Ultra-High Dose Rate Electron Facility @ Hammersmith Hospital

Centre for the Clinical Application of Particles

Dr Ruth McLauchlan & Claire Hardiman
Department Radiation Physics & Radiobiology

Outline

- Case for FLASH-RT
- Adapting a clinical linac
  - The Stanford experience
  - Use of Hammersmith facility

Case for FLASH-RT

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COMMENTARY

Faster and safer? FLASH ultra-high dose rate in radiotherapy

[1]MARCO DURANTE, PhD, [2]ELKE BRÄUER-KRISCH, PhD and [3]MARK HILL, PhD

[1]National laboratories, Trento Institute for Fundamental Physics and Applications (TIFPA), National Institute of Nuclear Physics (INFN), University of Trento, Trento, Italy
[2]National laboratories, ESRF-The European Synchrotron, Grenoble, France
[3]Department of Oncology, CRUK/MRC Oxford Institute for Radiation Oncology, Gray Laboratories, University of Oxford, Oxford, UK

Address correspondence to: Professor Marco Durante
E-mail: *Marco.Durante@tifpa.infn.it*

Case for FLASH-RT

- Results from Institute Curie and Centre Hospitalier Universitaire Vaudois in a mouse model indicate substantial enhancement of the therapeutic window for ultra-high dose rate electron delivery compared with conventional dose rate (~5 Gy/min exc. FFF)
  - Electrons delivered in a single short pulse (<500 ms) at ultra-high dose rate (>40 Gy/s = 2400 Gy/min) produced fewer pulmonary lesions
  - Spatial memory preserved after whole-brain mouse FLASH irradiation at 10 Gy
- Experiments limited
  - Co-operation of two groups
  - Two similar prototype linear accelerators
  - Side effects in two parallel organs (lung & brain)
  - Dosimetry notoriously complicated
    - IC, radiochromic pellets, TLD, alanine pellets

Adapting a clinical linac

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Biology Contribution

Experimental Platform for Ultra-high Dose Rate FLASH Irradiation of Small Animals Using a Clinical Linear Accelerator

Emil Schüler, PhD,* Stefania Trovati, PhD,* Gregory King, PhD,* Frederick Lartey, PhD,* Marjan Rafat, PhD,* Manuel Villegas,* A. Joe Praxel,* Billy W. Loo, Jr, MD, PhD,*,† and Peter G. Maxim, PhD*,†

*Department of Radiation Oncology and †Stanford Cancer Institute, Stanford University School of Medicine, Stanford, California

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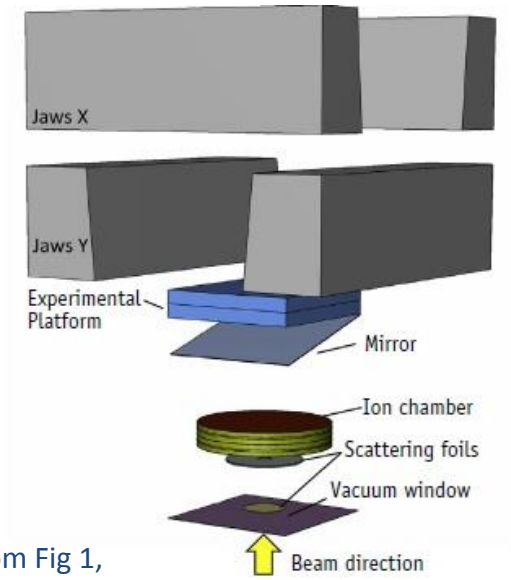
Adapting a clinical linac – Stanford Experience

- Adaptation of existing commercial device: Varian Clinac 21 EX
  - Normal clinical operation settings; tune for maximum dose-rate delivery
  - Small animal irradiation locations
    - Ion chamber
    - Positioning mirror
    - Inner jaws (Y-jaws)
- Obtained dose-rates >200 Gy/s
  - Clinical mode
    - <74 Gy/s
  - Tune
    - >900 Gy/s
      - 220 Gy/s @ 1 cm depth, >4 cm field size, 90% homogeneity throughout 2 cm thick volume



From Fig 1, Schuler et al

Adapting a clinical linac – Stanford Experience

- Monte Carlo model of Varian Clinac 21 EX (FLUKA)
- Animal irradiation platforms
- Tuning used spare 20 MeV program printed circuit board
  - Removed standard 20 MeV board to preserve clinical settings
  - Clinical treatments halted for entire duration of experiments
    - Full annual QA completed before return to clinical use
  - Dosimetric verification using pinpoint ion chamber and Gafchromic film
  - Beam controlled via micro-controller connected to gating interface

Adapting a clinical linac – Stanford Experience

- 20 MeV electrons produced very low dependence of absorbed dose with depth
  - More homogeneous dose in irradiated small animal compared with using experimental LINACS (dose rates >50 Gy/s; energy range 4.5-6 MeV)
- Gating interface not ideal
  - Dose measured in fixed interval could vary
  - Propose implementing a toroid with real-time measurements before exposure
    - Quick read out of beam charge
    - Beam off controlled using microcontroller directly connected to Linac control computer

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A Toroidal Charge Monitor for High-Energy Picosecond Electron Beams ⋆

Robert H. Simmons and Johnny S. T. Ng *
Stanford Linear Accelerator Center, Stanford University, Stanford, CA 94309, USA

Abstract

A monitor system suitable for the accurate measurement of the total charge of a 2-ps 28.5 GeV electron beam over a large dynamic range is described. Systematic uncertainties and results on absolute calibration, resolution, and long-term stability are presented.

Key words: beam charge, toroidal current transformer, absolute calibration
PACS: 41.85.Qg, 07.50.-e, 07.55.-w

Adapting a clinical linac - Hammersmith

- Varian Clinac iX
  - 6, 9, 12, 16, 20 MeV
  - No gating interface
  - Potentially non-clinical from late summer 2019
- Related projects
  - Monte Carlo model of linac
  - Dosimetry
    - We have access to
      - Pinpoint chamber
      - GafChromic film
      - TLD