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UPDATE ON SAMPLE HOST CAVITY DESIGN WORK FOR MEASURING FLUX ENTRY AND QUENCH FIELD*

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Abstract

Current state-of-the-art Niobium superconducting radio-frequency (SRF) accelerator cavities have reached surface magnetic field close to the theoretical maximum set by the superheating field. Further increasing accelerating gradients will require new superconducting materials for accelerator cavities that are capable of supporting higher surface magnetic fields. This necessitates measuring the quench fields of new materials in high power RF fields. Previous work at Cornell University has used electromagnetic simulations to optimize the shape of a dipole mode sample host cavity such that the surface magnetic fields on the sample are high compared to the energy inside the cavity and the surface magnetic field on the rest of the cavity. In this paper we present an update of the design that includes how to mount samples in the cavity and the addition of a low field chamber.

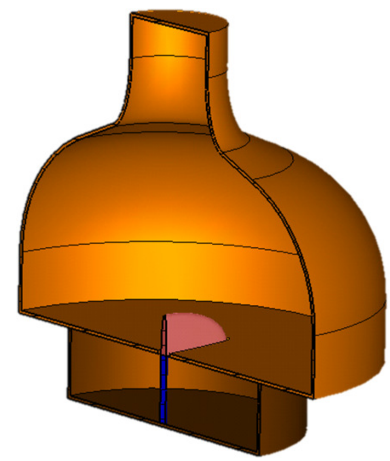
INTRODUCTION

State-of-the-art niobium SRF cavities have reached surface magnetic fields close to the superheating field, the theoretical maximum [1, 2]. Further increasing accelerating gradients will require superconducting materials with superheating/quench fields that are greater than niobium's. This necessitates identifying materials with high superheating fields and processes for creating these materials that attain high quench fields. This can be measured using single cell cavity tests [3], but for some materials it might not yet be possible to create the complex cavity geometry, and creating full cavities is both time consuming and expensive.

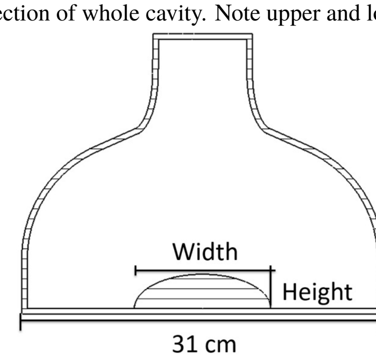
This paper presents preliminary designs of a sample host cavity for measuring quench fields of material samples. We want this cavity to be capable of achieving peak magnetic fields on the sample that are greater than the superheating field of niobium, and capable of making measurements at a temperature greater than the critical temperature of niobium, ideally reaching T_c of whatever the sample material is so that the quench field can be explored near T_c.

DESIGN

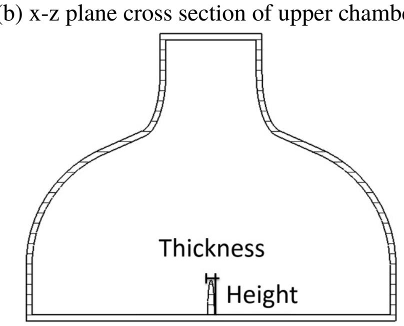
The cavity consists of an upper and lower chamber, with the upper chamber being the resonant cavity (see Fig. 1). The upper chamber is based on a geometry created by Yi Xie at Cornell University [4]. The cavity geometry had been previously optimized to maximize the peak surface magnetic field in the center of the plate, achieving 48.9 mT/$\sqrt{\text{J}}$. The geometry was modified to change the frequency to 1.3 GHz so that we can use it with our high pulsed-power klystron.



(a) Cross section of whole cavity. Note upper and lower chambers



(b) x-z plane cross section of upper chamber.



(c) y-z plane cross section of upper chamber.

Figure 1: Sample host cavity design.

To further increase the peak surface magnetic fields on the sample, the sample has been designed as an elliptical bump. This shape enhances the surface magnetic fields on the tip of the sample [5, 6]. Previous work [7] showed how the peak surface magnetic fields depends on the bump dimensions (see Fig. 4 and that peak fields of 400 mT/$\sqrt{\text{J}}$ or higher is possible.

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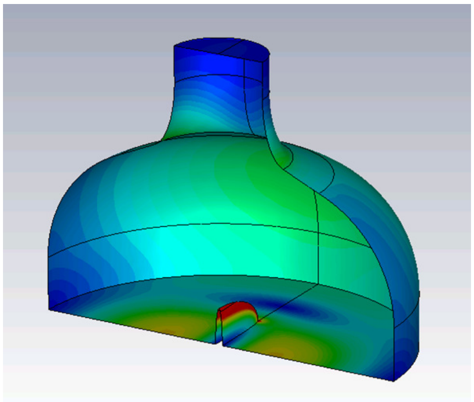
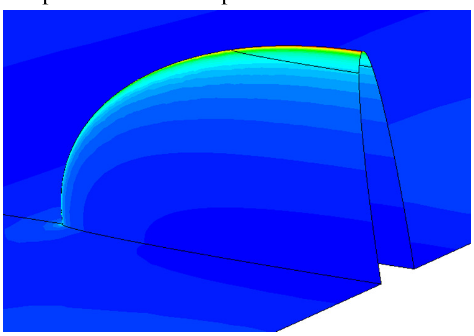
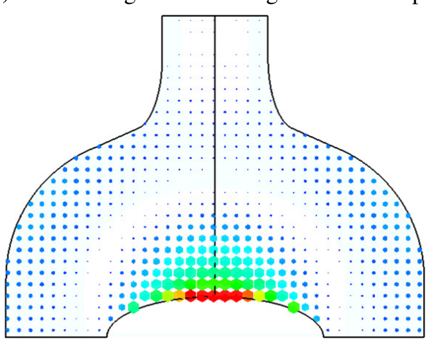


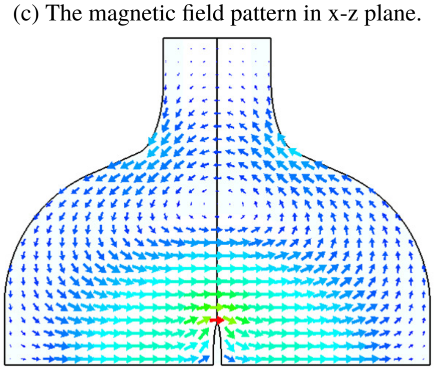
(a) Surface magnetic field magnitude. The scale has been adjusted so that field pattern off the sample is visible.



(b) Surface magnetic field magnitude on sample.



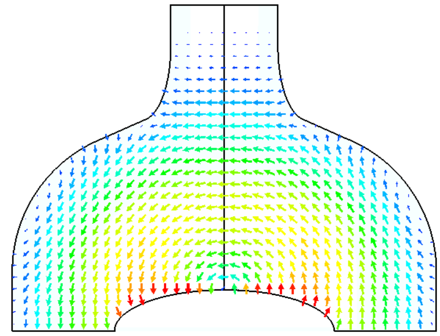
(c) The magnetic field pattern in x-z plane.



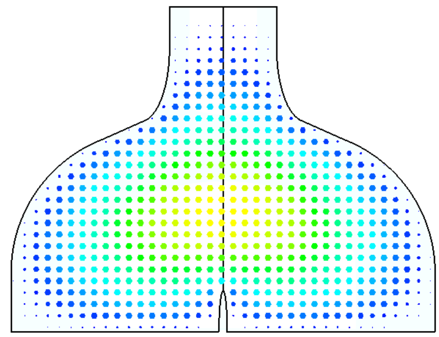
(d) The magnetic field pattern in y-z plane.

Figure 2: Surface magnetic fields and magnetic field pattern.

The resonant mode in the cavity is a 1.3 GHz dipole mode. The magnetic and electric field patterns in the upper chamber are shown in Fig. 2 and 3 respectively. The maximum electric field on the surface is $\approx$ $100\,\mathrm{MV/m/\sqrt{J}}$ for $400\,\mathrm{mT/\sqrt{J}}$.



(a) The electric field pattern x-z plane.



(b) The electric field pattern in the y-z plane.

Figure 3: Electric field patterns.

We require the cavity to go above the temperature of niobium, preventing using superconductors for the cavity. Instead we will make the cavity out of copper and use high-pulsed klystron power to reach high magnetic fields. This requires that the superconducting sample be thermally separated from the RF cavity walls. To accomplish this we have added a small gap between the superconductor and the RF cavity wall. Below the sample we have added a small cavity, creating an upper and lower cavity. The sample is supported by a sapphire rod in second lower chamber, where thermometry will be used to detect quench.

FIELD REJECTION IN LOWER CAVITY

Electromagnetic simulations were conducted to check how far the magnetic fields penetrated into the lower cavity and how much losses this caused. For the cryogenic sapphire a loss tangent of $2 \cdot 10^{-10}$ at 2.45 GHz [8] and dielectric constant of 9.2 was used. Figure 5 shows the surface magnetic fields in the upper and lower cavity. The field in the lower chamber was $\approx 1/100^{\text{th}}$ the peak fields on the cavity for a variety of gap widths (around the sample, $1-3$ mm and lower chamber sizes ($2-10$ cm height). For a 1 mm gap, 5 cm lower cavity height, and 10 cm lower cavity diameter, the sapphire rod had 10^{-5} the losses of the superconducting sample ($10\,\mathrm{n\Omega}$ surface resistance), suggesting losses on the sapphire will be negligible.

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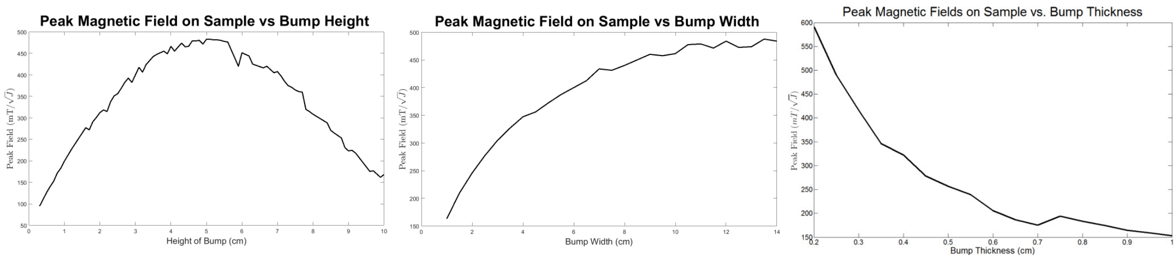
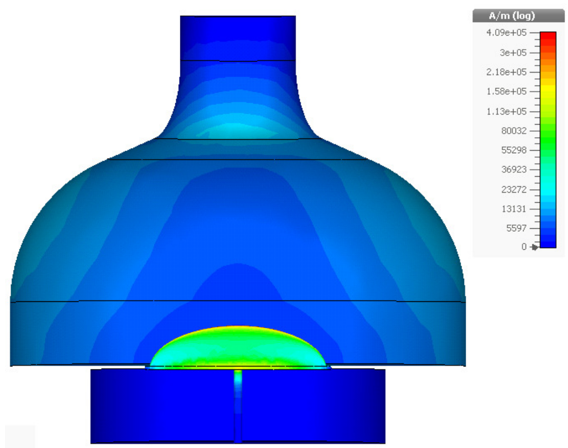
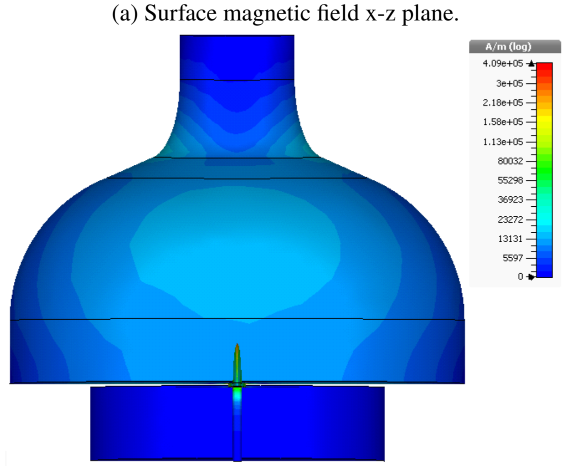


Figure 4: Peak surface magnetic field on sample for 1 J in the cavity. In each plot the unlisted dimensions are Height = 3 cm, Width = 6 cm, and Thickness = 0.3 cm. There is some noise in simulated data due to meshing.



(a) Surface magnetic field x-z plane.



(b) Surface magnetic field in the y-z plane.

Figure 5: Surface magnetic field in upper and lower cavities.

CONCLUSION

The current design can reach high magnetic fields on the superconducting sample–greater than 400 $\mathrm{mT}/\sqrt{\mathrm{J}}$ and with little magnetic fields present in the lower field portion of the cavity. Further work is needed to determine sensitivity of the peak surface magnetic fields to bump shape errors, the thermal and mechanical stability, and design forward and transmitted power couplers.

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