Testing Nb_3Sn Superconducting Cavities in B-fields at Fermilab

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18 November 2020

Premise

For the sake of completeness, some familiar facts:

- $P_{a\gamma\gamma} \propto Q$
- $Q \propto 1/R_s$
- External B-fields increase R_s in a very geometry- and material-dependent way.

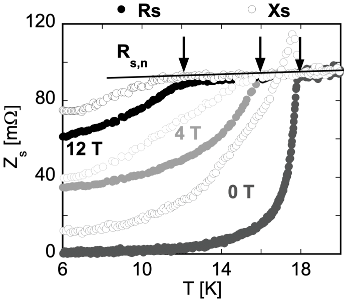


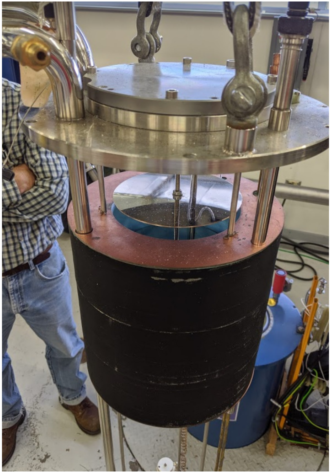
Figure: 15 GHz example: A. Alimenti *et al.*, arXiv:1901.03819

Let's try it!

- We have Nb_3Sn cavities and we have strong magnets. Let's put a cavity in a magnet.
- We expect some degradation in Q, but with a field-free $Q > 10^{10}$ we can tolerate quite a lot of dissipation before Nb_3Sn performance is equivalent to Cu.

The Oxford Instruments "Teslatron" test stand is available to us.

- Guaranteed max. B-field on axis is 10 tesla at 2.2 K.



Test setup

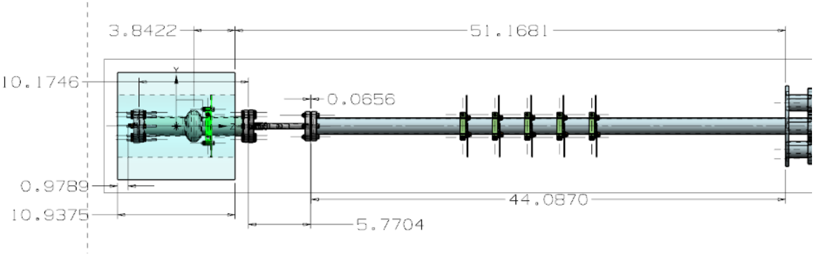


Figure: Blue shaded box indicates magnetic field region.

Nb_3Sn cavity and insert ready to go.

Figure: 3.9 GHz "elliptical" Nb_3Sn cavity ready for testing.

Experimental status and plans

- We're approaching the end of a long safety review process.
- Remaining approvals from safety committee:
  - Electrical safety final approval (RF line trip hazards, etc.)
  - Vacuum system safety audit underway.
- (1) Insert cavity into cryostat; (2) measure Q across a range of B-fields.

What if it works?

- If we see $Q \gtrsim 10^5$...
- ...make a Nb_3Sn cavity + rod and test; and
- ...explore other material possibilities.
- Any other ideas?

Thanks for your attention!

Supplemental: Nb_3Sn cavity fabrication and performance reference

Advances in Nb_3Sn superconducting radiofrequency cavities towards first practical accelerator applications

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Nb_3Sn is a promising next-generation material for superconducting radiofrequency cavities, with significant potential for both large scale and compact accelerator applications. However, so far, Nb_3Sn cavities have been limited to cw accelerating fields <18 MV/m. In this paper, new results are presented with significantly higher fields, as high as 24 MV/m in single cell cavities. Results are also presented from the first ever Nb_3Sn-coated 1.3 GHz 9-cell cavity, a full-scale demonstration on the cavity type used in production for the European XFEL and LCLS-II. Results are presented together with heat dissipation curves to emphasize the potential for industrial accelerator applications using cryocooler-based cooling systems. The cavities studied have an atypical shiny visual appearance, and microscopy studies of witness samples reveal significantly reduced surface roughness and smaller film thickness compared to typical Nb_3Sn films for superconducting cavities. Possible mechanisms for increased maximum field are discussed as well as implications for physics of RF superconductivity in the low coherence length regime. Outlook for continued development is presented.

Figure: S. Posen *et al.*, arXiv:2008.00599, Aug. 2020