Development Of Improved Dosimetry Standards at Laser Accelerator Facilities: UHDpulse

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Introduction

FLASH radiotherapy (FLASH-RT) is a modern and promising cancer treatment modality still in its early stages of development and application. The prescribed dose is delivered in few radiation pulses of ultra-high dose rate [1]. Laser-driven accelerators are seen as a compact and cost-effective future accelerators for radiotherapy with very high energy electrons [2], as well as with protons [3]. In fact, laser-driven accelerators can deliver ultra-short radiation pulses of extremely high dose rate (up to 10^9 – 10^{12} Gy/s).

Unfortunately, dosimetry at laser facilities present serious metrological challenges. This is due to the very nature of the beams used: pulsed ultra-high dose rates beams. Fig. 1 shows typical achievable doses per pulse and the pulse lengths for radiotherapy based on these emerging techniques and at conventional radiotherapy centers. The dashed red line in the figure indicates the upper limit, where commonly used ionization

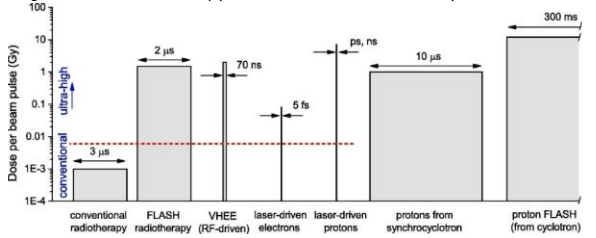


Fig. 1 Typical achievable dose per beam pulse and the pulse duration at medical LINACs.

The UHDpulse Project

The project “Metrology for advanced radiotherapy using particle beams with ultra-high pulse dose rates” (UHDpulse) was established exactly for this purpose [6]. UHDpulse aims at developing metrological tools needed for traceable absorbed dose measurements at ultra-high pulse dose rate particle beams facilities. These tools are essential for accurate comparison of radiobiological experiments, for the comparison of their efficacy, and for allowing future clinical application. This is a Joint Research Project in the framework of the European Metrology Program for Innovation and Research, supported by the European Association of National Metrology Institutes (EURAMET).

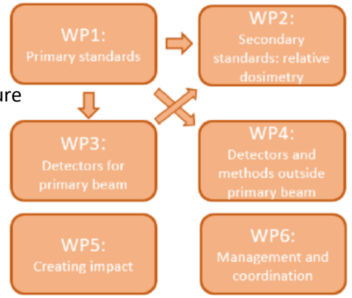
UHDpulse started in September 2019 with an initial duration of three years. Subsequently, due to the COVID-19 pandemic, its end was postponed to February 2023.

Objectives

The objectives of the project are to be addressed in the four work packages

1. The development of a metrological framework, including SI-traceable primary and secondary reference standards and validated reference methods for dosimetry measurements for particle beams with ultra-high pulse dose- rates (UHPDR).
2. Dosimetric characterization of available detector systems in particle beams with ultra-high dose-per-pulse or with ultra-short pulse duration.
3. Development of traceable and validated methods for relative dosimetry.
4. Provision of the input data for development of new Codes of Practice for absolute dose measurements in particle beams with ultra-high pulse dose-rates.

Fig. 2– Work Package Structure



A further packages were also set-up to collect and organize the exploitation/dissemination efforts and to manage/ coordinate the project.

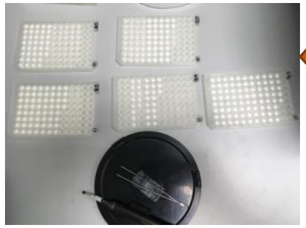


Fig. 3 - At ELI Beamlines, BeO OSL chips are used. The chip measure 4.7 x 4.7 x 0.5 mm^3

Fig. 4 - Lexsyg Smart Reader by Freiberg Instruments

Passive Dosimeter Outside the Primary Beam

Secondary radiation fields have the same pulsed time structure of the primary beams. Additionally, they are mixed radiation fields composed of different types of particles with different energies. The various field components need to be identified, thus adding to the metrological difficulties.

While, novel active detectors are being developed and successfully tested for this purpose, passive solid-state dosimeters are being investigated as well. Optically stimulated luminescence and thermoluminescence detectors are an ideal choice. These passive detectors have many advantages for these types of applications. They are robust and relatively inexpensive. They can easily be adapted to be placed in vacuum and comply with clean room environment: important aspects when laser optics are involved. Also, they are not susceptible to electromagnetic pulses present at laser-driven accelerators. Most importantly, they were already successfully tested in pulsed field with ultra-high dose rates [7-8].

ELI Beamlines in UHDpulse

ELI Beamlines is involved in testing the response of thermoluminescent detectors (TLD) and optically stimulated luminescence (OSL) detectors in stray radiation fields outside the UHPDR primary particle beam. Both optically and thermally stimulated luminescence are used routinely in continuous fields worldwide. However, their suitability for detection in UHPDR particle fields needs to be investigated and verified.

OSLs made with BeO (Fig. 3) have a central role at ELI Beamlines. They are used for environmental monitoring system and for the dose characterization of complex radiation fields produced.

- Few hundreds of dosimeters are located inside the experimental halls, control rooms, and corridors to monitor the ambient dose.
- Ten sets are placed in the surrounding areas and are read every 3 months.

Their calibration is performed using a Cs-137 source. The chips are annealed at 700°C for ~15 minutes. Then they are wrapped in a thin aluminum foil thus shielding them from visible light. Readout is performed using a Lexsyg Smart Reader by Freiberg Instruments (Fig. 4)

Consortium

The multidisciplinary consortium consists of:

- 7 national metrology institutes - leading in the field of dosimetry
- 7 universities - experts in detector development /pioneers in laser-driven beams
- 5 national research institutes -pioneers in detector development/stray
- radiation expert/access to radiation facilities
- 1 European research institute - laser-driven beam research infrastructure (ELI Beamlines)
- 8 private sector companies - experts in detector development
- 6 academic hospitals - pioneers in FLASH-RT/dosimetry expertise

Conclusions

One of the main objectives of the UHDpulse project is the development of new and the improvement of existing dosimetry standards for laser-driven accelerators. The project was briefly presented here in order to raise awareness of its objectives, structure, and results. The role of ELI Beamlines in this project was highlighted.

References

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