SUPERCONDUCTING 345 MHZ TWO-SPOKE CAVITY FOR RIA

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Abstract

This paper reports development of a two-cell 345 MHz spoke-loaded superconducting cavity intended for the U.S. RIA Project driver linac. The 3 cm aperture cavity has a useful velocity range 0.3c < v < 0.6c. In initial tests at 4 K the prototype cavity operated cw at peak surface electric fields as high as 40 MV/m, and with 20 Watts of rf input power provides 3 MV of effective total accelerating voltage. As constructed, the niobium cavity shell was fully housed in an integral stainless-steel helium vessel using pure copper braze joints at the niobium to stainless-steel transitions.

1 INTRODUCTION

A superconducting (SC) multi-ion driver linac for the RIA project will consist of nearly 400 SC cavities of several types which span the velocity range $0.02<\beta<0.84$. This paper reports the first cold test results on one of these cavities, a fully jacketed two-cell spoke cavity with geometric $\beta=0.4$. This represents the first test of a multi-cell spoke cavity and continues the development of spoke cavities that began with 350 MHz single-spoke cavities of $\beta=0.29$ and $\beta=0.4$ successfully tested at ANL previously[1-3]

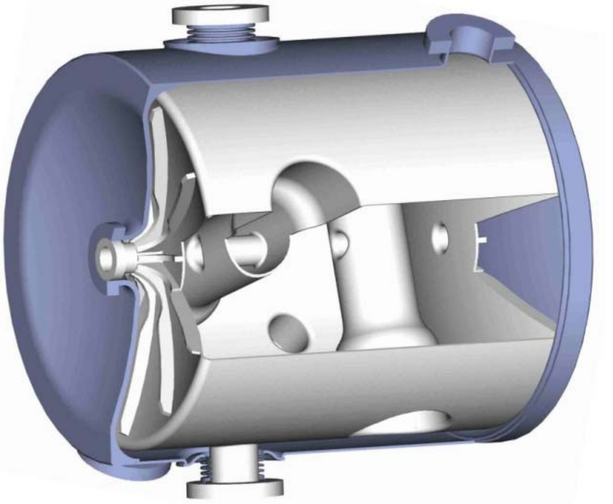

Figure 1: Cut away view of a 345 MHz two-cell spoke cavity. The niobium housing diameter is 48 cm and the active length is 39 cm.

2 FABRICATION

The major niobium components of the two-cell spoke resonator were formed from 3 mm RRR=250 niobium sheet. The transverse spoke elements were die formed in halves (Advanced Energy Systems). The niobium housing was rolled from flat 3 mm sheet. The spherical end walls were die-formed and then stiffened with 12 radial gussets cut from 6.25 mm niobium sheet. The dies constructed would be entirely suited for a production run. Existing dies for the two-cell spoke cavity are suitable for mass production for RIA.

The integral stainless steel helium jacket, shown partially cut away in Figure 1, was rolled from 3mm sheet while the end walls were machined from plate stock. Liquid helium can circulate in the annular space, of about ½ inch, between the niobium cavity and the stainless steel jacket. A niobium to stainless steel transition, using a pure copper braze, was used for the two axial beam ports, of 3 cm diameter, and the three radial coupling ports, of 5.08 cm diameter.

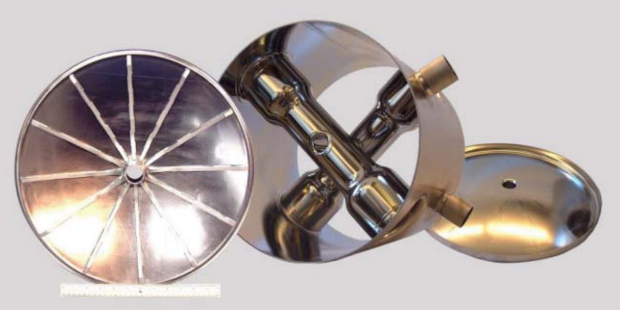

Figure 2: Three pieces of the two-cell spoke cavity after receiving a heavy electropolish.

3 CAVITY TESTING

3.1 Surface Processing

The cavity has no access ports sufficiently large to permit electropolishing of the completed cavity. To enable adequate surface processing while minimizing surface roughness, the niobium elements of the cavity as shown in Fig. 2 were initially processed just prior to the final closure EB welds by a heavy electropolishing which removed 100~150 microns of niobium. The completed cavity was then finally processed by a light, ~10 micron, chemical polish in a solution of 1:1:2 BCP at T = 15 C to remove possible weld residue. This technique greatly reduces the surface roughness that would result from a heavy BCP alone. Following the BCP, the cavity was rinsed and filled with clean deionized water.

The ANL high-pressure rinsing system, consisting of a high-pressure pump and an automated spray wand, was used to remove particulates from the interior cavity

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surface prior to final assembly into a test cryostat. The rinsing system supplied 15 liters per minute of ultrapure deionized water through eight 6.1 mm diameter jets at a nozzle pressure of 115 bar. The cavity was rinsed for 80 minutes in a curtained clean room while moving the spray wand in and out along the beam axis several times.

3.2 Clean Assembly

A horizontal test cryostat was built for the two-cell cavity incorporating the following features:

- A cleanable, low-particulate, variable 7 kW rf coupler.
- Clean room assembly of the cavity and rf coupler, the cavity vacuum being sealed prior to installation into the cryostat (See Figure 4.)
- Separate cavity and cryogenic vacuum spaces to maintain cavity cleanliness
- A dedicated connection to the existing ATLAS He refrigeration system which enables long-term tests
- A 7 kW cw 345 MHz rf power source which enables pulse-conditioning and also overcoupling to maintain phase control in the presence of microphonic- induced frequency fluctuations.

3.3 Cold Tests

Tests following the first cooldown to 4.2 K were performed with up to 5.5 kW of rf power for pulse conditioning of surface emitters at the higher fields. The observed Q for low fields was $\approx 1.3\text{x}10^9$ corresponding to a residual surface resistance R_S of 17 nΩ. BCS resistivity contributes 38 nΩ at this frequency and temperature. Following rf pulse conditioning, stable cw accelerating fields of E_a=11.5 MV/m were reached as shown in Figure 3., which correspond to a peak surface electric field of E_{peak}=40 MV/m. RF parameters for the two-cell spoke cavity are shown in Table I.

Electron loading was observed first at accelerating fields around 5 MV/m as evidenced by x-ray emission, but was reduced by conditioning for with short duration (~10 ms) high-power pulses and with the cavity strongly overcoupled. After several hours of conditioning, no further reduction of electron loading could be obtained.

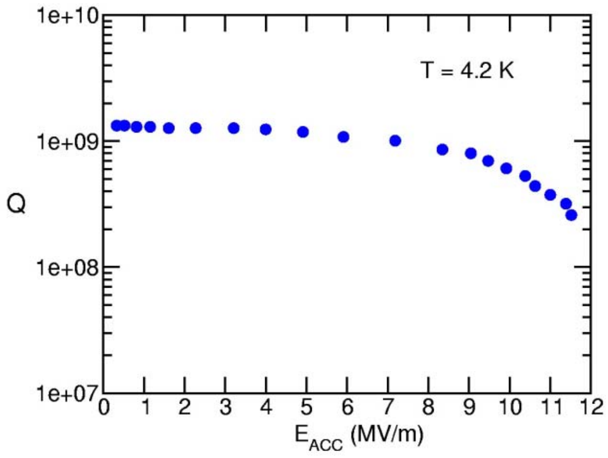

Figure 3: The first cold test results of a two-cell spoke cavity at 4.2 K following high-pressure rinse, clean assembly and high-power rf pulse conditioning

Table I. RF parameters for the β=0.4 two-cell spoke

	Calculated	**Measured**
frequency	347.072 MHz	347.623 MHz
Active Length =	-	39 cm
β_{Geom} =	0.393	0.393
QR_S =	71	-
U_o* =	151 mJ	147 mJ
E^*_{peak} =	3.47 MV/m	-
B^*_{peak}=	69 G	-

*At an accelerating field of 1 MV/m

Figure 4: Clean room assembly of a horizontal test cryostat for the two-cell spoke cavity. The system incorporates separate cavity and cryostat vacuum systems to enhance cleanliness.

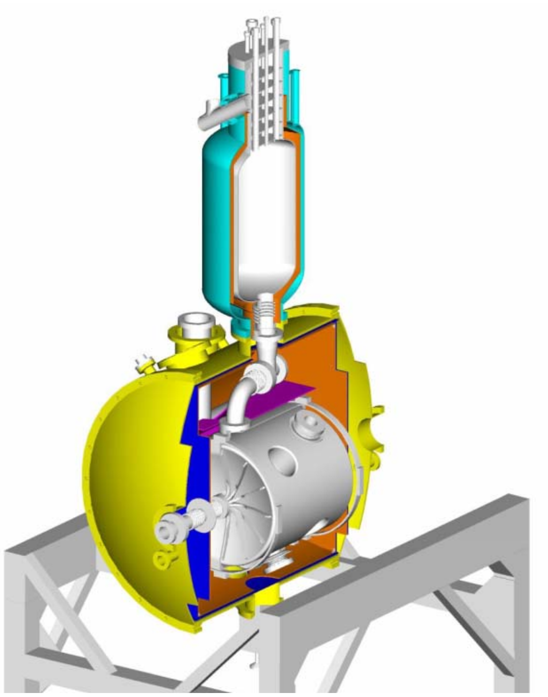

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Figure 5: The horizontal test cryostat for the to-cell spoke cavity with separate vacuum systems for the cavity interior and the cryogenic insulating vacuum

3.4 Horizontal Test Cryostat

The present series of tests represent the first tests of a fully-featured SC drift-tube cavity suitable for the RIA linac operated on a refrigerator in a realistic accelerator environment. The two-cell cavity has been tested oriented horizontally as shown in Figure 5. and uses a stainless steel jacket fully integrated with the niobium cavity to house the liquid helium bath. A movable high-power rf coupler was assembled in a clean room together with the cavity and is an integral part of the separate cryostat and cavity pumping systems required to maintain cleanliness for long term operation at high fields.

4 CONCLUSION

The first two-cell spoke loaded SC cavity, which operates at f_o=345 MHz and has β_{opt}=0.4, has been successfully tested at cw accelerating fields up to 11.5 MV/m (E_{PEAK}=40 MV/m). Surface processing using a combination of electropolishing, chemical polishing, and high-pressure rinsing has resulted in a low level Q of 1.3x10^9 at 4.2 K, implying a residual surface resistance of 17 nΩ. As tested, the resonator is in a 'fully dressed' form with forming dies and fabrication techniques suitable for production for the RIA driver linac.

5 ACKNOWLEDGEMENTS

The authors would like to thank Jean Delayen (JLAB) and Dale Schrage and Tsuyoshi Tajima (LANL) for many helpful discussions. We also acknowledge the contribution of Sciaky, Inc. in developing and performing the required electron-beam welds.

This work was supported by the U.S. Department of Energy, Nuclear Physics Division, under contract number W-31-109-ENG-38.

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