# MEASUREMENT OF THIN FILM COATING ON SUPERCONDUCTORS

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*Abstract*

In order to investigate performances of superconducting thin film coatings, a measurement system for superconducting thin film coating is under construction. Based on the third order harmonic measurement, it will measure the $H_{c1}$ of the thin film coatings. Samples are cooled down through a copper plate tab whose bottom end is immersed in liquid Helium. The tab is fixed under a sample stage and the temperature of the stage can be controlled by a heater on the stage. The temperature is monitored by Cernox sensors. The current status of the system is reported.

## INTRODUCTION

Multilayer thin film coating of superconducting materials is a promising technology to enhance performance of superconducting cavities. Until recently, principal parameters to achieve the sufficient performance had not been known, such as the thickness of each layer. We proposed a method to deduce a set of the parameters to exhibit a good performance [1] (see Figure 1). In order to verify the scheme, we are trying to make some experiments on the subject at Kyoto University.

## MEASUREMENT METHOD

In order to evaluate the performance of the thin film coated material, we selected the third order harmonic detection method [2,3]. Figure 2 shows the schematic diagram of the prepared system, where the FPGA controls the generation of a sinusoidal wave and the amplified current excites the coil to generate the AC magnetic field. The FPGA is controlled by a PC through USB. The magnetic field is applied to superconducting samples and the excitation current and the self-induced voltage of the coil are monitored. The third harmonic component is measured through a high pass filter (HPF) eliminating the fundamental frequency component. Figure 3 shows the measurement system for the third order harmonic component. When the applied magnetic field is less than $H_{c1}$ of the superconducting film material, the Meissner effect completely repels the magnetic flux and the magnetic field flux does not penetrate the superconducting films. The self-induced voltage of the coil is proportional to the time derivative of the coil current as long as the Meissner effect is maintained. This linear behavior is broken when the magnetic field level exceeds $H_{c1}$, and the self-induced voltage of the coil becomes distorted. Then the third order harmonic appears in the voltage. This tiny component is picked up among the large fundamental component by the HPF. In order to reduce the heat generated by the coil current, the AC current is applied intermittently with duty factor of less than 10%. The frequency of around 5kHz is assumed in this system and the ADC has 20-Bit resolution at 250ksps. The obtained data is Fourier transformed in the PC and analyzed.

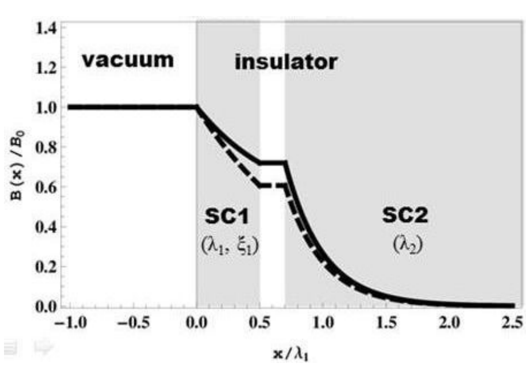


Figure 1: The multilayer thin film coating on superconducting bulk surface. The simplest case of two layers of an insulator and a superconductor is shown. The solid line shows the RF magnetic field amplitude as a function of the coordinate along the axis normal to the surface.

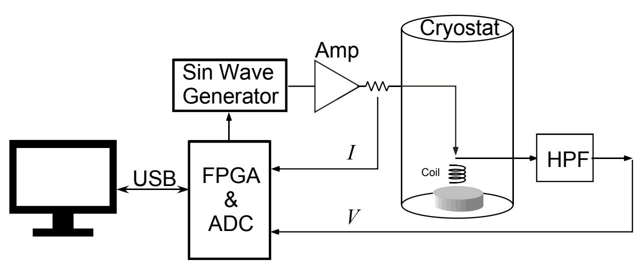


Figure 2: Block diagram of the measurement system of the third order harmonic component.

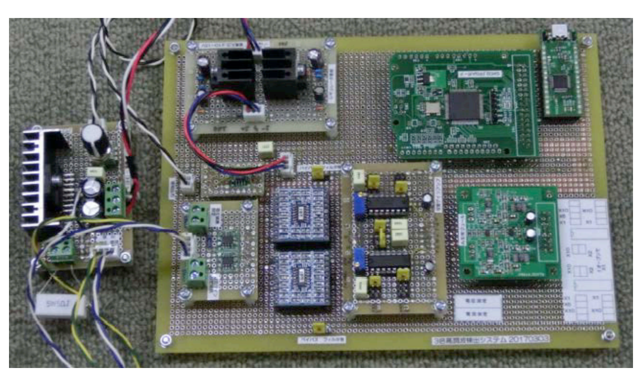

Figure 3: Circuits of the measurement system for the third order harmonic component.


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## CRYOGENIC ENVIRONMENT

Our cryostat is almost ready to start the measurement. The cryogenic environment has been prepared to have temperature sensors, liquid helium quantity monitors, and a magnetic shield [4]. We purchased one CERNOX sensor with calibrated data (CX-1030-SD-1.4L) and four CX-1030-BG-HT without calibration data. The latter ones are calibrated by the data from the former one, where the temperature range is limited down to 4.2K. The region out of range is extrapolated. Figure 4 shows the mounted CX-1030-SD-1.4L together with a platinum resistance thermometer pt100 for > 50 K region. Figure 5 shows the CX-1030-BG-HT in bare chip profile mounted on a copper strip with varnish as suggested by the supplier. Figure 6 shows the mounted sensors for the calibration configuration.

Figure 4: Mounted temperature sensors. Left: CERNOX Model: CX-1030-SD-1.4L. Right: pt100

Figure 5: Mounted CERNOX sensor CX-1030-BG-HT.

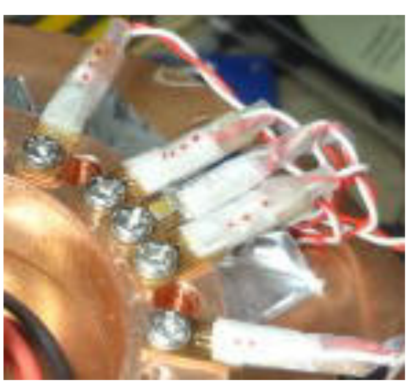

Figure 6: Mounted CERNOX sensors for calibration. Four bare chips are located around the CX-1030-SD-1.4L.

Figure 7 shows the cryogenic stage for the temperature calibration configuration with a heater for the temperature control. Figure 8 shows the stage for the third order harmonic measurement configuration, which has two copper plates for the exciting coil and samples. Since a sample is put on the bottom plate, the sample temperature should follow the bottom plate. Both plates have copper tabs whose bottom ends are immersed in the liquid helium independently (see Fig. 8). The stage can be pulled up to control the depth of the immersion to the liquid helium. The wiring for this setup will start soon.

As to the cryostat, an experiment can last for more than 12 hours after the filling of liquid helium as shown in Fig. 9. The temperature returns back to the room temperature after three days. The experimental room has slightly higher environmental stray magnetic field ~100 μT, maybe because a big superconducting magnet had sit in the room and the reinforcing bars in the floor concrete seems

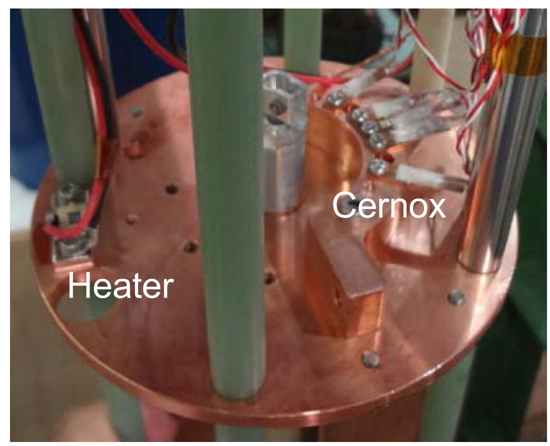


Figure 7: The cryogenic stage for temperature calibration configuration that has a heater to control the temperature.

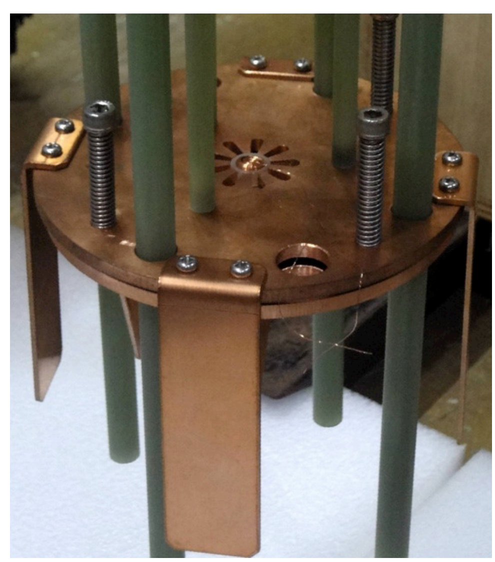

Figure 8: The heat conduction tabs are attached on the two plates; the upper plate holds the coil and the bottom plate support the samples. The bottom ends of the tabs are immersed in liquid helium. The bottom plate will have a heater to control the temperature of samples.

magnetized. In order to reduce the stray magnetic field, galvanized iron sheets are wrapped around the cryostat. Figure 11 shows the magnetic field (vertical component Bz) distribution along the axis. With this cheap care, the magnitude became about one tenth. Further magnetic shielding may have to be added later.

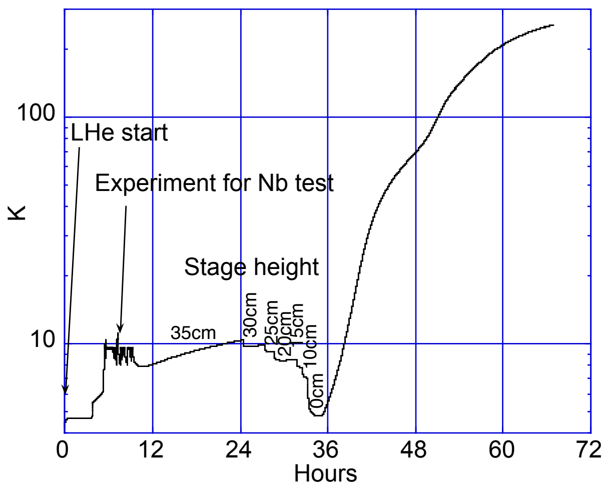


Figure 9: Stage temperature as a function of time. Cryogenic temperature can be maintained for more than 12 hours after the filling of liquid helium. The temperature returns back to the room temperature after three days.

Figure 10: Galvanized iron sheets are wrapped around the cryostat to reduce the stray magnetic field.

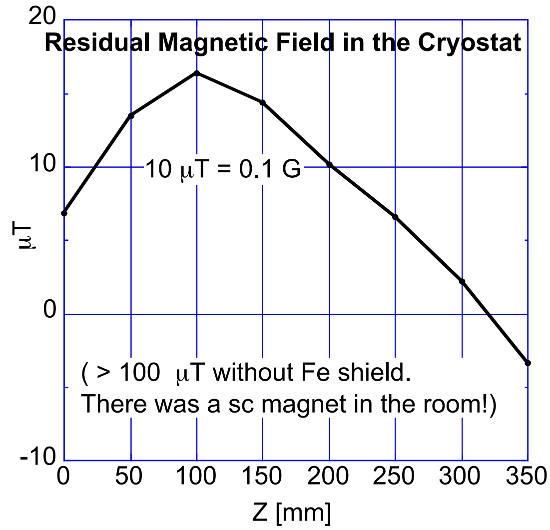


Figure 11: Magnetic field (vertical component Bz) distribution along the axis after galvanized iron sheets are wrapped around the cryostat. The magnetic field was measured by Fluxgate sensor located at the stage position. The stage height is moved by pulling up the pipe hanging the stage.

## SUMMARY

The measurement setup for the third harmonic component is almost ready. It includes the electric circuits, cryogenic system, and magnetic field shields. The last one, magnetic field shields may have to be added further after the measurement starts up.

## ACKNOWLEDGEMENT

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