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DEVELOPMENT OF TEMPERATURE AND MAGNETIC FIELD MAPPING SYSTEM FOR SUPERCONDUCTING CAVITIES AT KEK

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Abstract

A temperature and magnetic field mapping system have developed at KEK. The temperature measurement system consists of 540 carbon resistors. The magnetic field is measured by the anisotropic magnetoresistive effect (AMR) sensors. Three sensors are mutually orthogonal to each other measure 3-axis magnetic field on the equator of a cavity. The sensors are mounted boards that are arranged every 10 degrees on the cavity outer surface. We evaluate the relation of the temperature and resistance of carbon sensors at low temperature. AMR sensors also tested the sensitivity of the magnetic field at 293 K and liquid nitrogen temperature, and 2 K. The measurement system uses the digital multimeter and multiplexer switch module by National Instrument. We show the structure of the mapping system.

INTRODUCTION

Performance of a superconducting radiofrequency cavity cannot reach the ideal maximum accelerating gradients by the local quench or the field emission, multipacting. The quench is caused by local heating. In KEK, the present temperature mapping system for a single cell cavity is rough in spacing [1]. We have developed a higher spacing resolution temperature mapping system for a superconducting single cell cavity. Furthermore, an unloaded Qvalue is essential for the performance of cavities. The Q-value is associated with rf losses in the wall. The temperature independent surface resistance from among those resistances increase by trapped magnetic flux. A superconductor expels all most ambient magnetic field in the vicinity of the cavity. However, some magnetic flux is trapped with the cavity for a few reasons. The trapping flux cause low Q-value for the cavity. Elucidation of the flux trapping is necessary to increase the performance of the cavity. That mapping system includes the 3-axis magnetic sensors and can estimate the location of trapped magnetic flux.

MAPPING SYSTEM

The mapping system consists of two type sensors that one is carbon resistor temperature sensor and AMR magnetic sensor. Figure 1 shows the sensor and board design. 15 carbon resistors and 3 AMR sensor that are orthogonal to each other are mounted on a board. A total of the board is 36; it can cover around the outer surface of a single superconducting cavity every 10 degrees. The spatial thickness of a board with sensors is less than 3 cm.

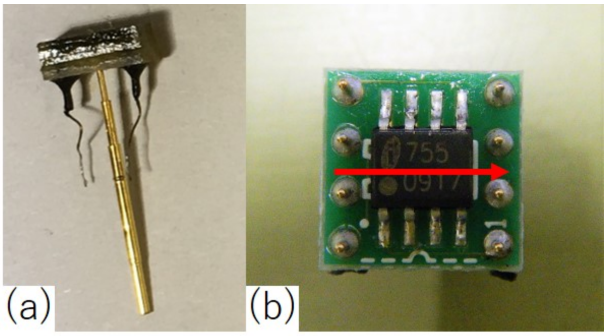

Figure 1: (a) shows Allen-Bradley carbon resistor with G10 housing. A pogostick support to contacts on the outer surface of a cavity by the elasticity. (b) shows AMR magnetic field sensor by Sensitec. The sensitivity is maximum in parallel to the long side of the sensor.

Carbon Resistors

The mapping system consists of a total of 540 Allen-Bradley carbon resistors. Also, those resistors have 100 Ohm resistance. A pogo stick presses the resistor against the surface of the cavity. Temperature variation detected by the relationship of temperature and resistance of carbon resistors. These resistors reused from the other temperature mapping system [2, 3].

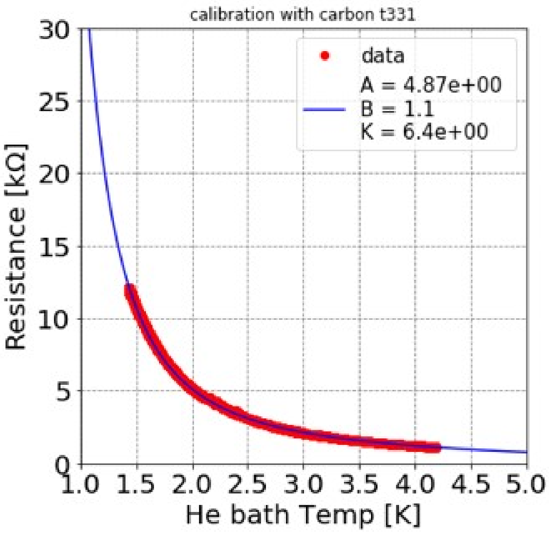

Figure 2: Calibration curve for one carbon resistor. It needs to calibrate for each all sensors.

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We tested the sensors independently of the board at low temperature. We attached Some carbon resistors choice from total sensors near the equator of the single-cell cavity. The resistance of those resistors is around over 100 Ohm at 293 K. Some resistors have over 200 or 300 Ohm. A current of carbon resistors is 10 μA. The measuring voltage applied to carbon resistors decides the temperature of sensors. We cooled sensors and cavity from 293 K to 1.5 K. The silicon di thermometer on the equator of the cavity detected the temperature. Figure 2 shows the one calibration result of one carbon resistor.

We fit the relation of resistance of carbon and temperature used by this equation:

$$\log_{10}(R) + \frac{K}{\log_{10}(R)} = A + \frac{B}{T}. \tag{1}$$

where, fitting parameters are K, A, and B and we used the least squares method with 10% errors for estimating parameters. All carbon resistors work well at superfluid helium temperature.

AMR Sensors

Anisotropic magnetoresistance (AMR) sensors measure a magnetic field. AMR sensor is used AFF755 by Sensitec [4]. This sensor is low-cost and small for mapping system. The sensor can measure only one axis of magneic field component.

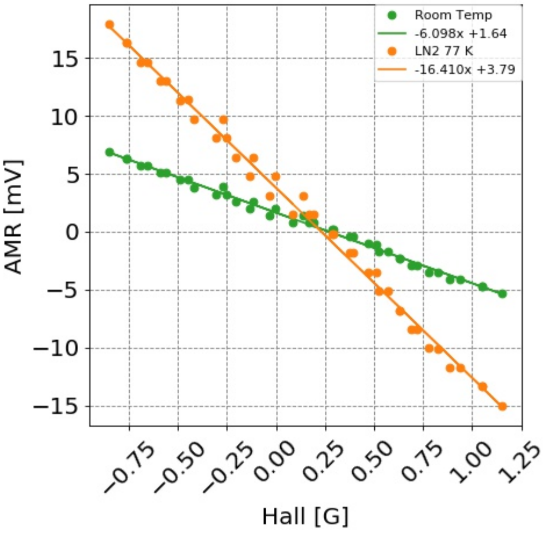

Figure 3: Sensitivity at 293 K and liquid nitrogen temperature. Magnetic field was controlled by helmholtz coils.

We used another measurement system for investigating AMR sensors. This system has 3-axis square Helmholtz coils to control the magnetic field. Calibrated Hall sensor detected the magnetic field and currents of coils controll to magnetic field. We compare the voltage of the output of the AMR sensor and magnetic field to decide the sensitivity of the AMR sensor.The sensitivity of AMR sensor is linear response with the voltage and the temperature. Liquid nitrogen cools the sensor to 77 K from 293 K. Figure 3 shows the magnetic sensitivity of the AMR sensor at 293 K and 77 K. The sensitivity is around 6 mV/G at 293 K and 16.4 mV/G at 77 K.Therefore, the sensitivity increase with decrease temperature.

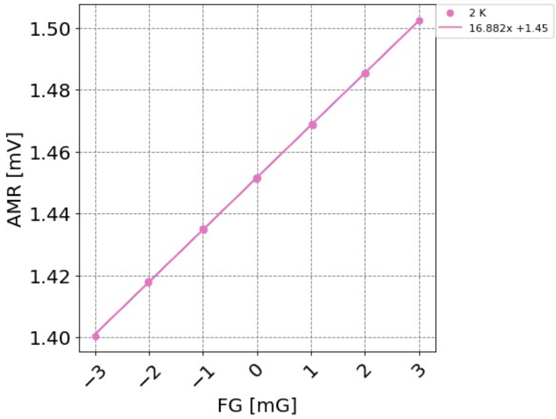

Figure 4: Sensitivity at liquid helium temperature.

We also tested the sensitivity at 2 K. We attached the AMR sensor and fluxgate on a cavity. The magnetic field was controlled by solenoid coil at vertical test stand. Figure 4 shows the result of the sensitivity at 2 K However, the sensitivity is around 16.8 mV/G same as a result at 77 K.

Board Design

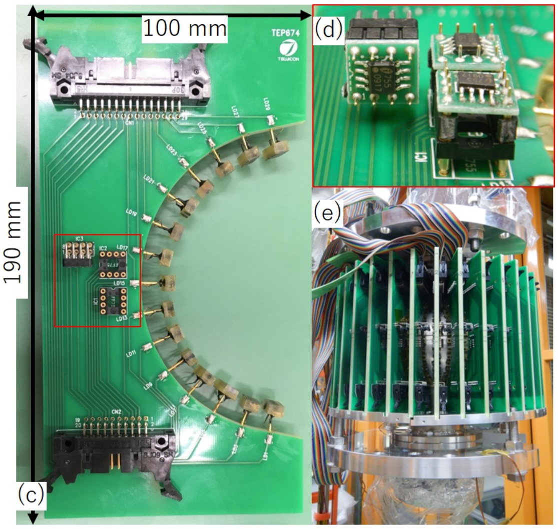

Figure 5: (c) shows design of a board. The board consists 15 carbon resistors and 3 AMR sensors. AMR sensors can detect magnetic field on the equator of a cavity. (d) shows alignment of AMR sensors. These sensors are orthogonal to each other to measure 3 axis magnetic field. (e) shows a single cell cavity with mapping boards.

A sensor board consists of 15 carbon resistors and 3 AMR sensors on the equator of the cavity. Figure 5 shows the design of a board. A total of the boards is 36, and it can cover around the cavity every 10 degrees. Thereby identify the location of the heating spot of the cavity. The board equips MIL connectors on top and bottom that does not disturb for installing solenoid coil. This mapping system measures the 3-axis magnetic field by AMR sensors that are orthogonal to each other. AFF755B has 8 wires for supply and output and flip coil to remagnetize, test coil. The boards have designed supply voltages to parallel for 3 sensors. The other wires of flip coils and test coils combined to serial in a cryostat.

SUMMARY AND FUTURE PLAN

We have developed the temperature and magnetic field mapping system. 540 carbon resistors measure temperature on the outer surface of the cavity and identify a location of the heating spot. 3 AMR sensors have mounted on the board that equips around cavity per 10 degrees measure 3-axis magnetic field. We plan to measure temperature and magnetic field during the cooling to expel the magnetic field and the vertical RF measurement.

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