Pulse Resolved Beam Characterization and Feedback for FLASH-RT Using Radioluminescent Dosimeters

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1) 10 MV at treatment console

2) Target Retracted (~ 10 MeV FLASH Beam)

3) Feedback Mechanisms turned off!
• Dose Monitoring for FLASH-RT is Non-Trivial

• Radioluminescent Detection Techniques for FLASH-RT


Two Distinct Approaches Presented here:

1) Camera Based Single Pulse Central Axis Beam Profiling

2) Fiber Optic Based Detectors and Fast Electronics for Pulse Resolved Dosimetry and Feedback
Radially Symmetric Beam allows recovery of central axis data from single projection image using Abel Inversion.

Projected Measurement

\[ P(y) = 2 \int_y^R f(r) \frac{r}{\sqrt{r^2 - y^2}} \, dr \]  

Inverse Abel Transform

\[ f(r) = -\frac{1}{\pi} \int_r^R \frac{dP(y)}{dy} \frac{1}{\sqrt{y^2 - r^2}} \, dy \]  

Central Axis Comparison vs GafChromic Film-XD

- Discrete data points using Film!
- However, optical imaging provides complete picture!

Jaws Open

1.5 cm

- Optical
- Film
Beam energy was stable from one pulse to the next. However, a ramp-up in intensity was observed for the first few pulses!
Although data is collected at 2 ns resolution, it is processed after dose delivery. We need dose accumulation in real-time.
Field Programmable Gate Array (FPGA) Based Hardware: Use Dose as a Feedback

1) Exradin® W1 Scintillator

2) Dual Channel Gated-Integrator

- Reset
- Integrate/Hold
- ADC

Rising Edge Sync

- Time (μs)
- Voltage

CompactRIO (NI 9045)

- Real-Time Processor
- FPGA

Input/Output Modules
- ADC
- Signal Conditioning
- DAC
- Signal Conditioning
- DI
- Signal Conditioning
- DO
- Signal Conditioning

Sync

PMT/Photodiode

Detector

RTU
User Interface Displaying Quantities Pertinent to the FLASH Effect

1) Dose per pulse information
2) Number of pulses
3) Pulse Repetition Rate
4) Pulse Width

Beam On
Exradin W1 Characterization and In-Vivo Dosimetry

Initial 4 Pulses: 0.045 Gy/Pulse

Last 20 Pulses: 0.65 Gy/Pulse
Conclusions

• Single Pulse Central Axis Beam Profiling Using a time-gated Camera.

• Temporal Analysis of the beam using a PMT-Based Cherenkov detector revealed a ramp-up period.

• Ramp-up necessitates that feedback be in terms of dose accumulation for each pulse. A FPGA based monitoring system was developed.
  • The monitoring system can be coupled to other potentially attractive dosimeters for FLASH (i.e., microdiamond detector)
  • The code for the FPGA can be requested and easily implemented at other institutions performing FLASH experiments.

• Arduino controller has been replaced with new hardware (for pulse counting feedback) and dose-based feedback is currently being worked on.
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