SAMPLE HOST CAVITY DESIGN FOR MEASURING FLUX ENTRY AND QUENCH*

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Abstract

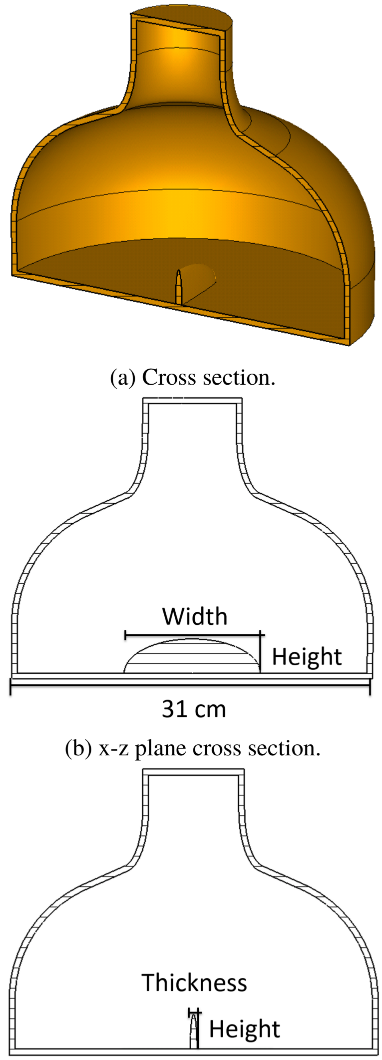
Current state-of-the-art Niobium superconducting radio-frequency (SRF) accelerator cavities have reached surface magnetic field close to the theoretical maximum set by the superheating field. Further increasing accelerating gradients will require new superconducting materials for accelerator cavities that can support higher surface magnetic fields. This necessitates measuring the quench fields of new materials in high power RF fields. In this paper, we present designs and simulations of a sample host cavity. The cavity design is optimized to maximize the surface magnetic field achieved on the sample.

INTRODUCTION

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 [1, 2]. Further increasing accelerating gradients will require new superconducting materials for accelerator cavities that can support higher surface magnetic fields. This necessitates measuring the quench fields of new materials in high power RF fields. We are also interested in measuring the superheating/quench field over a wide temperature range–ideally reaching the critical temperature of the material. These measurements can be done using single cell cavities [3], but it is time consuming and expensive to make new single cell cavities for new materials or changes in production method, and may be impossible for materials that cannot yet be applied to complicated geometry. Here we present preliminary designs of a sample host cavity to measure the superheating/quench fields of samples. The design is optimized to achieve strong surface magnetic fields on an elliptical material sample.

DESIGN

We require that the maximum magnetic fields on our sample be high, but since we are only trying to get the sample to quench, we are unconcerned with the field being uniform on the sample. Previous work at Cornell University done by Yi Xie optimized a cavity geometry (see Fig. 1 to see shape after our modifications) to create high surface magnetic fields in the center of the plate using a dipole mode [4].



(a) Cross section.

(b) x-z plane cross section.

(c) y-z plane cross section.

Figure 1: Sample host cavity design.

We have adopted this design and adjusted the geometry to change the frequency to 1.3 GHz so that we can use it with our high pulsed-power klystron.

Several other simple designs were simulated in CST Microwave Studio: the design optimized by Yi Xie attained $48.9\,\mathrm{mT}/\sqrt{\mathrm{J}}$ peak surface magnetic field; a simple cylindrical pillbox cavity attained $34.2\,\mathrm{mT}/\sqrt{\mathrm{J}}$ peak surface magnetic field; and half an ILC cavity (in the first dipole mode) attained $34.1\,\mathrm{mT}/\sqrt{\mathrm{J}}$ peak surface magnetic field.

To further increase the maximum magnetic fields on the sample, the sample has been designed as an elliptical bump.

* Travel to IPAC'17 supported by the Division of Physics of the United States National Science Foundation (Accelerator Science Program) and the Division of Beam Physics of the American Physical Society. This work was supported by the U.S. National Science Foundation under Award PHY-1549132, the Center for Bright Beams.

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ISBN 978-3-95450-182-3

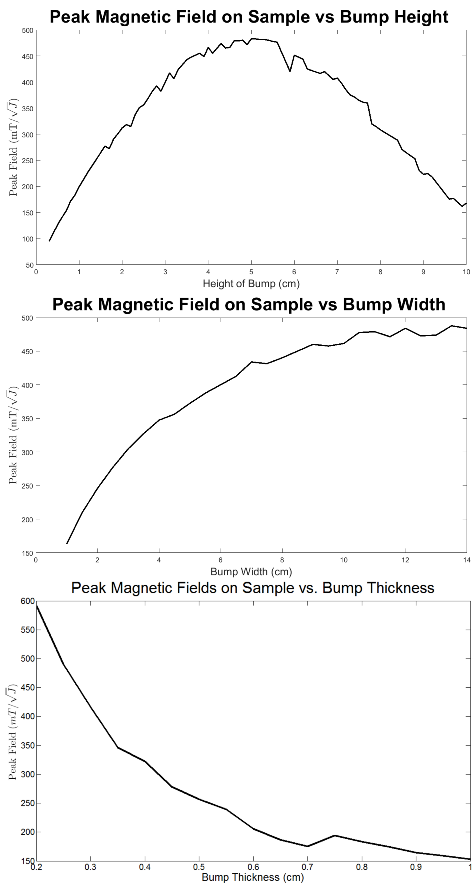
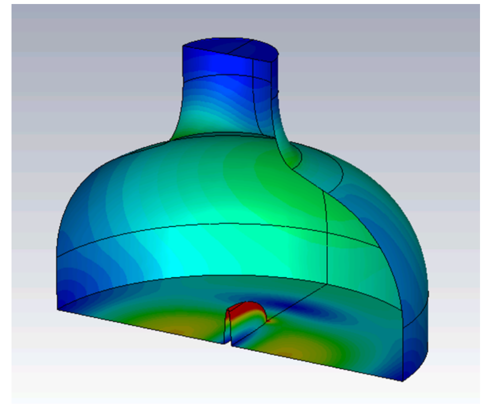
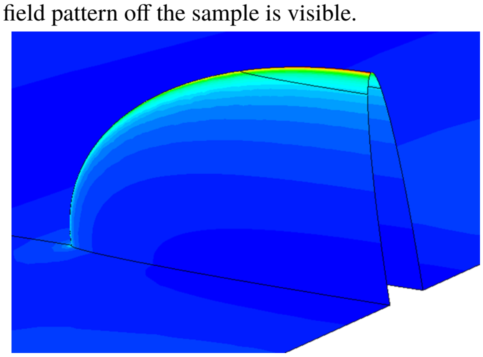


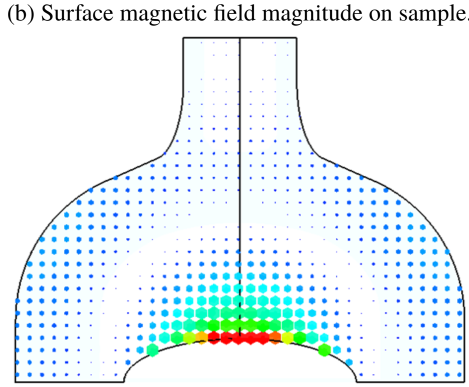
Figure 2: Peak surface magnetic field on sample for 1 J in the cavity. In each plot the unlisted dimensions are Height = 3 cm, Width = 6 cm, and Thickness = 0.3 cm. There is some noise in simulated data due to meshing.



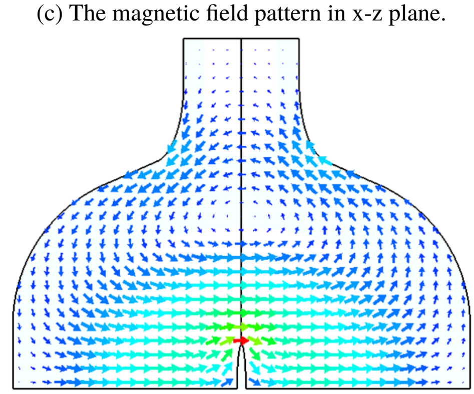
(a) Surface magnetic field magnitude. The scale has been adjusted so that field pattern off the sample is visible.



(b) Surface magnetic field magnitude on sample.



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



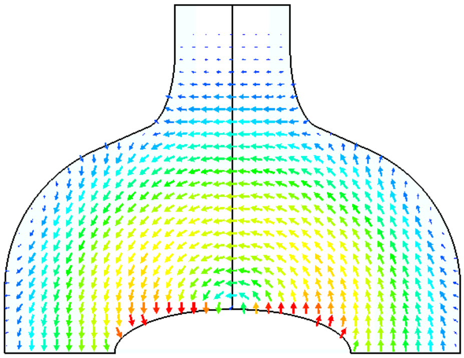
(d) The magnetic field pattern in y-z plane.

Figure 3: Surface magnetic fields and magnetic field pattern.

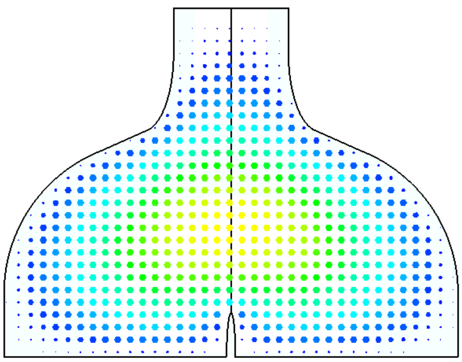
This shape enhances the surface magnetic field on the tip of the sample [5, 6]. The dependence of the bump dimensions on the maximum surface magnetic fields is given in Fig. 2. For a bump height of 3 cm, width of 6 cm, and thickness of 3 mm, the peak magnetic field on the sample is $\approx 400\,\mathrm{mT}/\sqrt{\mathrm{J}}$ and a ratio of peak magnetic fields on the sample to peak magnetic fields on the host cavity of 5.3.

The resonant mode in the cavity is a 1.3 GHz dipole mode. The magnetic and electric field patterns are shown in Fig. 3 and 4 respectively. the maximum field on the surface is $\approx 100\,\mathrm{MV}/\mathrm{m}/\sqrt{\mathrm{J}}$.

Two major design options are still being debated: a copper host cavity utilizing klystron pulsed power, or a niobium superconducting host cavity utilizing either continuous or pulsed klystron power. The copper design would require creating a gap between the sample and the host cavity, supporting the sample on a sapphire rod, and detecting the quench using thermometry. The niobium cavity would have the sample connected directly to the host cavity and would use the change in quality factor ($\approx 3 \cdot 10^{10}$) to detect quench. This design is less complicated, but will be limited by the maximum field on the niobium host (if we could only reach 110 mT on the host cavity we would be able to



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



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

Figure 4: Electric field patterns.

reach 110 mT × 5.3 ≈ 600 mT on the sample) and by the critical temperature of niobium. Furthermore, we still need to analyze potential losses at the flange connection between the host cavity and the sample since in the dipole mode the currents pass from the cavity to the sample.

CONCLUSION

Current designs can reach high magnetic fields on the superconducting sample–greater than $500\,\mathrm{mT}/\sqrt{\mathrm{J}}$ with the ratio of peak magnetic fields on the sample to peak magnetic fields on the cavity greater than 5. Further work is needed to determine the flange losses, 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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ISBN 978-3-95450-182-3