ISBN: 978-3-95450-168-7 doi:10.18429/JACoW-IPAC2015-WEPTY076

RF PERFORMANCE STUDIES OF THIN-FILM SUPERCONDUCTORS USING A SAMPLE HOST CAVITY *

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Abstract

Thin-film superconductors have the potential for reducing cost and for improved SRF performance over traditional bulk niobium superconducting cavities. Materials such as Nb3Sn, multilayer NbN/MgO, and thin-film Nb are currently under investigation for cost reduction or possible improvements in RF losses and accelerating gradients. Due to the complex geometries of traditional RF cavities, it is preferable to use a sample host cavity to study flat samples of the novel materials. The Cornell sample host cavity has been commissioned and has now reached peak magnetic surface fields of 100 mT. We present updates on the recent performance of the cavity.

INTRODUCTION

In the field of superconducting radio frequency (SRF) accelerators, many materials are currently being studied as alternatives to bulk niobium for RF operation. Particularly, thin film materials such as Nb_3Sn, nitrogen-doped niobium, and thin-film niobium show promise as future materials.

In order to study the material properties of candidate SRF materials, Cornell has developed a series of versatile sample host cavities [1–4]. The third and most recent of these cavities operates at a frequency of 4 GHz. Recent tests of the cavity have reached peak fields of 100 mT on the surface of the sample plate.

The sample host cavity operates in a TE mode, with a coupler extended upwards through the single beam tube. The clamp at the top of the cavity holds a removable sample plate in place. The plate, a flat five-inch disk, is mounted with an indium seal and can be manufactured, treated, and examined separately from the rest of the cavity. Figure 1 shows the assembled cavity.

RECENT RESULTS

The sample host cavity has now reached peak fields of over 100 mT on the sample plate. This is a significant step towards the empirically inferred limit of 120 mT, based on thermal runaway in previous TE cavities [4].

Recent tests of the sample host cavity have shown a Q-slope, as shown in Fig. 2. This is problematic, since the utility of the sample host cavity relies on achieving high Q at all fields: reaching high Q increases the sensitivity of the measurements of sample performance by reducing the background signal from the rest of the cavity.

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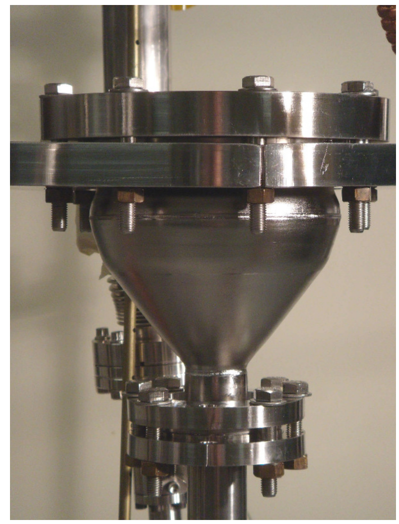

Figure 1: Third-generation Cornell TE sample host cavity.

It was speculated that the observed Q-slope effect was caused by indium losses, which can occur if the indium sealant approaches the RF surface at the cavity-sample plate interface. In order to investigate this possibility, we examined the relation between the quality factor Q and the temperature T for this high-field test, shown in Fig. 3. If the indium used as a sealant between the sample plate and cavity was interfering enough to bring rise to RF losses, we would expect that Q would decrease significantly above the superconducting critical temperature of indium, 3.4 K. However, the data do not suggest any such change in Q, implying that the observed Q-slope was not caused by indium losses. More work is needed to investigate this Q-slope.

A more recent test featuring a niobium-tipped coupler (discussed below), also seen in Fig. 2, aligns with the Q-slope of the high-field test, though the test did not reach fields high enough to make a direct comparison.

NIOBIUM COUPLER TIP

Previous tests of the sample host cavity suggested that the copper coupler assembly was introducing losses and affecting the intrinsic quality factor of the cavity [4, 5]. In light of this, and in an effort to increase the Q of the system, the tip of the coupler for the sample host cavity was replaced with a duplicate made with niobium. In theory, a superconducting coupler tip would lower coupler losses significantly due to the strongly decreased resistance.

As Fig. 4 shows, to first order this coupler tip replacement does not appear to decrease the impact of the coupler on the

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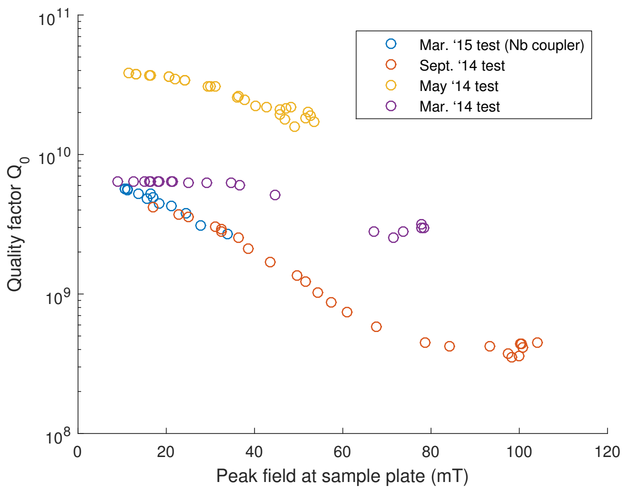

Figure 2: Quality factor Q_0 measured against peak field at the sample plate for several tests. The September 2014 test reached fields of 100 mT, but a significant Q-slope was observed. The March 2015 test featured a niobium-tipped coupler but did not reach high fields.

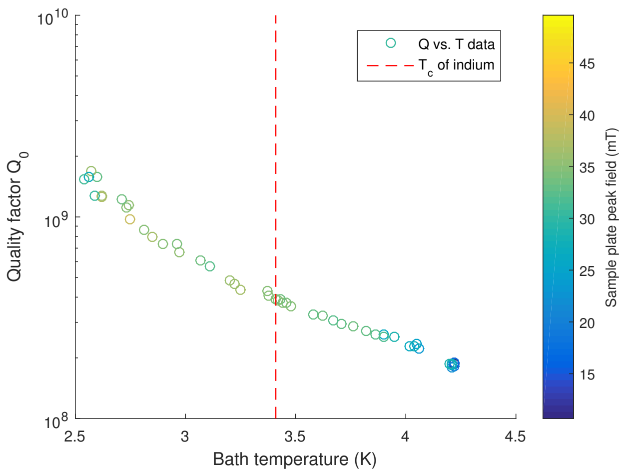

Figure 3: Quality factor Q_0 measured against temperature for the September 2014 test, which exhibited a Q-slope. Since there is no significant change at the critical temperature of indium, it does not appear that the Q-slope was caused by indium losses.

intrinsic quality factor as compared with the previous copper coupler. This means that the cavity is likely still dominated by coupler losses. It is possible that the niobium coupler tip is in a normal-conducting state due to insufficient cooling of the coupler during RF operation, which would override the benefits of using a superconductor.

OUTLOOK AND FUTURE PLANS

The recent result of a 100 mT peak field on the sample plate surface is very promising and demonstrates the utility of the Cornell sample host cavity.

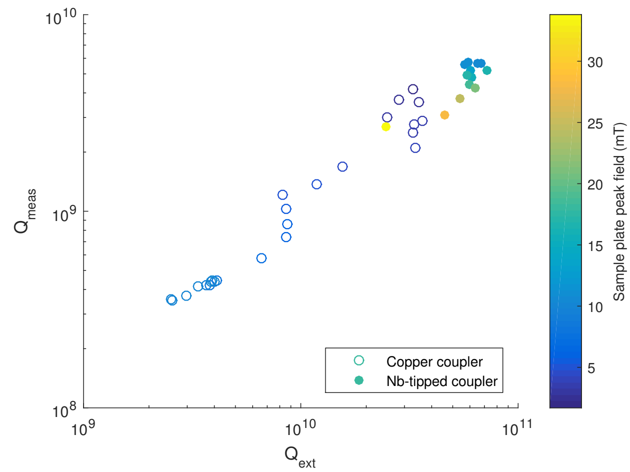

Figure 4: Intrinsic quality factor Q_m plotted against external quality factor Q_{ext} for the test with niobium-tipped coupler and a representative copper coupler test. The niobium tip does not appear to decrease the impact of the coupler on the measured quality factor.

In order to reduce the risk of surface contaminants which may introduce increased surface losses, steps are being taken to improve the assembly and cleaning procedure of the sample host cavity for future tests.

In the near future, Cornell will be using the sample host cavity in collaboration with several other laboratories, including Jefferson Lab, Los Alamos National Lab, Alameda Applied Sciences, and Saclay/Orsay, to test the RF performance of thin film materials such as NbN on MgO, thin-film Nb, Nb on Cu on Nb, and MgB2.

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