MOP019

Comparison of linacs for small-scale inverse Compton scattering light source applications

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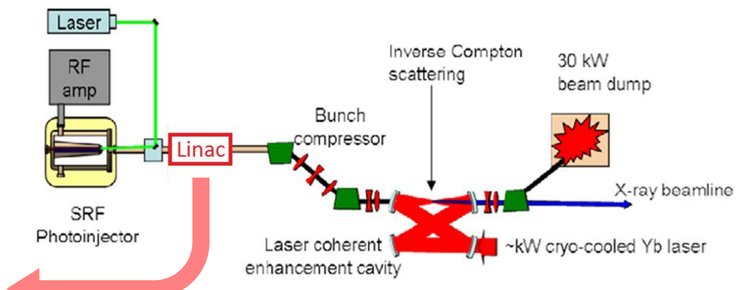
Motivation

Great interest has been generated by the possibility of compact, high brilliance X-ray source based on inverse Compton scattering (ICS) since the rapid advancement in laser and accelerator technologies. MIT proposed such an affordable concept to produce 20keV X-ray, but the linac for electron acceleration after injector was not well defined then [1]. JLab has been founded by BES to demonstrate the SRF technology for this application, and various options are investigated

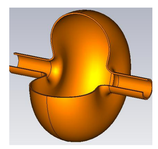
Requirement to the linac	
Beam current	1 mA
Repetition rate	100 MHz CW
FWHM length	1.1 ps
ε_n	0.3 mm*mrad
Energy in	4 MeV
Energy out	21 MeV

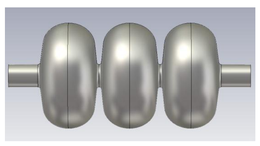


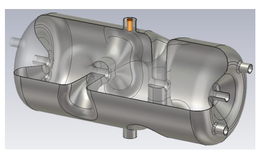
Our choice: 4K linac consists of two 400MHz 3-cell elliptical cavities

Options on the linac

1. Normal conducting (NC) vs. Superconducting (SC)
   Re-entrant shape in low frequency is typical for NC CW machine;
   Elliptical SC cavities is commonly preferred for CW operation.
2. 4K vs. 2K for SC linac
   The cavity performance improves a lot from 4K to 2K;
   Though, cryogenic efficiency and capital cost are way different, too.
3. Elliptical vs. spoke shape
   Elliptical cavity is typically used for β=1 applications;
   Spoke cavity at high beta is being studied recent years, too.
4. Various frequency and number of cells
   BCS resistance and R/Q are sensitive to this two variables
5. What if Nb3Sn works
   Could it be a game changer?



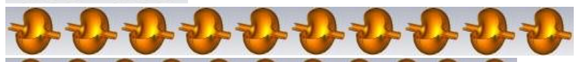




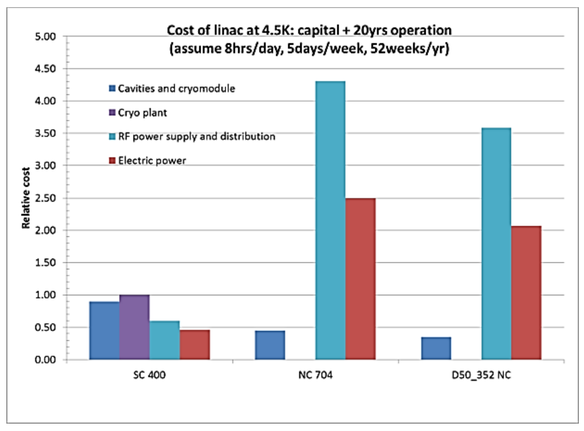
Comparison

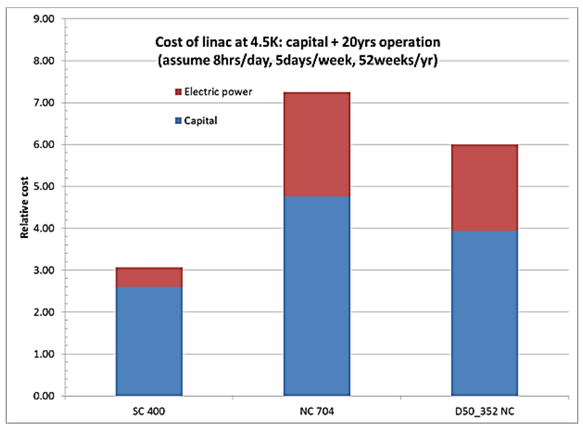
- **Why superconducting?**
  - SC linac is **~3.6 m** long, while NC linac is **~10 m** at wall loss of 50kW/cavity
  - RF source for NC linac dominates the cost for 17 MV voltage gain in CW mode

400MHz SC  **(2 cavities, 4m long)**

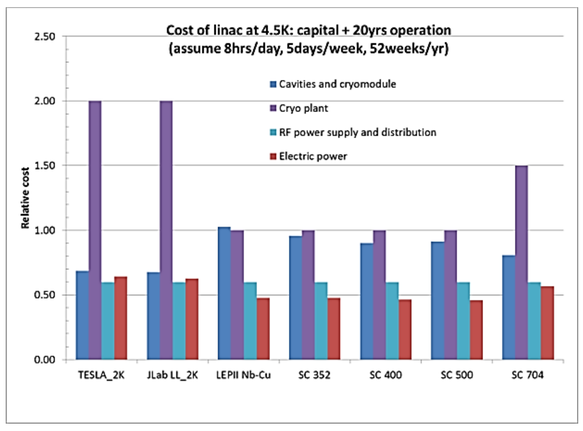
352MHz NC  **(14 cavities, 10m)**

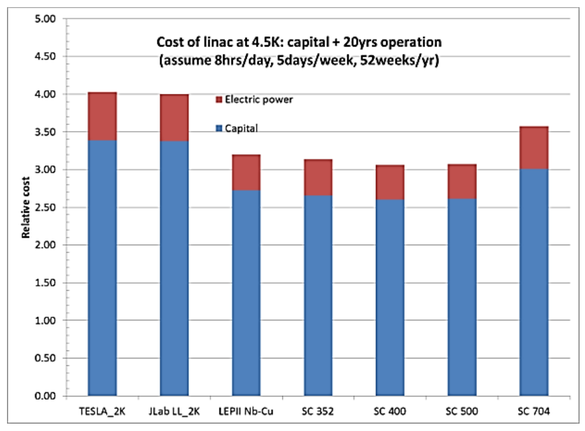
700MHz NC  **(18 cavities, 9m)**



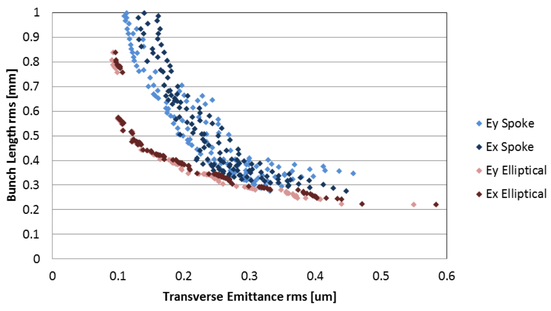


- **Why 400 MHz?**
  - **Key point:** on the harmonic of 200MHz injector gun
  - 2K operation at higher frequency costs more in small scale cryo-system
  - 352, 500, and 704MHz optimized shape, as well as existing LEPII 352MHz cavities were studied for comparison
  - 352-500 MHz are similar in terms of cost, but 500MHz needs **3 cavities**
  - The Linac is **~6m** long if using LEPII cavities (compared with **~4m**)



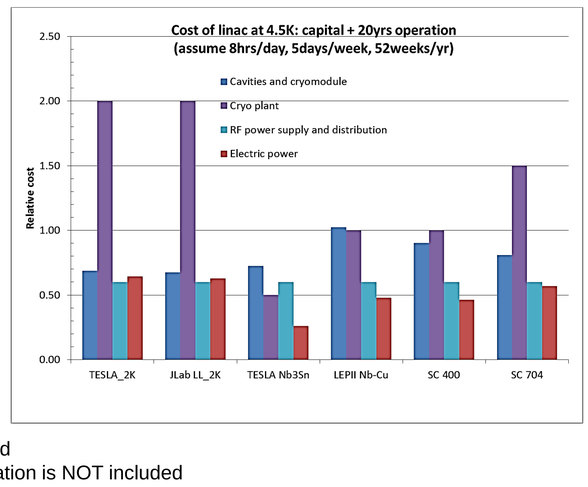


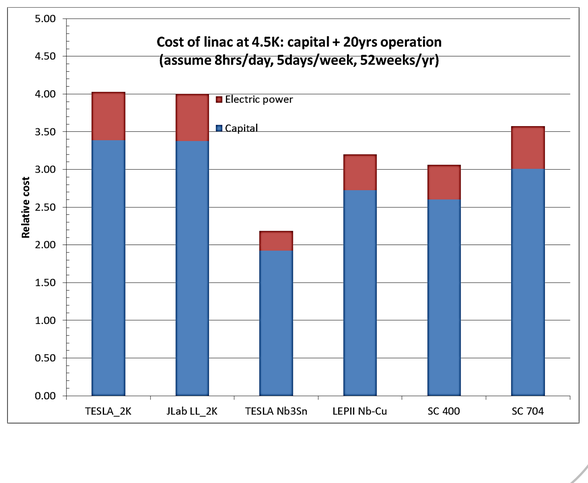
- **Why elliptical cavity?**
  - The spoke and elliptical cavities at 352MHz were compared
  - Optimized spoke and elliptical cavities have similar dynamic heat load
  - Elliptical cavity is preferred in emittance and peak surface field, meanwhile it is easier to fabricate and clean.
  - Spoke cavity is better in frequency stability and smaller in size



	Double spoke	Elliptical
Frequency [MHz]	352.2	352.2
Cavity inner diameter [mm]	**578**	**719.9**
Aperture diameter[mm]	50	170
Ep/Ea	**4.3**	**2.5**
Bp/Ea [mT/(MV/m)]	**7.6**	**3.3**
Geometry factor [Ω]	179	289
Ra/Q [Ω]	781	488
Ra*Rs (=G*Ra/Q) [Ω^2]	**1.40×10^5**	**1.41×10^5**
Pressure sensitivity [Hz/torr]	9	25

- **One more word on why 4K**
  - **Capital cost of the cryo-plant dominates,** and 4K at lower frequency (<500MHz) is much favorable.
  - Operation of 4K small-scale (i.e. 100-500W) commercial cryo-plant is way more stable than those at 2K
- **If Nb_3Sn works…**
  - Assume 30 nΩ below 10 MV/m is achievable at 4K for TESLA 9cell cavity (Q0~1e10)
  - Cryo-plant and electric bill will be half the current choice, which yields about 30% less cost of the whole linac. And it will be much more mature to handle the 1.3GHz size.





Assumptions

- Cavity shapes are all optimized to reduce dynamic heat load, and max gradient is limited by either Ep, Bp or dynamic heat load
- Capital cost includes cavity, cryomodule, cryo-plant(if any) and RF power source. Real-estate is NOT counted. Labor for operation is NOT included
- Detailed assumptions are available in [2]

Conclusion

- Various linac designs were compared for the application to the proposal of an ICS X-ray light source
- 4K linac consists of two 400MHz 3-cell elliptical cavities are chosen
- Detailed design of the 3-cell cavity could be found in [3]

Reference :

[1] W. Graves, et al. "MIT Inverse Compton Source Concept.", NIM.A 608, no. 1, Supplement (2009): 103-105

[2] F. He, et al. "Linac comparison for the ICS Application", JLAB-TN-12-029, 2012

[3] F. He, et al. "A prototype cavity for inverse compton scattering light source applications", THP014, this conference.

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