STATUS OF THE LANL ACTIVITIES IN THE FIELD OF RF SUPERCONDUCTIVITY*

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Abstract

The activities at LANL in the past two years since the last workshop are described. The main theme of our activity was the development of spoke cavities for low-energy sections of high-power proton accelerators. We designed and procured two 350 MHz, beta=0.175, 2-gap spoke cavities from industry and tested them. Both cavities have shown excellent performance, i.e., accelerating gradients of 13-13.5 MV/m with low-field unloaded Q of >1E9 as compared to required 7.5 MV/m and 5E8, respectively. Some results on the Q-disease tests using these cavities and RF surface resistance measurements of magnesium diboride (MgB_2), a relatively new high Tc material with transition temperature of 39 K, will also be shown.

INTRODUCTION

Through the formerly-called Advanced Accelerator Applications (AAA) project for the transmutation of nuclear waste, we have developed low-β (0.175) 350-MHz spoke cavities for the lower-energy section of the Accelerator Driven Test Facility (ADTF) [1].

Due to the decision of DOE to focus on the transmutation science, the funding has been stopped since FY03.

While we are looking for some other funding sources, some small R&D on higher-T_c materials for future advancement to exceed the benefit of Nb cavities has been carried out.

SPOKE CAVITY DEVELOPMENT

Table 1 and Figure 1 show the design RF parameters, and the design views with a photograph of the cavity manufactured at Zanon, Italy.

Table 1: Design RF parameters [2].

Q_0 (4 K)	1.05E+09 (for 61 nΩ)
T (β_g)	0.7765 (β_g=0.175)
T_{max}(β)	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

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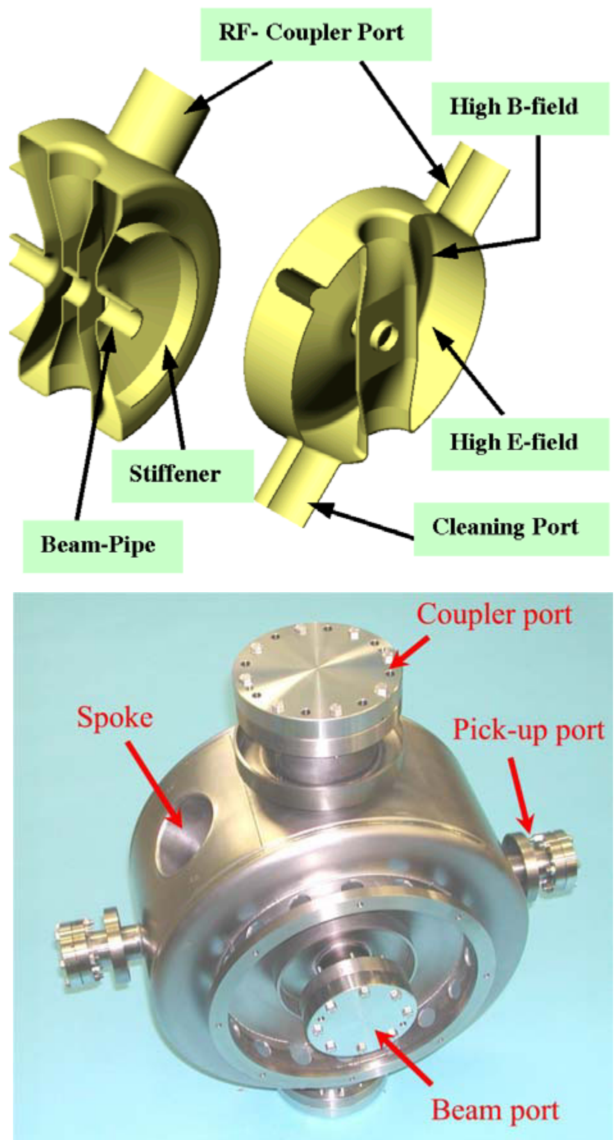

Figure 1: Cut-away design views (top) and the fabricated LANL β=0.175, 2-gap spoke cavity made of niobium (bottom).

Since further details are written in [3-5], the results are only shown briefly here. 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.

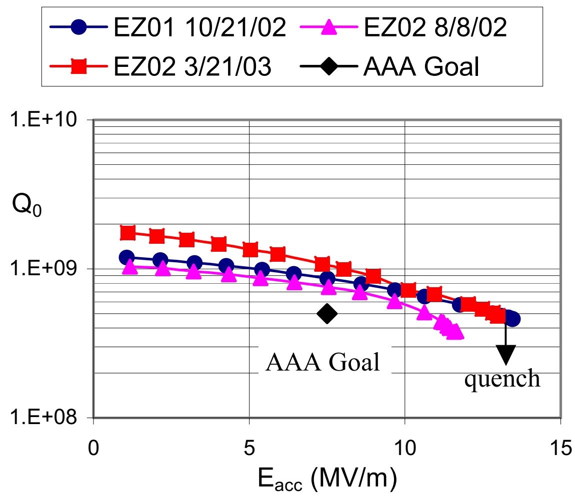

Figure 2: Q_0-E_{acc} curves of the two LANL/AAA cavities at 4 K. Test dates are written in the legend. Repeated high-pressure rinse and helium processing improved the EZ02 result in the second test.

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

Cavity	EZ01	EZ02
Low-field Q_0	1.04E+9	1.74E+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

Field Penetration through 103-mm Ports

The above results are obtained with the 103-mm-diameter ports blanked with Nb flanges. These large ports are for a nominal input power coupler for 100-mA operations and cleaning purposes. It turned out that the port length (9.2 cm) is too short to avoid the effect of normal conducting loss on the flange attached. Experiments and MWS calculations predict that an extension of 5 cm is enough to eliminate this effect [5].

Issues Remaining to be Addressed

Due to the funding shortage, we were unable to continue testing. The following are the issues that remain to be addressed

- Effect of the nominal coupler on the cavity resonant frequency and unloaded Q
- Cavity stiffening and measurements of microphonics
- Identification of the cause of the field limitation
- Procurement and test of the nominal couplers designed [6]
- Beam tests of the cavity-coupler module in a horizontal cryostat in an accelerator

Q-DISEASE TESTS

Since we have not degassed hydrogen by baking at high temperatures (>600), we were concerned about this effect. A detailed study has been carried out using the above-mentioned spoke cavities [7, 8].

The test results have shown that the Q disease does not occur up to 24 hours of holding the cavity at 100 K, but longer holding time will increase the RF surface resistance linearly with the holding time. Figure 3 shows the result and it was also found that the slope of this increase is different between the two cavities, which seems to be dependent on the hydrogen content in the material. We started studying the hydrogen content and depth profile in our Nb material with various treatments such as BCP, EP and exposure to water. Some results on this are shown in [9].

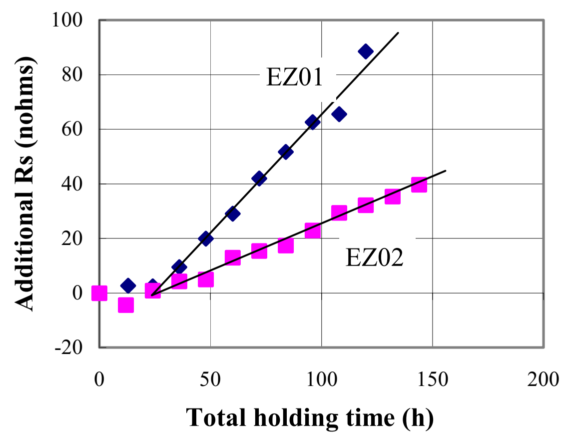

Figure 3: Additional surface resistance due to Q disease as a function of accumulated holding time at 100 K. The data was taken at E_{acc}=4 MV/m.

HIGHER-T_C MATERIALS STUDY

Thanks to the TESLA collaborations, the Nb cavity technology has advanced to the point that the achievable electromagnetic field is approaching ~80 % of the theoretical limit even with 9-cell cavities [10].

It would be a long way to improve the fields further in a practical sense and may not be worthwhile to pursue it. Therefore, we need to start developing new superconducting materials that have potential to exceed the Nb theoretical limits and lower RF losses.

Since some successful demonstration has been made with a 1.5-GHz single cell cavity [11], Nb_3Sn is presently the closest to the practical applications. While we are planning to learn the method of forming the Nb_3Sn layer and improve it in the future, we have also started to study magnesium diborite (MgB_2) for this application [12].

In collaboration with University of California, San Diego (UCSD), we have measured the RF surface resistance of a MgB_2 disk (25.0 mm in diameter 4.60 mm in thickness) fabricated at UCSD [13] using our 21-GHz TE011 mode copper cavity and a cryo cooler.

Figure 4 shows the RF surface resistance (R_s) scaled with f^2 law to 10 GHz as a function of temperature. In the figure, three results are shown. One (green) is of the as-received surface, i.e., grit 120 SiC grinding and the other two are those after polished with sand paper down to 0.3 µm and 0.1-µm diamond lapping paper followed by 1500-psi ultra-pure water rinse in the clean room. The figure also includes the results of Findikoglu et al. of Superconducting Technology Center (STC) at LANL [14] using the MgB_2 sample fabricated by the same method at UCSD and the BCS surface resistance of Nb at 4 K. Our polished and high-pressure rinsed data show significantly lower R_s than those of Findikoglu, indicating that there is still room to improve with better surface treatment. Also, SEM images of the surface show some porosity and this can probably be reduced with an improved fabrication method. More results and further details are described in Ref. [15].

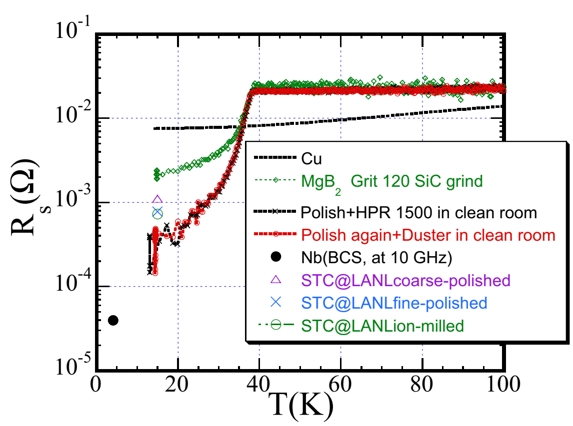

Figure 4: RF surface resistance of MgB_2 scaled to 10 GHz with f^2 law, together with the data from [14], oxygen-free copper and Nb BCS resistance.

SUMMARY AND FUTURE PLANS

Despite the funding shortfall in FY03, we have done a significant amount of work with spoke cavities and in higher-T_c cavity studies.

We plan to address those issues mentioned above on the spoke cavities as soon as funding gets available and will continue studies on the higher-T_c materials such as Nb_3Sn and MgB_2 for the application to future RF structures.

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