DESIGN, COMMISSIONING AND PRELIMINARY RESULTS OF A MAGNETIC FIELD SCANNING SYSTEM FOR SUPERCONDUCTING RADIOFREQUENCY CAVITIES*

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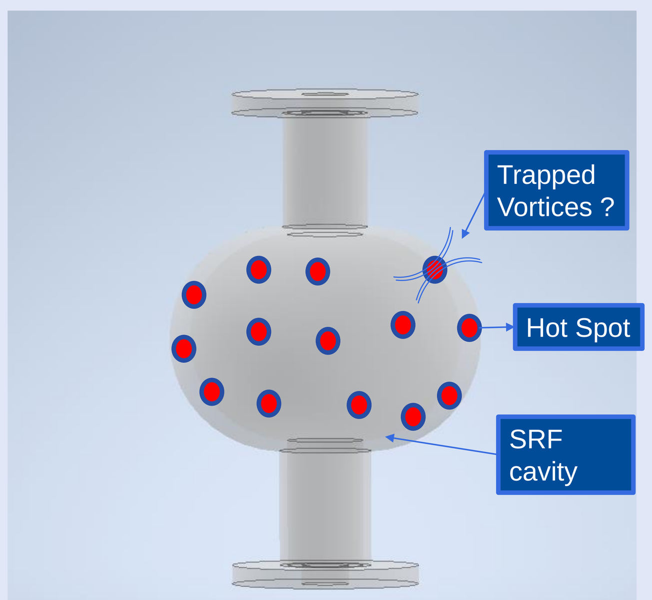
INTRODUCTION

- Niobium Superconducting radiofrequency (SRF) cavities are essential building blocks of modern particle accelerators. They operate at cryogenic temperatures (2-4 K) to achieve superiorly high quality factors ($10^{10} - 10^{11}$).
- Residual RF losses at high fields prevent achieving optimum quality factors at a higher accelerating gradient in SRF cavities. The magnetic flux trapping is a leading cause of residual loss that depends on cool-down conditions, surface preparation, and the ambient magnetic field [1 - 4]. Suitable diagnostic tools are in high demand to study the effects of such conditions on magnetic flux trapping to enhance cavity performance.
- A new magnetic field scanning system (MFSS) is developed to measure the local magnetic field trapped in SRF cavities at 4 K. The design of the newly commissioned system and preliminary results of the measurements of the magnitude and distribution of trapped flux at different cool-down conditions using Hall probes (HPs) and Fluxgate magnetometers (FGMs) in a 1.3 GHz single-cell SRF cavity are presented.

OBJECTIVES OF THE EXPERIMENT

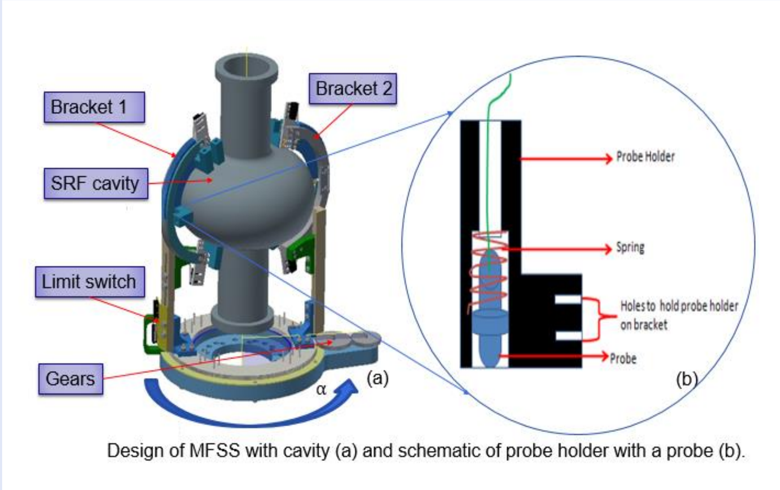


Schematic of a cavity with hot-spots and trapped vortices threading through it.

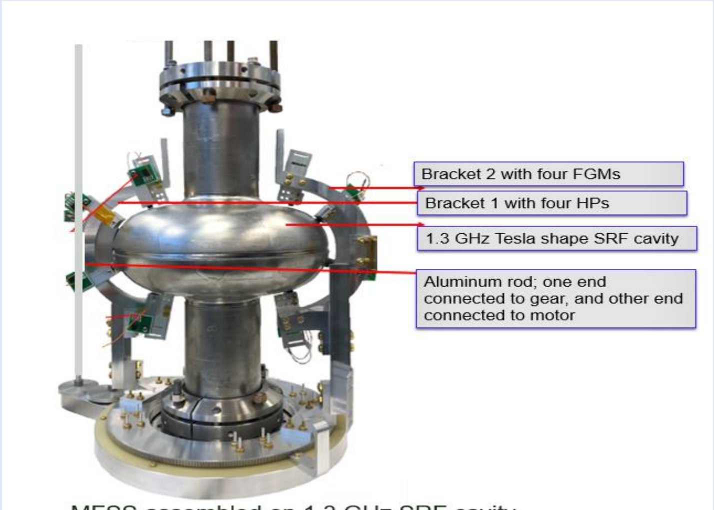
- ❑ While testing SRF cavity performance at cryogenic temperatures, we typically observe several hot-spots (dissipative regions) around the cavity surface at a high RF field.
- ❑ Are those hot-spots arose due to trapped magnetic flux lines (vortices)?
- ❑ How many vortices are pinned at the cavity surface, and what is their distribution?
- ❑ What cool-down conditions can minimize the trapping of vortices in the cavities?
- ❑ Do trapped vortices appear even if a cavity is screened from as low as stray magnetic fields?

We want to answer these questions.

EXPERIMENTAL DESIGN



Design of MFSS with cavity (a) and schematic of probe holder with a probe (b).



MFSS assembled on 1.3 GHz SRF cavity.

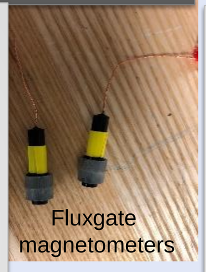
- MFSS consists of two brackets
- Each bracket can hold up to eight sensors
- The motor can rotate MFSS from 0-360 degrees around the axis of the cavity.

Detail of the experimental design of magnetic field scanning system can be found on [5].

TYPES OF SENSORS

Fluxgate Magnetometer (FGM)

- ❑ **Working principle: Magnetic and electric induction.**
- ❑ Single axis magnetometer useful in cryogenic temperature.
- ❑ Cylindrical shape with diameter 1mm and 28 mm long.
- ❑ Measure field as low as 0.1 nT up to 0.2 mT.



Fluxgate magnetometers

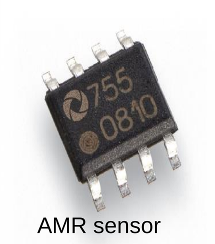
Hall Probe (HP)

- ❑ **Working principle: Hall Effect**
- ❑ Single axis HP useful in cryogenic temperature.
- ❑ Active area 20 μm × 20 μm.
- ❑ Sensitivity at room temperature is 50 $\frac{mV}{T}$ and sensitivity at 2 K, 4 K and 9 K is ~94 $\frac{nV}{\mu T}$.

Hall probe

Anisotropic Magnetoresistance (AMR) Sensor

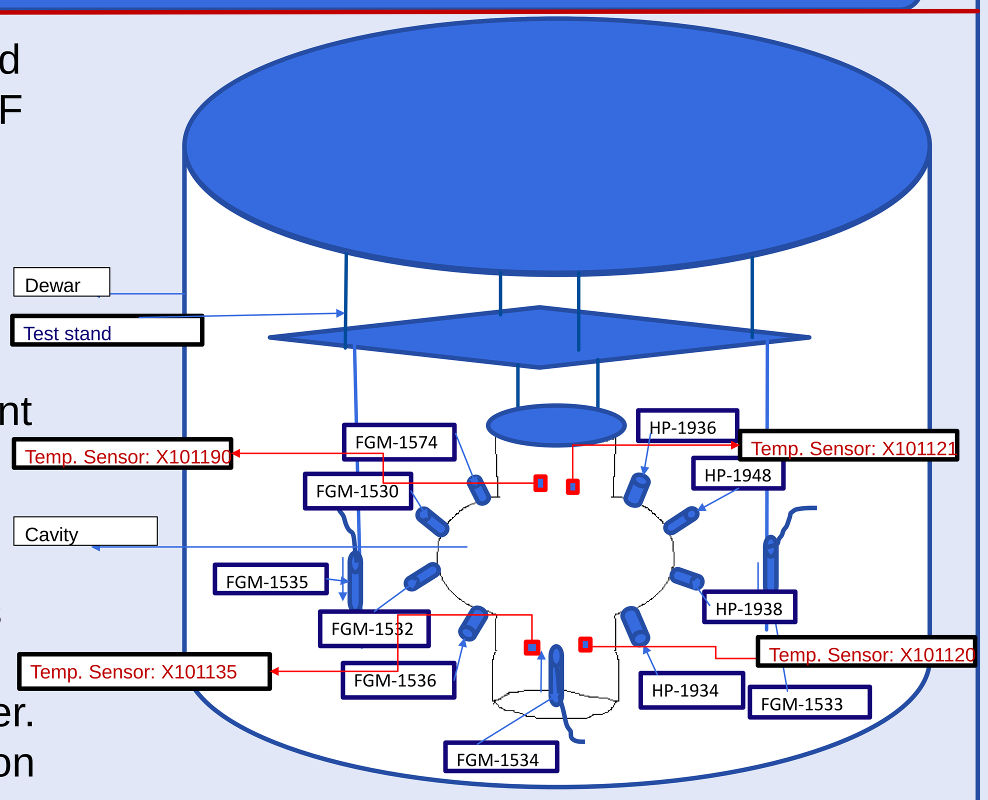
- ❑ **Working principle**: **Change in resistance of ferromagnetic file with applied B-field.**
- ❑ Useful in cryogenic temperature.
- ❑ Single axis sensor with active area 0.7×0.8 mm^2.
- ❑ Sensitivity at 4 K is ~ 200 $\frac{\mu V}{\mu T}$.



AMR sensor

EXPERIMENTAL PROCEDURE

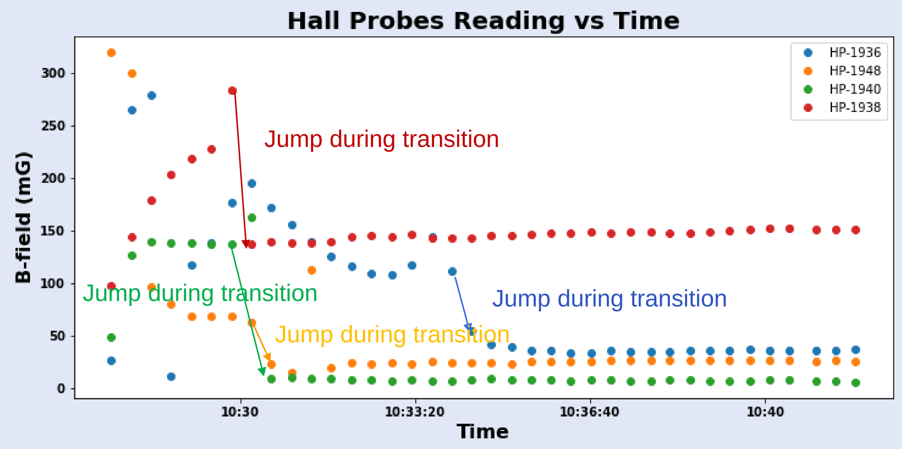
- Take a 1.3 GHz single-cell cavity subjected to typical surface treatments for optimal RF performance.
- Assemble the MFSS on cavity after installing into a test stand.
- Load the assembled test stand into a dewar.
- Perform magnetic field scanning at different **cool-down conditions and external magnetic fields**.
- Hall probes reading is taken by USB2ad data acquisition system, FGMs reading is taken by Mag01-H module, and AMRs reading is taken by Keithley 2701 voltmeter.
- Instrumentation control and data acquisition is performed by labVIEW program.



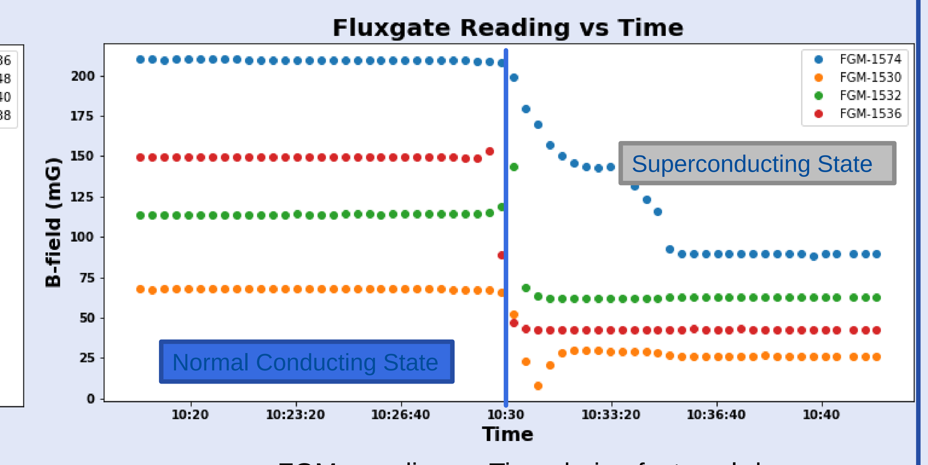
Current experimental setup layout

PRELIMINARY RESULTS

- The cavity was subjected to "fast-cooldowns" through the critical temperature at an external magnetic field of ~ 200 mG. Both HPs or FGMs used in MFSS detected the superconducting transition.

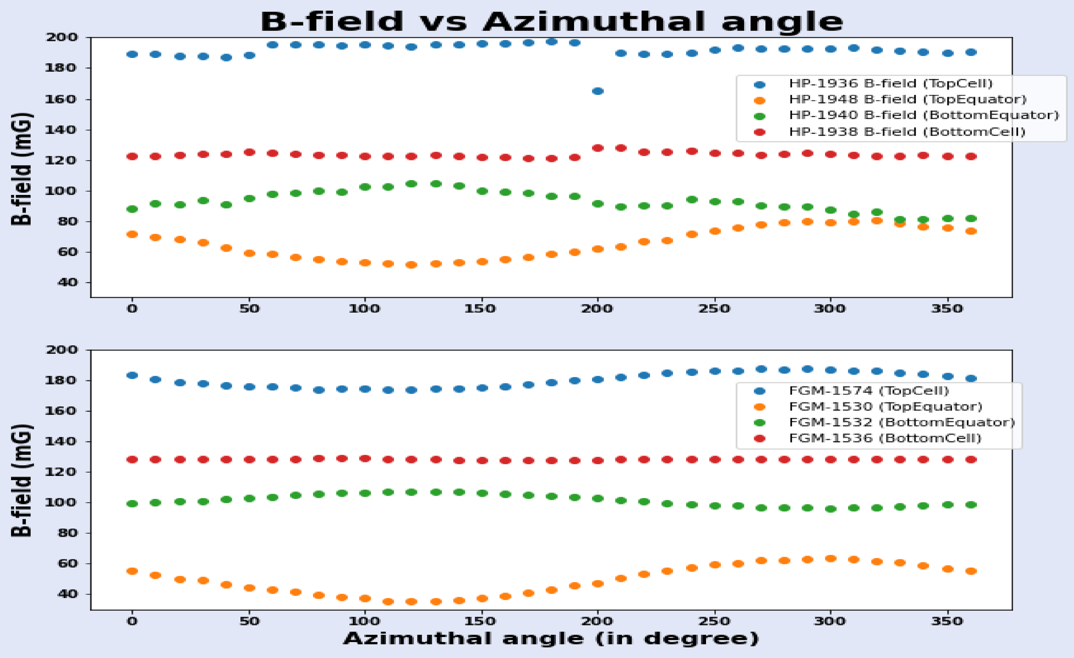


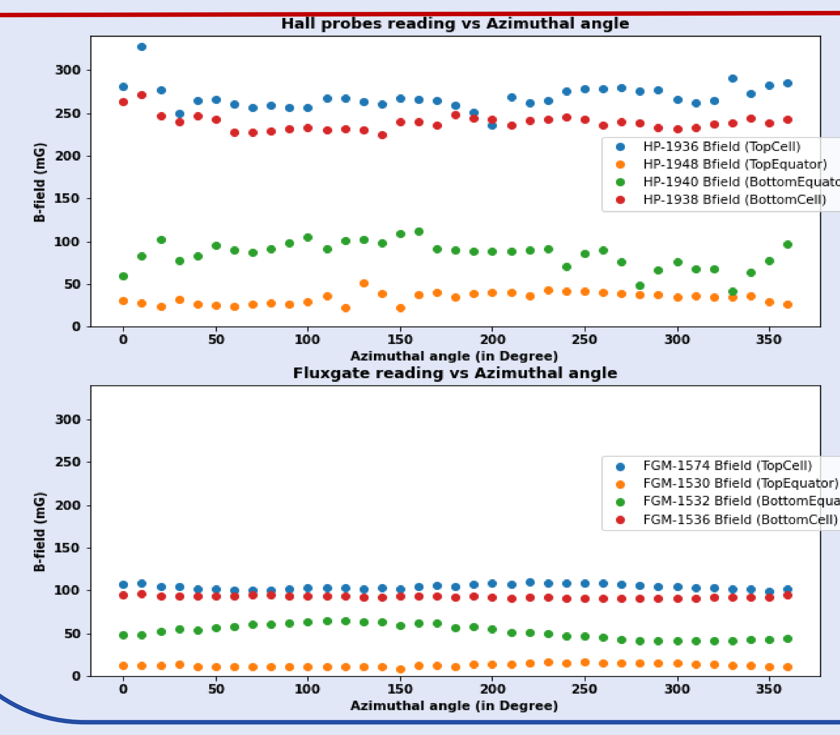
HPs reading vs Time during fast cool-down



FGMs reading vs Time during fast cool-down

- **Before performing a magnetic field scan**: we applied an external magnetic field of ~ 200 mG and cool the cavity to 12 K.
- We performed the magnetic field scanning test.
- These are plots of HPs reading and FGMs reading during magnetic field scan around the cavity axis.





Before performing a magnetic scan:

- ❑ We did slow cool-down with B_{ext}~ 200 mG and ΔT~ 200 mK.
- ❑ The cavity temperature was kept at 4.4 K immersing in liquid He.
- ❑ We decreased the B_{ext}~2 mG.
- ❑ The values shown in plots are trapped flux on the cavity surface.

MFSS successfully detected the trap fluxes !

SUMMARY AND FUTURE WORK

- ➢ **A New system** for measuring magnetic flux trapped in the walls of 1.3 GHz SRF cavities has been designed, built and tested at cryogenic temperature.
- ➢ The system can detect the superconducting transition. Magnetic field scanning of a cavity surface was successfully carried out to measured the distribution of trapped magnetic fields around the cavity wall.
- ➢ Currently, we have used only four sensors in each bracket. In the future, we are planning to install 8 sensors in each bracket.
- ➢ We plan to perform a magnetic field scan during a high power RF testing of cavities prepared with different surface treatments at different cool-down and different external magnetic fields.

Acknowledgments:

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