SUPERCONDUCTING RF ACTIVITIES AT LANL*

T. Tajima[#], G.V. Eremeev, F.L. Krawczyk, LANL, Los Alamos, NM 87545, U.S.A.

Abstract

Activities related to superconducting RF at LANL in the last 2 years are presented. They include developments of a full cavity thermometry system for standard 1.3 GHz 9-cell cavities, a surface inspection system and high-gradient SRF cavities at 805 MHz, the frequency at which LANL's 800-MeV proton accelerator operates, in order to boost the energy to ~1.2 GeV with only 2 cryomodules. Additionally, we have been studying thin-film superconductors coated on Nb separated by an insulator to increase achievable surface magnetic field for very high accelerating gradient (hopefully ~100 MV/m or higher) to realize a compact accelerator system. High gradient SRF cavities would benefit such applications as the International Linear Collider (ILC), XFELs and cargo interrogation systems using proton or muon beams,

INTRODUCTION

LANL has been involved in 4 activities in the last 2 years: 1) development of a fixed-type full temperature mapping system for 1.3 GHz 9-cell "standard shape" cavities, 2) development of cavity surface inspection system, 3) development of high-gradient 805 MHz cavities, and 4) study of thin film superconductors aiming at future enhancement of cavity accelerator gradients. In the following sections, each activity will be briefly summarized with references for detailed descriptions elsewhere.

1.3 GHZ 9-CELL CAVITY T-MAPPING SYSTEM

We have developed and commissioned a full T-map system for standard shape 9-cell cavities. A total of 4608 temperature sensors made of 100 Ω Allen Bradley carbon resistors surround the entire cavity at every 10 degrees azimuthally, except for the end parts where part of He vessel is installed. The details of the system and some T-map results are described in Refs. [1] through [4].

The advantages of this full T-map system are 1) fast mapping of the entire cavity (within a few seconds), 2) detection of RF losses on the surface before quench, and 3) detection of the heating caused by the electrons generated at other cells.

CAVITY SURFACE INSPECTION SYSTEM

We have developed a system consisting of a cavity holding and moving mechanism and a scope based on a Karl Storz 6.2 mm diameter video scope having a working distance of 7-40 mm and an 80-degree field of view with remote articulation. The image is captured on a 1/10-inch CCD chip installed in the tip having 250,000 pixels in an aspect ratio of 16:9. Figure 1 shows the cavity surface inspection station located in a class 100 clean room.

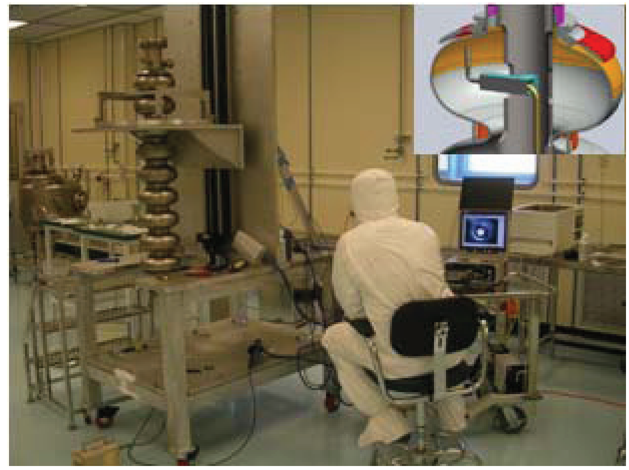

Figure 1: Cavity surface inspection station. Presently, only up/down control is computer controlled. In the inset shown is a design drawing of the inspection with a videoscope.

Theoretically, with our present videoscope, at the shortest distance (~7 mm), the highest resolution is approximately 20 μm/pixel. By replacing the present scope with an 8 mm diameter one with 1/6-inch, 480,000 pixel CCD chip, the resolution will likely be improved.

HIGH-GRADIENT 805 MHZ CAVITY DEVELOPMENT

We are studying the possibility of producing very high gradient (40-50 MV/m) Nb cavities in order to shorten the length of accelerator. The reasons for choosing 805 MHz are its compatibility with LANL's LANSCE proton linac frequency, larger beam pipe aperture, fewer cells, less BCS losses for the same energy gain and operating temperature compared to popular 1.3 GHz cavities.

The disadvantage would be larger diameter and surface area, making the cavity surface quality control more difficult and would lead to larger-diameter cryostats. On the other hand, reducing the number of cells per cavity might lead to a better yield of high-quality cavities and depending on the application, the cryostat diameter can be reduced.

We optimized the cavity design parameters with a constraint of the beam pipe inner diameter of 100 mm. Following the recent trend of reducing the ratio of B_{peak} to E_{acc} to get higher gradient, we designed 3 types, i.e., standard, low-loss and re-entrant shapes [6]. By "standard", we mean a cell shape with inclined walls to facilitate easy draining of rinsing water in a vertical

*Work supported by DTRA
[#]tajima@lanl.gov

position. The optimized B_p/E_a ratios for standard, low-loss and re-entrant cavities are 3.75, 3.60 and 3.57 mT/(MV/m), respectively. Compared to the ILC standard shape B_p/E_a = 4.15, we were able to obtain significantly better ratio.

In collaboration with JLab, we have fabricated 3 standard-shape single-cell cavities and tested one of them so far. See the detail of test results in Ref. [6]. Unfortunately, the 150 μm buffered chemical polishing (BCP) performed at LANL created a number of bubble traces on the cavity surface, causing a lot of field emissions. However, the achieved accelerating gradient of ~22.5 MV/m, limited by available power as shown in Fig. 2, was not so bad. The other 2 cavities will be tested after BCP by the end of 2009, and we might add electropolishing (EP) later to see the difference in the result.

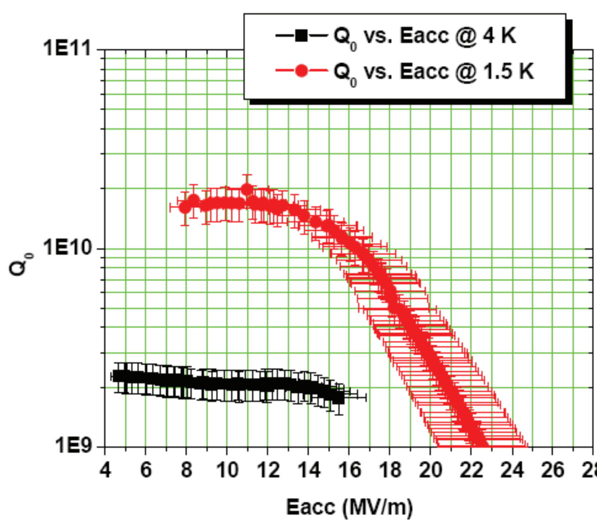

Figure 2: First result of β=1 805 MHz single-cell cavity having standard shape with the parameters optimized for high gradient.

STUDY OF THIN FILM SUPERCONDUCTORS COATED ON NB

The hard limit on accelerating gradient for Nb cavities in standing wave mode seems to be ~50 MV/m due to the RF critical field of ~200 mT for Nb, assuming the B_p/E_a ratio of ~4 mT/(MV/m).

In 2005, Gurevich suggested a way to increase this limit using multi-layer coating of a different superconductor that has higher T_c than Nb [7]. One of the key elements of this proposal is the fact that the lower critical magnetic field H_{c1} that is parallel to the material surface significantly increases if the film thickness gets less than its London penetration depth.

Following this idea, we tested a sample of MgB_2(100 nm)/B(10 nm)/Nb at SLAC using TE_{013} mode Cu host cavity. Here, the Nb substrate was a single-crystal bulk of 2 inches in diameter and ~1 mm thick. The details of coating method and results are described in Refs. [8] and [9].

Figure 3 shows Q_0 as a function of temperature at low power for the coated and uncoated Nb samples. The effect of MgB_2 layer is clearly seen as the increase of Q_0 starting from ~37 K where superconducting transition of MgB_2 occurred. After the Nb transition at ~9 K, the Q_0 seems to become dominated by the resistance of host copper cavity. To know the detail of surface resistance at 4 K or 2 K, the host cavity needs to be made of Nb.

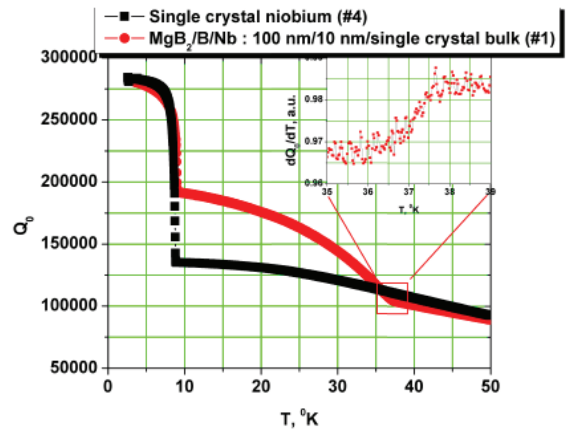

Figure 3: Q_0 vs. Temperature at low field for bulk Nb (black) and MgB_2/B/Nb sample (red). The T_c of MgB_2 was measured to be ~37 K. The transition of Nb is also seen since the MgB_2 thickness (100 nm) is thinner than the penetration depth.

Figure 4 shows cavity Q_L as a function of peak surface magnetic field on the sample for Nb and MgB_2 coated Nb. It was found that, for this sample, the breakdown field was significantly lower (~40 mT) than Nb sample. Since this is the only one sample tested, we do not know if this is caused by the coating or some defects on the Nb.

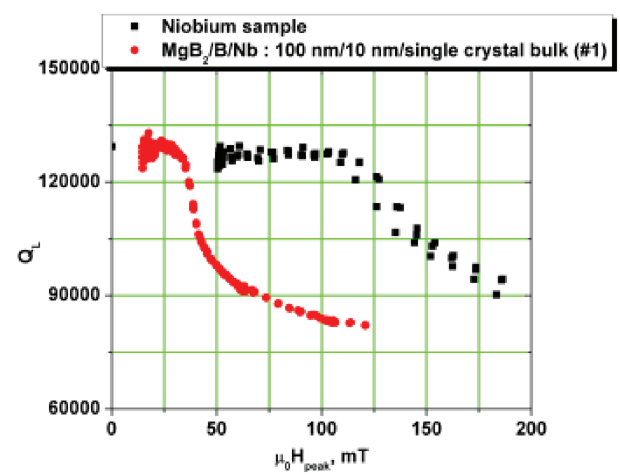

Figure 4: Cavity loaded Q as a function of peak surface field on the sample for Nb (black) and MgB_2/B/Nb (red) samples.

Figure 5 shows cavity Q_L as a function of temperature at different peak fields. The drop of Q_L at 42 mT at T<9

K suggests that the breakdown occurred in Nb, not in MgB_2.

We plan to increase the field to see at what level MgB_2 quenches. Also, we plan to test thicker MgB_2 film to determine the characteristics and quality of MgB_2 film that we are depositing as well as identifying the reason of early quench in the Nb substrate.

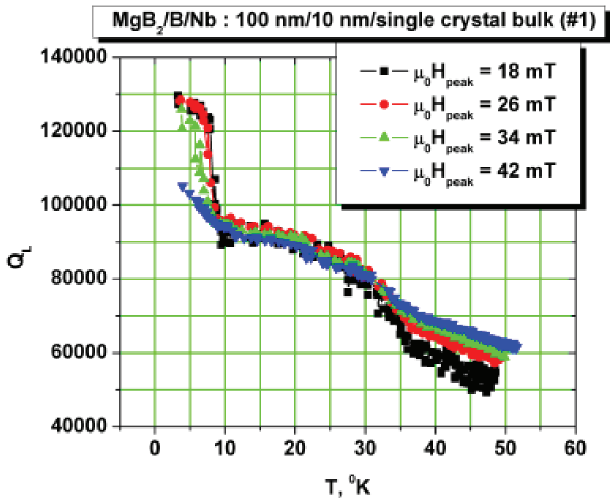

Figure 5: Cavity loaded Q as a function of temperature of the MgB_2/B/Nb sample for different peak surface fields.

ACKNOWLEDGMENTS

We would like to thank the following people for their help, collaboration and cooperation.

- LANL: A. Bhatty (now at a company), A. Burrell, A. Canabal (now at U. Maine), A. Burrell, Q. Jia, G. Zou (NbN coating), P. Chacon, J. Sedillo (T-mapping hard and software), Vacuum team members (assembly, etc.)
- JLab (805 MHz cavity fabrication, etc.): W. Clemens, P. Kneisel, R. Manus, R. Rimmer, L. Turlington
- FNAL (commissioning of T-map system, etc.): M. Champion, S. Mishra, C. Ginsburg
- ORNL (superconductor testing) : I. Campisi
- SLAC (superconductor testing): S. Tantawi, V. Dolgashev, D. Martin, C. Nantista, C. Yoneda
- STI (MgB_2 coating): B. Moeckly

REFERENCES

[1] A. Canabal et al., “Development of a Temperature Mapping System for 1.3-GHZ 9-Cell SRF Cavities,” PAC’07, Albuquerque, June 2007, p. 2406 (2007); http://www.JACoW.org.

[2] A. Canabal et al., “Full Real-Time Temperature Mapping System for 1.3 GHz 9-cell Cavities,” EPAC’08, Genoa, June 2008, p. 841 (2008); http://www.JACoW.org.

[3] G. Eremeev et al., “Report on AES 003 1.3 GHz 9-cell Superconducting Niobium Cavity Test Results at LANL,” LANL Report LA-UR-09-01090; http://laacg.lanl.gov/scrflab/pubs/ILC/LA-UR-09-01090_AES_003_test_final_report_rev_1_1.pdf.

[4] T. Tajima et al., “Full Temperature Mapping System for Standard 1.3 GHz 9-cell Elliptical SRF Cavities,” PAC’09, Vancouver, B.C., Canada, 4-8 May 2009.

[5] T. Tajima et al., “Conceptual Design of Automated Systems for SRF Cavity Optical Inspection and Assembly,” ibid. [2], p. 922.

[6] T. Tajima et al., “SRF Cavity High-Gradient Study at 805 MHz for Proton and Other Applications,” ibid [4].

[7] A. Gurevich, “Enhancement of rf breakdown field of superconductors by multilayer coating,” Appl. Phys. Lett. 88, (2006) 012511.

[8] T. Tajima et al., “RF Critical Magnetic Field Measurement of MgB_2 and NbN Thin Films Coated on Nb,” The 9th European Conference on Applied Superconductivity (EUCAS2009), Dresden, Germany, 13-17 September 2009.

[9] G. Eremeev, “Review of RF properties of NbN and MgB_2 thin coating on Nb samples and cavities,” this conference.