MEASUREMENTS OF MAGNETIC FIELD PENETRATION IN SUPERCONDUCTING MATERIALS FOR SRF CAVITIES

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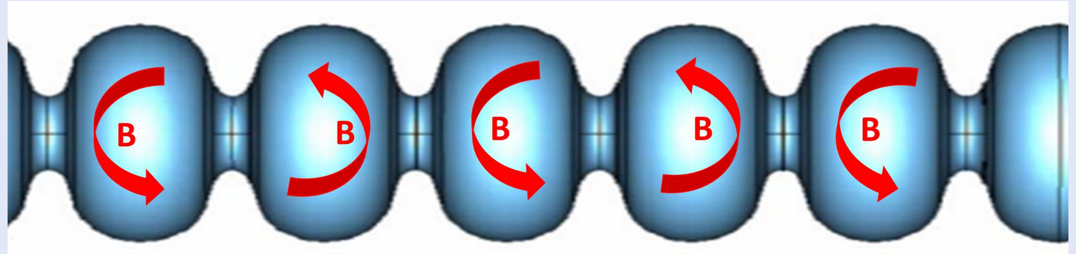
ABSTRACT

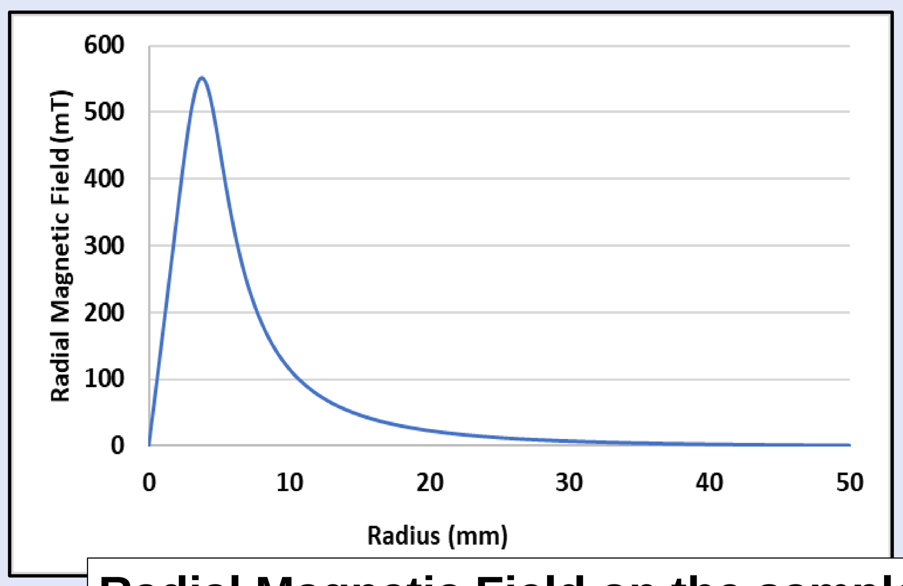
Superconducting radiofrequency (SRF) cavities used in particle accelerators operate in the Meissner state. To achieve high accelerating gradients, the cavity material should stay in the Meissner state under high RF magnetic field without penetration of vortices through the cavity wall. The field onset of flux penetration into a superconductor is an important parameter of merit of alternative superconducting materials other than Nb which can enhance the performance of SRF cavities. There is a need for a simple and efficient technique to measure the onset of field penetration into a superconductor directly. We have developed a Hall probe experimental setup for the measurement of the flux penetration field through a superconducting sample placed under a small superconducting solenoid magnet which can generate magnetic fields up to 500 mT. The system has been calibrated and used to measure different bulk and thin film superconducting materials. This system can also be used to study SIS multilayer coatings that have been proposed to enhance the vortex penetration field in Nb cavities.

INTRODUCTION



- Maximum accelerating gradient is determined by the peak surface magnetic field at the inner cavity surface.
- **Field Onset of Magnetic Flux Penetration** is a key characteristic of the breakdown field and the high-field performance of SRF cavities.
- A simple and efficient technique to measure the field of flux penetration in SRF materials has been developed.

CALIBRATION



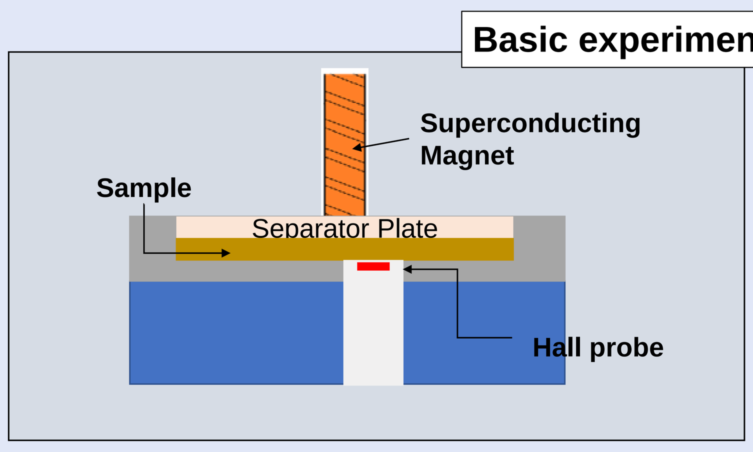
Radial Magnetic Field on the sample surface from Poisson Simulations

Calibration of the system was carried out in few steps to find out

Maximum Surface Field = 5.5 mT/A

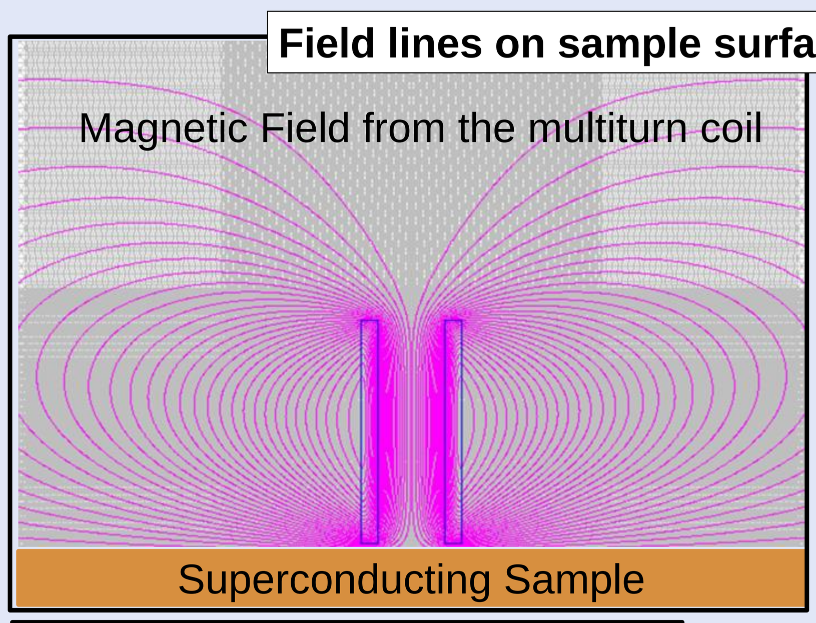
EXPERIMENTAL SETUP

Basic experimental setup

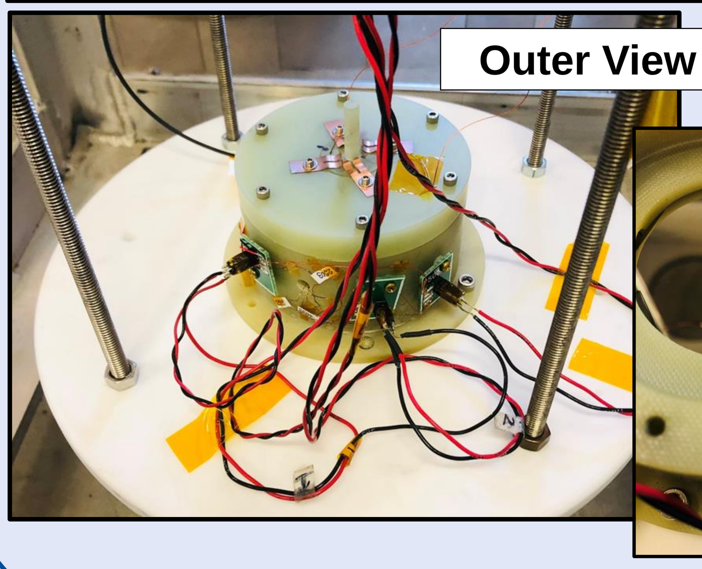


- Superconducting magnet to generate magnetic filed on the sample surface.
- Hall probes to measure full penetration of magnetic filed through the sample.
- Samples are bulk and thin film superconductors 50 mm in diameter

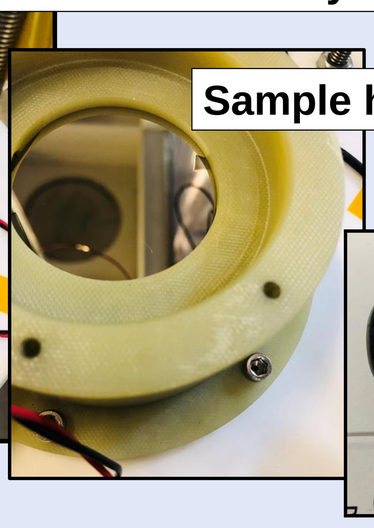
Field lines on sample surface in the Meissner State



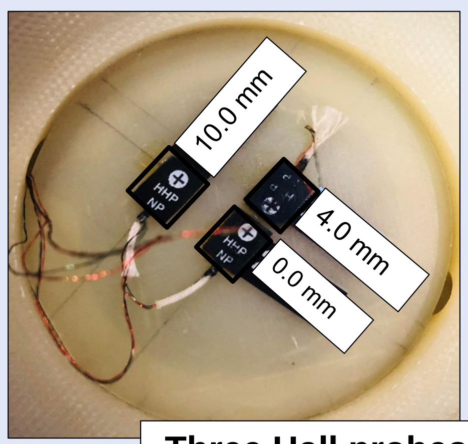
- Superconducting magnet produces parallel magnetic field on one side of the sample
- Field configuration is similar to that in an SRF cavity



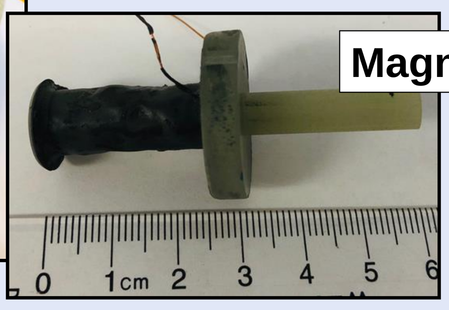
Outer View the assembly



Sample holder



Three Hall probes mounted under the sample

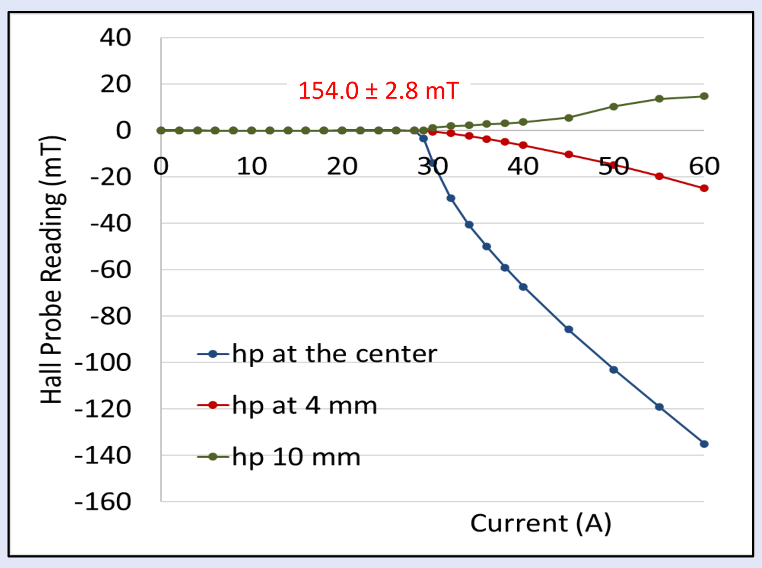


Magnet

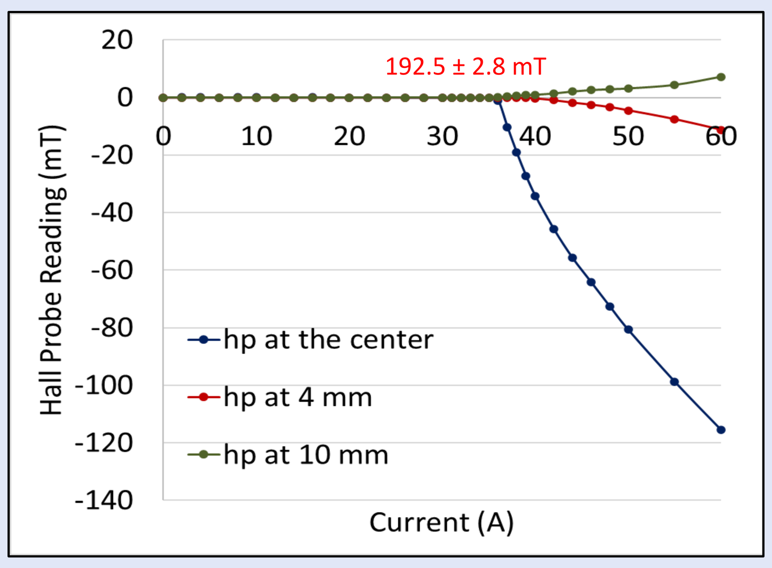
MEASUREMENTS

Bulk Nb Superconductor (0.25 mm thick)

At 4.35 K

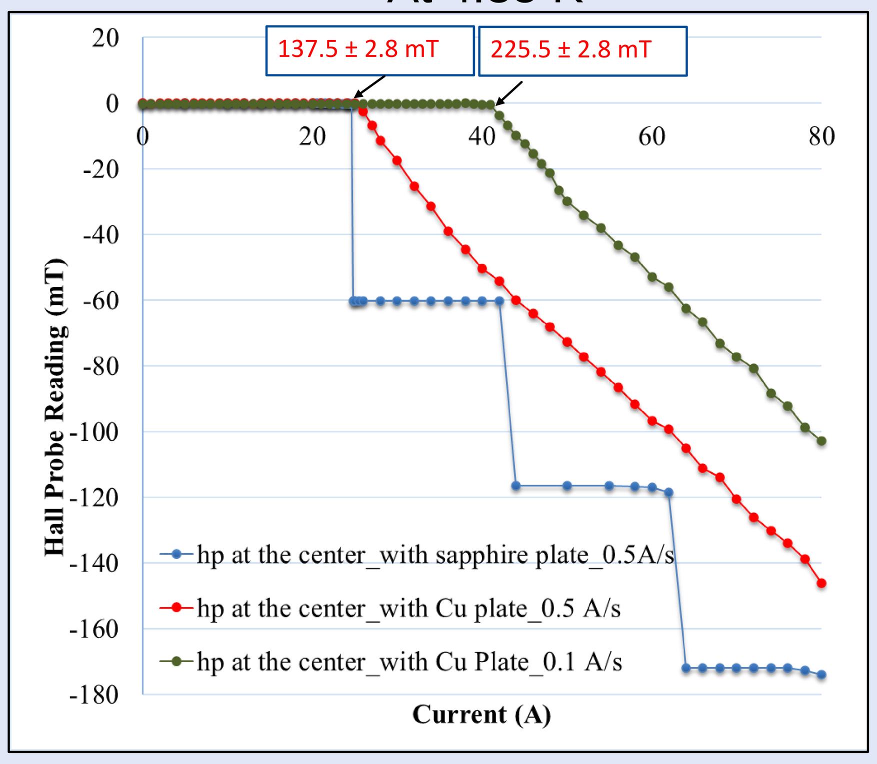


At 1.97 K



Nb_3Sn Thin Film Superconductor (1.5 µm thick)

At 4.35 K



- Behavior of thin film superconductors under external magnetic field is different.
- We can see flux jumps due to thermo-magnetic avalanches (**blue curve**).
- The sapphire separator plate is placed between the magnet and the sample
- When the sapphire plate is replaced by a copper plate, thermal conductivity increases and the flux jumps disappear (**red curve**).
- When current rate reduced from 0.5 A/s to 0.1 A/s, field limit is increased (**green curve**).

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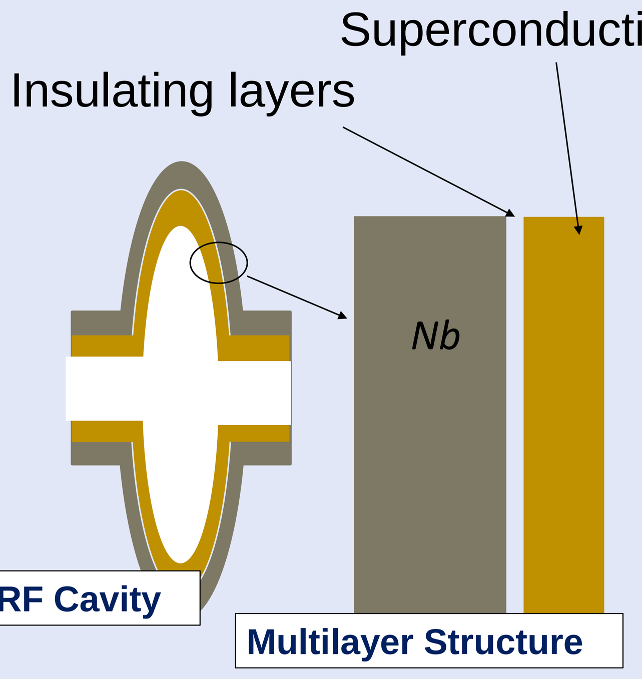
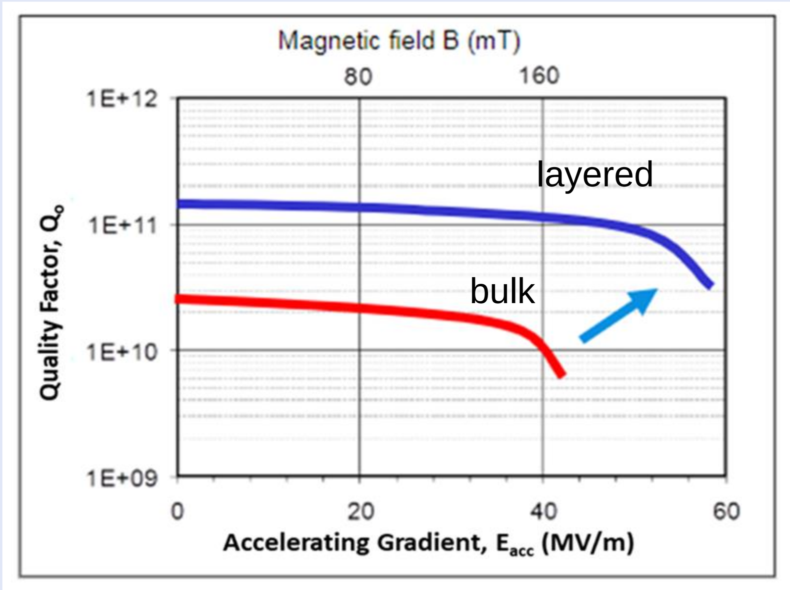
CONCLUSION & FUTURE WORK

- The new experimental technique for magnetic field penetration measurement of superconducting samples was designed, built and calibrated at Jefferson Lab.
- This technique is appropriate for bulk samples as well as thin films.
- Thin films show flux jumps due to thermo-magnetic instability, which is mitigated by increasing thermal conductivity across the sample.
- The penetration limit is increased by slowing down the current ramp rate
- The system is ready for the measurements to study S-I-S multilayer coatings.



Single Cell SRF Cavity

Multilayer Structure



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