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

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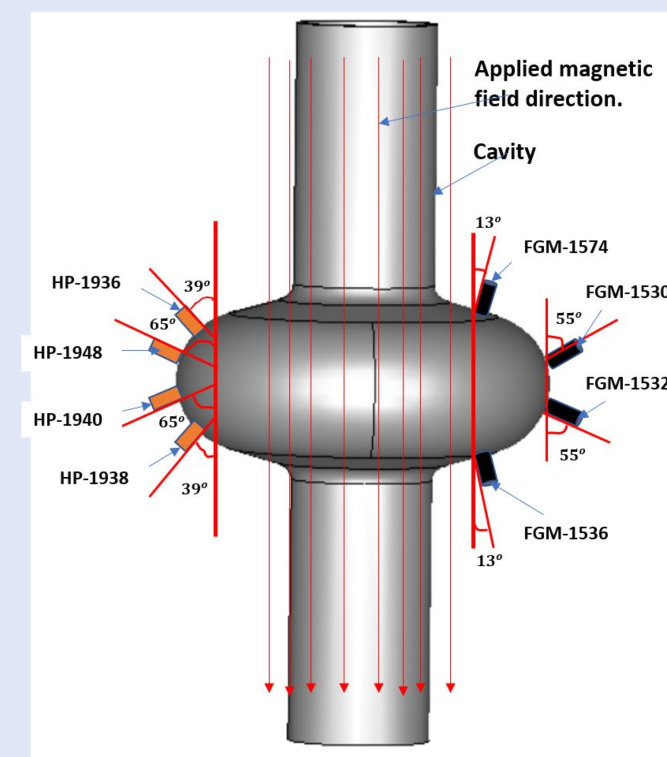
INTRODUCTION

- 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 trappinNi;g 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.

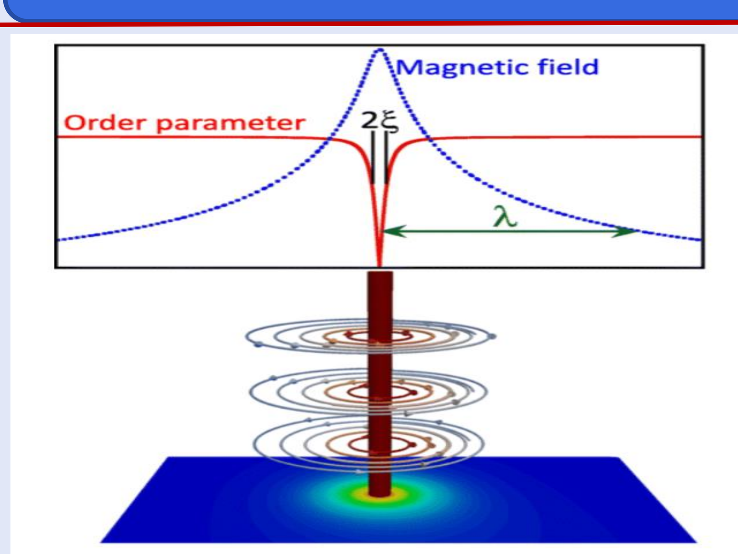
EXPERIMENTAL PROCEDURE

- Assemble the MFSS on a 1.3 GHz SRF cavity with typical surface treatments. Insert the assembled setup in a liquid helium Dewar.
- Perform magnetic field scanning at different **cool-down conditions and external magnetic fields**.
- Experiment was performed in two mode: Monitor mode and Scan mode.



Schematic diagram of cavity and sensor's locations in MFSS

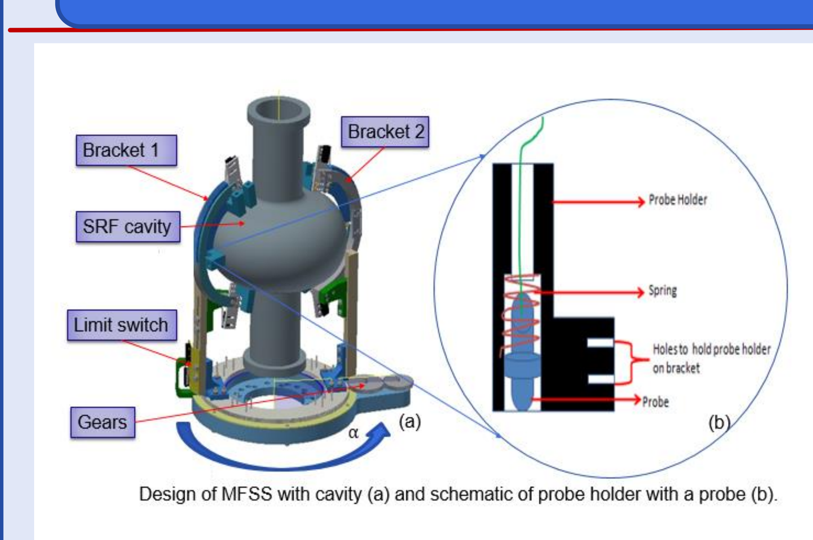
OBJECTIVES OF THE EXPERIMENT



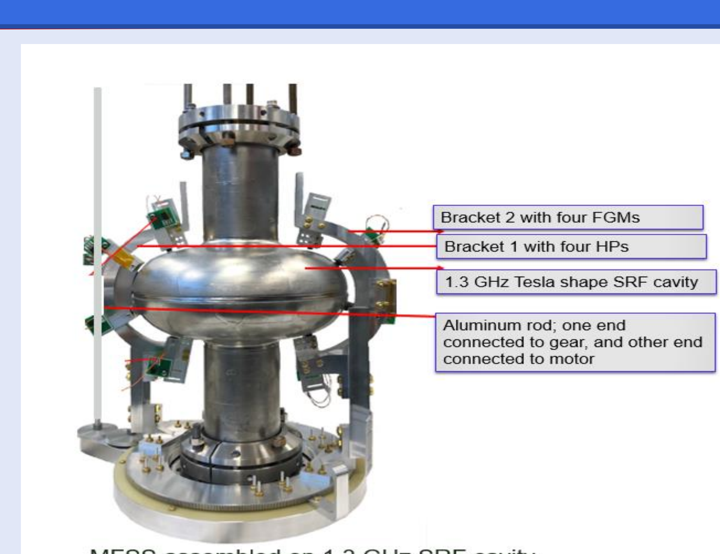
Characteristics of an isolated vortex line: (top) radial distributions of the magnetic field and order parameter amplitude; (bottom) visualized vortex line (red) with circulating currents, screening the magnetic flux.

- ❑ Trapped vortex dissipates power under high RF field test, which increases the cryogenic cost.
- ❑ We want to investigate the trapped flux mechanism using newly design MFSS. So that we can help to increase the efficiency of SRF cavities.

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.

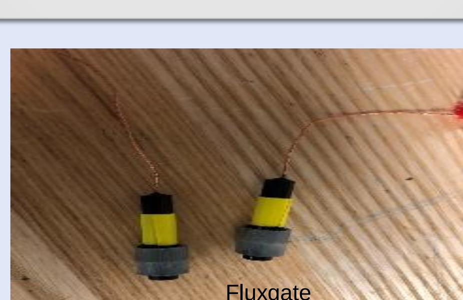
- MFSS consists of two brackets
- Each bracket can hold up to eight sensors
- The motor can rotate MFSS from 0-360 degrees around the axis of the cavity.

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)

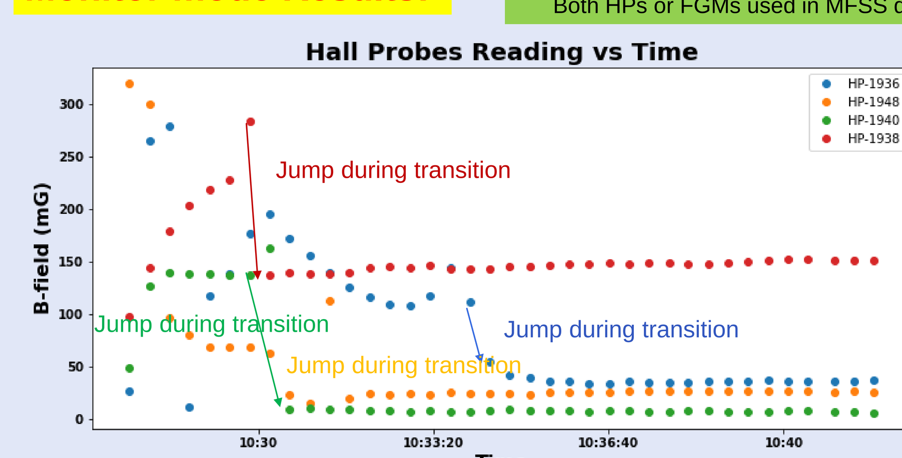
- ❑ **Working principle: Hall Effect**
- ❑ Single axis HP useful in cryogenic temperature.
- ❑ Active area 20 μm × 20 μm.
- ❑ Sensitivity at room temperature is 50 $\frac{mV}{T}$ and sensitivity at 2 K, 4 K and 9 K is ~94 $\frac{nV}{\mu T}$.

Hall probe

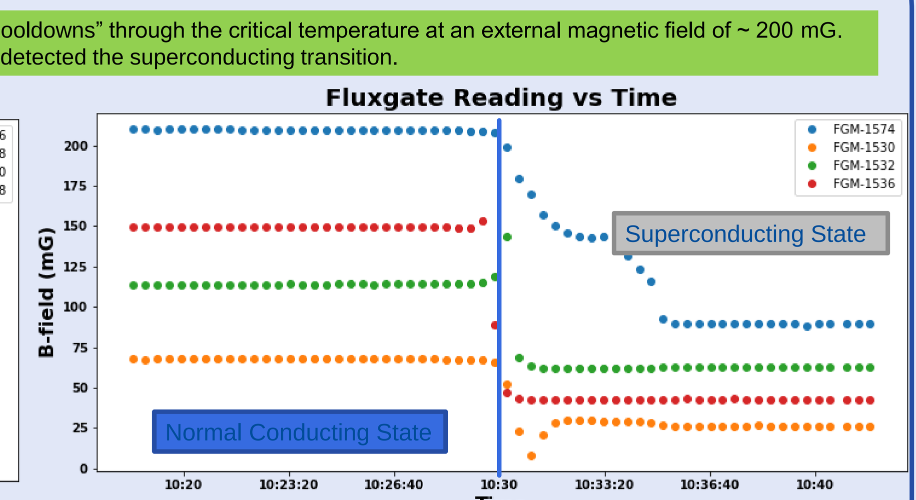
PRELIMINARY RESULTS

Monitor mode 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.



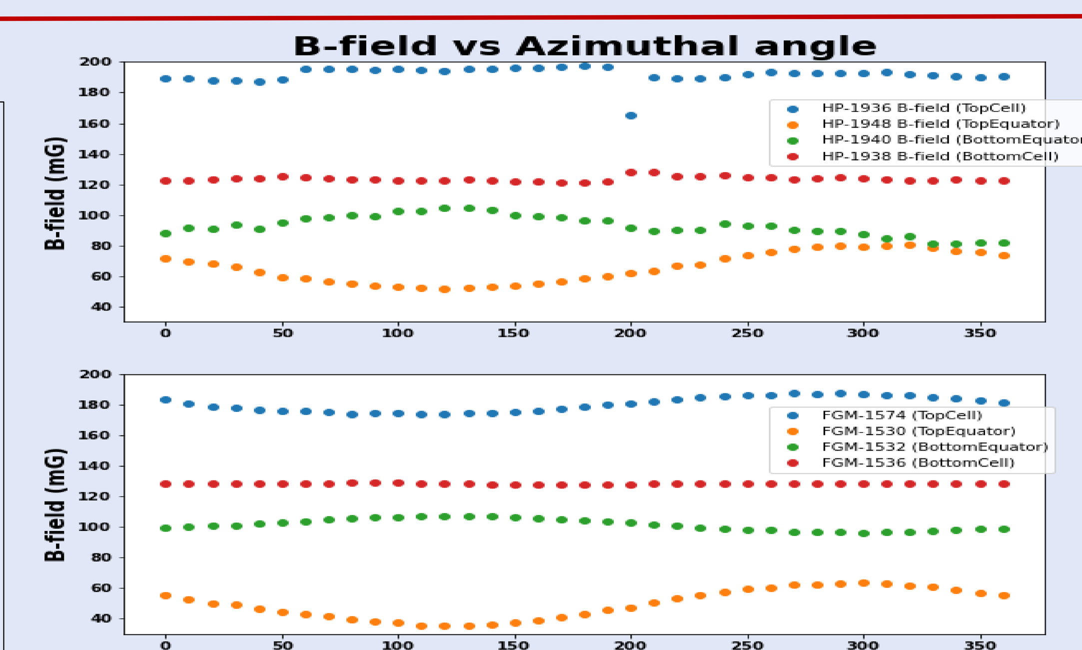
HPs reading vs Time during fast cool-down

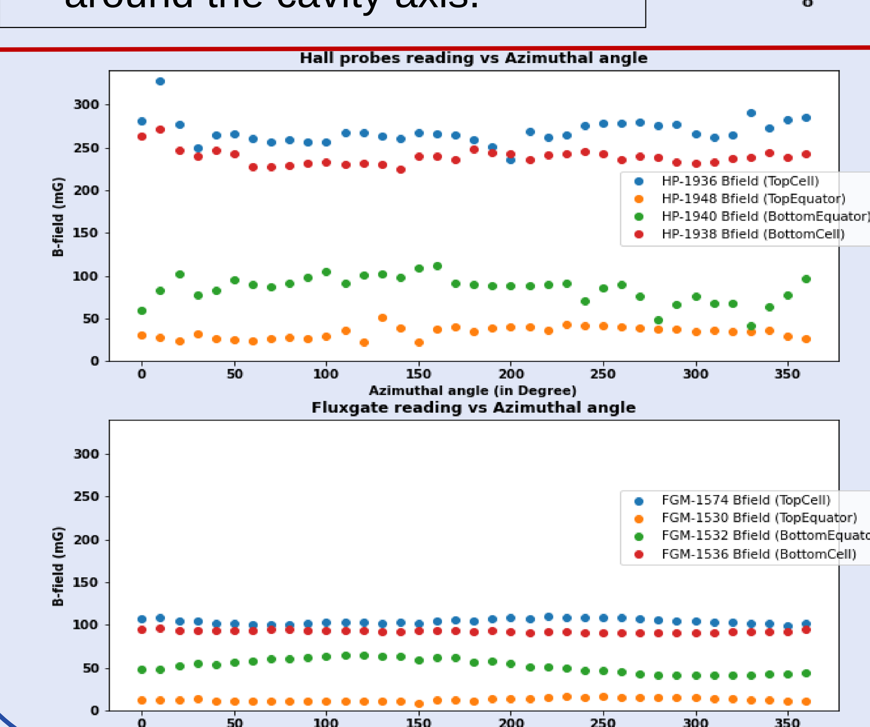


FGMs reading vs Time during fast cool-down

Scan mode Results:

- **Before performing a first 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 second magnetic field scan:

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

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:

* Work supported by NSF Grant 100614-010. G. C. is supported by Jefferson Science Associates, LLC under U.S. DOE Contract No. DE-AC05-06OR23177.

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