Characterization of multilayer thin film superconductors

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1 - Abstract

The maximum accelerating gradient can be increased by using multilayer SIS coatings. Delaying the initial flux penetration to higher fields in the first superconducting layer, a greater accelerating gradient can be achieved. Magnetometry is a commercially available process but consists of limitations, such as SQUID measurements apply a field over both superconducting layers, so the initial flux penetration through the sample cannot be measured. If SIS structures are to be investigated, a magnetic field must be applied from one plane of the sample, with no magnetic field on the opposing side to allow the initial flux penetration to be measured. A magnetic field penetration experiment has been developed at Daresbury laboratory, where a VTI has been created for a cryostat where the field penetration of a sample can be measured. The VTI has been designed to allow flat samples to be measured to reduce limitations such as edge effects by creating a DC magnetic field smaller than the sample. A small, parallel magnetic field is produced on the sample by the use of a ferrite yoke. The field is increased to determine when the vortices penetrate the sample by using 2 hall probes either side of the sample. The VTI will be placed in a Cu tube which is connected to the first stage of the cryostat by a Cu baffle and will be cooled with He gas.

2. Multilayer thin film SIS structures

By using multiple layers of superconductor – insulator – superconducting (SIS) layers, a superconductor can remain in the Meissner state until higher fields due to the screening potential at boundaries [1]. This has been shown theoretically, but not experimentally.

$$B_i = B_o e^{\left(-\frac{Nd}{\lambda}\right)} \qquad (1)$$

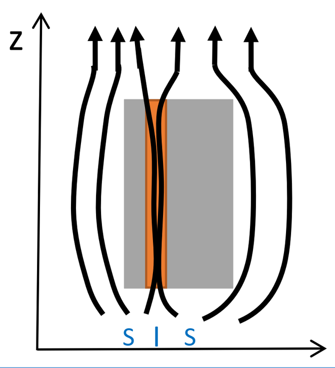

Figure 1 – A visual representation of the field lines through a multilayer SIS sample in a squid magnetometer. The field lines pass through the insulating layer.

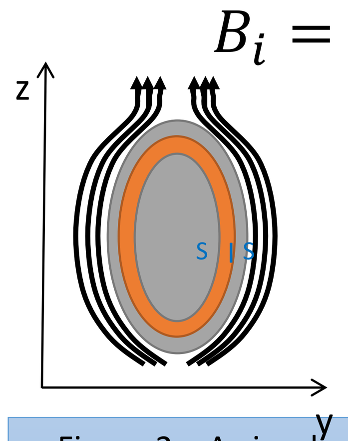

Figure 2 – A visual representation of how a SIS sample would have to be deposited in order for the screening effect to be observed.

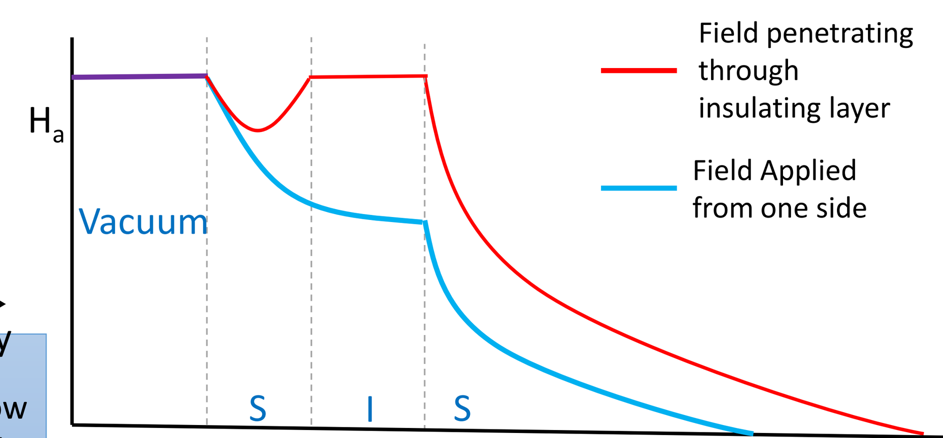

Figure 3 – A visual representation on how the field changes through a SIS structure depending on how the external field is applied.

Previous experiments have been performed using tubular samples [3]. Tubular samples are not a standard deposition technique, and can be difficult to do with varying superconducting samples. Standard deposition technique is on a flat copper gasket, of which there is a back-catalogue of at Daresbury laboratory. A variable temperature insert was designed to be able to test these samples.

3. Variable temperature insert

Figure 4 – Full variable temperature insert

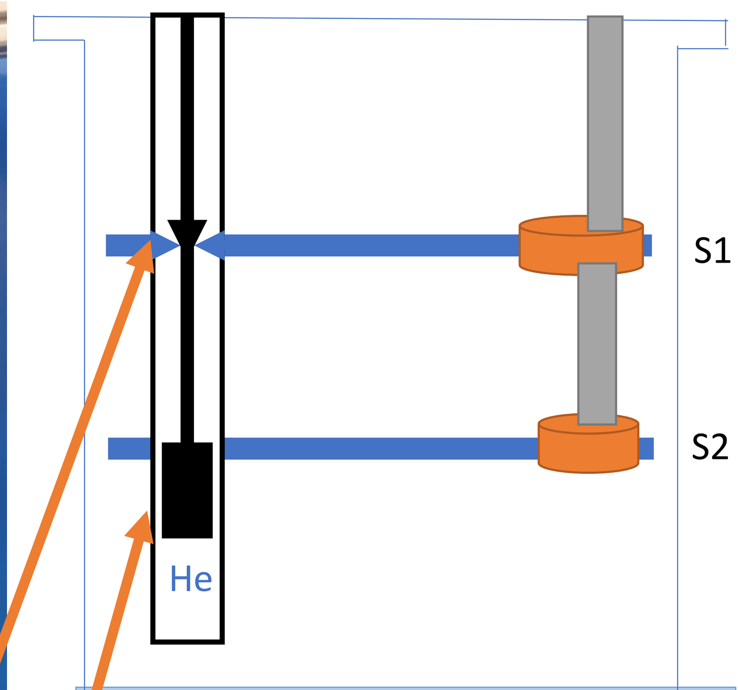

Figure 5 – Schematic view of the cryostat and how the insert fits inside.

The variable temperature insert sits inside a separate tube inside a cryostat. There is a baffle that sits on the first stage (S1) so that the insert thermalizes. A spring is mounted just above the baffle to ensure constant pressure on S1. The cage is not in contact with the second stage, and is thermalized by He gas.

A parallel field is applied by the use of a superconducting coil, which is wrapped around a ferrite yoke. An external parallel field is created between the dipoles of the yoke up to 0.65 T at 20 A. A hall probe is placed in between the dipoles of the yoke, and underneath the sample holder as shown in figure 8.

Figure 6 – The cage containing the sample and superconducting coil.

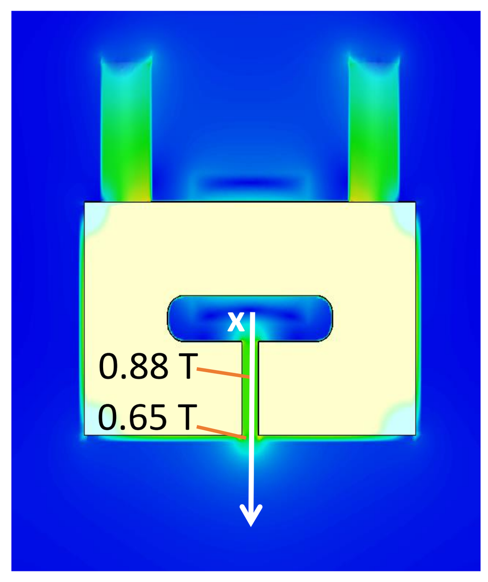

Figure 7 – A CST simulation of the superconducting coil on the C-shaped ferrite yoke

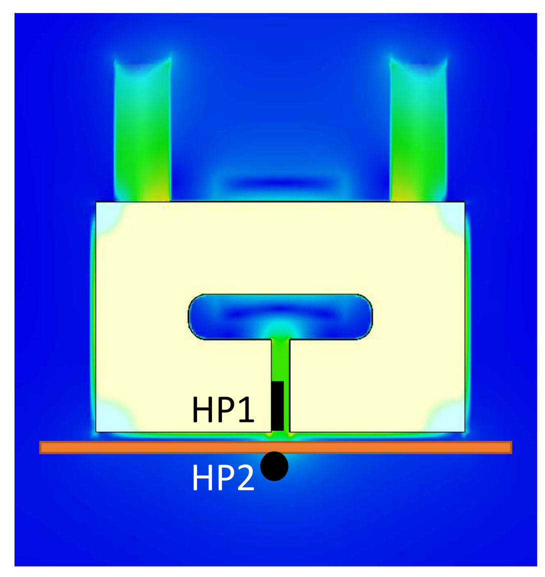

Figure 8 – The placement of the hall probes with respect to positioning of the sample

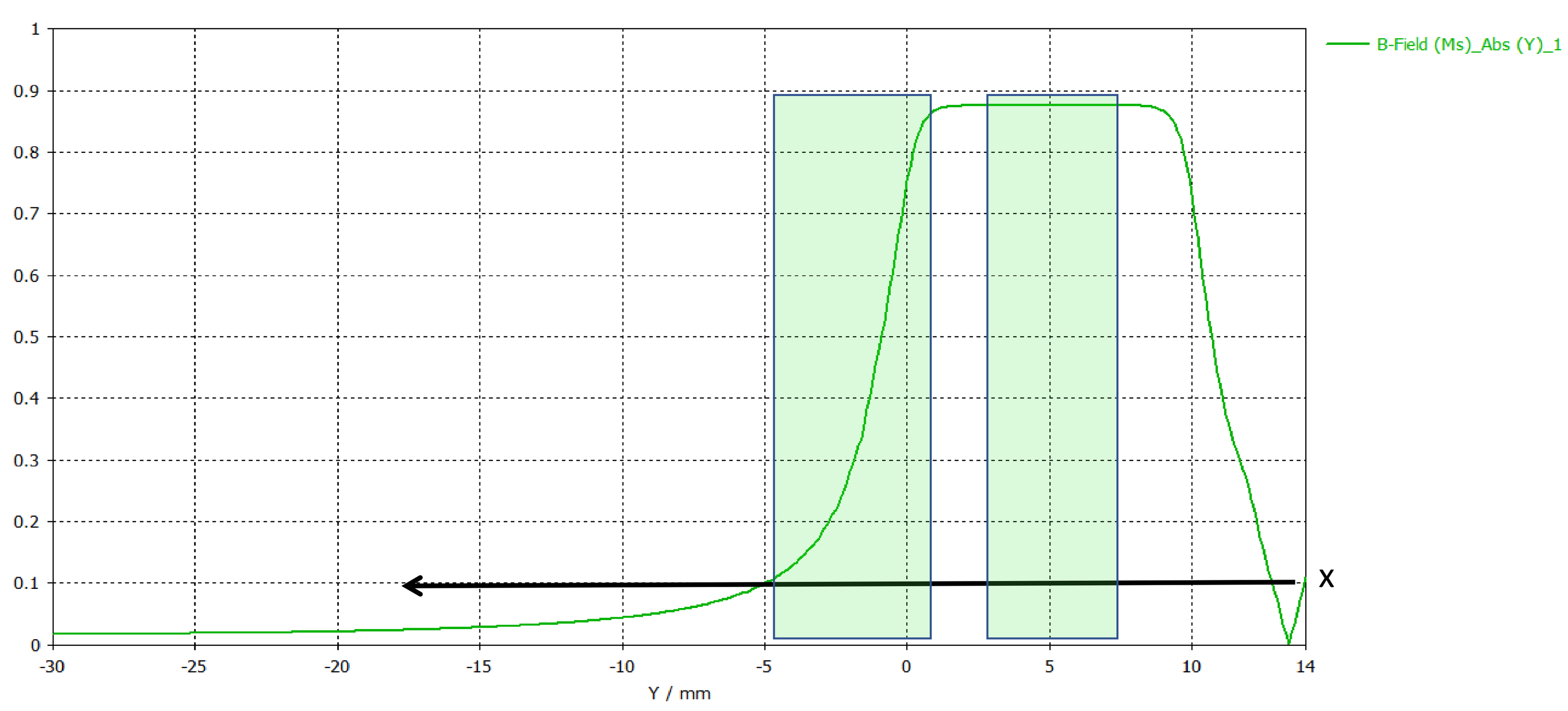

Figure 9 (left) – How the magnetic field decays over distance away from the dipole.

Table 1– The temperature of the sample cage varying with pressure of injected He gas, where T_A and T_B are the thermometers above the cage and under the sample respectively.

He pressure (mbar)	T_A (K)	T_B (K)
25	8.887	8.527
50	9.067	8.755
100	9.174	8.901
150	9.021	8.900

4. Conclusion and next steps

- Insert has been built and tested
- Electronics are operational (Hall probes, thermometers, superconducting coil)

The VTI can be used with liquid He, but not in the cryostat due to not reaching the desired temperature. There are a few more steps that must be covered to optimise the performance:

- Reduce the temperature of the cryostat from 8-4 K, to ensure the magnet can be used.
- Automate the control and recordings.
- Test known samples to allow comparison of data.

Finally, freshly deposited samples can be tested.

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References

[1] A. Gurevich, APL 88, 012511 (2006).
[2] A. Gurevich, AIP Advances, 5, 017112 (2015).
[3] O.Malyshev, SRF 2015 Proceedings, ISBN 978-3-95450-178-6 (2015)