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Realization and characterization of novel diamond detector prototypes for FLASH Therapy applications

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THERAPY



Confilct of interest disclosure

- Gianluca Verona Rinati, Marco Marinelli, Giuseppe Prestopino and Claudio Verona, signed a contract with PTW-Freiburg involving financial interests deriving from the PTW microDiamond 60019 dosimeter commercialization
- The prototypes reported in this presentation were developed in cooperation with PTW-Freiburg
- Giuseppe Felici is SIT S.p.A. shareholder.
- Matteo Pacitti and Federica Galante are employees at SIT S.p.A.



UH-DR and UH-DPP dosimetry

- Radiation beams utilized in FLASH-RT are characterized by high dose rates (>40Gy/s)
- In many cases they consist of pulsed beams leading to extremely high instantaneous dose rates



- Active dosimeters (real time reading) suffer of response nonlinearities and saturation effects in such extreme regimes
- Dosimetry of UH-DR/UH-DPP beams typically performed by passive dosimeters: Alanine, Fricke, Gafchromic films...



To produce novel detectors specifically designed for operation in UH-DPP conditions



microDiamond detector in UH-DPP beams



The unavoidable presence of a resistance along the circuit generates a drop voltage opposite to the built-in one (V = Ri)

Reduce the current (sensitivity) —

Reduce the resistance

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 $\frac{EXAMPLE}{DPP = 1Gy}$ $t_p = 1\mu s$ Sensitivity = 1 nC/Gy i = 1 mA $V_{drop} = 1.5 V$ $R_s = 1.5 k\Omega$

Lower sensitive area diameter

Higher boron concentration



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Experimental setup

ElectronFlash linac (SIT S.p.A., Italy) beam characteristics:

- 7 MeV and 9 MeV electrons
- 1 µs to 4 µs pulses

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- PRF: from single pulse up to 245 Hz
- **Circular applicators diameter:**

120 mm, 100 mm, 50 mm, 40 mm, 35 mm, 30 mm and 10 mm









DPP changed by:

- Using different PMMA applicators
- Placing the detectors at different SSDs



Optimized diamond detectors

Two optimized "flashDiamond" detectors fD-A and fD-B

• fD-A tested at SIT up to 10 Gy/pulse

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• fD-B tested at the Curie Institute up to 26 Gy/pulse





PRF and pulse width dependence

Pulse duration dependence

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• Pulse length varied from 1 µs to 4 µs



PRF / Average dose rate dependence

- PRF varied from 5 Hz to 245 Hz at about 3.9
 Gy/pulse DPP.
- Average dose rate ranging from 20 to 960 Gy/s



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PDDs

Measurements performed in motorized water phantom

"Conventional" beam modality

• Comparison among fDs, Markus IC and mD



"FLASH" beam modality

• Comparison between fD and EBT-XD





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Profiles

Measurements performed in motorized water phantom

"Conventional" beam modality

Profiles at D_{max} for all the 7 applicators ٠



"FLASH" beam modality

Profiles at D_{max} for all the 7 applicators



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Detailed dosimetric and metrological characterization in progress in the framework **UHDpulse** project **FRAT** 2(0)21



Conclusion

- ✓ The response linearity of the diamond prototypes is affected by the size of their active volume as well as by their series resistance
- Linearity achieved up to at least: DPP = 20 Gy/pulse; IDR = 5 MGy/s, DR = 1 kGy/s
- The feasibility to produce diamond detectors for dosimetry of UH-DR/UH-DPP beams is demonstrated
- Comprehensive metrological and dosimetric investigation on the proposed device is currently underway in the framework of the UHDpulse European project



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