TE Sample Host Cavities Development at Cornell *

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Abstract

In order to measure surface resistance of new materials other than niobium such as Nb_3Sn and MgB_2, two sample host niobium cavities operating at TE modes have been developed at Cornell University. The first one is a 6GHz pillbox TE_{011} cavity modified from an older vision enabling testing 2.75 inch diameter flat sample plates. The second one is an optimized mushroom-shape niobium cavity operating at both 4GHz TE_{012} and 6GHz TE_{013} modes for 10cm inch diameter flat sample plates. First results from the commissioning of the two TE cavities will be reported.

INTRODUCTION

In the past three decades, different types of sample host cavities were designed and used to test niobium or alternative materials for superconducting cavities [1], [2], [3], [4]. Most of them employed oscillating TE modes in the host cavities. However, none of them has achieved magnetic field higher than 650Oe (65mT) on the sample, and often the sensitivity in surface resistance is well above the desirable nΩ range. Since niobium is approaching its theoretical superheating field around 2000Oe, a high field and high sensitivity sample host cavity is ideal for studying various field-dependent loss phenomena in niobium. Also since the alternative materials such as Nb_3Sn and MgB_2 are expected to have a very high breakdown field, a sample host cavity can reach above 2000Oe is especially needed to test those materials.

At Cornell University, two sample host TE cavities have been designed and are currently under commissionning. In the following sections, rf design considerations, the cavity preparation apparatus and RF test results using baseline niobium bottom plates will be presented.

TE PILLBOX CAVITY RF DESIGN

Various versions of TE pillbox cavities have been used at Cornell University to study surface resistance of high temperature superconductors $YBa_2Cu_3O_7$, ultra-high vacuum cathodic arc films coated samples and MgB2 [3], [4], [5]. For the first TE pillbox cavity, the sample was introduced into the cavity by a sapphire rod through a niobium cutoff tube aligned along the cavity axis. A thermometer was attached to the sapphire rod near the sample and a heater was attached to the bottom of the sapphire rod. The heater and both thermometers were placed well beyond RF cutoff.

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This cavity was used to measure $YBa_2Cu_3O_7$ rf surface resistance at various temperatures with magnetic field on the sample of 1 Oe [3]. The highest magnetic field reached on the sample surface was around 11 Oe. Later the bottom plate of the cavity was replaced by the Nb/Cu end plate with a groove on the surface of the sample which was intended for removing the degeneracy between TE_{011} and TM_{110} modes. This cavity had a very high residual resistance above $1\mu\Omega$ and the maximum surface field achieved was around 300 Oe. Therefore, a new TE pillbox cavity was designed to enable testing flat surface samples and was aimed to reach high surface magnetic field by using carefully treatments and improved rf designs.

In order to test a flat sample, the groove was moved to the top plate near the coupler port. Fig.1 shows the magnetic field distribution of the new TE pillbox cavity. The maximum field on the cavity surface is located near the coupler port due to the presence of two separate grooves. S21 data measured by a network analyzer during cool down confirmed that the new groove design successfully seperated the two degenerate modes TE_{011} and TM_{110}. Fig.2 shows another bottom plate design that introduced two symmetric ports. One of the port is blanked off by a niobium plate. The other port enables placing a sample into the high magnetic field region by using the existing cutoff tube with the sapphire rod. Compared with single cutoff tube aligned with the cavity axis, the new design increase the surface magnetic field on the sample placed on the sapphire rod. The design parameters of this TE pillbox remake are shown in Table.1

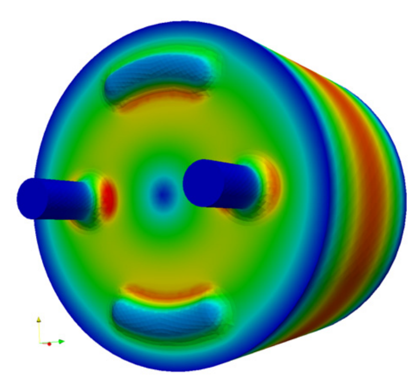


Figure 1: Surface magnetic field distribution of the TE_{011} mode of TE pillbox cavity.

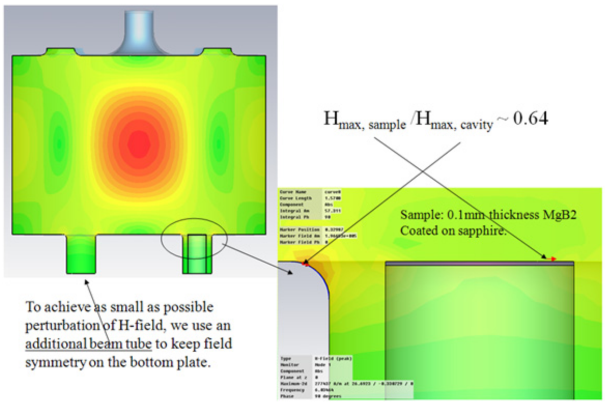


Figure 2: Symmetric ports on bottom plate enabling placing a sample on a sapphire rod in the high magnetic field region.

Table 1: The design parameters of the TE pillbox cavity

	Big flat sample plate	Small round sample
f(GHz)	5.88	5.88
H_{max} @ sample (Oe)	1200	1200
Sample diameter (cm)	7.0	1.0

Cavity Fabrication and Processing

The new TE pillbox cavity was made of RRR300 niobium and was electron beam welded together. A sample EP system was designed and used to electron-polish top plate, two bottom plates and the cavity tube. Fig.3 shows the EP setup. The EP current density was around 15 mA/cm^2 and the bath temperature was 17°C. After fabrication, the TE pillbox cavity received a 120 μm heavy EP. High pressure rinsing attachments were also developed for the various components of the TE pillbox cavity. After the initial heavy EP, the cavity received 2 hours HPR in class 10 cleanroom and was baked 800C in a high temperature vacuum furnace. Another 20 μm light EP was applied to this cavity. After a final HPR, the TE pillbox cavity was 120C baked and available for rf test.

RF Test Results of TE Pillbox Cavity

A dedicated 6GHz rf phase-lock-loop system was assembled in the Cornell rf test area. Since cable loss in the 6GHz range is relatively larger compared with the cable loss at 1.3GHz, special low-loss coaxial cables LMR600 were used for the signal transmission between amplifier and cavity. A pre-amplifer before the 250W TWT amplifier was used to enable delivering over 200W to the test dewar.

The first rf results at 1.8K is shown in Fig.4. The maximum field achieved on the sample surface was around 180 Oe. The maximum power coupled into the cavity was around 3W. However, repeatedly heating was observed with all the forward power reflecting back from the input coupler as shown in Fig.5. The temperature was recorded

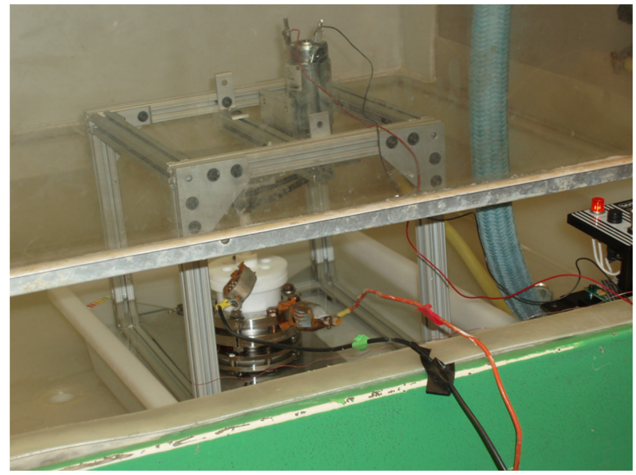


Figure 3: EP setup for TE cavites.

by a calibrated Cernox sensor attached near the coupler port. Therefore, efforts was made to upgrade the old copper coupler into a niobium coupler with the assumption that the copper coupler and its related SMA line connector had a serious cooling problem in its copper body. Fig.6 shows the old copper coupler that was using a tri-axial design that may trigger multipacting events. The new niobium coupler was made of a Ceramtec SMA feedthrough connector welded to a mini-CF flange and a niobium rod with a hook end was threaded into the feedthrough needle. The coupler niobium body is shown in Fig.7 . The new niobium coupler was made of reactor grade niobium and received a light BCP. However, there were several leaks due to the new feedthrough failing at cryogenic temperatures, Due to the leaks, the TE pillbox cavity was contaminated and had to be reprocessed with a 100 μm BCP.

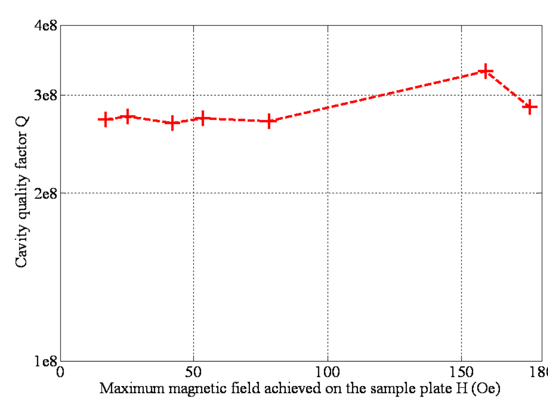


Figure 4: Q vs H for copper input coupler at 1.8K for TE pillbox cavity baseline niobium sample plate.

The latest rf test results at 1.6K is shown in Fig.8. The maximum field achieved on the flat niobium sample surface increased to 300 Oe. However, a relatively low quality factor was measured. Latest calculations show that there was a coupler resonance around 5.9Hz which was very close

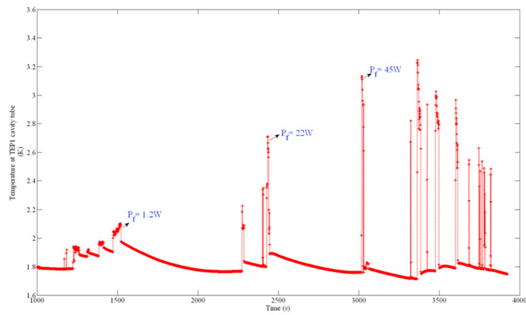


Figure 5: Heating observed during rf test with copper input coupler.

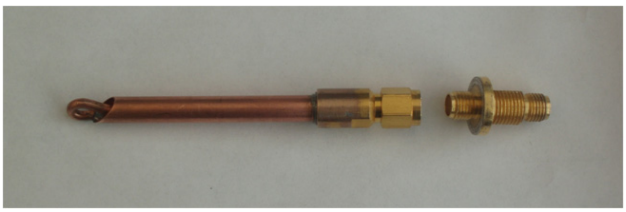


Figure 6: The copper input coupler and its SMA line connector feedthrough.

to the pillbox cavity TE_{011} resonance peak. Fig. 9 shows the magnetic field distribution along the 3 inch long coupler tube. Modification of the coupler length will be done to avoid this coupler resonance and thus to improve cavity performance even further.

A ring of 8 thermometers(Allan-Bradley resistors) has been mounted near the highest magnetic field region at the bottom plate of the TE pillbox cavity and can successfully detect around 10 nΩ surface resistance. Fig.10 shows the thermometer setup.

TE MUSHROOM CAVITY DEVELOPMENT

As reported before, three optimized shapes of high field TE cavity using TE monopole modes have been obtained [6]. One of the three shapes can not accommodate a siz-

Figure 7: Niobium input coupler body after a light BCP.

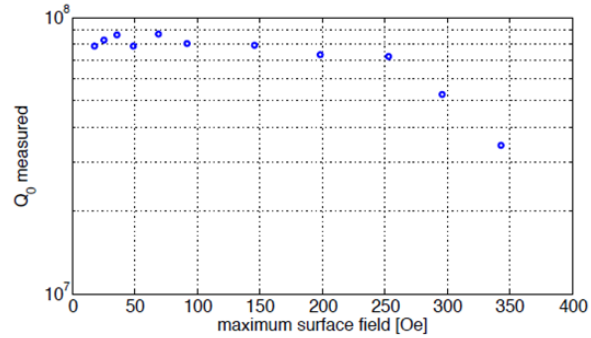


Figure 8: Q vs H for new niobium input coupler at 1.6K for TE pillbox cavity baseline niobium sample plate.

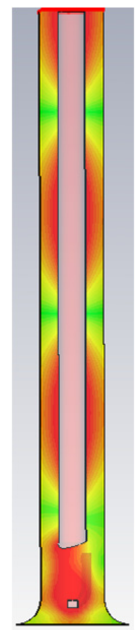


Figure 9: Magnetic field distribution of a coupler resonance near 5.9GHz.

able input coupler and another one of the three shapes may have strong rf losses at the flange joint. Therefore only a mushroom-type TE cavity was fabricated using RRR300 niobium.

The mushroom shape cavity operates at both TE_{012} and TE_{013} modes as shown in Fig.11. The rf design parameters are shown in Tab.2. The maximum magnetic field which can be achieved at sample plate is estimated based on niobium critical field of 2000 Oe. The design enables that the sample plate is exposed to the maximum field in the entire cavity. The main design goal was to maximize the ratio R of maximum sample plate surface magnetic field to maximum host cavity surface magnetic field. The maximum of the surface magnetic field on the sample plate is at the same location for both modes as seen in Fig.12.

The input coupler port is located at the center top of the mushroom type cavity and the pickup probe and pumping probe are distributed symmetrically at the input cou-

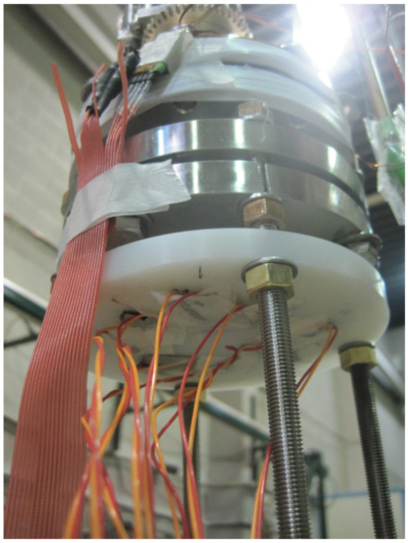
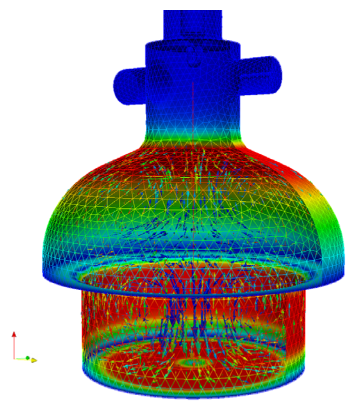
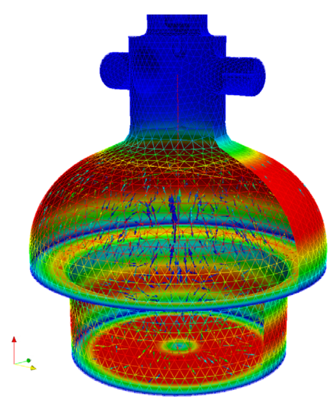


Figure 10: Sample plate thermometry system for TE pillbox cavity.



(a) Spacial magnetic field distribution of TE_{012} mode.



(b) Spacial magnetic field distribution of TE_{013} mode.

Figure 11: Magnetic field distribution of TE mushroom cavity.

pler port. The rf design of the input coupler, possible coupler heating considerations and 3-dimensional multipacting simulations using SLAC A3P codes is reported elsewhere [7].

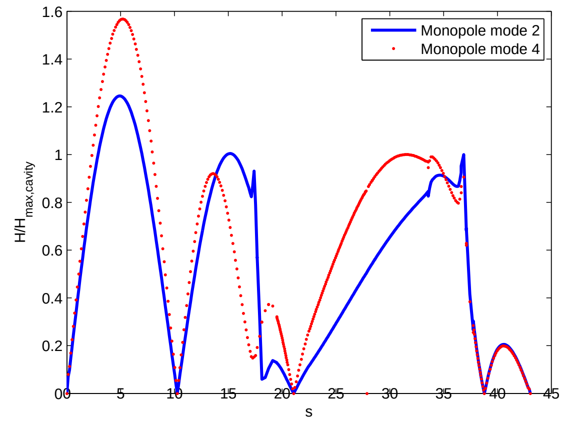


Figure 12: Normalized surface magnetic field along the sample plate and walls of the host cavity. Sample plate: s=0 to 10 cm. Host cavity: s=10 to 43 cm.

Table 2: The design parameters of the TE mushroom cavity

	TE_{012}	TE_{013}
f(GHz)	4.78	6.16
H_{max} @ sample (Oe)	2480	3480
Sample diameter (cm)	10.0	10.0

This cavity now is successfully fabricated and has received a 120 μm heavy BCP as show in Fig.13 A dedicated insert and relatively high power (compared with TE pillbox cavity input coupler) is under fabrication. A first rf test of TE mushroom cavity with a niobium flat bottom plate is planned for Fall 2011.

Figure 13: TE mushroom cavity after a heavy BCP.

CONCLUSIONS

Two TE cavities have been successfully fabricated at Cornell University to systematically study niobium surface resistance and new alternative materials. The TE pillbox cavity has achieved over 300 Oe magnetic field on the sample surface. Higher sample surface magnetic field is expected after a coupler resonance problem is removed. The TE mushroom cavity is awaiting the first rf test with a dedicated test insert and relatively high power input coupler.

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