Development of a Low Frequency Superconducting RF Electron Gun

Contract DE-FG02-07ER84861

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Outline

- Collaboration
- Concept
- Scientific justification
- Design
  - electromagnetic
  - mechanical
- Fabrication
- Test results and plans

Collaboration

This DOE Nuclear Physics SBIR project has been conducted by Niowave in collaboration with Brookhaven National Lab (Ilan Ben-Zvi, head of Accelerator R&D in the Collider-Accelerator Department)

Concept

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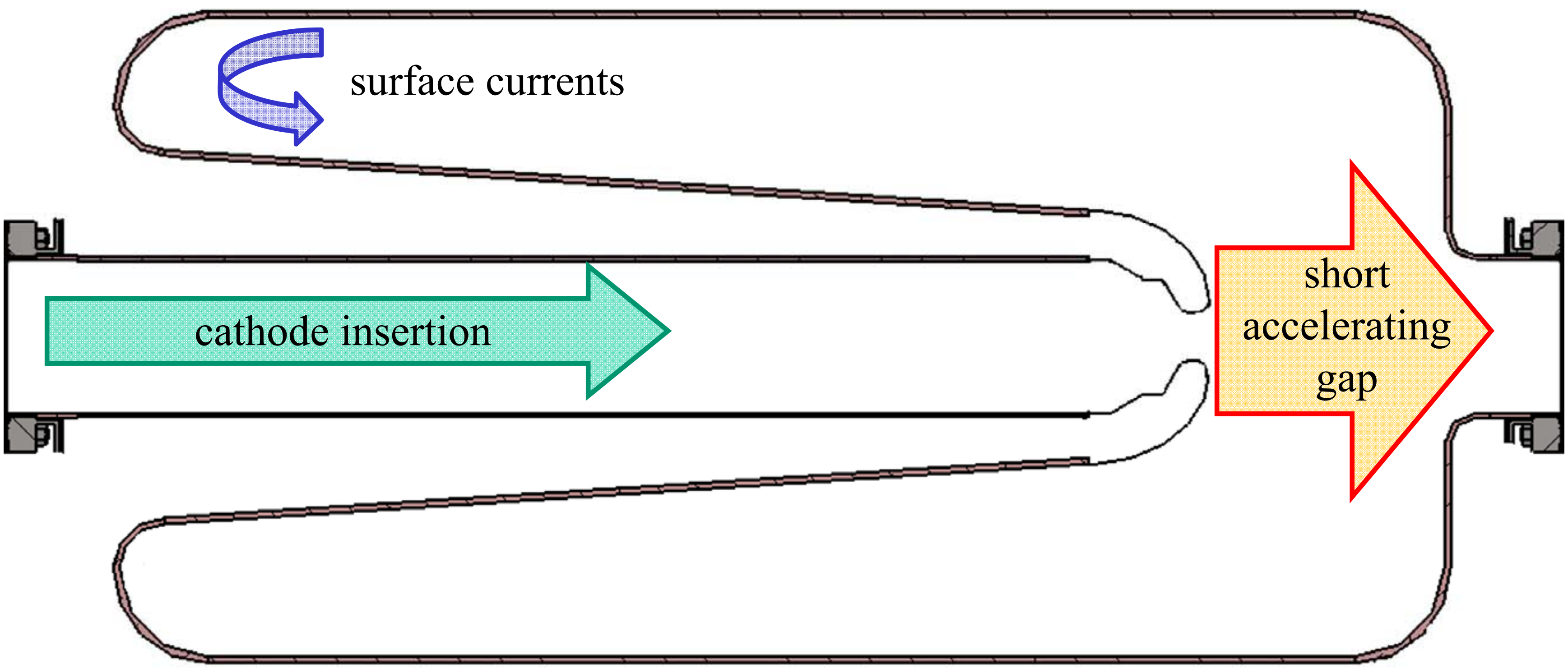
We have developed a quarter wave superconducting cavity as a high brightness electron source… taking a cavity design well known in the heavy-ion community and adapting it for use to accelerate electrons.



cavity cross section

Concept [2]

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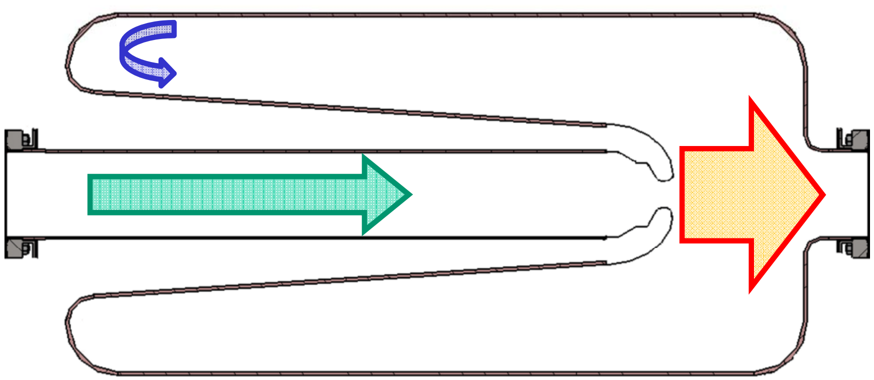
at low frequency, the accelerating gap looks like a constant field to the short electron bunch – minimal distortion

not necessary for the cathode to be mechanically connected to the superconducting structure – great flexibility in cathode types and potential for electron source R&D

superconducting cavity has low dissipated power even for very high average beam currents



Scientific justification

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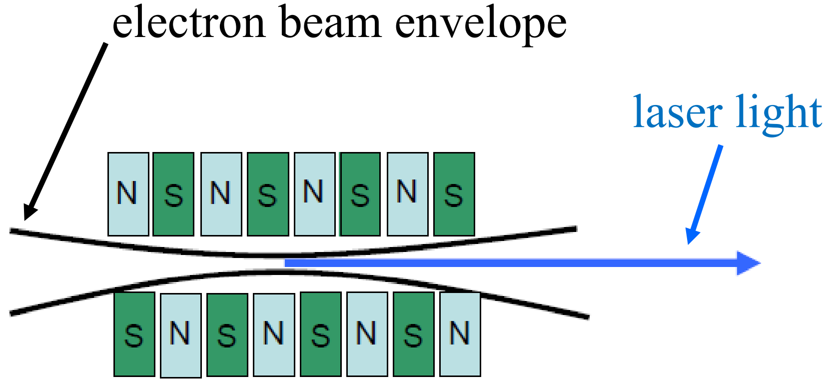
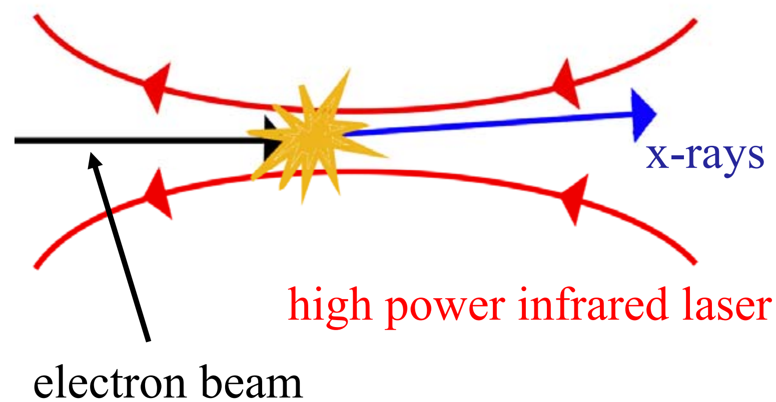
free-electron lasers

- for hard x-rays, requires exceptionally bright electron beam
- electron beam must be focused inside the growing light wave



Compton backscatter x-ray sources

- spectral brilliance (x-rays per area, per solid angle, per bandwidth) is directly proportional to the electron beam brightness



other next generation light sources

Scientific justification [2]

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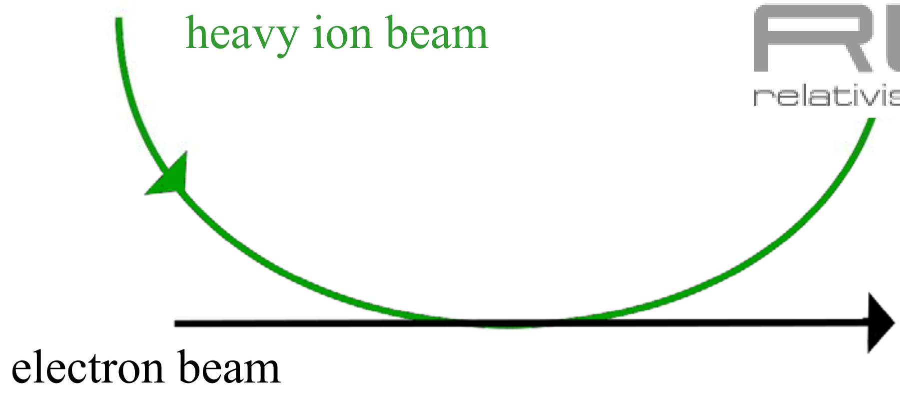
A specific need for this gun has already been identified by Ilan Ben-Zvi: an electron cooler for the RHIC ring.



RHIC
relativistic heavy ion collider

- the high-brightness electron beam has a low "temperature" – electron paths can be made nearly parallel
- mingling the electrons with the RHIC beam at the same velocity "cools" the heavy ion beam by collisions, leaving that beam brighter
- requires lots of electrons (1 to 5 nC) in a dense bunch

Design – electromagnetic

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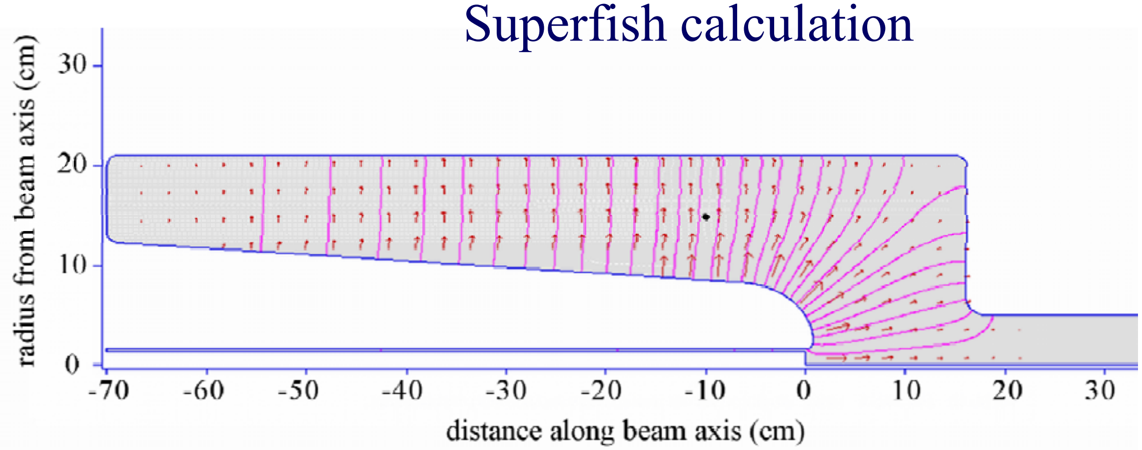
frequency (MHz)	112
V_0 (MV)	1.6
$E_{cathode}$ (MV/m)	11.5
E_0 (MV/m)	4.0
E_{peak} (MV/m)	30.2
B_{peak} (mT)	57.6
B_{peak}/E_{peak} (mT/(MV/m))	1.91
R_{res} (nOhm)	5
R_{BCS} (nOhm)	98.9
P_d (W)	5.4
T(K)	4.2
Q	$3.7 \cdot 10^9$
G(Ohm)	41
R/Q (Ohm)	130
TTF	0.99

The operation frequency has been chosen as a harmonic multiple of the RHIC ring frequency.

parameters from Superfish calculation



Design – mechanical

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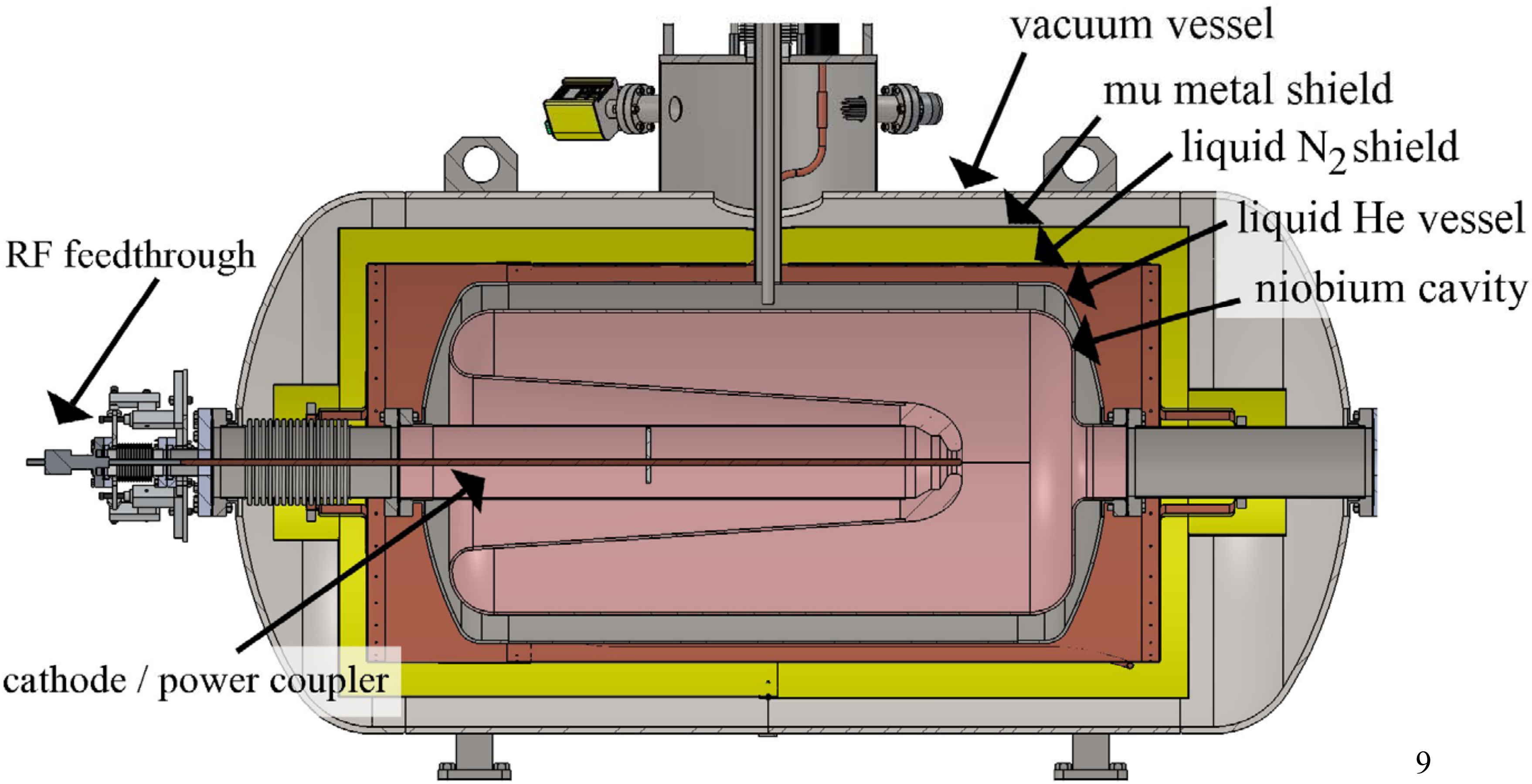
For operation at 4.2 K, the cavity is surrounded by a custom-designed cryomodule.



Fabrication

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Steps throughout the fabrication process insure the quality of the superconducting niobium surface.

stamping and machining of niobium parts

electron beam welding

inner surface preparation by acid etch

Fabrication [2]

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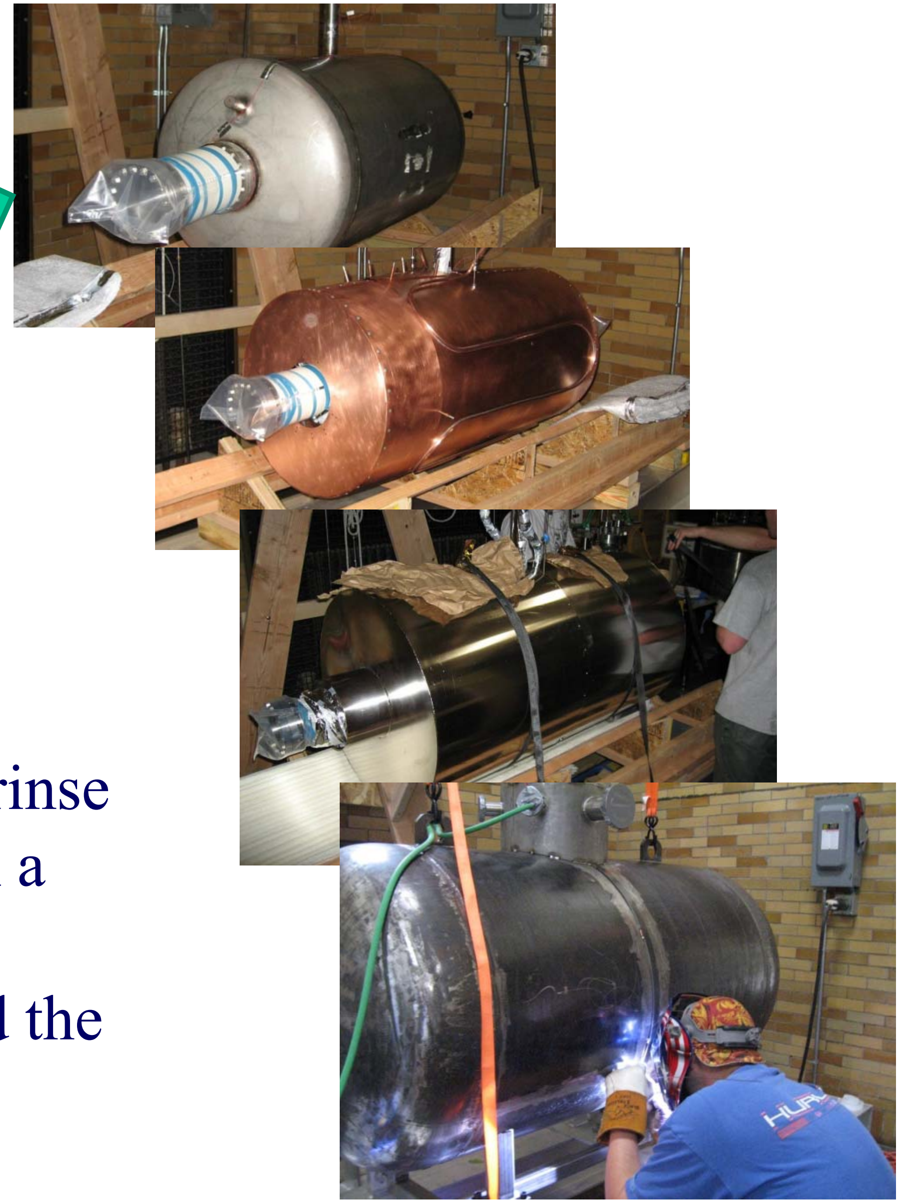

After the acid etch, a high pressure rinse with ultrapure water is performed in a cleanroom at Niowave. Then the cryomodule is assembled – we build the bottle with the ship already inside!

Room-temperature RF tests

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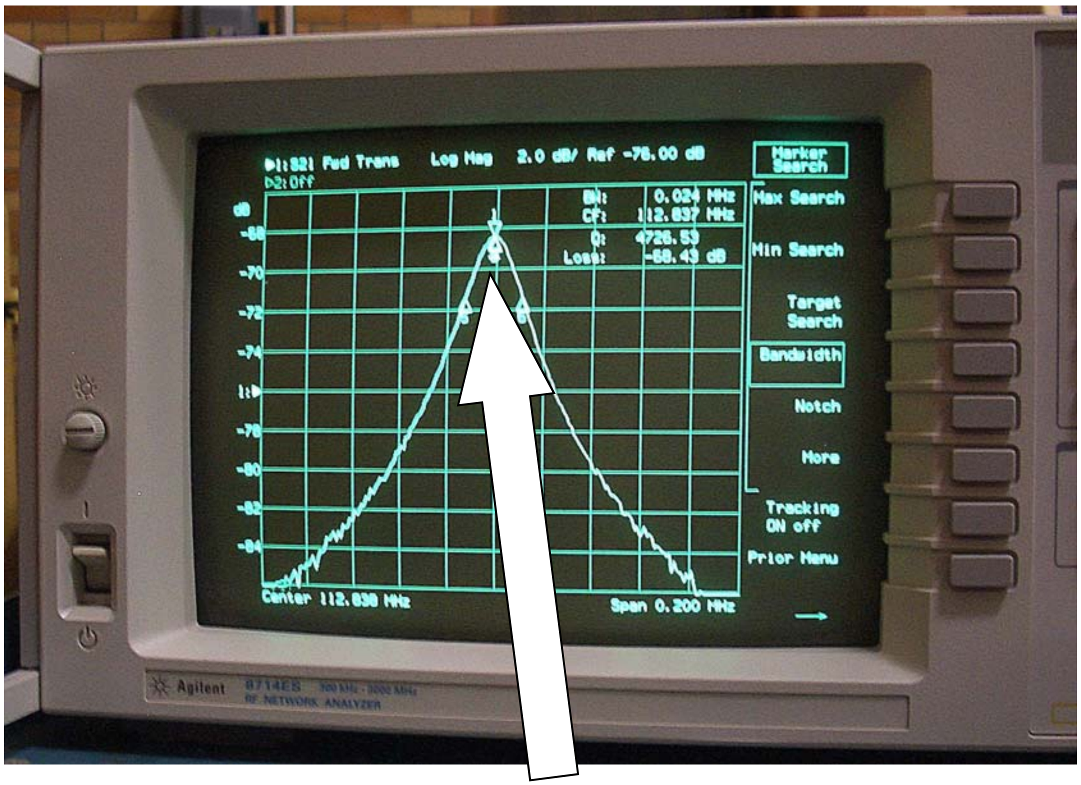
Measured room-temperature frequency and Q value show good agreement with the design simulations.



Resonant frequency = 112.8 MHz
(Superfish gives 112.3 MHz with cathode)

- With input and pickup antennas very weakly coupled, cavity Q = 4700
- Calculated value for resistance of room-temperature niobium based on skin depth at 112 MHz = 8.5 mΩ (good agreement with literature)

Cryogenic test plan

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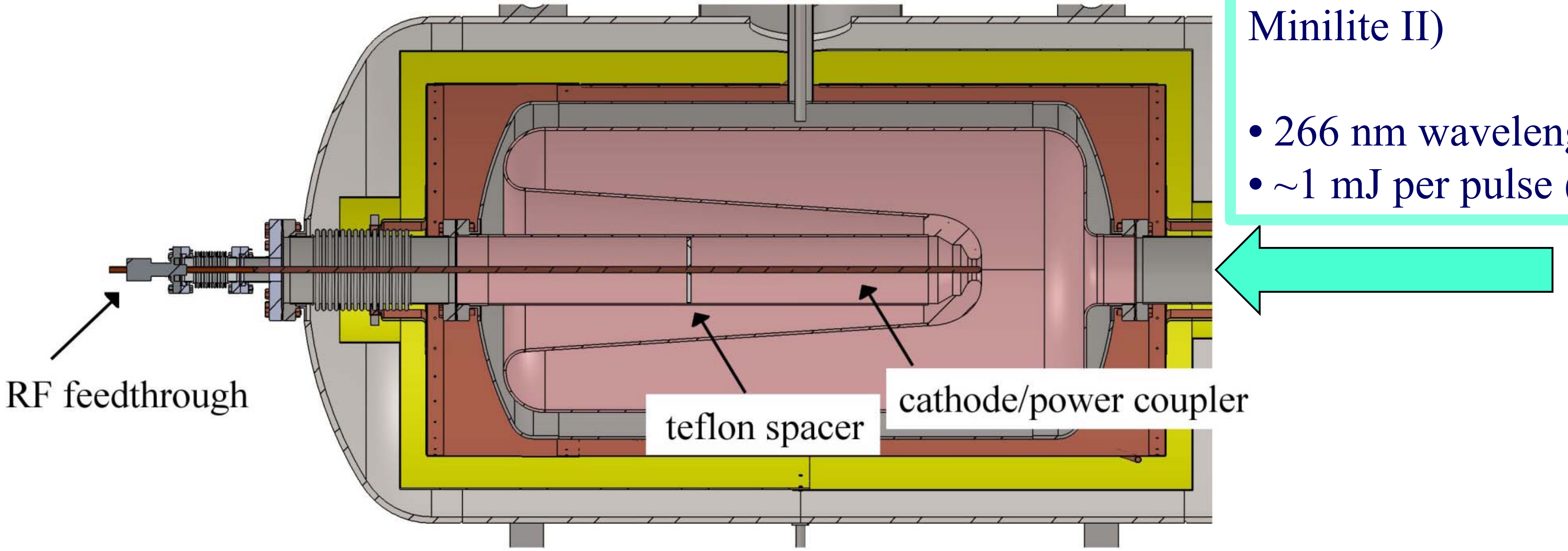

UV laser (Continuum Minilite II)

- 266 nm wavelength
- ~1 mJ per pulse @ 10 Hz

- Cavity cooled in its cryomodule to liquid helium temperature
- SRF performance tested using a solid-state amplifier
  - Q vs. electric field
  - resistance to multipacting/field emission
- Test photoelectron bunches generated with ultraviolet laser

Finished cryomodule

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ready for cryogenic tests, fall 2010