

RECENT RESULTS FROM THE CORNELL SAMPLE HOST CAVITY*

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Abstract

Many novel materials are under investigation for the future of superconducting radio-frequency accelerators (SRF). In particular, thin-film materials such as Nb₃Sn, NbN, SIS multilayers, and also thin-film niobium on copper, may offer improvements in cost efficiency and RF performance over the standard niobium cavities. To avoid the difficulties of depositing thin films on full cavities, Cornell has developed a TE-mode sample host cavity which allows for RF measurements of large, flat samples at fields up to and over 100 mT. We present recent performance results from the cavity, reaching record high fields and quality factor using a niobium calibration plate. We also discuss plans for future collaborations.

INTRODUCTION

In the field of superconducting radio-frequency accelerators (SRF), research groups are investigating many novel materials which may offer improvements over the performance of niobium, the standard material used in cavity fabrication. Thin-film materials are of particular interest; however, manufacturing RF cavities with these thin film materials can be expensive and challenging due to the complex geometry and size of traditional accelerator cavities. Thus it is ideal to find another way to measure the RF performance and properties of these materials in more easily-fabricated configurations.

To solve this, Cornell has developed a cavity that supports a removable sample plate of the material under investigation [1–4]. Now in its third generation, the TE-mode sample host cavity takes a five inch disk, clamped to the face of the cavity with an indium seal (Table 1). The cavity also features a temperature-mapping system (T-map) on the sample plate to locate quenches and hot spots. Figure 1 shows the cavity mounted on the test insert with the T-map as well as external bath temperature sensors. Figure 2 shows a 3D CAD representation of the cavity, without sample plate or dressing; Figures 3 shows the normalized magnetic field profile on the RF-active portion of the sample plate.

In recent tests over the past year, several issues resulting in a low-field quench of the cavity have been considered and addressed, and the cavity has now reached a peak magnetic field on the sample plate of 106 mT, higher than ever before in the history of this cavity. The cavity operates at a quality factor Q_0 reaching a maximum of 4.1×10^{10} at a temperature of 1.6 K. Figure 4 shows the Q_0 vs. H_{sample} for this test.

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Figure 1: Third-generation Cornell TE sample host cavity with temperature map and external temperature sensors installed.

Table 1: Sample Host Cavity Parameters

Parameter	Value
Frequency	3.96 GHz
Geometry factor G	309 Ω
$H_{\text{sample}}/H_{\text{peak}}$	0.892
RF mode	TE ₀₁₁
Sample plate diameter	5 in (12.7 cm)
Sample plate diameter exposed to RF	4 in (10.2 cm)
Pct. of losses on sample plate (Nb)	13.2%

PERFORMANCE IMPROVEMENTS

In late 2014, during a calibration test, the sample host cavity reached a peak field of 105 mT, limited by quench. Since then, we have made a number of improvements to the cavity, testing equipment, and testing procedures. These included replacing a faulty traveling-wave-tube amplifier with a new, 100 W solid-state system; disassembling and thoroughly cleaning the coupler; “resetting” the cavity surface with first a nitric acid soak, followed by an electropolishing (EP) treatment to remove 10 μm of material, and ending with a 120° C bake for 48 hours; replacing the sample plate clamp with a new design that applies azimuthally symmetric pressure to the plate; improving the cavity assembly process and inspecting and replacing most of the components in the RF circuit (mixers, directional couplers, etc.).



Figure 2: A CAD representation of the Sample Host Cavity, shown without sample plate. During testing, the plate is affixed to the wide opening (“mouth”) of the cavity with a 20/1000” indium seal.

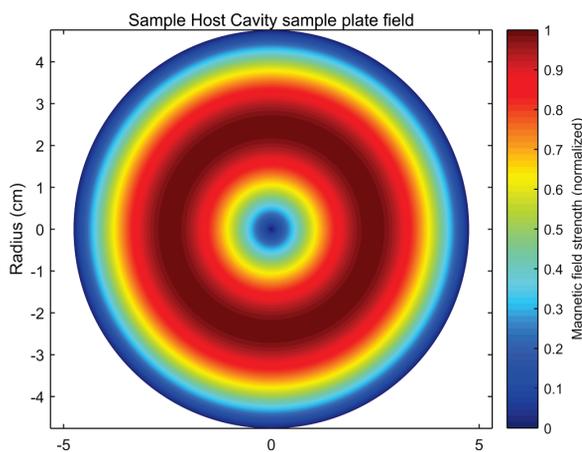


Figure 3: A 2D heatmap representation of the RF magnetic field on the sample plate (normalized).

As an end result to this array of improvements, in the most recent calibration test (using a niobium sample plate of the same stock material as the cavity), the cavity reached up to a peak field on the sample plate surface of 106 mT operating at a temperature of 1.6 K. This was not limited by quench but by running out of liquid helium, so higher fields may be possible. The quality factor reached a maximum of 4.1×10^{10} . A slight Q -slope was observed, though the minimum quality factor observed, 7.9×10^9 , is higher than any previous quality factor of the cavity, at any field, since May 2014 (Fig. 5). Further, the Q -slope was accompanied by higher temperatures at high fields due to the higher dissipated power. More investigation is needed to determine the strength of the thermal effects on lowering the Q at high fields.

With this recent result, the cavity is ready to test new materials at fields exceeding 100 mT with high sensitivity due to the high Q_0 of the cavity. Further, the T-map system can help to locate quench spots, areas of high surface resistance, and other defects on the sample surface for post-RF microscopy or other investigation.

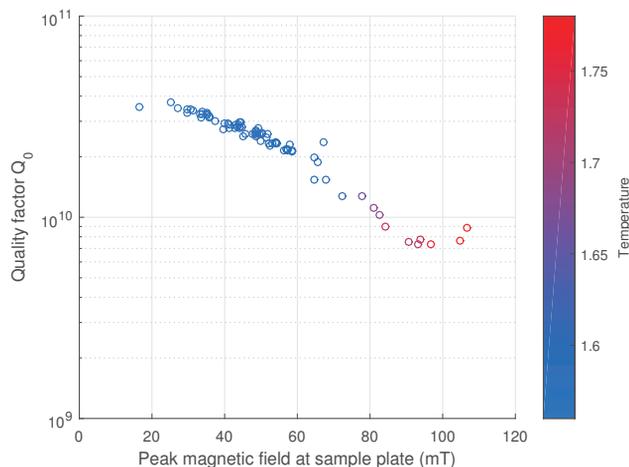


Figure 4: Quality factor Q_0 displayed against peak sample plate field H_{sample} . The color scale shows liquid helium bath temperature during testing.

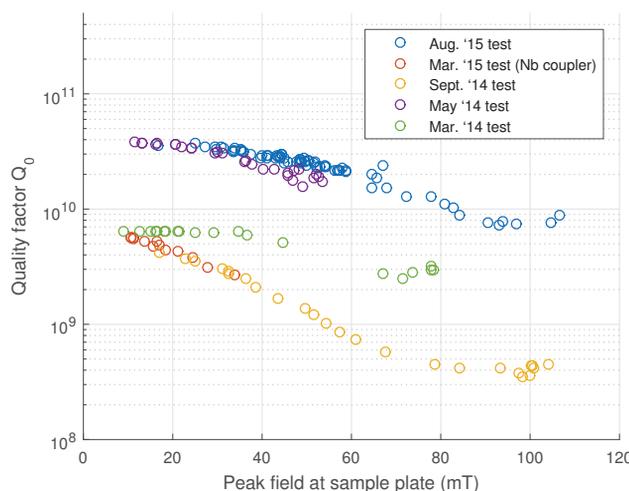


Figure 5: Quality factor Q_0 displayed against peak sample plate field H_{sample} for several recent tests. The most recent test, from August 2015, exhibited the highest quality factor and reached the highest fields yet.

UPCOMING INVESTIGATIONS

We have previously reported on replacing the copper tip of the coupler with a new tip made with niobium [5, 6]. At the time, results were inconclusive as to whether the niobium tip offered any improvements over the original tip. In the coming months, we will investigate the new coupler more thoroughly to see if the superconducting material lowers coupler losses.

In addition, we plan on making updated Q vs. H_{sample} measurements at 2 K and 4 K, as well as Q vs. T measurements in the 1.6 to 4 K range in order to complete baseline calibration with the niobium sample plate. Further, we will continue to investigate improvements to the cavity setup to push the upper field limit towards the theoretical maximum of 120 mT.

FUTURE PLANS

Moving forward, the sample host cavity will continue to be a strong tool for measuring the RF performance of novel materials. Cornell is currently making collaborative efforts with Jefferson Lab, the international labs Saclay/Orsay and Daresbury, and private companies such as Alameda Applied Sciences. These studies will investigate thin-film materials such as NbN on MgO, thin-film Nb, Nb on Cu on Nb, and MgB₂.

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