Towards primary and secondary standards for dosimetry in Flash radiotherapy

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What is Flash?

➢ The total prescribed radiation dose is delivered with ultra-high dose rate (UHDR) in less than a second

➢ Studies support the hypothesis that this significantly reduces the adverse side effects on the healthy tissue for equal dose delivery

➢ The ultra-high dose rate is challenging, both for delivery and dosimetry

The UHDpulse project aim to develop reliable dosimetry methods for Flash modality and guidance for CoPs.
Measurement set-up

- Metrological Electron Accelerator Facility (MELAF) at PTB, Germany

- Tests carried out at 20 MeV, 5 Hz PRF, pulse width of 2.5 μs

- Dose varied between 0.5 Gy and 2.0 Gy per pulse

- Detector response compared to beam current monitor
Detectors

- Alanine is considered to be the reference

- 3 parallel plate ionization chamber model
  - PPC05 (sensitive volume depth of 0.6 mm)
  - Advanced Markus (sensitive volume depth of 1 mm)
  - PPC40 (sensitive volume depth of 2.0 mm)

- A probe-type graphite calorimeter; Aerrow
  - Developed at McGill University
  - Provided by SunNuclear
  - Quasi-adiabatic mode
 Ionometry of Flash beams

- Standard dosimeter for external beam reference dosimetry is the ionization chamber

- The ultra-high dose rate means that ion recombination is very large > 50%!

- Do not follow current model (Boag)

- Integrating dosimeters such as alanine can be used to measure the ion recombination

Bourguoin et al., DOI:10.3389/fphy.2020.567340
Ion recombination

![Graph showing ion collection efficiency versus dose-per-pulse (Gy). The graph includes data points for AdvMarkus SN1279, AdvMarkus SN1280, PPC40 SN1888, PPC05 SN1551, PPC05 SN1552, and PPC05 SN1496.](image)

*Petersson et al., https://doi.org/10.1002/mp.12111*

Intra-type variation 2 to 5 %

- AdvMarkus SN1279
- AdvMarkus SN1280
- PPC40 SN1888
- PPC05 SN1551
- PPC05 SN1552
- PPC05 SN1496

![Intra-type variation](image)
Calorimetry of Flash beams

- Gives absorbed dose directly from a measure of the radiation-induced temperature rise

- \( D = c \cdot \Delta T \cdot \frac{k}{n_c} \)

- Time constant should be unaffected by dose-rate

- Simpler compared to conventional dose rate
Calorimetry

Depth in water (cm)

Normalized value

- Monte Carlo
- AdvMarkus
- Calorimeter

Physical and Technical Bureau
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Braunschweig and Berlin
National Metrology Institute
Calorimetry is showing promising results for NMI and clinical use

- Gets simpler at Flash
- Advanced insulation is not required, nor the use of a heat lost correction factor

Ionometry

- Intra-type variations in the 2-5% range
- Development on theory/model to explain the observed ion recombination

For relative measurement

- Plastic scintillators, diodes, or diamond detectors are under investigation
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http://uhdpulse-empir.eu/