THP050

MEASUREMENT OF THE MAGNETIC FIELD PENETRATION INTO SUPERCONDUCTING THIN FILMS*

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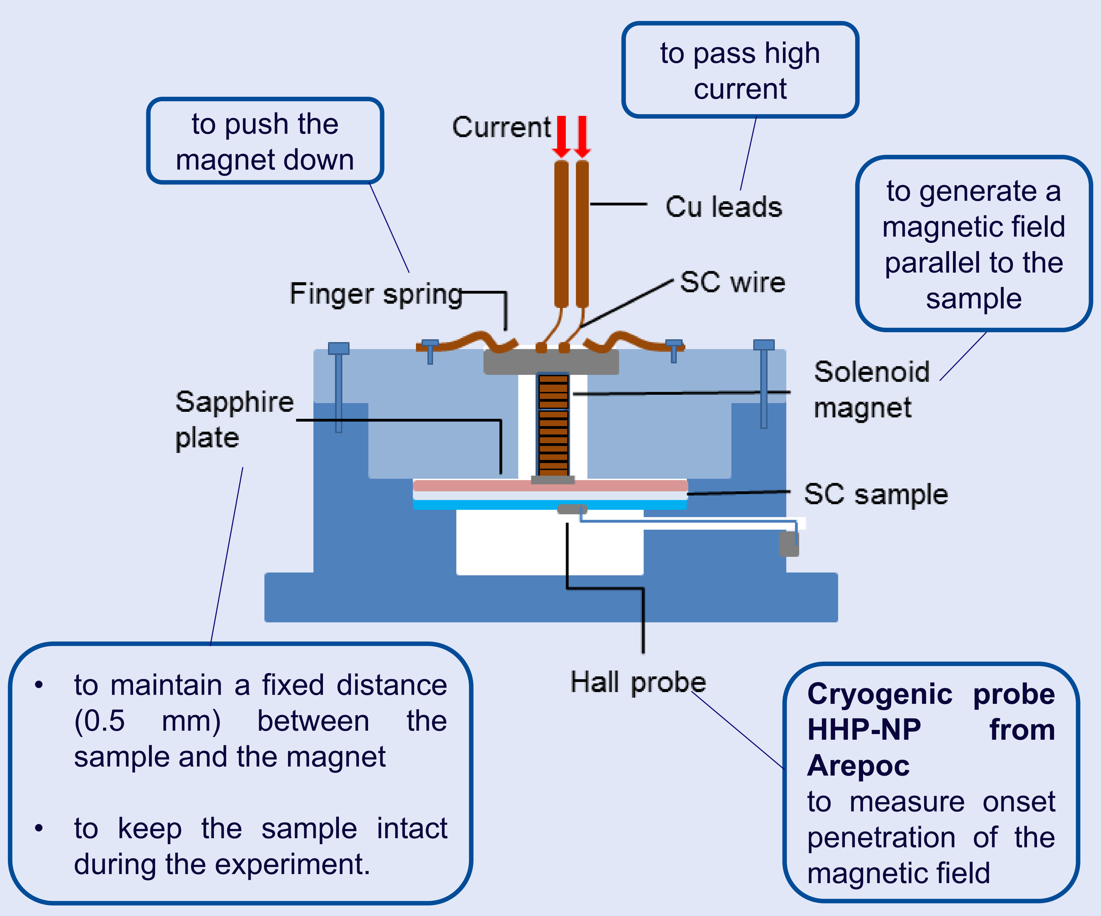
ABSTRACT

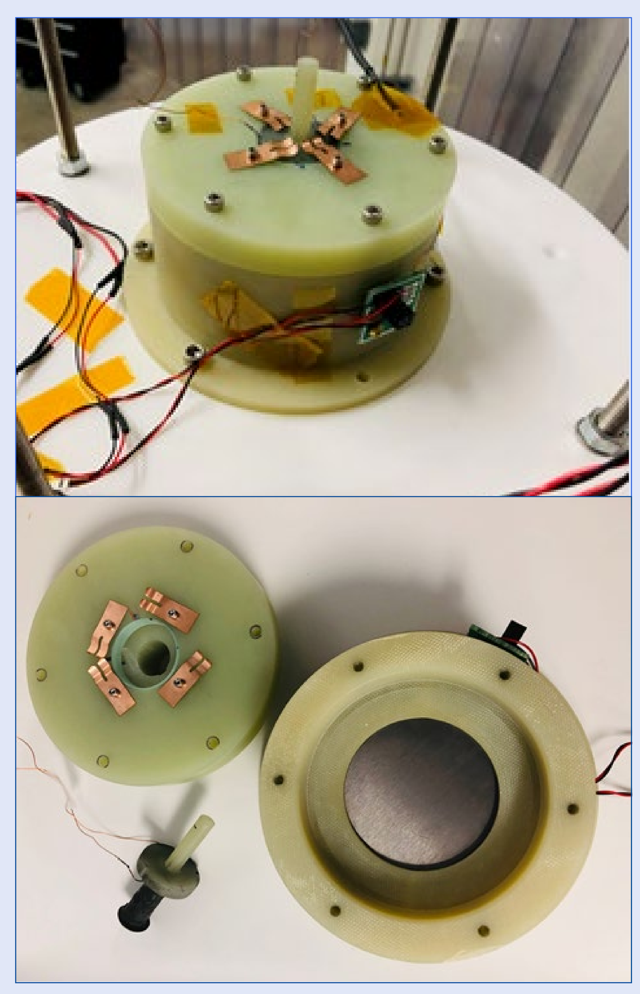
The magnetic field at which first flux penetrates is a fundamental parameter characterizing superconducting materials for SRF cavities. Therefore, an accurate technique is needed to measure the penetration of the magnetic field directly. The conventional magnetometers are inconvenient for thin superconducting film measurements because these measurements are strongly influenced by orientation, edge and shape effects. In order to measure the onset of field penetration in bulk, thin films and multi-layered superconductors, we have designed, built and calibrated a system combining a small superconducting solenoid capable of generating surface magnetic field higher than 500 mT and Hall probe to detect the first entry of vortices. This setup can be used to study various promising alternative materials to Nb, especially SIS multilayer coatings on Nb that have been recently proposed to delay the vortex penetration in Nb surface. In this paper, the system will be described and calibration will be presented.

1 EXPERIMENTAL SETUP

Designed and built to measure onset penetration directly through bulk, thin film and multilayer superconducting samples.

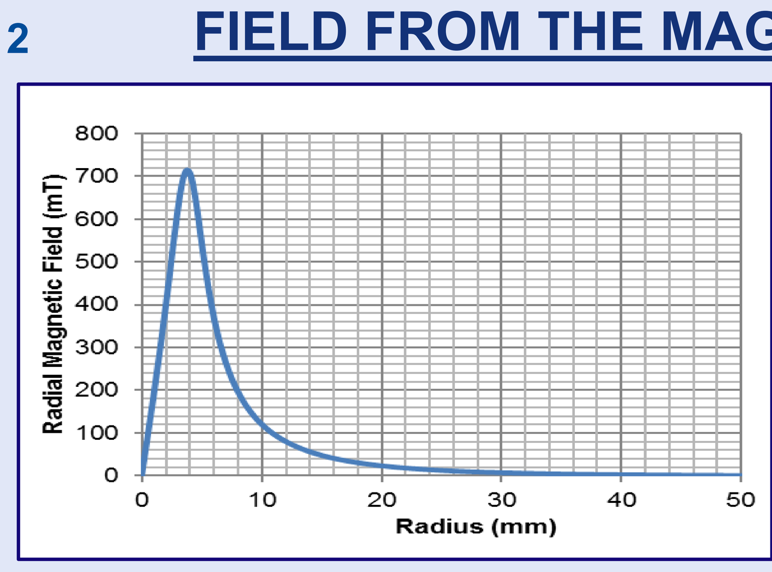


Schematic cross section of experimental setup

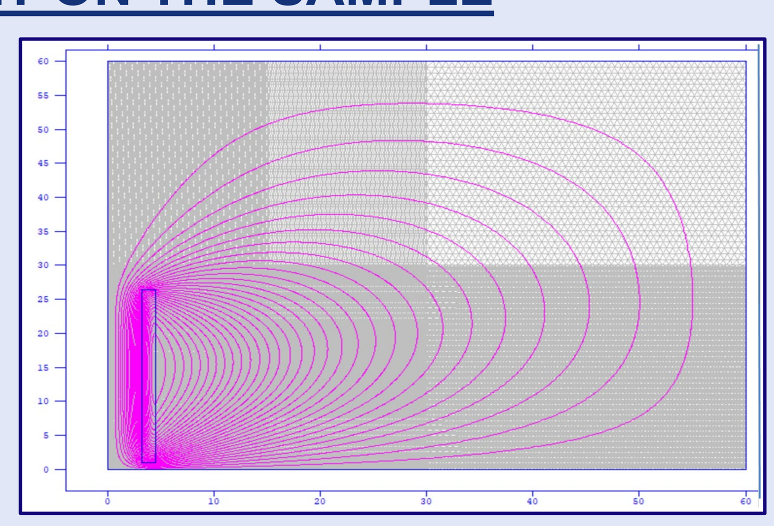


External (top) and internal (bottom) view of nonmagnetic container which supports the sample, solenoid magnet, and Hall probe symmetrically.

2 FIELD FROM THE MAGNET ON THE SAMPLE



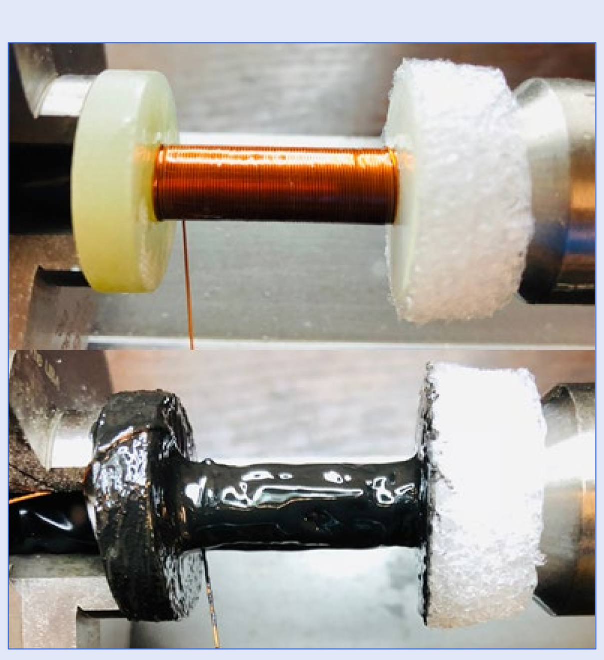
Variation of the radial magnetic field along the sample radius at 100 A (From Poisson Simulations)



Field lines from the right half of solenoid magnet placed at 1 mm above the superconducting sample (From Poisson Simulations)

- In the Meissner state the sample acts as a magnetic mirror.
- Vertical component of the magnetic field cancels out.
- The field felt by the sample is equal to twice the radial component of the magnetic field.
- Since the radial magnetic field is parallel only to one side of the sample, this field configuration closely resembles the SRF cavities.

3 MAGNET FABRICATION



Superconducting solenoid magnet before (top) and after (bottom) applying an epoxy.

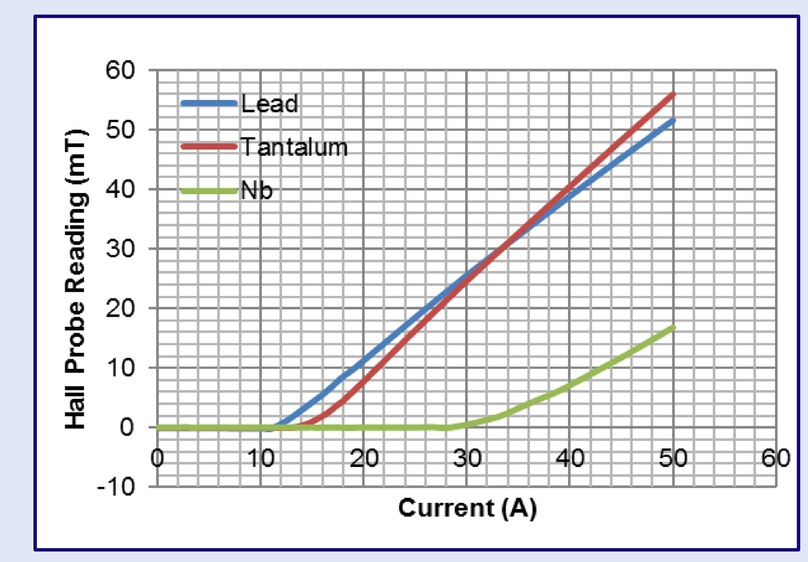
Magnetic coil was fabricated by winding NbTi thin wire carefully on dielectric spool using strategies followed in magnet fabrication. An epoxy was used after winding to obtain a good insulation and a monolithic structure which cannot allow any movement of the conductor inside the coil.

Magnet Dimensions

Wire thickness	0.317 mm
No of turns per layer	80
No of layers	4
Length	25.36 mm
Outer diameter	9.04 mm
Core diameter	6.50 mm
Expected maximum field on the sample	> 500 mT

4 CALIBRATION

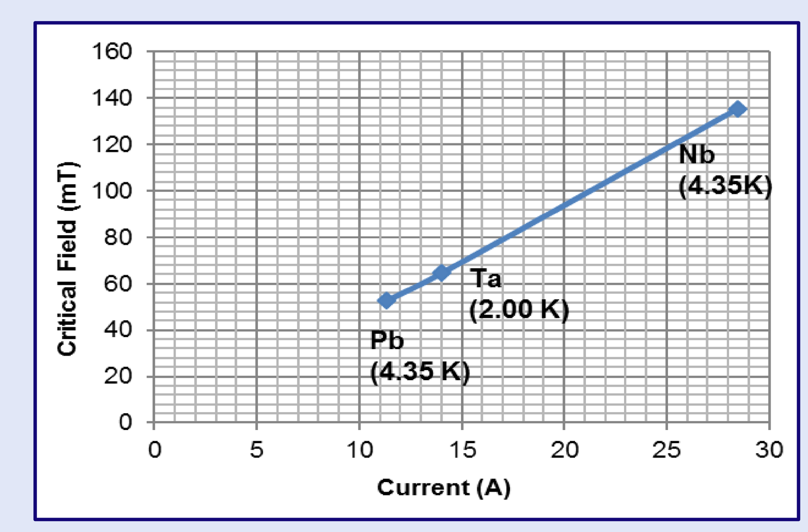
System was calibrated using 99.99 % pure bulk Lead (Pb), Tantalum (Ta) and Niobium (Nb) samples with 50 mm in diameter and 0.1 mm in thickness.



Hall Probe response against Pb, Ta, Nb samples while powering up the magnet with gradually increasing current

Details of the reference samples

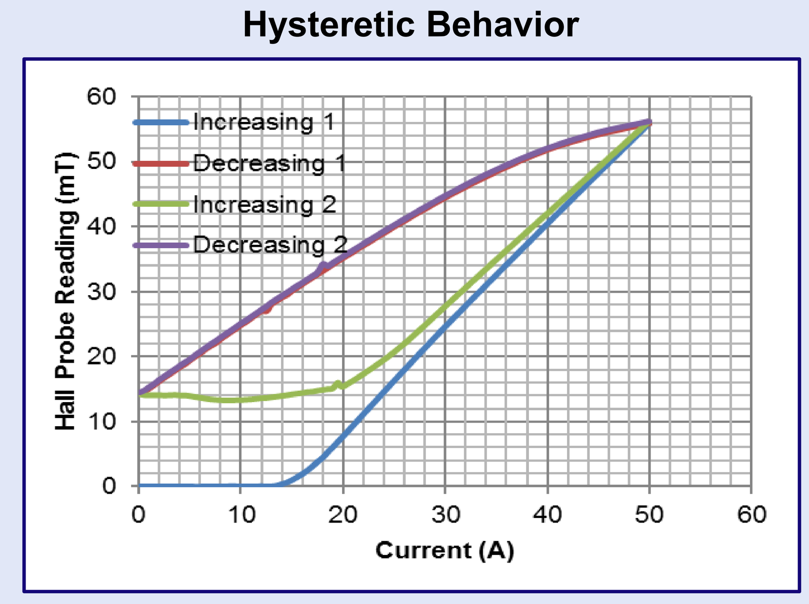
Reference sample	Critical Temperature (K)	Temperature at Measurements (K)
Pb	7.20	4.35
Ta	4.50	2.00
Nb	9.26	4.35



The calibration curve of the experimental setup

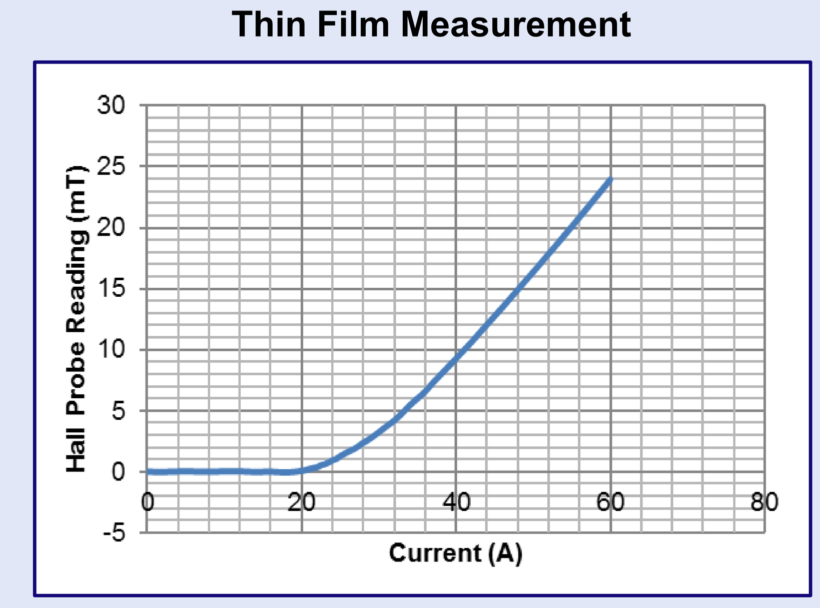
5 OTHER MEASUREMENTS

Hysteretic Behavior



The magnetic response of Tantalum sample with thickness 0.1 mm at 2.0 K under forward and reverse current describes the hysteretic behaviour of superconducting sample due to formation of trapped vortices inside it.

Thin Film Measurement



The Hall Probe response against Nb(110) thin film, coated on a-plane sapphire by electron cyclotron resonance post-ionization (ECR) with the thickness about 1 μm and a Tc of 9.34 ± 0.07 K and RRR value of about 50. Calibration indicates that the first field penetration occurred at 94 mT.

6 CONCLUSION AND FUTURE WORK

- The new experimental setup for magnetic field penetration measurements of superconducting samples was designed, built and calibrated successfully at Jefferson Lab. This experimental system is appropriate for bulk samples as well as thin films.
- The linearity of calibration curve confirms that the system is ready for the future measurements to study
  - the possible alternatives to Nb and multilayer system.
  - the dependence of field penetration on the sample thickness and different coating parameters which contribute to the film quality.

The dependence of the current at first penetration on the sample thickness

Reference sample	Thickness (mm)	Current at first penetration (A)
Pb	0.1	11.3
	0.5	15.0
Ta	0.1	14.0
	0.5	17.0

* Work supported by NSF Grants PHY-1734075 and PHY-1416051, and DOE Award DE-SC0010081

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