Linear Accelerator for Demonstration of X-ray Radiotherapy With FLASH Effect

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Sergey V Kutsaev

on behalf of RadiaBeam team

FLASH Radiotherapy

- Recent trials have shown that ultrafast delivery of large doses (>40 Gy/s) to a tumor significantly reduces damage to surrounding tissues and increases the treatment efficacy . This method of irradiation is called FLASH therapy

Advantages:

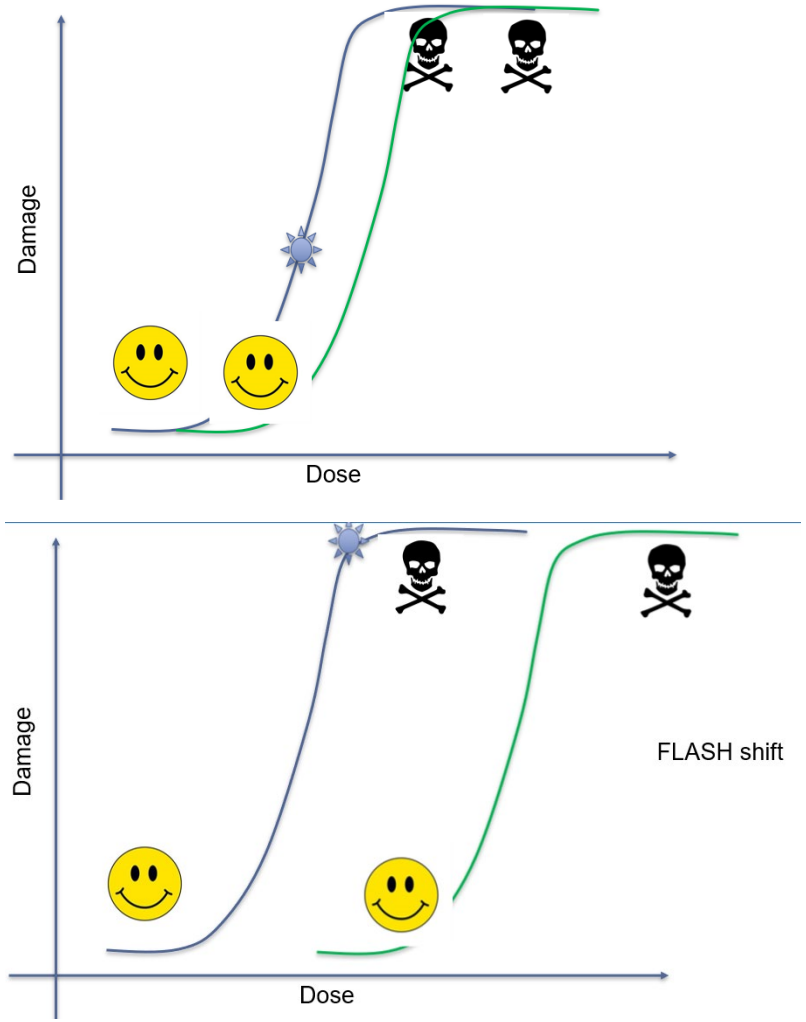
reduced the normal tissue toxicity

the same or better tumor cell killing

Technical challenges:

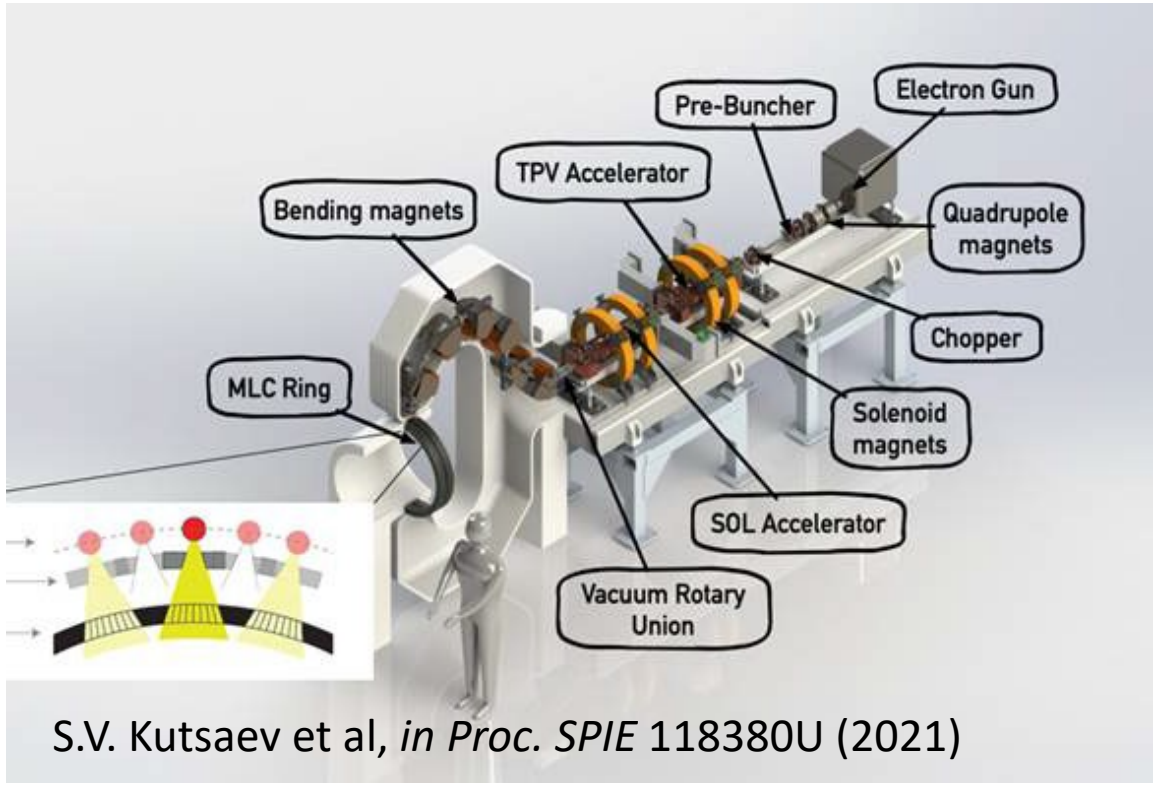
Electrons: only applicable to superficial tumors

X-rays: a high output X-ray linac and a method to intensity-modulate the high-dose-rate X-rays



ROAD Project

- RadiaBeam with UCLA are working to design and build a single linac solution based on a ROtational direct Aperture optimization with a Decoupled (ROAD) multi-leaf collimator (MLC) ring
- The linac pulses are timed to align with a counter-rotating ring of 75 pre-shaped MLC apertures. As both the linac and MLC ring rotate in opposite directions at 60 rpm, 150 modulated beams are delivered in 1 s, with each delivering up to 0.67 Gy to the tumor
- For clinical system, 100 Gy/s @ 80cm (collimated) is required



S.V. Kutsaev et al, *in Proc. SPIE* 118380U (2021)

Q. Lyu et al, *Phys. Med. Biol.* 66(3), 035020 (2021)

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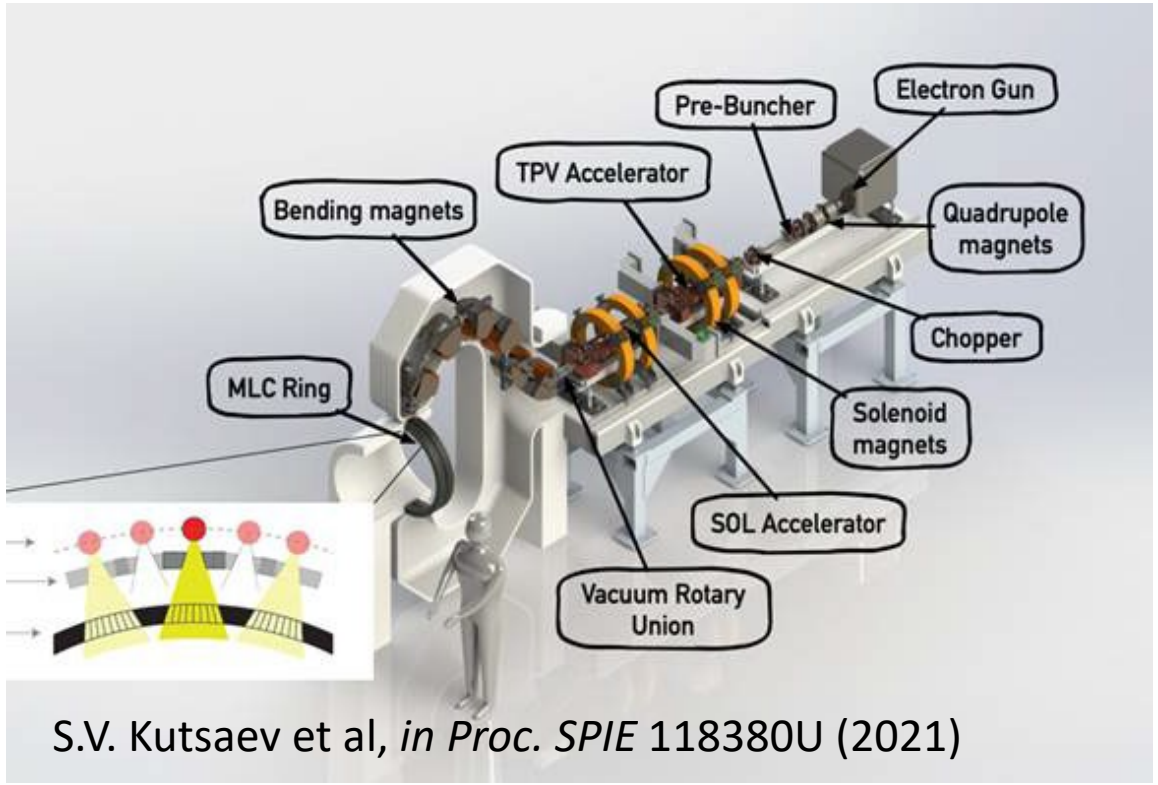

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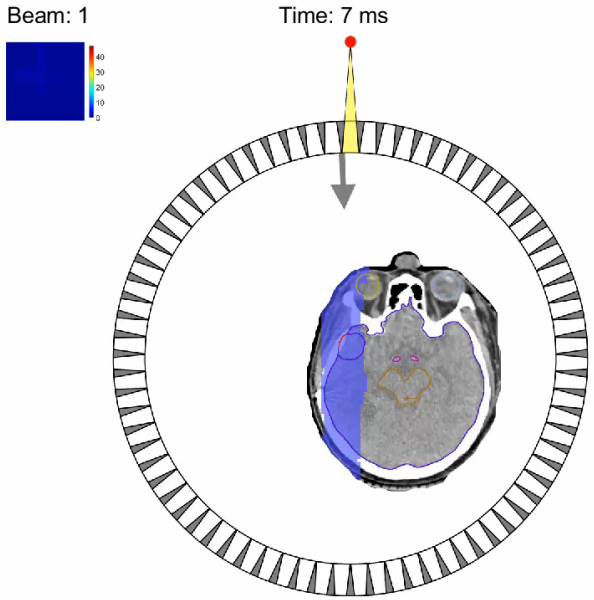

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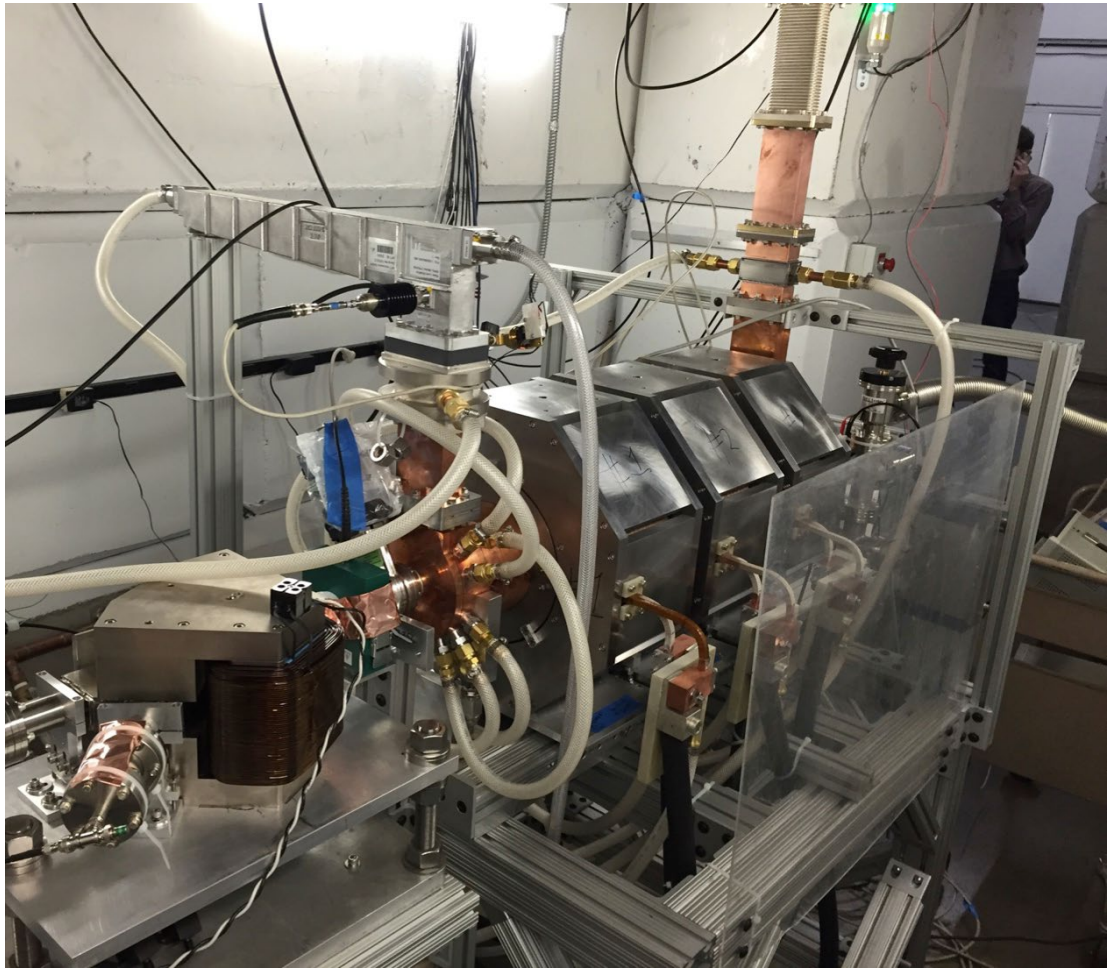
FLASH Linac Parameters

- Demonstration system is designed to produce 400Gy/s @ 20cm, uncollimated
- Recently, RadiaBeam has developed a 9 MeV electron linac with 75 Gy/s @ 20cm
  - We plan to reuse the expensive infrastructure from this linac
  - And build a new accelerating structure to increase the dose to 16.5 Gy/s @ 1m (x5.5 higher)
  - Using the same amount of RF power!
- Available power source:
  - S-band klystron (amplifier)
  - 5 MW peak power
  - 0.4% duty cycle = 20 kW average power
  - 16 μs pulse length @ 250 pps

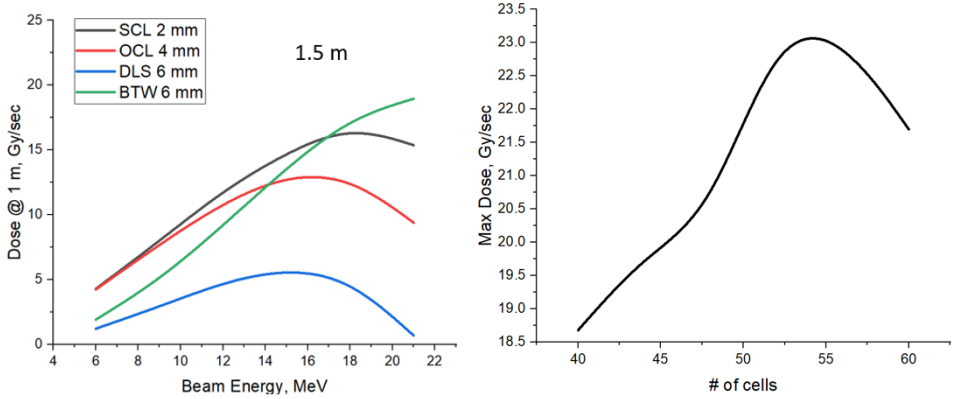


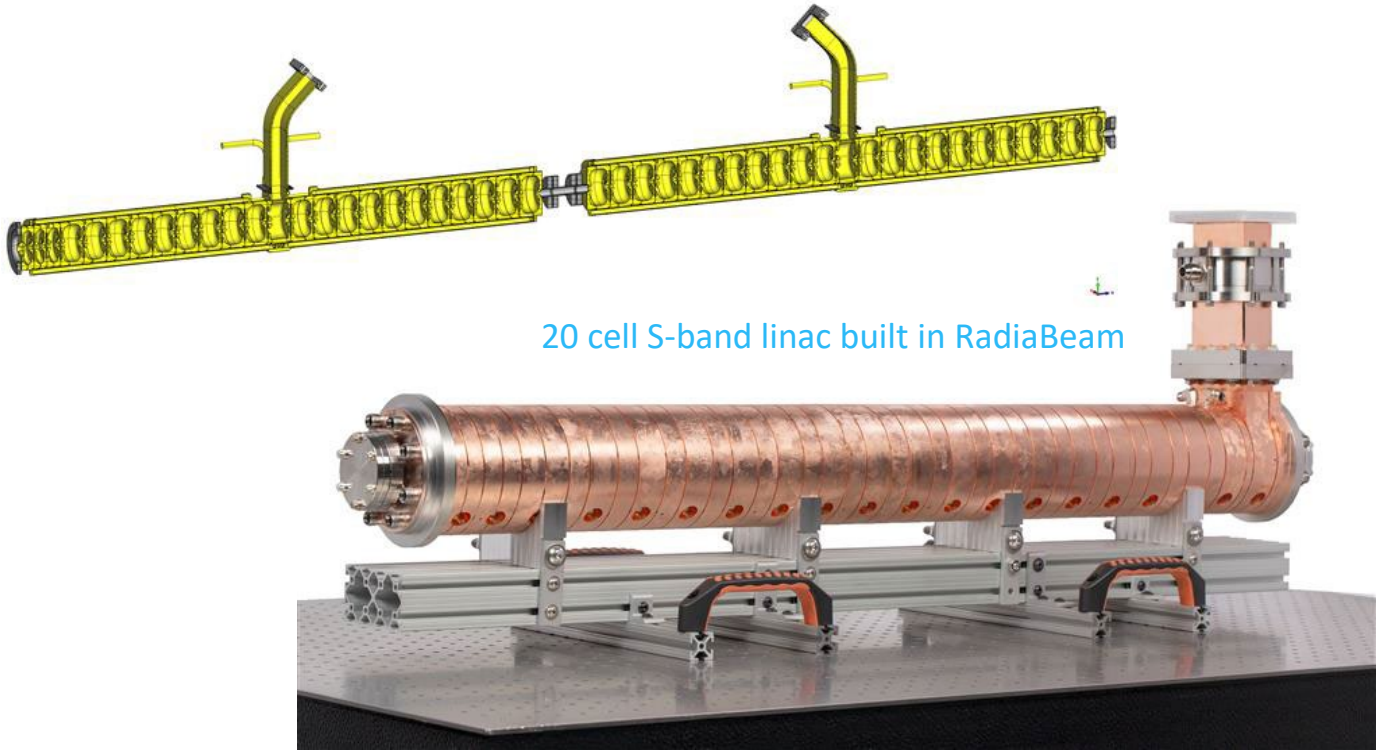
S.V. Kutsaev et al., "Linear Accelerator for Security, Industrial and Medical Applications with Rapid Beam Parameters Variation", *Radiat. Phys. Chem.* **183**, 109398, 2021.

Linac for FLASH Demonstration

- How to improve the dose yield by a factor of 5 with the same amount of RF power?
  - $D \sim I * E^{2.7\text{-}3.0}$ $P_{RF} = E^2/Z + E*I$
- First – increase beam current
  - Longer linac = more current
- Second – increase beam energy
  - Higher energy = higher dose yied

Linac	FLEX	FLASH Demo	FLASH Clinical
Structure	TW const. impedance	SW on-axis coupled	TW const. gradient
Frequency, MHz	2856	2856	1300
Length, m	0.85	2.6	~4.5
RF power	5 MW klystron @ 0.4% duty		10 MW @ 4% duty
Beam energy, MeV	2-9	18.0	18
Beam current, mA	100-500	130	325
Expected dose @ 1 m, Gy/sec	4.4	17.5 ± 2.0	271





20 cell S-band linac built in RadiaBeam

RadiaBeam

Thank you!

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