ISBN: 978-3-95450-211-0 doi:10.18429/JACoW-SRF2019-TUP070

THE SRF THIN FILM TEST FACILITY IN LHe-FREE CRYOSTAT

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Abstract

An ongoing programme of development superconducting thin film coating for superconducting radiofrequency (SRF) cavities requires a facility for a quick sample evaluation at the RF conditions. One of the key specifications is a simplicity of the testing procedure, allowing an easy installation of the sample and quick turnover of the testing samples. Choked test cavities operating at 7.8 GHz with three RF chokes have been designed and tested at Daresbury Laboratory in a LHe cryostat verifying that the system could perform as required for future superconducting thin film sample tests. Having the sample and cavity physically separate reduces the complexity involved in changing samples - major causes of low throughput rate and high running costs for other test cavities - and also allows direct measurement of the RF power dissipated in the sample via power calorimetry. However, changing a sample and preparation for a test requires about two-week effort per sample. In order to simplify the measurements and achieve a faster turnaround, a new cryostat cooled with a closed-cycle refrigerator has been designed, built and tested. Changing a sample, cooling down and testing can be reduced to 2-3 days per sample. Details of the design and results of testing of this facility will be reported at the conference.

INTRODUCTION

An ongoing ASTeC Thin Film SRF program includes the four parts: (1) Surface preparation and deposition of the samples using PVD and CVD methods [1-4]; (2) Characterisation of the samples using various surface analysis techniques including SEM, XPS, XRD, EDX, etc.; (3) Measuring superconducting properties in DC and AC conditions: RRR, magnetisation (SQUID), magnetic field penetration, etc. [1, 2, 5-7]; (4) Testing of the various samples at RF frequencies using a dedicated cavity design [8-10].

Two choked cavities were designed at Daresbury Laboratory for testing of planar samples. The cavities were initially measured at room temperature [8], then a three-choke cavity was tested at cryogenic temperature with a copper and Nb samples [9,10]. Although, the LHe cryostat based system demonstrated that the suggested method can be employed, the required effort to change a sample was found to be still too high. A new facility based on pulsed cold head has been designed, built and tested.

This paper reports on the design detail, cryogenic test and troubles to be resolved.

CAVITY DESIGN

The RF design of the niobium cavity and its use in a LHe cryostat was detailed in [10]. The LHe system is still operable but it is still time and effort consumable to change a sample. In order to simplify the testing it was decided to design a simple and easy-dismountable facility base on a closed-cycle refrigerator cooling.

In its initial implementation, the two-choke cavity and sample plate assembly is connected using spacers. The surface resistance is measured using a DC-RF compensation method requiring the sample temperature to increase. The thermal contact between the cavity and the sample through the use of thermal strapping, was optimised to ensure an appropriate temperature rise at the operating power, to allow accurate measurements while keeping the temperature of the sample well below the transition temperature. The cavity is well strapped to the cryocooler to ensure a fixed temperature.

Figure 1 shows the Nb cavity mounted onto the second stage of the cryocooler. This section constrains the RF through the use of quarter-wave chokes. The input antenna is coupled into the cavity volume from the top. The antenna is mounted onto a thin-walled stainless steel tube attached to a micrometer at the top of the cryostat. A 2nd antenna can be inserted either inside one of the chokes or from the side to allow the stored energy to be measured, however due to the relatively low Q of the system stored energy can be measured from the reflected power on a network analyser instead.

CRYOGENIC FACILITY

The cryogenic set-up layout is shown in Fig. 2. The entire facility is assembled to the top flange of vacuum chamber, which is equipped with a cryocooler (Sumitomo RDK-415D 4K Cryocooler). RF feedthrough with a linear drive, thermometry and heater's wiring feedthroughs and ports for vacuum pumps and gauges. Vacuum vessel made of 304L stainless steel.

* The authors wish to acknowledge the support received from STFC and ASTeC management. O.B. Malyshev would like to acknowledge the support provided by European Union's ARIES collaboration H2020 Research and Innovation Programme under Grant Agreement no. 730871.
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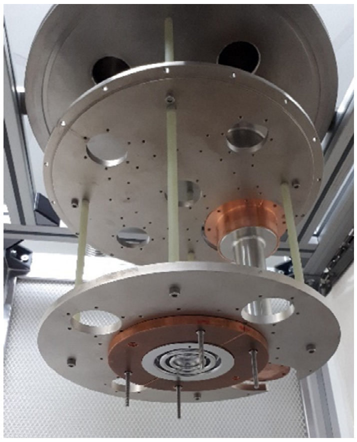

Figure 1: The two-choke cavity installed on Stage 2 plate at the facility.

Stage 1 plate is mounted to the top flange with four G10 rods (shown in Fig. 1), and Stage 2 plate is mounted similarly to Stage 1 plate. For providing good thermal conductivity, the Stage 1 and 2 plates, the thermal screen, the cavity and sample holders are made of OHF copper, while the sample screen is made of aluminium. Cooling of the Stage 1 and 2 plates and the sample holder is provided with the heat links $L_1 - L_3$. A good thermal contact was provided through the use of indium foil at all joins between metal parts.

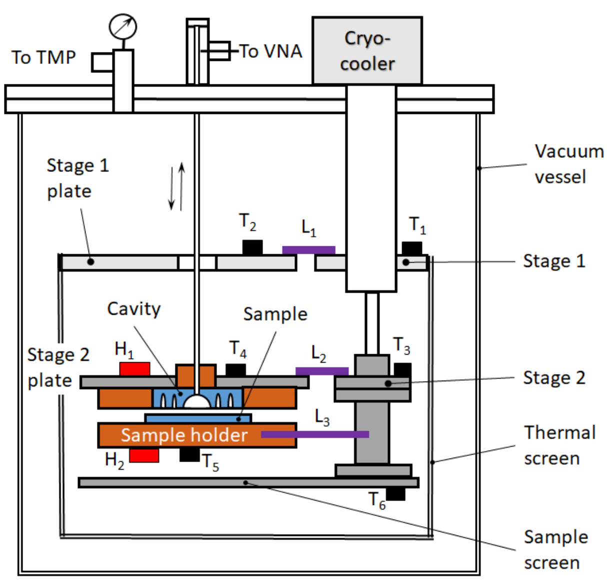

Figure 2: Schematic of the test cryostat assembly. T_1-T_6 are thermometers, H_1 and H_2 are heaters, L_1-L_3 are heat links, TMP is a turbo-molecular pump.

The facility is equipped with thermometers T_1-T_6 allowing to now the temperature of different parts of the cryostat.

Cavity and sample temperatures can be controlled through the use of heaters H_1 and H_2 attached to Stage 2 plate and to sample holder plate.

Calorimetric measurements, using the DC-RF compensation method, are required for the experiment, and a system similar to the one implemented on the LHe cryostat [9] can be used.

The system has been improved in terms of ease of sample changing. The following has been implemented:

– Single vacuum, i.e. no vacuum joints and sealing at cryogenic temperatures;
– No need of disconnection of many thermometer and heater wires, however, if necessary to disconnect a sample holder plate, all wires can be disconnected with a single connector.
– To change a sample one have simply to lose four nuts holding the sample holder plate and slide the sample (see Figs. 2 and 3).

Assembling the facility after changing a sample takes now about 1 hour. It take about 24 hours pumping to pump down to 10^{-4} mbar when cryocooler could be switched on.

CRYOGENIC TEST

After 12 hours of cooling the temperature of 4.6 K reached on the Stage 2 plate and the sample holder plate. The heaters and thermometers connected to temperature controllers Lakeshore model 335 controller allows to control the cavity and the sample temperature in the range 4.6 – 60 K.

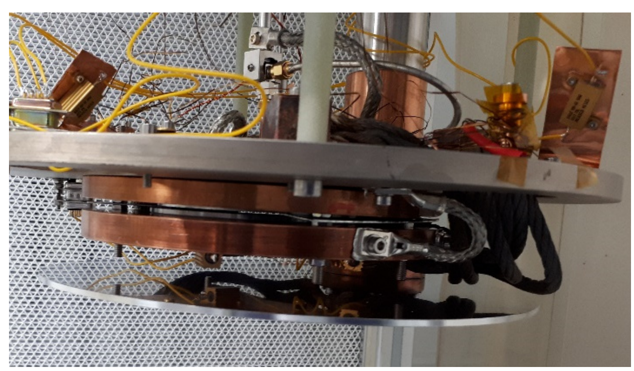

Figure 3: Detailed view of the cavity cradle.

RF TEST

RF measurements were taken using a vector network analyser (VNA) connected to the input probe (see Fig. 4 for overall operational setup). The input power was restricted to 100 mW due to radiation limits in the testing area. This allowed us to take low power measurements only.

All measurements are preferably taken in matched conditions, which can be achieved by using the tunable input coupler through manipulation of the micrometer on the top flange. This system had been very effective when used with the LHe cryostat [9], but the pulsed nature of the

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cooler used in this experiment generated microphonics that caused the input coupling to jump, preventing accurate measurements.

Efforts have since been made to damp the microphonics through better control of the coupling rod, by adding stiffening brackets connecting the rod to the Stage 1 and 2 plates. The brackets do not prevent vertical movement over the required tuning range. This has provided substantial damping, but should one decide to further reduce the microphonics the antenna support system should be replaced with a cryogenic drive or similar system mounted solidly onto the Stage 2 plate.

The first measurements of the cavity with an aluminium sample, chosen to avoid any radiation safety issues, have been taken. This test has demonstrated that the tuner is still functional and the Q-factor of the cavity can be measured.

The surface resistance calculated from this measurement at f = 7.75 GHz and T = 4.6 K was R_s = 0.015±0.003 μΩ which is in line with literature data [11].

Figure 4: Test facility in operation.

CONCLUSIONS AND FUTURE PLANS

A new facility for the RF testing of superconducting thin films deposited on Cu or Nb planar samples has been built. The first cryogenic RF tests demonstrated that the cryostat and RF instrumentation operated as designed. It has been demonstrated that sample surface resistance can be measured at temperatures in the range of 4.6 – 60 K. Vacuum and cryogenic tests proved a confidence that the target of measuring one or two samples a week can be achieved.

Microphonic issues could potentially remain a problem with superconducting samples and this should be addressed in the future.

The next step will be to repeat the measurements using a bulk Nb sample to verify the ultimate performance and sensitivity of the facility in terms of surface resistance measurements.

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