TEST RESULTS OF THE LANL 350 MHZ, BETA=0.175, 2-GAP SPOKE RESONATOR*

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Abstract

Two 350-MHz β = 0.175 two-gap superconducting (SC) spoke resonator cavities have been fabricated in industry under an R&D project for the Advanced Accelerator Applications (AAA) program at LANL. This paper describes the structure, presents the test results of mechanical properties, tuning sensitivity at room temperature, and Q – E curves at 4 K. A maximum accelerating field of 11.6 MV/m has been obtained, which exceeds our present goal of 7.5 MV/m with ample margin.

1 INTRODUCTION

The AAA program goal is to develop the technologies required for transmuting radioactive nuclear waste into shorter-lived, less-toxic material [1]. A proton linac operating at 600 MeV and 13.3 mA has been considered for demonstration of the transmutation [2].

SC spoke cavities are good candidates for low-energy sections of this linac. In addition to significantly less operational costs as compared to normal conducting structures, SC spoke cavities would give benefits such as fewer activation problems due to larger beam aperture.

2 DESIGN OF THE CAVITY

A RF and mechanical design using MAFIA, Microwave Studio (MWS) and MICAV has been performed [3]. Table 1 summarizes the geometry of the cavity. Figure 1 shows cut-away design views (top) and the fabricated cavity made of niobium (bottom).

Table 1: The cavity dimensions [4]

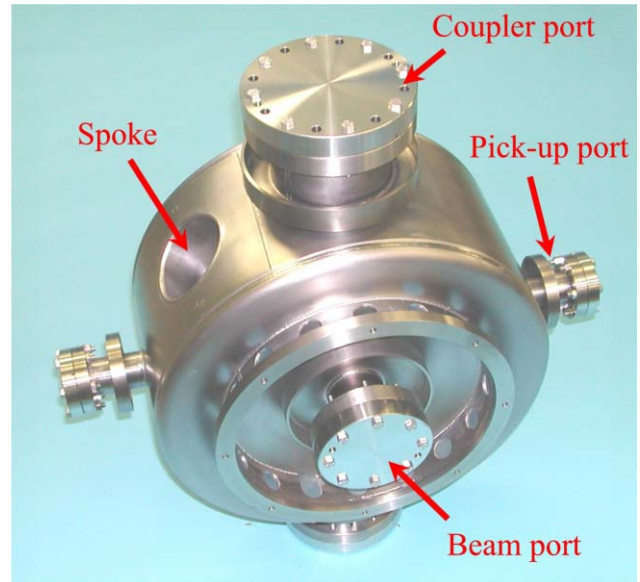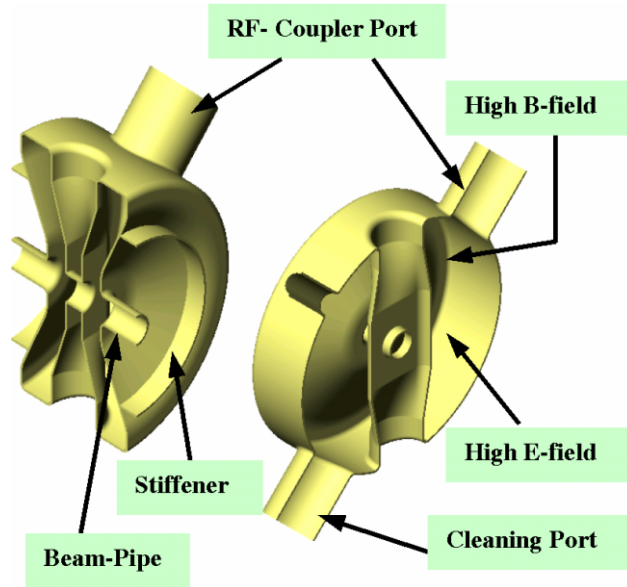| Cavity Radius	19.609 cm
Spoke Radius at Base	4.5 cm
Spoke Thickness at Aperture	3.5 cm
Spoke Width at Aperture	11.44 cm
Aperture Diameter	5.00 cm
Cavity Length (gap-to-gap)	9.99 cm
Cavity Overall Length	19.99 cm
Cavity Length (flange-to-flange)	28.6 cm
Coupler Port Diameter	10.3 cm
Pick-up Port Diameter	3.81 cm
Initial Nb thickness	3.5 mm

Figure 1: Cut-away design views (top) and the fabricated LANL β=0.175, 2-gap spoke cavity made of niobium (bottom).

Table 2 shows the RF parameters. The E_{peak}/E_{acc} and B_{peak}/E_{acc} ratios have been well optimized as shown in the Table.

Table 2: Design RF parameters [5]

Q_0 (4 K)	1.05E+09 (for 61 nΩ)
T (β_g)	0.7765 (β_g=0.175)
$T_{max}(\beta)$	0.8063 (@ β=0.21)
G	64.1 Ω
E_{pk}/E_{acc}	2.82
B_{pk}/E_{acc}	73.8 G/MV/m
P_{cav} (4 K)	4.63 W @ 7.5 MV/m
R/Q	124 Ω

3 PREPARATIONS FOR THE TESTS

We have prepared one cavity (EZ02) for RF tests. After buffered chemical polishing (BCP) with a mixed solution of $HF:HNO_3:H_3PO_4$=1:1:2 by volume, we high-pressure rinsed (HPR) the cavity with ultra-pure water at ~1200 psi for ~ 40 minutes in a class-100 clean room. Figure 2 shows the cavity being high-pressure rinsed.

Figure 2: The cavity being high-pressure rinsed with ultra-pure water at ~1200 psi. The cavity rotates at ~ 23 rpm and the HPR wand sweeps the cavity vertically at 3.9 mm/s (up) and 7.5 mm/s (down).

We baked the cavity at 90 – 120 °C for ~ 50 hours, after setting on the cryostat insert and pumping, right before inserting it into the vertical cryostat. The cavity was then indirectly pre-cooled by filling the liquid-nitrogen layer of the cryostat. Our vertical cryostat has an inner diameter of 965 mm and is 2934 mm deep at the center. Table 3 shows some cryogenic data.

Table 3: Cryogenic data during cooling

Cavity Temp. after Pre-	251 K
Time to reach 50 K after start of LHe transfer	10 min. (bottom), 27 min. (top)
Time to reach 4 K from start	42 min.
Change of helium level from 4 K to 2 K	26.5 % (Start at 81.1 %)
Time needed to reach 2 K	~ 4 hours

The cavity vacuum monitored at the cryostat lid was 1.5E-8 Torr before helium transfer and 4.9E-9 Torr at minimum during the test.

4 TEST RESULTS

Table 4 shows the frequency change during the preparation and tests. It is especially important for us to obtain the effect of BCP since it is hard to get a good prediction with calculations due to the non-uniformity of the etching in the cavity. Regarding RF tests, we could get only 4 K results due to insufficient coupling at lower temperatures. We plan to measure at 2 K using a movable coupler in the next test.

Table 4: Frequency (MHz) of cavity EZ02

Before BCP at 1 atm	351.803 @ 25.4 °C
After BCP 150 μm at 1 atm	351.329 @ 25.6 °C
Under vacuum (with a vacuum support)	351.683 @ 24.7 °C
At 4 K during test	352.506 @ 4 K
At 2 K during test	352.792 @ 2 K
After warm up to room temperature under vacuum	351.601 @ 13.9 °C

4.1 4 K Test Result of EZ02

In the first test, we attempted to feed power through the nominal power coupler port with a movable coupler, but the loaded Q showed only 1E6 to 1E7 for a tip retraction of 6.3 cm and 12 cm from the cavity, respectively, indicating too much coupling.

In the second test, we used a fixed coupler attached to one of the beam ports and with the nominal coupler port blanked off with a niobium flange. Transmitted power was picked up with a coupler attached to one of the small radial ports.

Figure 3 shows the $Q_0 - E_{acc}$ curve at 4 K and Table 5 summarizes the result. We experienced some difficulty in locking the cavity phase for a few hours due to electron activity in the cavity.
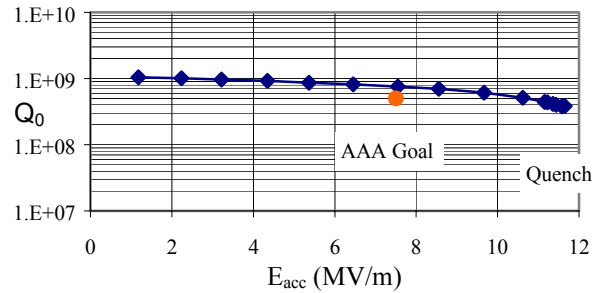

Figure 3: Q-E curve of the cavity EZ02 at 4 K.

Table 5: Summary of the cavity EZ02 test at 4 K

Low-field Q_0	1.04E+9 @E_{acc}=1.19 MV/m
$E_{acc, max}$	11.6 MV/m
Q_0 at E_{acc}=7.5 MV/m	7.6E+8
$E_{p, max}$	32.8 MV/m
$B_{p, max}$	856 Gauss
Field limitation	Quench
Frequency sensitivity of pressure (near 1 atm)	-260 Hz/Torr
Lorentz Force Detuning /E_{acc}^2	-6.4 Hz/(MV/m)^2

4.2 Mechanical tests at room temperature

Using cavity EZ01, we tested mechanical properties. Some details of the measurement are similar to [6]. Figure 4 shows the cavity set on the test bench. Two displacement sensors were set on the two ends in the axial direction. The right moving arm pushes or pulls the cavity along the cavity axis and its load was measured as well as cavity frequency shifts.
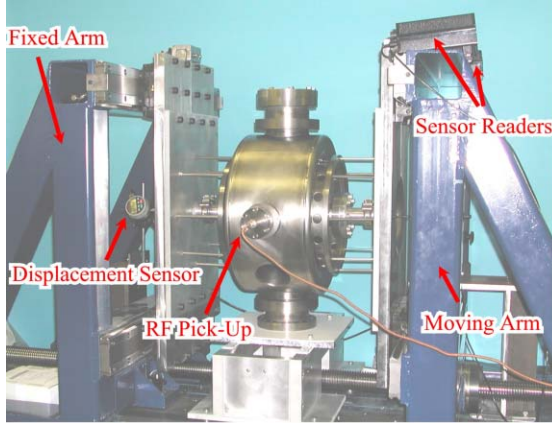

Figure 4: Test set up for tuning sensitivity and mechanical stiffness measurements.

Table 6 summarizes the results, which show good agreement with the MICAV predictions.

Table 6: Mechanical properties at room temperature.

PARAMETER	**MICAV**	**MEAS.**
Tuning Sensitivity (kHz/mm)	+894	+783
Structure Spring Constant (N/mm)	1.02E4	6.53E3

4.3 Field distribution

We performed a bead-pull measurement on the beam axis. Figure 5 shows the result. The field balance between the two gaps was excellent as shown in Fig. 5.
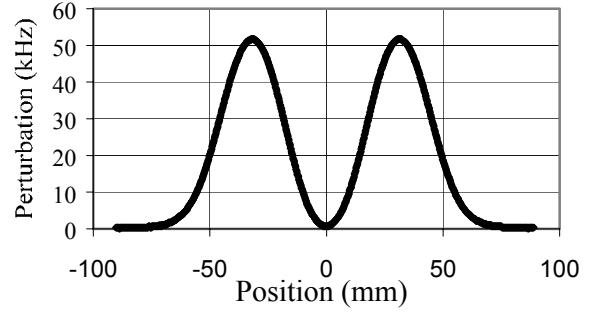

Figure 5: Result of bead-pull measurement of cavity EZ01. Position 0 denotes the center of the spoke. This equality of the two gaps shows the excellent field balance in the two gaps.

5   SUMMARY AND FUTURE PLAN

Two LANL spoke cavities have been fabricated at Zanon recently. One of the cavities has been tested at 4 K and has exceeded the AAA goal of 7.5 MV/m with enough margin for reliable operations. We will test the second cavity soon. In the future, we hope to install the cavities at the output of our Low Energy Demonstration Accelerator (LEDA) RFQ and to test with a beam.

Regarding R&D for the spoke cavity, we plan to develop a diagnostic system to locate the regions of electron activity and cause of quenches in the cavity.

6 ACKNOWLEDGEMENT

7 REFERENCES

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[4] F. Krawczyk et al., "Design of a β=0.175 2-Gap Spoke Resonator," ibid [1]. http://laacg1.lanl.gov/scrflab/pubs/spoke/LA-UR-01-4989.pdf

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