Comprehensive Characterization of Beam Current Transformers for the Performance Evaluation of FLASH LINACs Producing Ultra-High Dose Rates for FLASH Radiotherapy

Luke Connell, MS[1], Alan Eduardo Lopez Hernandez[2], Nolan M. Esplen[1], Raphaël Moeckli, PhD[3] and Emil Schueler[4], [1]Department of Radiation Physics, The University of Texas MD Anderson Cancer Center, Houston, TX, [2]MD Anderson Cancer Center, Houston, TX, [3]Institute of Radiation Physics, Lausanne, Switzerland, [4]MDACC, Houston

2026 JULY 19–22 VANCOUVER, BC
JOINT AAPM | COMP MEETING

INTRODUCTION

The beam output of LINACS producing Ultra High Dose Rates (UHDR) for FLASH Radiotherapy can exhibit significant and sometimes unpredictable variations in response to beam parameter adjustments, differing even among identical models. With multi-institutional preclinical trials being necessary for a full exploration of what mechanistically causes the FLASH effect, this study aims to characterize the beam output stability and pulse-structure dependence within and between three IntraOp Mobetron electron FLASH linacs using internal Beam Current Transformers (BCTs) for direct, non-invasive beam current monitoring.

METHODS AND MATERIALS

- Three IntraOp Mobetron electron LINACs with the FLASH-iQ upgrade were utilized.
- Equipped with a dual-BCT system integrated into the head, characterized such that the integral of the time resolved pulse is linear with dose[1].
- For each parameter being tested, the time resolved BCT trace was collected using a computer oscilloscope, and absorbed dose was measured utilizing Gafchromic film at the depth of maximum dose (d_{max}) in a solid water phantom, which is 1.5 cm depth for 6 MeV and 2 cm depth for 9 MeV.
- **Pulse Number Linearity** was measured by delivering 3µs pulses at a pulse frequency of 90 Hz, for 2, 5, 10, and 20 pulses.
- **Dose-per-pulse Linearity** was measured by delivering 5 pulses at 90 at a pulse frequency of 90 Hz, with pulse widths (PW) between 0.5 µs and 4 µs.
- **Pulse Repetition Frequency Linearity** was measured by delivering 5 pulses with a pulse width of 3 µs at pulse frequencies of 10, 30, 90, and 120 Hz.

CONTACT

Luke Connell
MD Anderson
LConnell@mdanderson.org
Schüler Lab

RESULTS

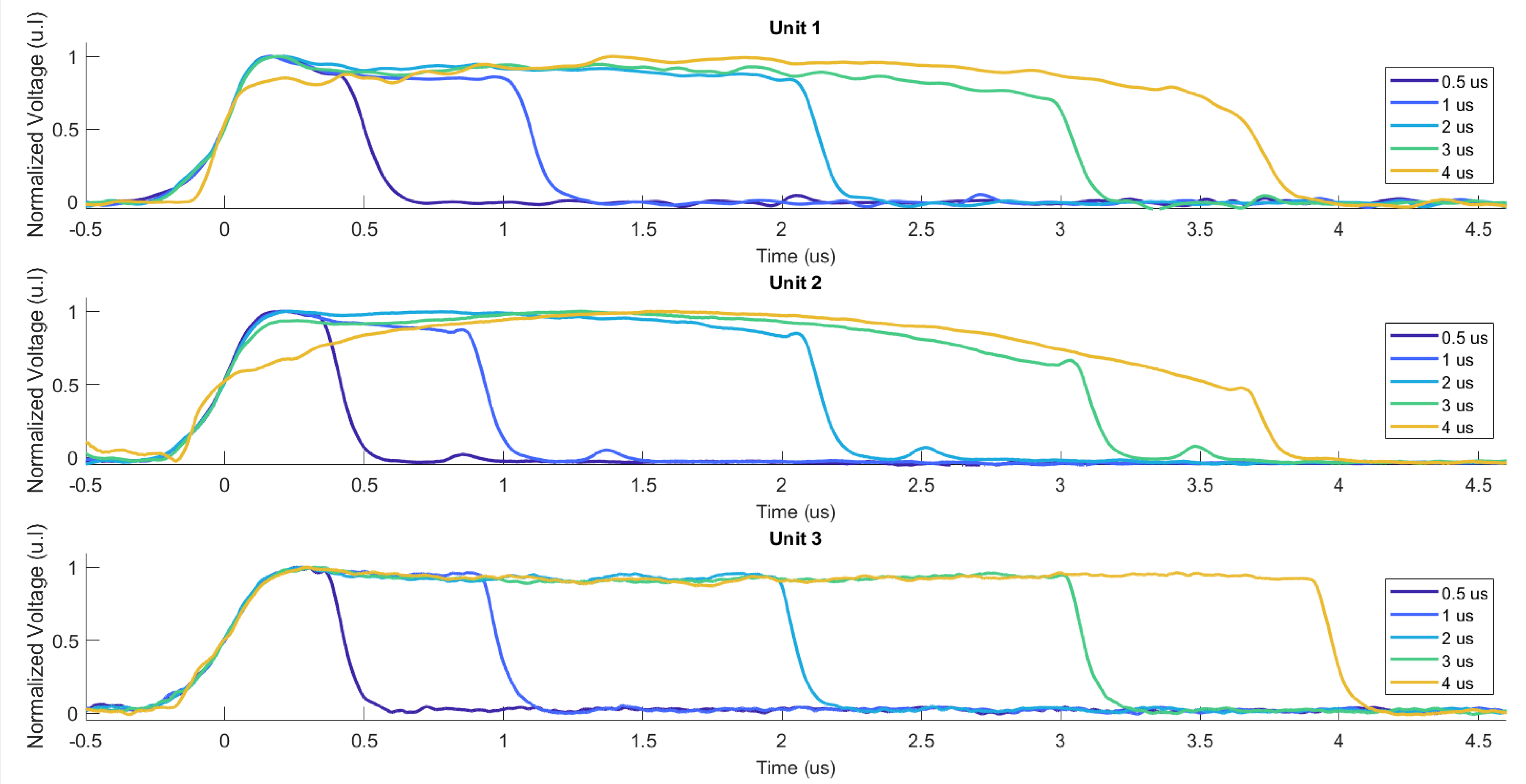

Figure 1: Time resolved BCT pulses in 9 MeV mode as the pulse width is gradually increased between 0.5 µs and 4 µs

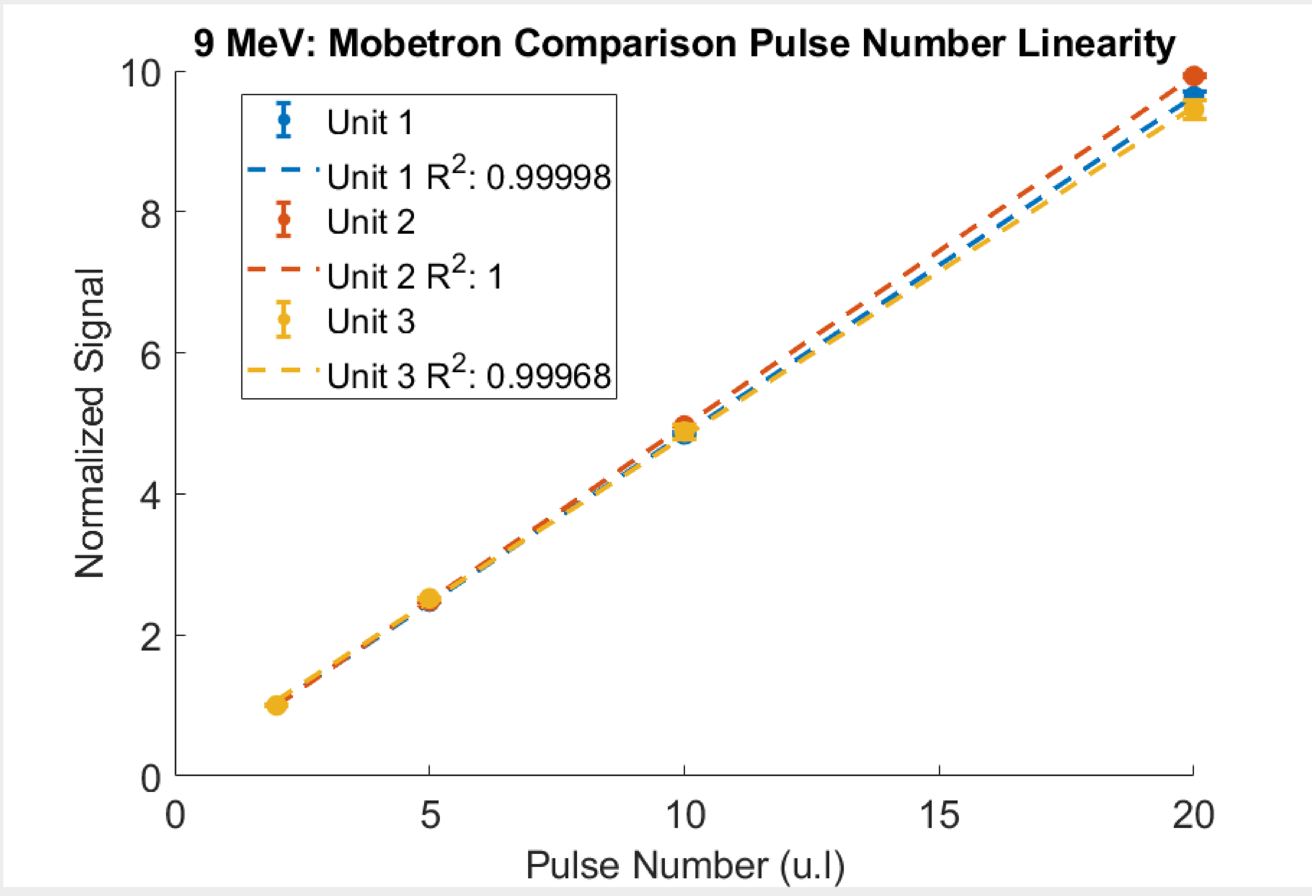

Figure 2: Pulse Number Linearity of each Mobetron Unit in 9 MeV mode between 2 and 20 pulses. Normalized to the signal recorded at 2 pulses.

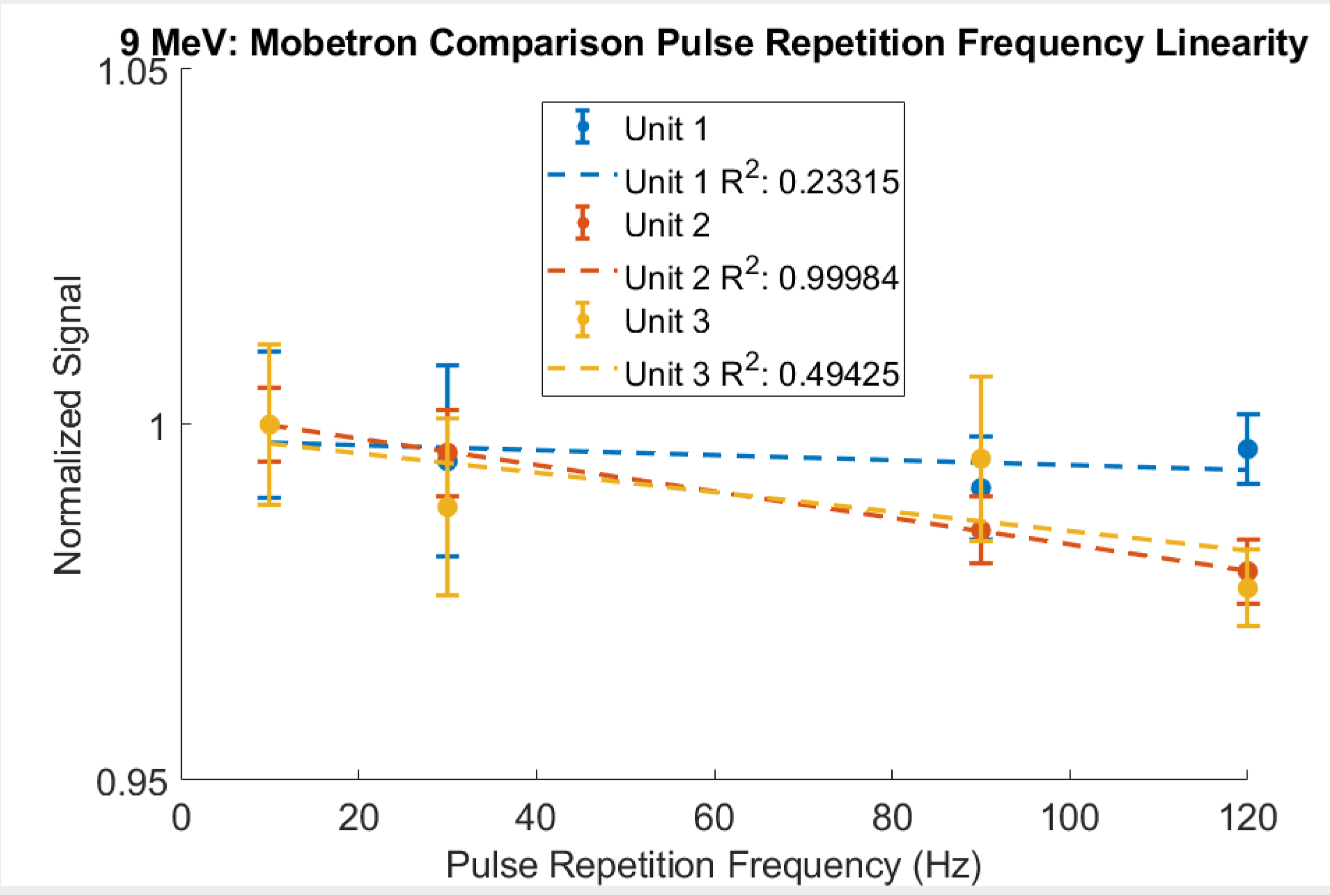

Figure 3: Pulse Repetition Frequency Linearity of each Mobetron Unit in 9 MeV mode between 10 and 120 Hz. Normalized to the signal recorded at 10 Hz.

CONCLUSIONS

Beam Current Transformers (BCTs) are able to accurately resolve the number of pulses, the pulse width, and the pulse repetition frequency of high DPP electron beams. The unique ability to directly visualize the temporal structure of the radiation pulse is a distinct advantage of utilizing BCTs as beam monitors for electron linacs. The integral of the BCT pulse was shown to be linear with output, and output was shown to be linear with increasing pulse number and pulse width, allowing users to finely adjust the total dose and the dose per pulse. The Mobetron output did not vary by a large degree, although two of the three units showed a slight decrease in output at higher PRF's, indicating output may be limited by power availability.

REFERENCES

1. Liu K, Palmiero A, Chopra N, et al. Dual beam-current transformer design for monitoring and reporting of electron ultra-high dose rate (FLASH) beam parameters. *J Appl Clin Med Phys*. Feb 2023;24(2)doi:10.1002/acm2.13891