCT signal variation as a function of the distance for the 6 and 9 MeV beams.

RESULTS

- Unshielded lower BCT (LBCT) signals decreased by up to ~22%, and 10%, for Virtual Water and de-ionized water phantoms, respectively, relative to air
- LBCT intra-pulse current decreases were observed
- Adding a grounded Faraday shield mitigated the LBCT signal reduction
- Upper BCT (UBCT) signal was unchanged by added external Faraday shield
- Increasing water conductivity (NaCl addition) and adding a submerged, grounded electrode restored unshielded LBCT stability within Type-A uncertainties

CONCLUSION

- Charge accumulation in insulating phantoms can reduce the BCT response and bias beam monitoring in ultra-high DPP electron beams
- UBCT signal is insensitive to charge accumulation in insulating phantoms
- Without mitigation, LBCT signal decreases as distance between liquid water surface and detector is reduced
- Grounding a conductive phantom or adding electrostatic shielding reduced charge accumulation or its effects on LBCT current

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