EMPIR Call 2018 – Health, SI Broader Scope, Normative and Research Potential

Selected Research Topic number: **SRT-h21**
Version: 1.0

Title: Metrology for advanced radiotherapy using particle beams with ultra-high pulse dose rates

Abstract

Recent, in vivo radiobiological experiments have shown that irradiation with electron beams with ultra-high dose per pulse may dramatically reduce adverse side effects in the healthy tissues whilst being equally as effective for tumour control as conventional irradiations. Such electron beams with ultra-high dose rates can be delivered by laser-based particle accelerators, which are considered the next generation of accelerators for radiotherapy. However, pulse dose rates several orders of magnitude higher than conventional radiation therapy present significant metrological challenges which need to be addressed to enable the translation of these advanced radiotherapy techniques to clinical practice. This includes development of SI-traceable primary and secondary reference standards and validated methods for dosimetry measurements and for the characterisation of radiation outside the primary pulsed particle beams.

Keywords

Radiotherapy, dosimetry, detector characteristics, ultra-high pulse dose rate, laser-based particle accelerator, ultrashort radiation pulses

Background to the Metrological Challenges

Approximately half of all cancer patients in Europe receive radiotherapy as it is one of the most cost-effective strategies in oncology. In order to further improve treatment outcomes in radiotherapy and to reduce adverse side effects, new treatment modalities and irradiation technologies are consistently being developed. However, such advanced radiotherapies require reliable and accurate dosimetry measurements so that performance, safety and effectiveness can be optimised.

Novel laser-based plasma accelerators are the current preferred choice for delivering electron beams with ultra-high pulse dose rates. Such ultra-high pulse dose rates can be delivered by retuning existing conventional radio-frequency (RF) accelerators, however laser-based plasma accelerators offer the ability to overcome the prohibitive cost of large conventional accelerators including their complex beam transport systems. In contrast to conventional RF accelerators the pulse duration of beams from laser-based accelerators is much shorter (typically femtoseconds compared to microseconds) and the dose rate during the short pulse is orders of magnitude higher.

According to International Commission on Radiation Units (ICRU) Report 24 a change of 7-10 % in dose to target volume results in a clinically significant change in tumour control probability. Therefore, accurate dose determination is vital for a treatment success. Further to this, the EU report Radiation Protection 162 states that for radiotherapy equipment: ‘All test equipment used in measuring functional performance must be well maintained, regularly calibrated and traceable (where appropriate) to national standard laboratories’. Water or graphite calorimeters are well established as primary standards for dosimetry in conventional radiotherapy. However, their application in in advanced radiotherapy, such as particle beams with ultra-high pulse dose rates, is complex and has not been fully explored.

Practical dosimetry in radiotherapy is based on Codes of Practice, in order to ensure the traceability of clinical measurements to primary dosimetry standards. But the currently available Codes of Practice are not readily applicable to particle beams with ultra-high pulse dose rates or with ultrashort pulse durations. Therefore, in order to develop new or extend the field of application of existing Codes of Practice, the properties of dosimetric detectors in particle beams with ultra-high pulse dose rates need to be investigated.

Another significant issue in radiotherapy is out-of-field dosimetry i.e. radiation outside the primary pulsed particle beams. The doses delivered to healthy tissues and critical organs in patients, outside of the target are crucial for the optimisation of therapy and are particularly for personalised dose management.

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Objectives

Proposers should address the objectives stated below, which are based on the PRT submissions. Proposers may identify amendments to the objectives or choose to address a subset of them in order to maximise the overall impact, or address budgetary or scientific / technical constraints, but the reasons for this should be clearly stated in the protocol.

The JRP shall focus on the traceable measurement of ultra-high pulse dose rates for advanced radiotherapy using particle beams.

The specific objectives are

1. To develop 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.
2. To characterise the response of available detector systems in particle beams with ultra-high pulse dose rates or with ultrashort pulse duration.
3. To develop traceable and validated methods for relative dosimetry and for the characterisation of stray radiation outside the primary pulsed particle beams.
4. Using the results from objectives 1-3, to provide the input data for Codes of Practice for absolute dose measurements in particle beams with ultra-high pulse dose rates.
5. To facilitate the take up of the project's achievements by the measurement supply chain, standards developing organisations (e.g. those associated with International Atomic Energy Agency (IAEA) and International Commission on Radiation Units (ICRU) reports) and end users (clinical and academic laboratories, hospitals and radiotherapy manufacturers).

These objectives will require large-scale approaches that are beyond the capabilities of single National Metrology Institutes and Designated Institutes, and it is expected that multidisciplinary teams will be required. To enhance the impact of the research, the involvement of the appropriate user community such as medical practitioners, hospitals and industry is strongly recommended, both prior to and during methodology development.

Proposers should establish the current state of the art, and explain how their proposed project goes beyond this.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 1.8 M€, and has defined an upper limit of 2.1 M€ for this project.

EURAMET also expects the EU Contribution to the external funded partners to not exceed 35 % of the total EU Contribution across all selected projects in this TP.

Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the "end user" community, describing how the project partners will engage with relevant communities during the project to facilitate knowledge transfer and accelerate the uptake of project outputs. Evidence of support from the "end user" community (e.g. letters of support) is also encouraged.

You should detail how your JRP results are going to:

- Address the SRT objectives and deliver solutions to the documented needs,
- Feed into the development of urgent documentary standards through appropriate standards bodies,
- Transfer knowledge to the medical and health sector.

You should detail other impacts of your proposed JRP as specified in the document "Guide 4: Writing Joint Research Projects (JRPs)"

You should also detail how your approach to realising the objectives will further the aim of EMPIR to develop a coherent approach at the European level in the field of metrology and include the best available contributions from across the metrology community. Specifically, the opportunities for:

- improvement of the efficiency of use of available resources to better meet metrological needs and to assure the traceability of national standards
- the metrology capacity of EURAMET Member States whose metrology programmes are at an early stage of development to be increased
- organisations other than NMIs and DIs to be involved in the work

Time-scale

The project should be of up to 3 years duration.