TIBARAY

CURING CANCER IN A *FLASH*

Compact linac design for FLASH radiation therapy

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Stanford Radiation Oncology

SLAC

FLASH RT and its Requirements

- Radiation therapy (RT) delivered at **>~50 Gy/s** constitutes FLASH RT
  - Typical conventional RT ~0.2-0.4 Gy/s
- Consistent preclinical data and now first in human case demonstrate ⇧ therapeutic index in FLASH RT

Clinical FLASH – **severely limited by** current technologies:

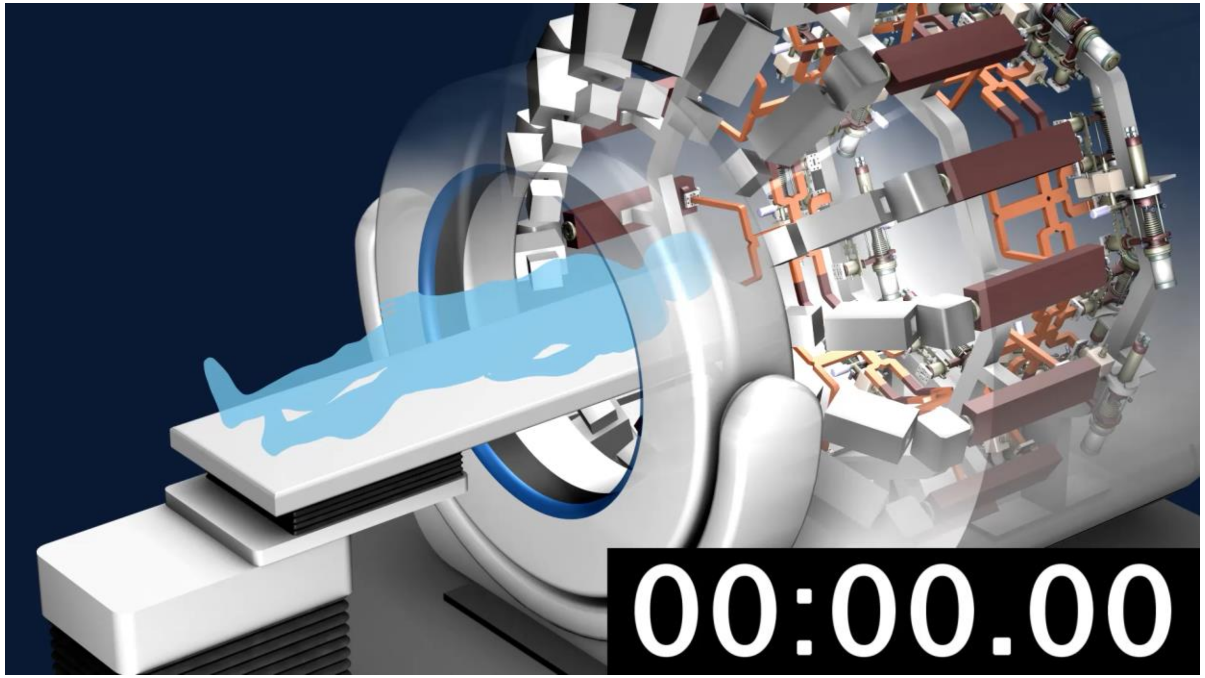
- 4-20 MeV **electron** beams: it can treat only superficial targets (<3 cm)
  - **General RT requirement**: Deep seated targets up to **~30 cm depth** to be treated
  - This needs 100-200 MeV electrons to match photon depth-dose
- 70-250 MeV **proton** pencil beams: it can treat only small volumes (1-4 cm wide)
- In all cases, there is **no option** for conformal (**multi-beam direction**) FLASH
- Motion management and high-quality imaging are other key factors necessary for achieving clinical FLASH
- System **cost** comparable to conventional RT is desirable

⇧⇧⇧ performance/speed/conformity ⇩ cost needed for FLASH to treat general cancer targets in patients:
Need radically new solution!

Radiation therapy: Conventional versus Next generation

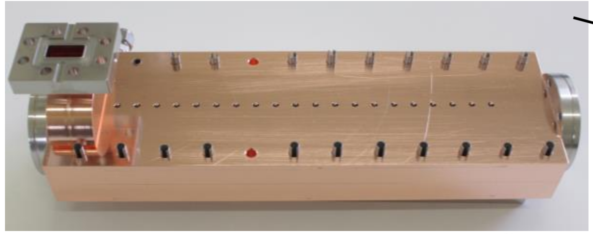
Current fastest clinical treatment in the world

Pluridirectional High-energy Agile Scanning Electronic Radiotherapy (**PHASER**)



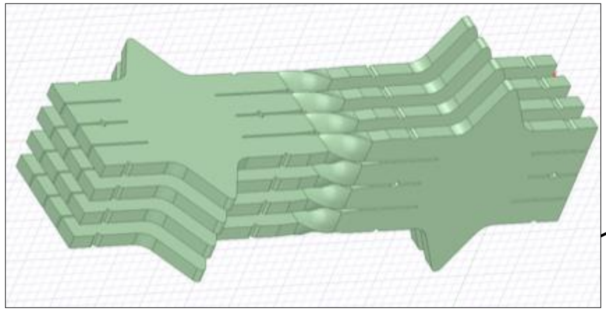
- ***300X faster:*** Freezes motion, ultimate precision
- FLASH RT: New biological advantages
- Compact & economical: Global access to RT

PHASER system – technical innovations

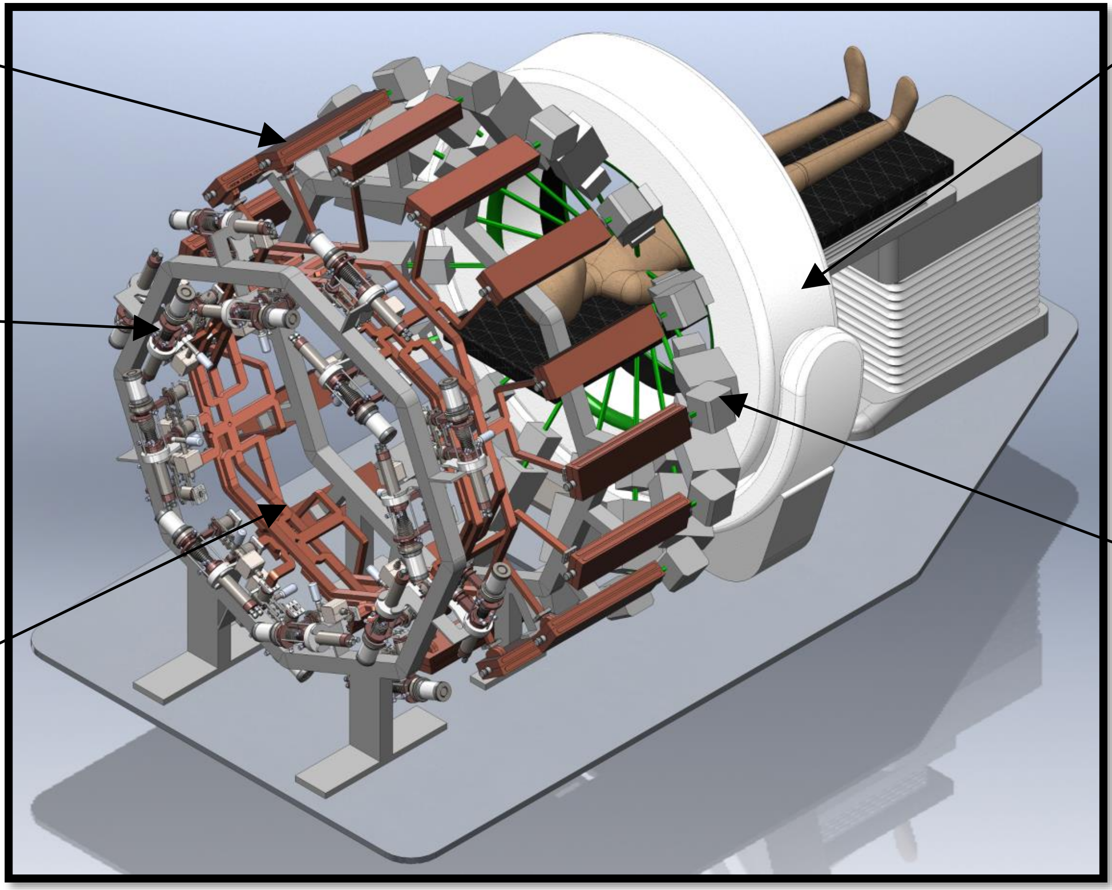


DRAGON linac

Array of klystrino RF sources



RAPiD power combiner network



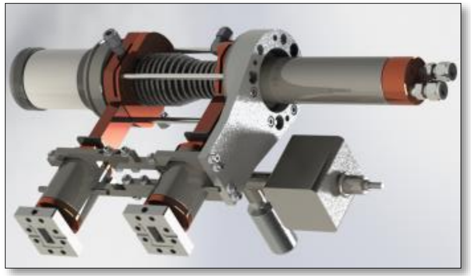
Full-ring CT imager

SPHINX all-electronic intensity modulation

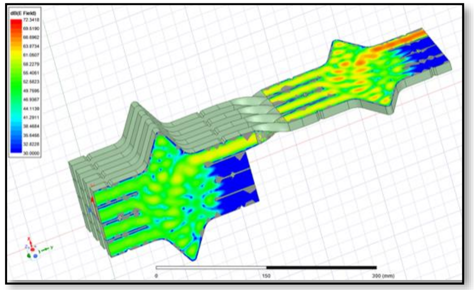
Maxim, Tantawi, Loo *Radiother Oncol* 2019

Novel RF source and distribution network

- Power generated by low power RF sources (Klystrinos) is combined using specialized RF network and directed towards an individual linacs electronically
- Though high peak power needed for FLAST RT is achieved, by phasing the power between linac, the average power is kept very low



Mini-klystron or “klystrino”

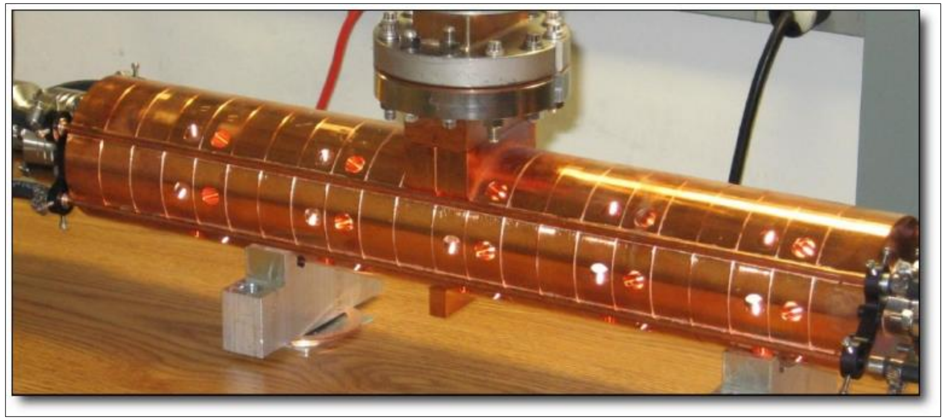


Scanning the beam achieved by sweeping through phases of the 16 RF sources

S.Tantawi, B. Loo, SLAC, Stanford.

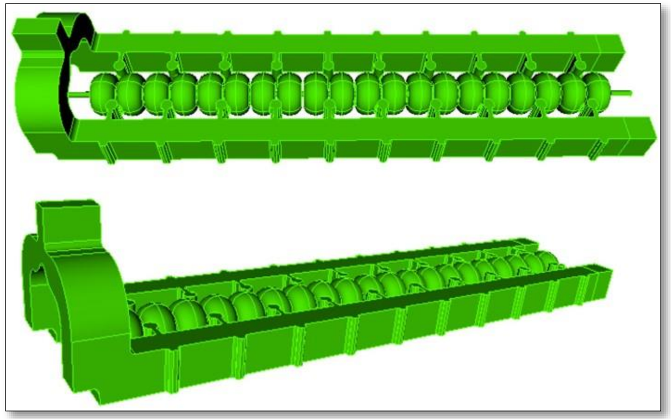
Design Specifications	Values
Max energy	**10 MeV**
Operating frequency	**9.3 GHz**
Pulse repetition rate	**1000 Hz**
Duty factor	**0.5%**
Total peak power/linac	**4.2 MW**
Avg. Beam Current /linac	**1.5 mA**
Average beam power/linac	**15 kW**
Total average RF power/linac	336 kW
Peak RF power/Klystrino	**300 kW**
Average power/klystrino	21 kW
RF to beam efficiency	**>70%**

Existing electron linac designs



- Basic design essentially unchanged for 60 years
- In conventional design, RF power is fed to accelerating cells through the beampipe
- Cells are coupled – modifying any particular cell will affect its neighbors
- Optimizing individual cells is compromised by the need to consider effects on neighboring cells because of this coupling
- Coupling severely limits the ability to vary RF power from cell-to-cell
- **Overall linac performance is therefore limited because of the coupling constraints;** typical shunt impedances of 70-90 MΩ/m and dose rate of ~0.2-0.4 Gy/s

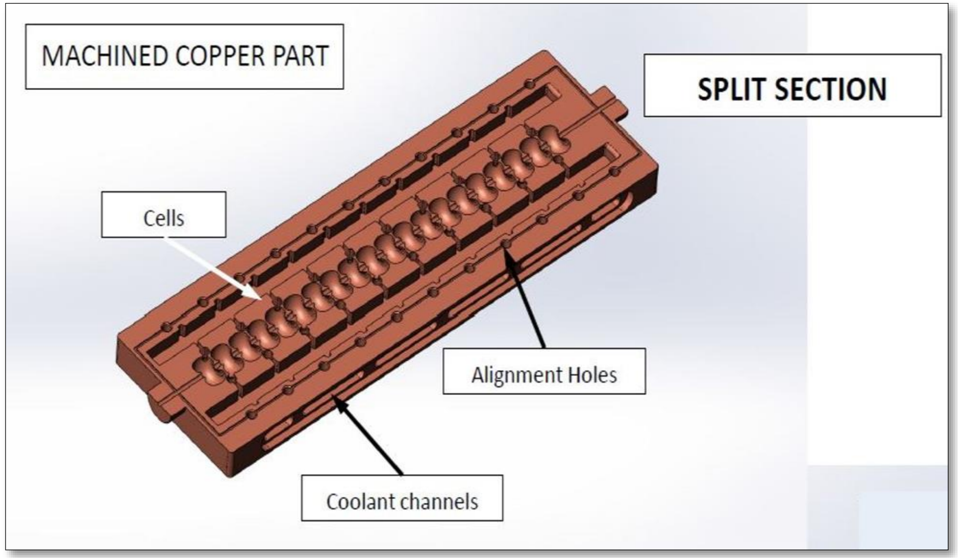
Novel electron linac design



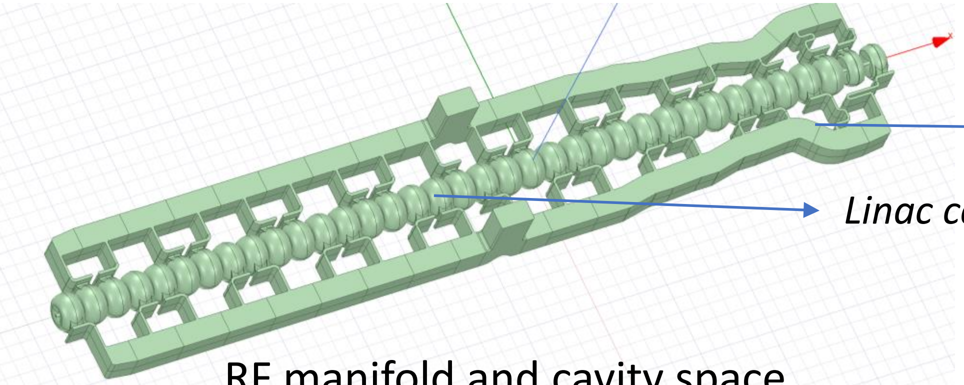
- Linac design leverages ***Distributed Coupling Accelerator Structures*** (Tantawi et al. US Patent 9,386,682).
- Accelerating cells are NOT coupled, can be optimized individually. No RF flows between cells
- RF power is fed to accelerating cells through an RF distribution network
- Greater control of RF phase & power going into any particular accelerating cell

TibaRay implementation

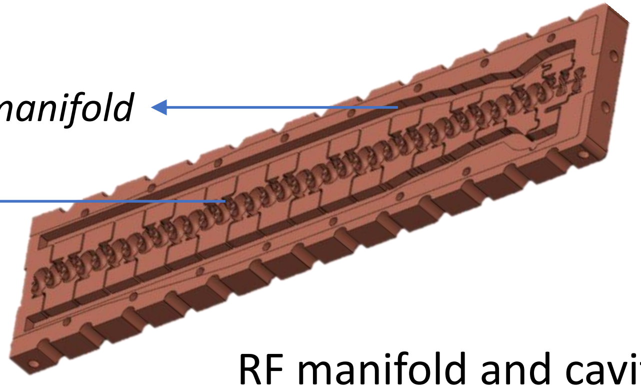
- Low-cost manufacturing designed-in at the outset
- Instead of having many cells each made of two parts and then brazed together, all the cells of a structure are machined in two halves that are brazed together.
- Cooling, alignment and beam diagnostics integrated into the two halves and machined at the same time as the cells.



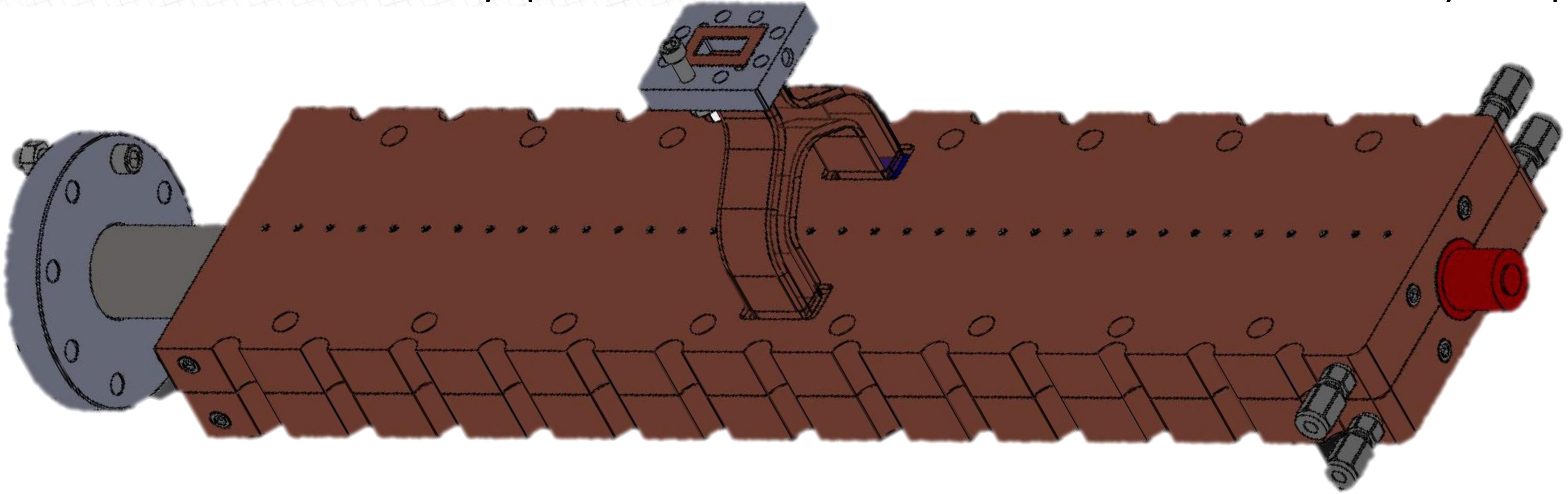
Linac Design



RF manifold and cavity space



RF manifold and cavity in copper



Full linac assembly

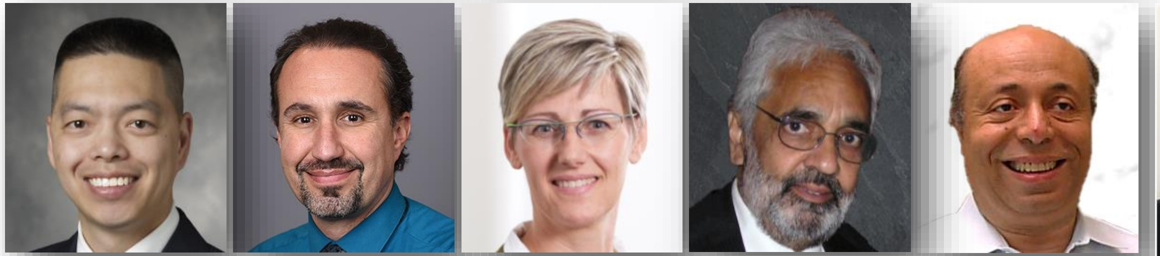
PHASER Summary

Novel ground-up design for medical linacs for cancer radiation therapy (RT) based on advances in high energy accelerators is being developed

- ✓ **Universal system** that can treat *all* cancers eligible for RT
- ✓ **Speed**
  - ✓ Rapid **(<1s)** freeze-motion **dose delivery – Highest precision**
  - ✓ 300x higher **dose rate – FLASH biological advantage**
  - ✓ Ultra-rapid delivery integrated with **simultaneous volumetric image-guidance** of same target volume
- ✓ **No moving parts**
  - ✓ Increased **reliability** from lack of mechanical moving parts
  - ✓ **No patient collision** risk
- ✓ **Designed explicitly for**:
  - ✓ Compactness
  - ✓ Economy, leveraging manufacturing innovation
  - ✓ Reliability and robustness
  - ✓ Clinical efficiency, global accessibility

TibaRay Team and Funding Sources

FOUNDERS



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Thank you for your attention!

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