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RESULTS OF TWO LANL β = 0.175, 350-MHZ, 2-GAP SPOKE CAVITIES*

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Abstract

Two β = 0.175, 350 MHz, 2-gap superconducting (SC) spoke cavities were fabricated in industry under the Advanced Accelerator Applications (AAA) project for the transmutation of nuclear waste. These cavities are promising candidates for the accelerating structures between a RFQ and the elliptical SC cavities for proton and heavy ion linacs. Since their delivery in July 2002, they have been tested in terms of mechanical properties, low-temperature performance, i.e., Q_0-E_{acc} curves at 4 K and 2 K, surface resistance dependence on temperature and for multipacting (MP). The two cavities achieved accelerating fields of 13.5 MV/m and 13.0 MV/m as compared to the required field of 7.5 MV/m with enough margin for the quality factor. These cavities seem to need more time to condition away MP than elliptical cavities, but MP does not occur once the cavity is conditioned and kept at 4 K. The length of the 103 mm-diameter nominal coupler port was found to be too short for the penetrating field.

INTRODUCTION

The spoke cavity was invented by Delayan and Shepard in the late 80s [1]. It is a half-wave resonator, but has a capability of having multi spokes so that the real estate gradient can be higher. Although this structure has not been used in a real accelerator yet, it has been proven from past bench tests that this structure can be an excellent candidate to support the velocity range of β<0.5 [2], and it could compete with well established elliptical cavities at even higher β [3].

At LANL, we modified our facility to test spoke cavities and successfully tested a spoke cavity on loan from ANL. The result was excellent and we then designed our own cavity at β=0.175. Two prototype cavities, named EZ01 and EZ02, were fabricated at Zanon, Italy, and have been tested at LANL since July 2002. As shown below, the results have been excellent and proved our capability of designing cavities to a predicted level of performance.

DESIGN OF THE CAVITY

A RF and mechanical design using MAFIA, Microwave Studio (MWS) and MICAV has been performed [4]. Figure 1 shows cut-away design views (top) and the fabricated cavity made of niobium (bottom). The cavity diameter is ~ 40 cm, which is about half the size of elliptical cavities of the same frequency. The detailed dimensions can be found in Ref. [5].

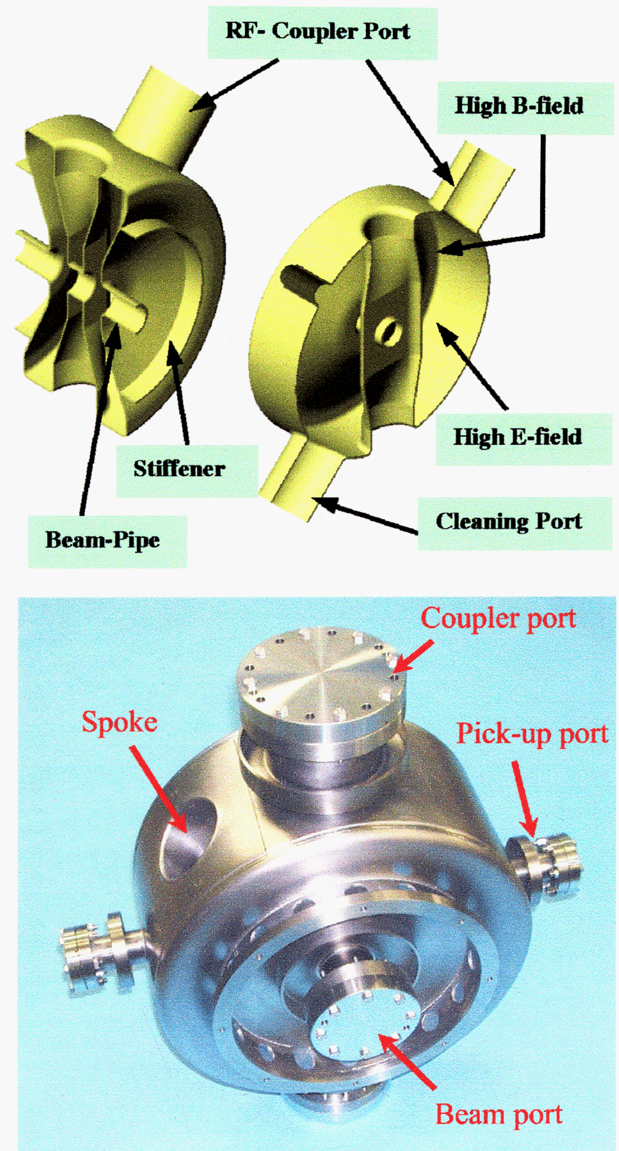

Figure 1: Cut-away design views (top) and the fabricated LANL β=0.175, 2-gap spoke cavity made of niobium (bottom).

Table 1 shows the RF parameters. The E_{peak}/E_{acc} and B_{peak}/E_{acc} ratios have been well optimized as shown in the Table.

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Table 1: Design RF parameters [6]

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}	7.38 mT/MV/m
P_{cav} (4 K)	4.63 W @ 7.5 MV/m
R/Q	124 Ω

TEST PREPARATIONS

The detail of the preparation is described elsewhere [5]. We performed standard 1:1:2 buffered chemical polishing (BCP) of 150 microns. We then high-pressure rinsed (HPR) the cavity with ultra-pure water at ~1200 psi for ~ 40 minutes in a class-100 clean room

After setting the cavity on the cryostat insert and pumping it down, we bake the cavity at ~110 °C for 2-3 days. The typical cavity vacuum monitored at the cryostat lid are 7E-9 to 3E-8 Torr at room temperature after baking, 5E-9 to 1E-8 Torr after pre-cooling and 2E-9 to 5E-9 Torr during the 4 K and 2 K tests.

TEST RESULTS

4 K Tests

Figure 2 shows the $Q_0 - E_{acc}$ curves of two cavities at 4 K and Table 2 summarizes the results. After the first test in August 2002, we disassembled the cavity EZ02 and high-pressure rinsed again and tested in March 2003. Both Q_0 and E_{acc} improved as shown in Fig. 2.

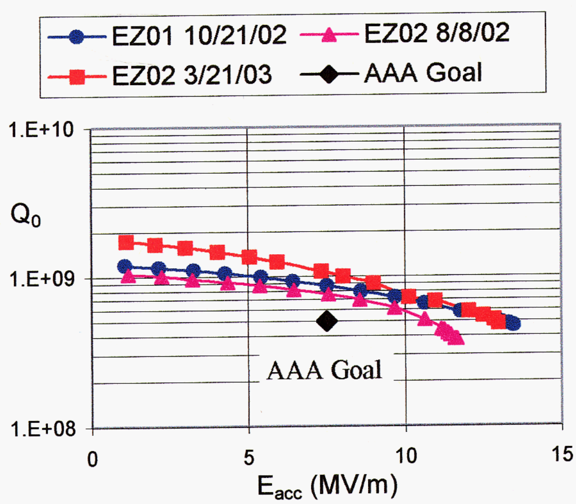

Figure 2: Q_0-E_{acc} curves of the two LANL/AAA cavities at 4 K. Test dates are written in the legend. Repeated high-pressure rinse and helium processing improved the EZ02 result in the second test.

Table 2: Summary of the LANL/AAA spoke cavities test results at 4 K.

Cavity	EZ01	EZ02
Low-field Q_0	1.74E+9	1.04E+9
$E_{acc, max}$ (MV/m)	13.5	13.0
Q_0 at E_{acc}=7.5 MV/m	8.6E+8	1.06E+9
$E_{p, max}$ (MV/m)	38.0	36.6
$B_{p, max}$ (mT)	99.4	95.8
Field limitation	Quench	Quench

2 K tests

Figure 3 shows the results of 2 K tests together with 4 K results. The quench level of the EZ01 at 2 K was the same as that at 4 K, but that of EZ02 was slightly higher than that at 4 K. The data of EZ02 also show the effect of helium processing. A short period (~12 minutes) of processing improved the performance drastically.

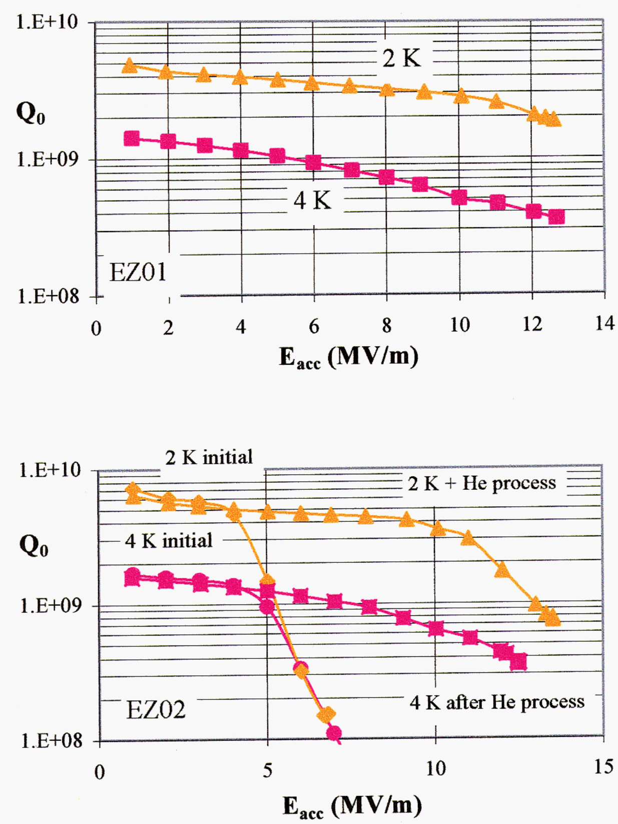

Figure 3: Q_0-E_{acc} curves at 2 K together with 4 K data. The EZ02 data also include the curves before helium processing. After ~12 minutes of helium processing the performance improved drastically.

Residual resistance

We measured Q_0 at E_{acc}~1 MV/m during the cooldown from 4 K to 2 K. By fitting the surface resistance, $Rs=G/Q_0$, as a function of 1/T, we determined the residual resistance of EZ01 and EZ02 to be 12 nΩ and 10 nΩ, respectively.

ISSUES FOR FUTURE DEVELOPMENTS

Penetrating field at the nominal coupler port

It was found during our tests that the length (9.2 cm) of the 103 mm-diameter nominal coupler port was too short to avoid penetrating field. The results shown above were measured with niobium (Nb) blank flanges attached on these ports. When we tested with one stainless steel (SST) flange on one of these ports and one Nb blank on the other, the Q_0 was ~ 80 % lower as shown in Fig. 4.

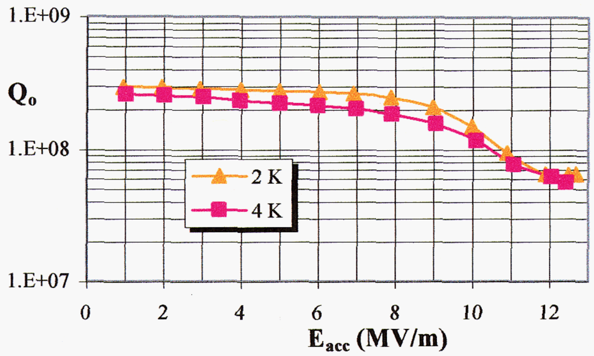

Figure 4: The Q_0-E_{acc} curves at 4 K and 2 K of the cavity EZ01 with one stainless steel flange attached on the 103-mm-diameter nominal coupler port. The small increase of the Q_0 from 4 K to 2 K indicates the loss being dominant at the SST flange.

A simulation using MWS with the real configuration, i.e., a SST flange and a copper gasket, predicted Q_0 of 2.4E8 in good agreement with the measured 2.6E8.

To know the port distance required to avoid the field penetration, a model that has a 10 cm long spool piece made of SST terminated with a Nb plate attached on the coupler port was generated as shown in Fig. 5. Figure 6 shows the cavity Q_0 calculated with different additional port length. An extension of 5 cm was determined to be enough to avoid the effect of the penetrating field.

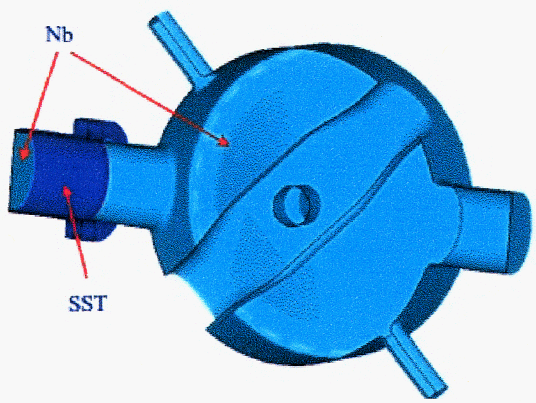

Figure 5: A model for the Microwave Studio calculations. A spool piece made of SST and ended with a Nb plate was added to one of the nominal coupler ports and the cavity port length was changed.

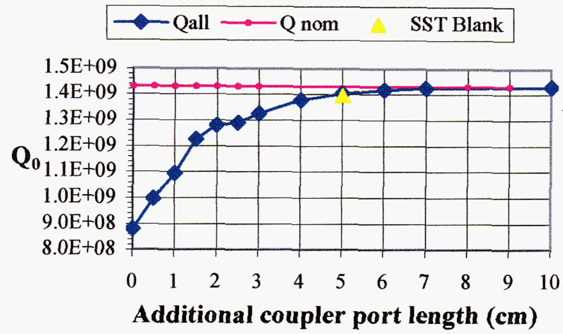

Figure 6: The MWS calculation of Q_0 as a function of the additional port length. This shows that the penetrating field will not affect Q_0 with > 5 cm extension.

Multipacting(MP), field emission and quench

We have encountered the situation where we need conditioning for a few hours to process the MP. This usually occurs the first time we cooldown the cavity to 4 K and after warming up to room temperature. The persistent MP levels are at E_{acc}=1-2 MV/m and 4-6 MV/m.

Regarding field emission, according to the X-ray data taken using a NaI detector put on the cryostat lid, EZ01 and EZ02 started showing some X-rays caused by emitted electrons from E_{acc} = 10.7 MV/m and 9.4 MV/m, respectively, after helium processing.

Both cavities quench at similar gradients. Whether this was caused by field emitted electrons or defect(s) is unknown and remains to be identified as well as the quench locations.

SUMMARY

The two LANL designed spoke cavities have shown excellent results, encouraging us to strive for multi-spoke cavities for better real estate gradients as well as the development of the nominal coaxial power couplers.

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REFERENCES

[1] J. R. Delayen, Nucl. Instrum. Meth. B40/41 (1989) 892.
[2] T. Tajima et al., Proc. PAC2001 (2001) 903.
[3] K. W. Shepard et al., Proc. LINAC2002 (2002).
[4] F. Krawczyk et al., 10th Workshop on RF Superconductivity, Tsukuba, Ibaraki, Japan, Sep. 6-11, 2001. http://laacg1.lanl.gov/scrflab/pubs/spoke/LA-UR-01-4989.pdf
[5] T. Tajima et al., Proc. LINAC2002 (2002).
[6] F. Krawczyk et al., Proc. EPAC2002 (2002) 272.