Electron Beam Characterization: Optimizing Dose per Pulse for Use in FLASH and Pencil Beam Scanning

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Outline

1. Important Concepts:
   a. FLASH RT
   b. Pencil Beam Scanning

2. Methods
   a. Modified Linac
   b. Measuring Depth Dose
   c. Optimizing the Electron Beam
   d. Pencil Beam Scanning
   e. Simulations

3. Future Plans
Background
Radiation Oncology

- Radiation is a common treatment for cancerous tumors
  - External Irradiation:
    - Proton therapy, X-Rays, Electrons
  - Brachytherapy

- Dose - the measure of ionizing radiation per unit mass
  - 1 Gy = 1 J/kg
  - Coined at the CRR!

- Conventional dose radiotherapy
  - 2-3 Gy/min
  - Typical treatment plan:
    - A few minutes/day, 5 days/week, up to 20 weeks
  - Short term and long term side effects
FLASH Therapy

- FLASH- Ultra-High Dose Radiation
  - >40 Gy/s
  - Shows equivalent tumor killing effects while sparing the surrounding normal tissue
    - Biology is unknown
  - Instantaneous
Modified Varian Clinac 2100C

Modifications allow for operation in FLASH and superFLASH mode (9 MeV and 6 MeV)
Beam Shaping

- Collimator
- Multileaf Collimators
- Pencil Beam Scanning
  - Very narrow particle beam scans over tumor
  - Established use in proton beam therapy
In case the videos didn’t work:
Methods
Irradiated films change in opacity. When scanned and processed by film reading software, Optical density is converted into dose measurements by the following:

Optical Density = \(-\log_{10}(\text{Pixel Value Irradiated}/\text{Pixel Value Control})\)

Dose = \((0.7404\times\text{Optical Density})/(0.818-\text{Optical Density})\)
GAFChromic EBT3 Films Measure Dose

Camera film can help to provide insight into how film dosimetry works.

Light is a form of radiation!
Reading Films

- Interested in the Distribution of Dose in PBS
  - Analyze film in cross-sections by going line by line in .dat file
  - Determine area where dose received > 90%*Max Dose
  - Surrounding dose vs Max dose
Experimental Depth Dose

- $h =$ height on optical rails
- SSD = Source to Surface Distance
Beam Scattering in PBS Collimators

- Want: A small beam for PBS
- Loss of Beam intensity due to beam scattering
Optimizing PFN V for Each Gun I

- Pulse Forming Network Voltage (PFN V) determines the power provided to electron beam
- Gun Current describes the density of electrons exiting the electron gun to be accelerated
- To optimize the dose, there must be the right amount of power to accelerate the electrons
- PFN V and Gun I work together to ensure maximum beam intensity
Limits to Optimization

- Limits to achievable PFN
- Incomplete curves at higher energies
Results
Pencil Beam Scanning

- First Successful PBS!
- 3x4 Scanned Pattern
- Scanned the beam in a desired shape

These colors are so similar because the background is a partially irradiated film!
FLASH effect in PBS

- Instantaneous vs. Average Dose Rate
Future Plans

● Next Steps in Pencil Beam Scanning
  ○ Moving the motor while beam is pulsing
  ○ Test different distances between scans to improve uniformity of dose

● Improve Circuitry for extended range in potentiometers
Simulations

- Mouse phantom simulation and CRR physical mouse phantom
- Different density materials allow accurate simulation of dose depth and distribution in mice
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References


