Cryogenic Test of a Two-Cell Passive SRF Cavity for NSLS-II

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Abstract

Brookhaven National Laboratory (BNL) is currently building NSLS-II, a third generation light source, and has identified SRF cavities as the technology of choice. Two passive two-cell SRF cavities at 1500 MHz (the 3rd harmonic of the accelerating RF system) are required to lengthen the bunch. The use of these cavities will increase the beam lifetime to greater than 3 hours.

Under a Dept. of Energy Small Business Innovative Research project, BNL and Niowave, Inc. have collaborated to develop, build and cryogenically test the 1500 MHz SRF Landau cavity and associated cryomodule. The cavity design is a slight modification to the previously designed Super-3HC cavities which used niobium sputtered onto high-purity copper. Updates to this design and the use of bulk niobium allow this cavity to handle the stringent specifications and requirements for the NSLS-II ring. Niowave is now in a position to build on the success with this cavity to help advance the design of advanced light sources which researchers can use for a wide range of experiments.

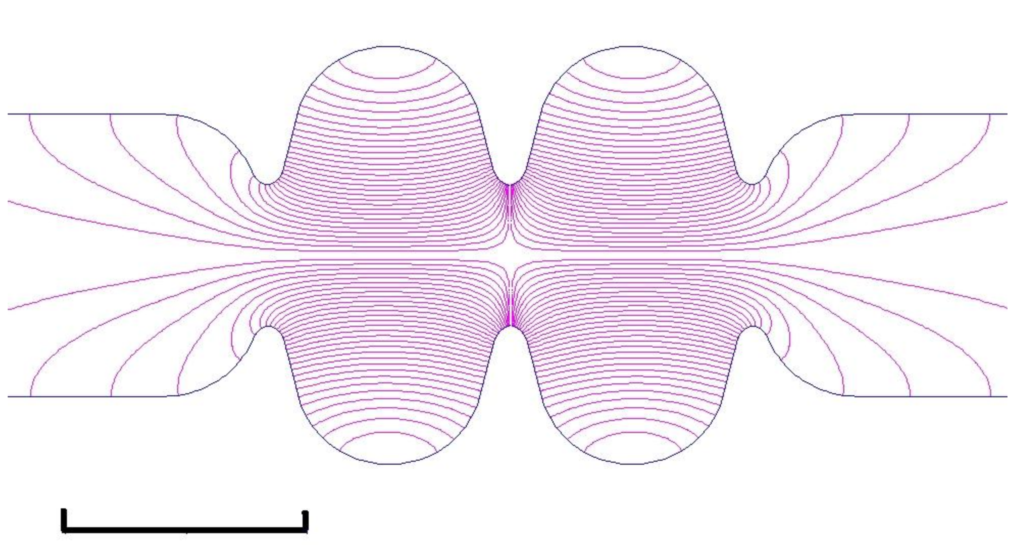
NSLS-II RF parameters

beam energy	3 GeV
bunch frequency	500 MHz
average current	500 mA
emittance, ε_x	0.5 nm-rad
emittance, ε_y	0.01 nm-rad
beam pipe aperture (ellipse x,y)	78 mm, 25 mm
RF acceptance $\Delta p/p$	3 %
accelerating RF voltage (500 MHz)	5 MV
RF beam power loss (500 MHz)	1 MW
RF amplifier power per cavity (500 MHz)	300 kW
# cavities (500 MHz single-cell)	4
RF voltage (1.5 GHz)	~1.5 MV
RF amplifier power per cavity (1.5 GHz)	none/passive
# cavities (1.5 GHz two-cell)	2
cryogenic temperature	4.5 K
cryoplant capacity	700 W

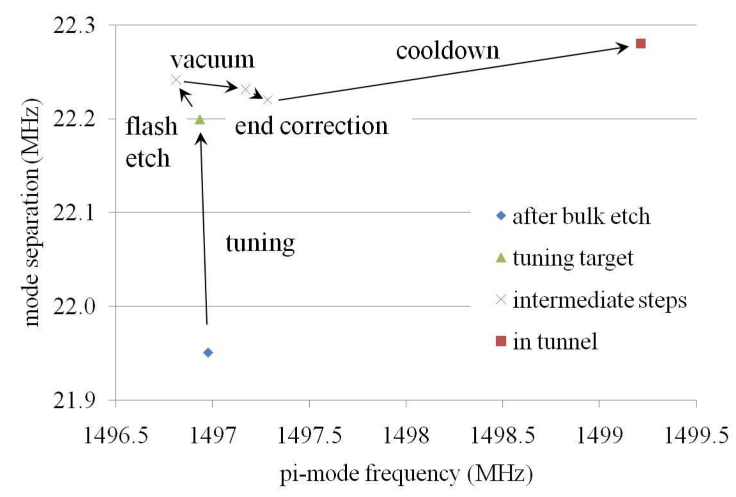
3rd harmonic cavity parameters

cavity frequency (pi-mode)	1499.27 MHz
superconducting cavity Q	$2.4 \cdot 10^8$
shunt impedance, R/Q (pi-mode)	112 Ω
peak electric field	12.8 MV/m
peak magnetic field	22 mT
integrated voltage	0.5 MV/cell
dissipated power	9.4 W
operating temperature	4.5 K

Two-cell cavity design

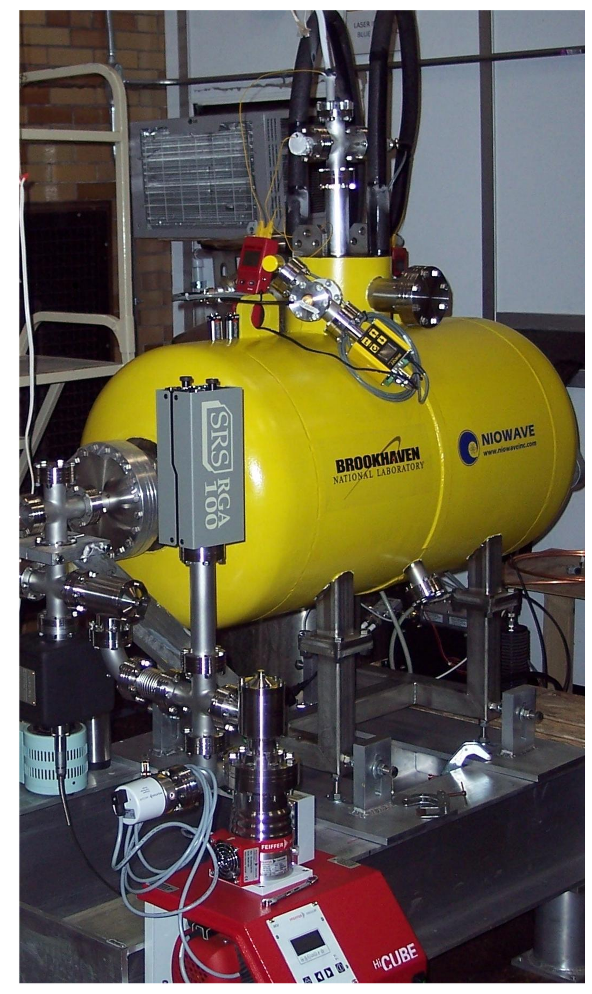


Welded cavity and tuning

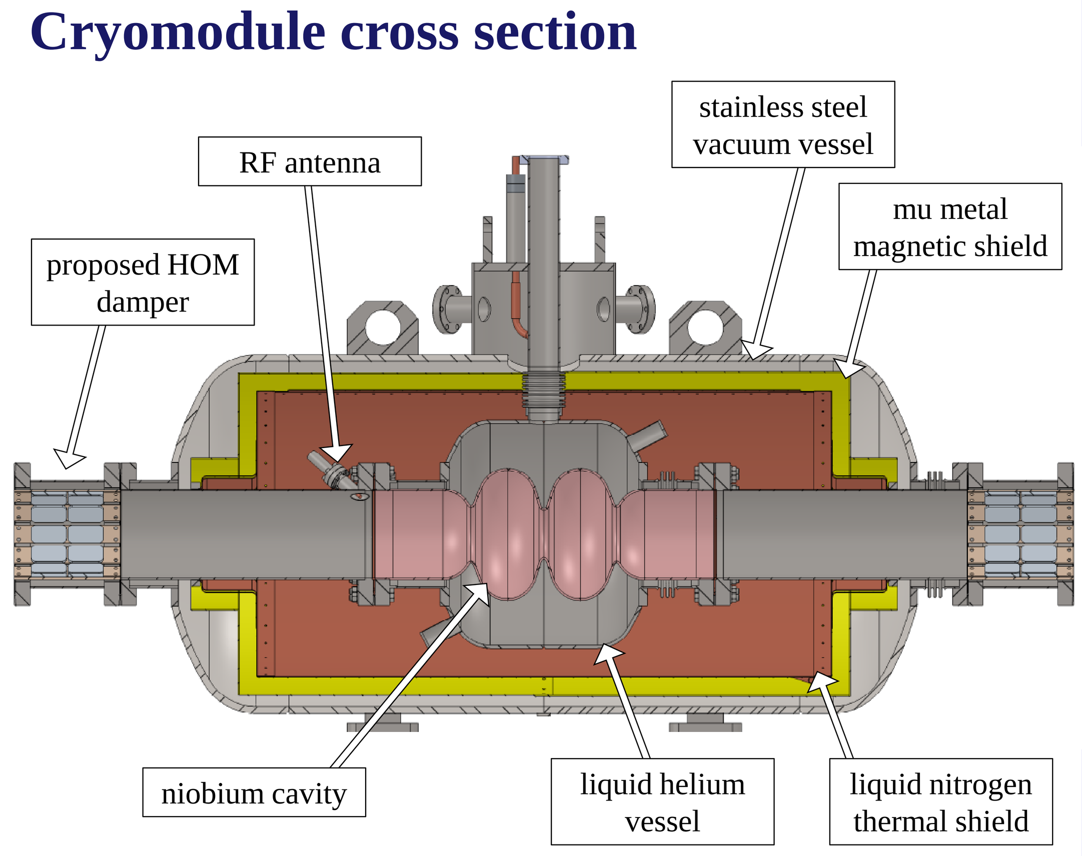


For this cavity, both the pi-mode and zero-mode frequencies are important. After electron beam welding of the niobium cavity, a number of experimental tests were performed to evaluate the frequency shifts of both the pi mode and the zero mode through the various steps of cavity processing – etching, pumpdown, cooldown, etc. These data were used to establish a target for mechanical tuning of the cavity prior to the cryomodule build.

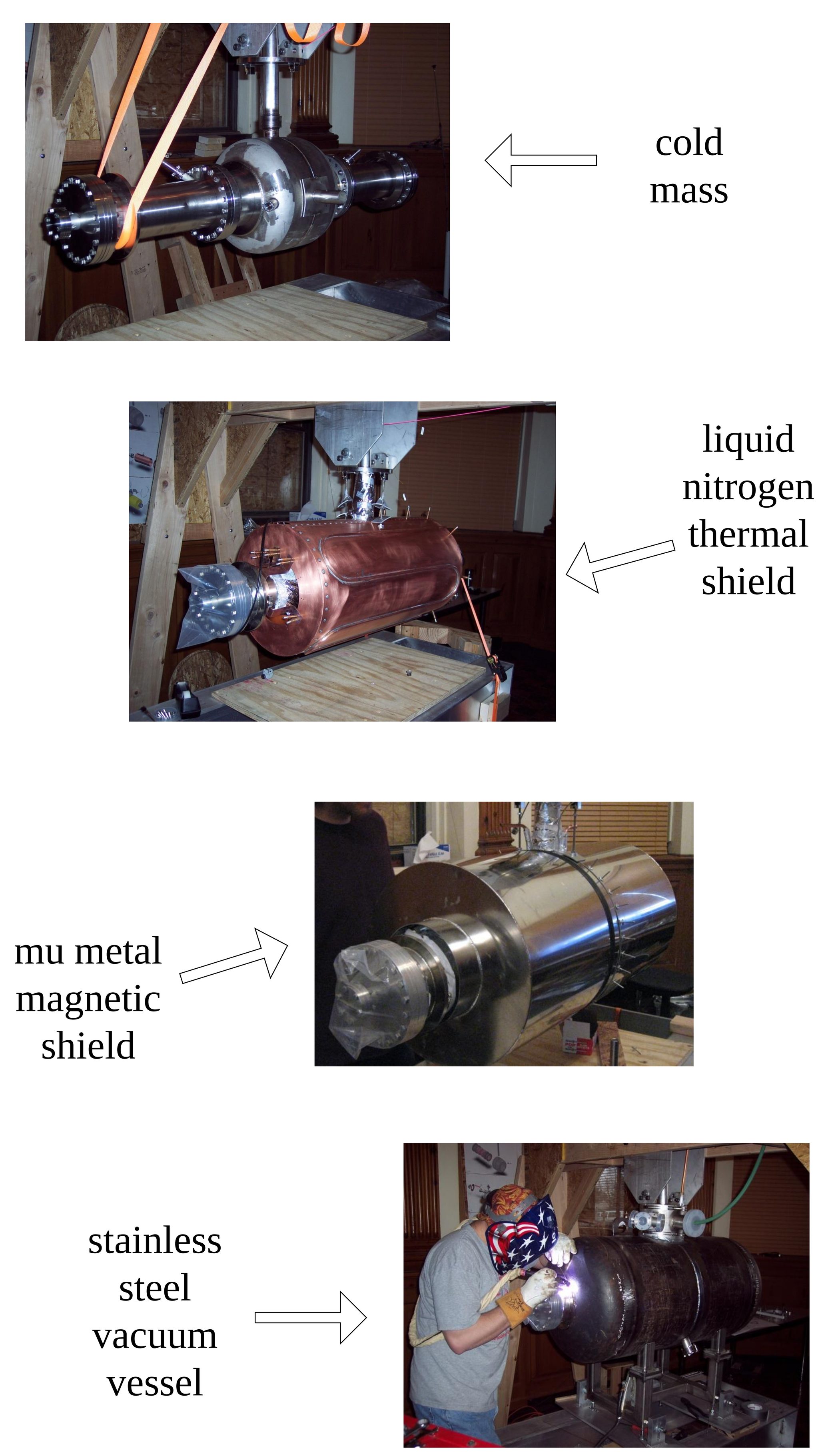
Cryogenic test setup



Cryomodule cross section



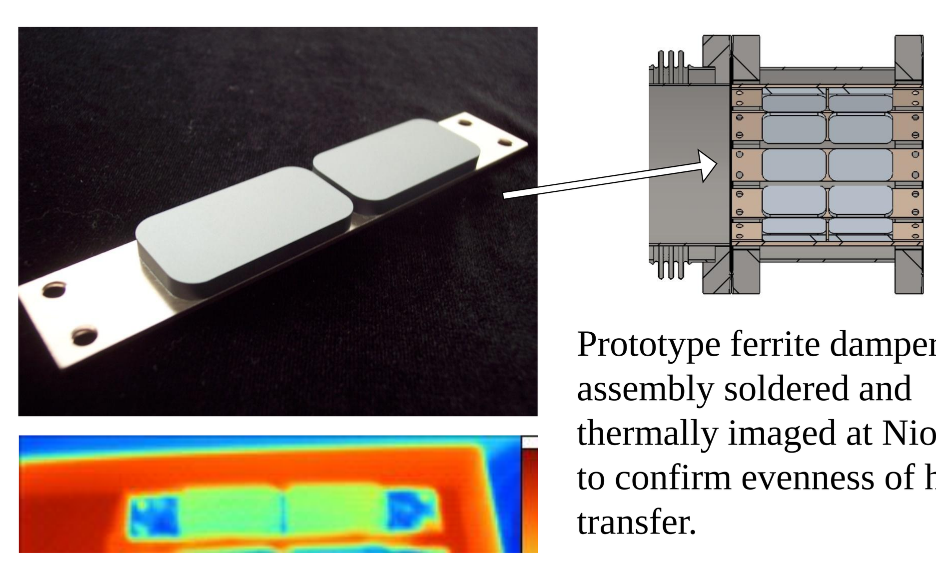
Cryomodule assembly



Cryotest results

- cavity cooled to 4.2 K in cryomodule at Niowave
  - temperatures were monitored at several points inside the cryomodule to track the cooldown progress
  - superconducting transition was observed within an hour of beginning the liquid helium fill (3 hours total cooldown time)
- superconducting design frequency of 1499.27 MHz reached for pi-mode operation
- proper mode separation maintained to prevent excitation of zero mode
- loaded cavity Q of $6{\cdot}10^7$ measured with no degradation up to 400 kV integrated field
- tuning range of approximately 1 MHz achieved with acceptable variation in mode separation

Higher-order mode dampers



Prototype ferrite damper assembly soldered and thermally imaged at Niowave to confirm evenness of heat transfer.

Conclusion

This project has demonstrated a passive two-cell Landau damping cavity suitable for operation at NSLS-II. The cavity was constructed from bulk niobium and installed in its own cryomodule. A cryogenic test of this module has now been performed by BNL and Niowave, Inc., demonstrating a successful cooldown. Furthermore, the design frequency for the pi mode was reached while maintaining the predicted mode separation necessary for operation in the NSLS-II ring. A tuning range of ~1 MHz was also shown, enough to establish a full range of excitation for the passive cavity. This includes bunch lengthening, bunch shortening, and unexcited modes of operation.

Acknowledgements

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