OSLD and Micro-diamond Performance under Ultra-High Dose Rate FLASH Radiation Therapy

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Introduction

We investigated two near real-time dosimetry methods for FLASH Radiation Therapy with both mean and instantaneous dose-rates up to 25MGy/s. Both Optically-stimulated-Luminescence-Dosimeters (OSLDs) and the PTW Micro-diamond detector with flashAdapter were directly compared to EBT-XD film with FLASH irradiations performed using a 35MeV electron beam from the injector component of a research linear accelerator: the High Intensity Gamma Source (HIGS – Fig 1) part of Triangle Universities Nuclear Laboratory (TUNL).

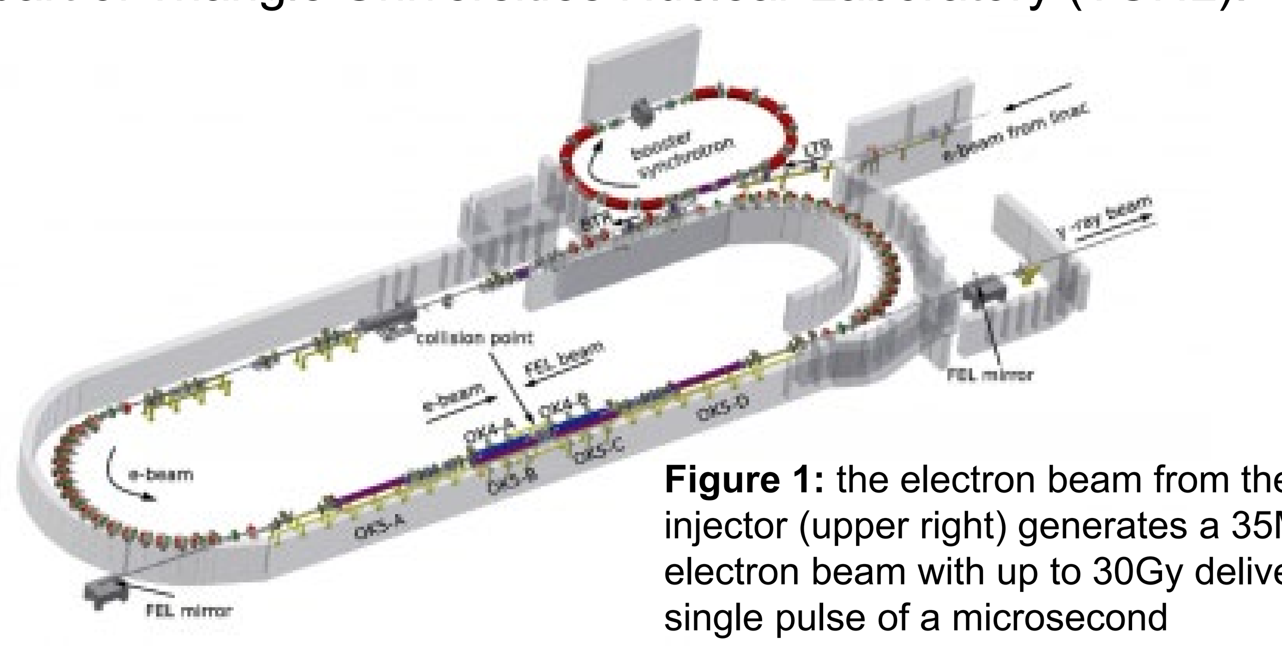

Figure 1: the electron beam from the HIGS injector (upper right) generates a 35MeV electron beam with up to 30Gy delivered in a single pulse of a microsecond

Methods and Dosimetry Tools

EBT-XD Gafchromic film (Ashland, NJ) is widely used for dosimetry under FLASH conditions and was used in this study as the ground truth dose measurement for all FLASH irradiations. Direct comparisons of EBT and OSLDS (Figure 2) were made using a combined dosimetry cassette (Figure 3) which held the film and OSLD together for irradiation, with the film being upstream in the beam.

Figure 2a: Beryllium Oxide (BeO) Optically Stimulated Luminescent Dosimeters (OSLDs) (RadPro, Germany) are currently being used clinically to verify patient surface doses. Their readout times are considerably shorter than film (30-40 min vs. 24 hrs) and could provide another, faster confirmation of dose to our irradiated subjects.

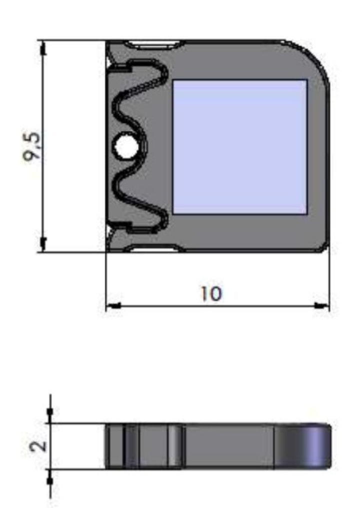

Figure 2: Technical drawing of the myOSL chip from RadPro

The PTW FLASH diamond detector has shown promise for real time FLASH dosimetry.[3] The diamond detector was mounted with EBT film at the extraction point as shown in Figure 8, enabling direct comparison of measurement.

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Oldham Laboratory
Duke Division of Laboratory Animal Resources (DLAR)
The Mouse Behavioral and Neuroendocrine Core Facility

Duke Cancer Institute

OSLD Irradiations

OSLDs were irradiated to doses ranging from 1-25 Gy. EBT-XD film was placed directly in front of the OSLDs, while EBT4 was placed on the back to verify the chip was within the field. Signal readout occurred 30 min post irradiation, while the film was scanned and analyzed 24 hours post irradiation. Clinical calibration irradiations were done on a TrueBeam to doses ranging from 5-20 Gy.

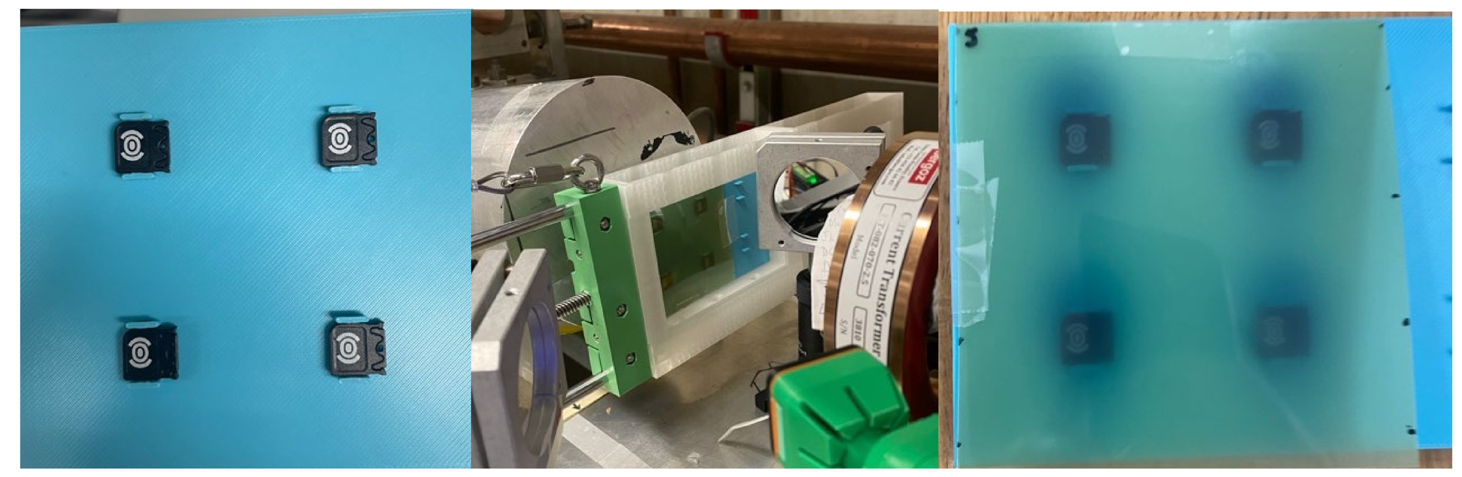

Figure 3: Setup of the OSLD irradiations. OSLDs were loaded into a custom 3D printed holder (left), then placed in the translation stage and irradiated (middle). Post irradiation is displayed in the image on the right.

Results

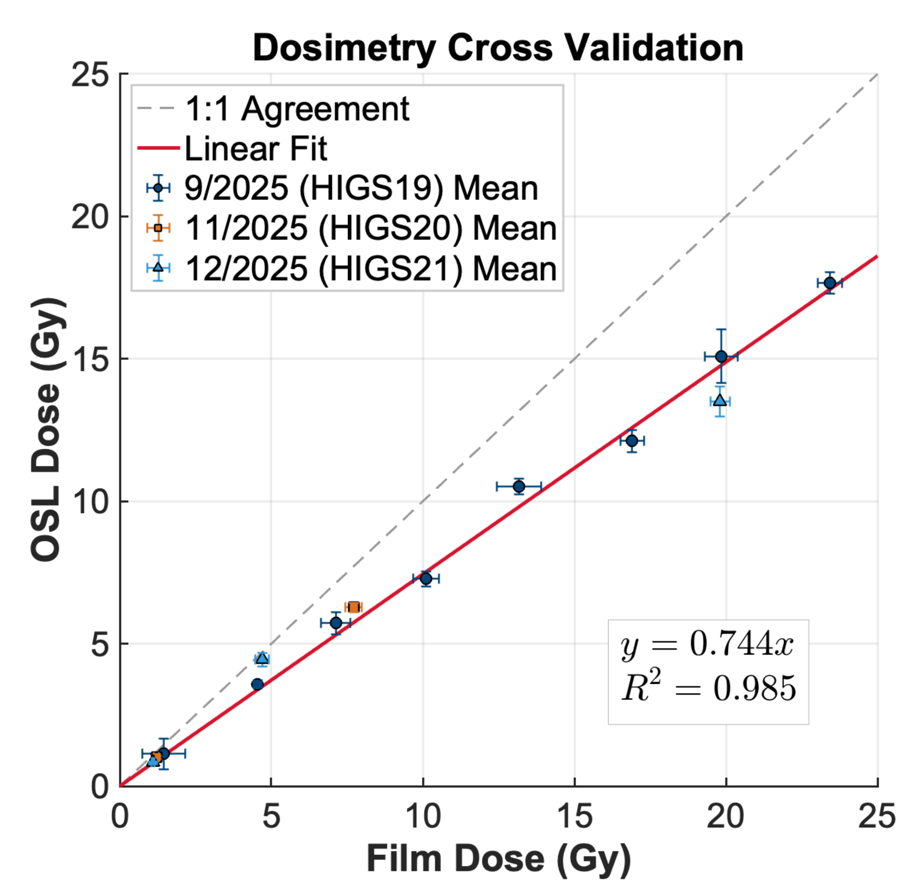

Figure 4: Resulting OSLD vs. film measured doses for the irradiations done on the HIGS.

The OSLDs demonstrated a strong linear relationship to the measured film doses (Figure 4) . We see very little deviation in the lower doses while the high doses exhibit a larger variability. An apparent under-response of the OSLD readings compared to film was observed with magnitude >20%.

Clinical irradiations (Figure 5) demonstrated the reliability of OSLDs in a regular clinical beam under careful calibration conditions. These OSLs were calibrated using 6MV, 10cm depth and 10x10cm field size with 100cm SSD.

Possible reasons for the discrepancy may include:

- Energy correction
- EBT-XD film over response
- OSLD under response

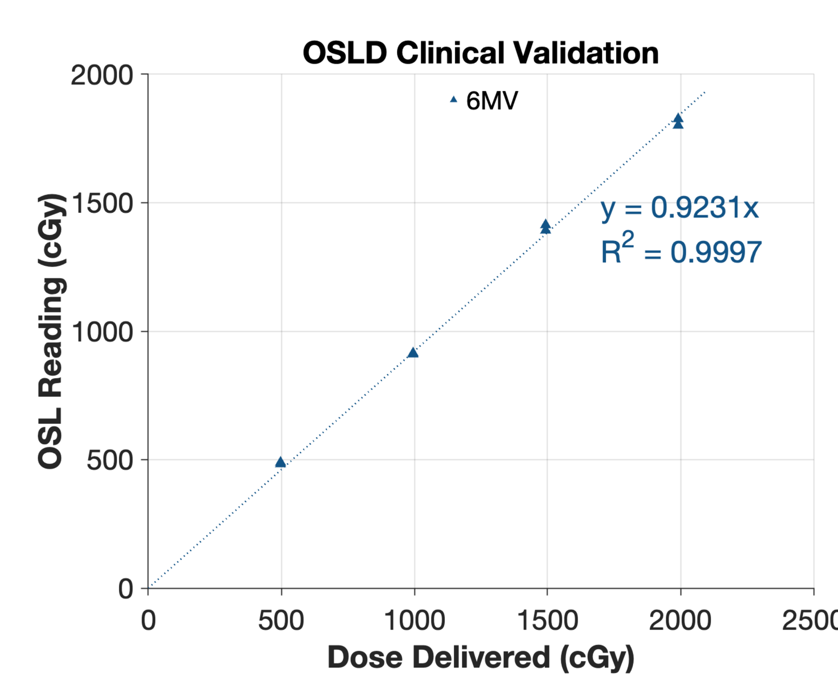

Figure 5: OSLD measured dose for dosimeters irradiated on a TrueBeam.

Micro-Diamond Detector

PTW micro-diamond was irradiated clinically first using an in-air setup (Figure 6). Irradiations were performed on a TrueBeam using doses ranging from 1-20 Gy. The charge collected is in figure 7.

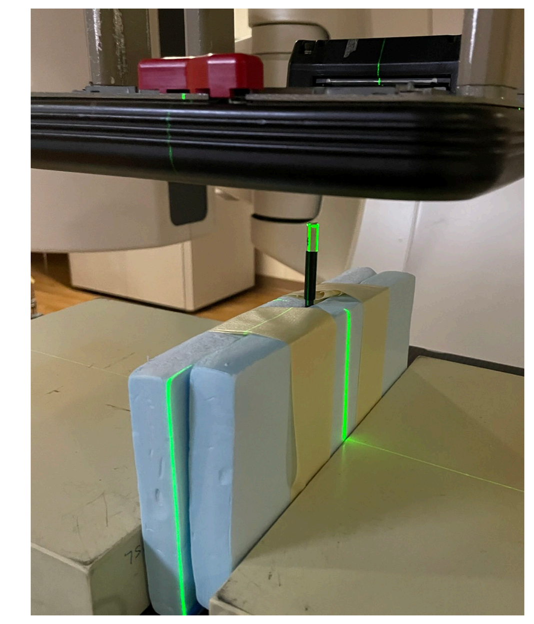

Figure 6: In-air setup for irradiation of the diamond detector on a TrueBeam

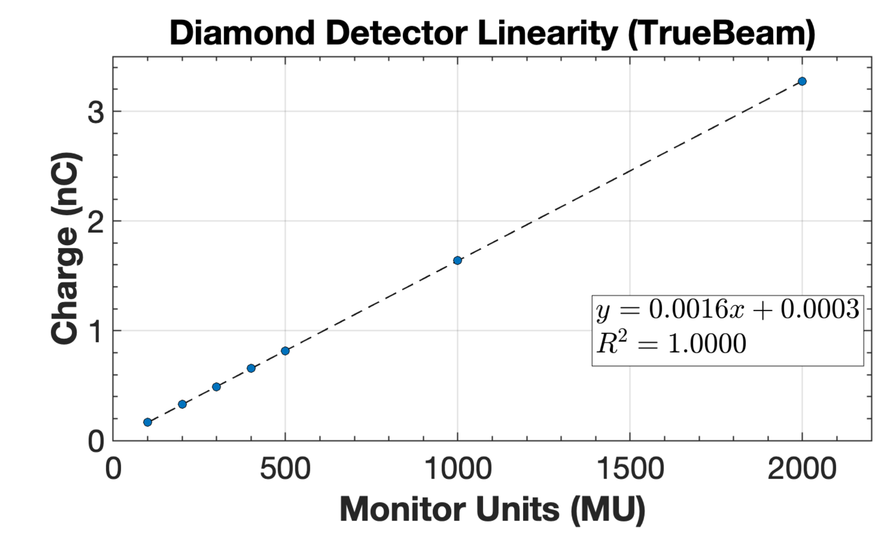

Figure 7: Charge readouts for the diamond detector irradiated using in-air setup on TrueBeam.

Irradiations on the HIGS (Figure 8) were over several HIGS faraday cup voltages (surrogate proportional to dose) and the resulting charge measured (Figure 9). This tests the linearity of the diamond detector response under ultra-high FLASH dose rate conditions.

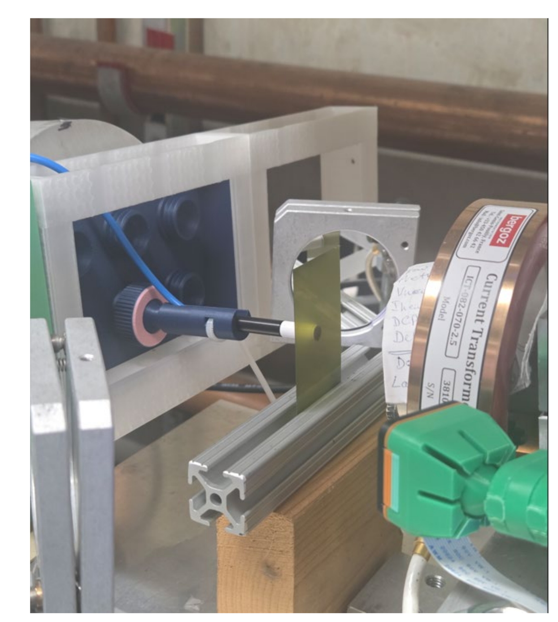

Figure 8: Setup of the micro-diamond detector on the HIGS accelerator.

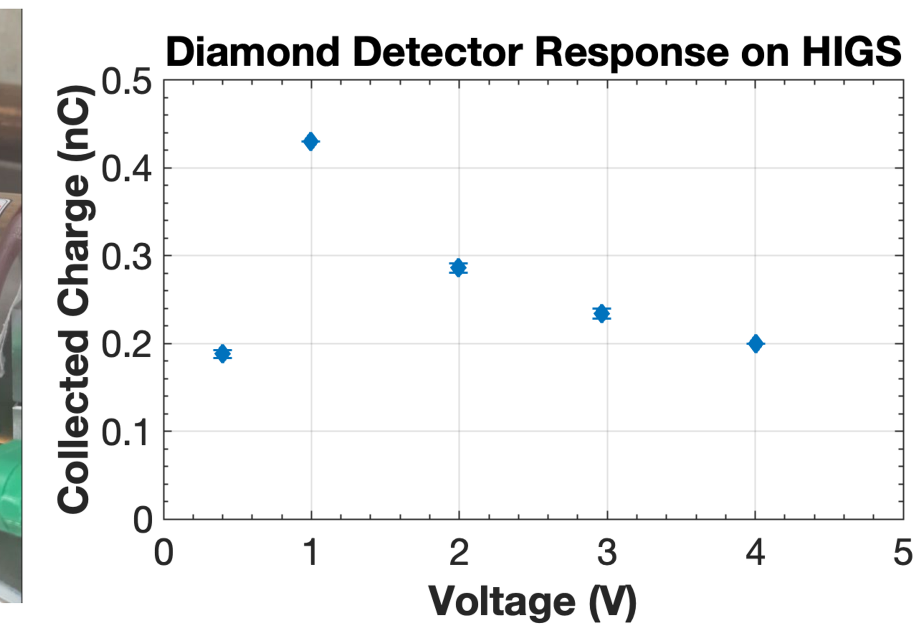

Figure 9: Charge readouts compared to voltage for irradiations done on the HIGS.

Conclusions

- FLASH dose rates incur an OSLD underdose response compared to EBT film, which is not seen at clinical dose-rates.
- FLASH OSLD response is linear with dose in the range studied
- The PTW FLASH micro-diamond detector performed well under clinical conditions however was not effective in HIGS-FLASH dosimetry probably because of targeting variability and challenges in the HIGS beam.

References

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