

# Dosimetry for ultra-high dose rate radiotherapy with electron beams

Andreas Schüller Department 6.2 "Dosimetry for Radiation Therapy and Diagnostic Radiology" on behalf of the UHDpulse consortium

Strathclyde Ultra-high Dose Rate Radiotherapy Workshop, 16.9.21, virtual





# Dosimetry for ultra-high dose rate radiotherapy with electron beams



#### **Contents**

- FLASH irradiation: Ultra-high dose rate / dose per pulse
- Dosimetry at ultra-high dose per pulse
- Joint Research Project UHDpulse
- Coming developments for dosimetry for FLASH



#### Pulsed electron beam from a Linac



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Wilson et al., Front. Oncol. 9:1563. http://dx.doi.org/10.3389/fonc.2019.01563

Pulsed electron beam from a Linac



#### <u>FLASH treatment of a human patient</u> (lymphoma on skin)

- delivered total dose: 15 Gy
- 167 Gy/s
- 10 pulses (of 1 µs duration)
- treatment time: 90 ms
- Dose per pulse: 1.5 Gy



Bourhis et al., Radiother. Oncol. (2019) http://dx.doi.org/10.1016/j.radonc.2019.06.019

#### FLASH irradiation of the skin of a pig



Conventional and FLASH Irradiation (with same total dose)

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Conventional (5 Gy/min)



necrotic lesions

FLASH (300 Gy/s) 3 Gy/pulse



normal appearance of skin

Vozenin *et al.*, Clin Cancer Res 25 (2019) 35 http://dx.doi.org/10.1158/1078-0432.CCR-17-3375



#### FLASH treatment of cancer at dogs

- Delivered total dose: 15 35 Gy in 7-16 pulses
- Treatment time: 30 75 ms
- Mean dose rates: 400-500 Gy/s
- Pulse dose rates: ~0.7 MGy/s
- Dose per pulse: 2 Gy



treatment of canine leg

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Konradsson et al., Front. Oncol. (2021) 11:658004 https://doi.org/10.3389/fonc.2021.658004

#### Behavior of ionization chambers



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#### Passive detectors

OSLD, TLD, alanine, radiochromic film

#### Advantage:

independent of dose rate,
suitable for ultra-high DPP

#### Disadvantage:

 not real-time readout, takes hours or days to get a dose value PTB's alanine dosimetry system

> Dose traceable to PTB's primary standard



#### Alanine pellets



ESR spectrometer

#### Passive detectors









irradiated EBT3 film front side

**PTB** Alanine dosimetry system: < 25 Gy

EBT3:

< 40 Gy



4 stacks of 4 alanine pellets on the rear face of the EBT3 films

#### Passive detectors



Karolina Kokurewicz, Investigation of focused Very High Energy Electrons (VHEEs) as a new radiotherapy method, PhD thesis (2020)

#### PTB reference field for ultra-high dose per pulse





PTB's Research electron accelerator

Beam line with water phantom

E = 0.5 - 50 MeV

up to 7 Gy/pulse (SSD 0.7 m, 20 MeV)

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#### PTB reference field for ultra-high dose per pulse





Alanine pellets at reference depth in water phantom



current transformer: Non-destructive beam pulse charge measurement (uncertainty < 0.1 %)

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PTB reference field for ultra-high dose per pulse

Detector under test at reference depth in water phantom

> Bourgouin et al., Front. Phys. (2020) 8:567340 https://doi.org/10.3389/fphy.2020.567340

Charge per pulse in nC

### **European Joint Research Project UHDpulse**

Titel:Metrology for advanced radiotherapy using

particle beams with ultra-high pulse dose rates

Duration: Sep/2019-Feb/2023

Start: 1. Sept. 2019

Funding: 2.1 M €

Coordinator: Andreas Schüller (PTB)

Topic: tools for traceable dose measurements for:

- FLASH radiotherapy
- VHEE radiotherapy
- laser driven medical accelerators

http://uhdpulse-empir.eu/



## **UHDpulse Partners and Collaborators**

Radiation detector developers



+ Proton therapy network



### **Coming developments for dosimetry for FLASH**

Corrections functions k<sub>s</sub> for available ionization chambers



commercially available ionization chambers

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Alexandra Bourgouin et al., to be published

### **Coming developments for dosimetry for FLASH**

#### Prototype ionization chambers for ultra-high DPP



### **Coming developments for dosimetry for FLASH**

#### Prototype ionization chambers for ultra-high DPP

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Physikalisch-Technische Bundesenstalt Brannschweig und Berlin

## **Coming developments on dosimetry for FLASH**

#### microDiamond detector for ultra-high DPP



Dose per pulse reference [Gy]

### **Coming developments on dosimetry for FLASH**

#### Prototype calorimeter



Aerrow (and Exradin A12 ionization chamber for size reference). The internal structure of Aerrow is shown as a blended rendering.





Detector response vs. dose reference from alanine/monitor.

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#### Alexandra Bourgouin et al., to be published

### **Coming developments on dosimetry for FLASH**

TimePix3 based detector for ultra-high DPP









MiniPIX TPX3 Flex in a water phantom in an ultra-high dose rate proton beam

Cristina Oancea et al., to be published

### Summary

- There is no real-time dosimetry system for FLASH RT with electron beams up to now.
- Commercially available ionization chambers show large deviations at ultra-high DPP due to ion recombination.
- Prototypes of parallel plate ionization chambers with very small electrode distances show linear response in the ultra-high DPP range.
- Commercially available microDiamond detectors show saturation effects at different DPP levels, the linear range can be extended to the ultra-high DPP range.
- Prototype calorimeter show linear response in the ultra-high DPP range.



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#### http://uhdpulse-empir.eu/

\*Diamond prototypes are produced at the Industrial Engineering Department of Rome Tor Vergata University in cooperation with PTW.

### **FLASH Conference**

3rd FLASH Workshop + workshops of the Joined Research Projects UHDpulse and INSPIRE

FRPT2021 special issues in

- Radiotherapy & Oncology
- Physica Medica

#### LATE-BREAKING ABSTRACT SUBMISSION IS OPEN UNTIL 22 SEPTEMBER 2021



#### https://frpt-conference.org/