Contribution ID: **40** Type: **Poster**

Investigation of HTS Magnetic Shielding for Ultralow Magnetic Fields in Precision Measurement Applications

Thursday 7 August 2025 17:50 (5 minutes)

Abstract：With the rapid advancement of cutting-edge fields such as quantum precision measurement and biomagnetic sensing, increasingly stringent requirements are being placed on the suppression of ambient magnetic fields. The sensitivity improvement of atomic magnetometers is currently limited by the residual magnetization and intrinsic magnetic noise of conventional soft magnetic shielding materials. In this study, we propose a novel high-temperature superconducting (HTS) magnetic shield and investigate its performance in ultra-low magnetic field environments, aiming to meet the demands of next-generation quantum sensing and biomedical imaging applications.

A theoretical model based on the London equations was established to simulate the magnetic shielding behavior of HTS materials in extremely weak magnetic field environments. The model's results were compared with those obtained from the widely used critical state model under the same conditions. Finite element simulations were conducted to systematically analyze the influence of key structural parameters, including aspect ratio and wall thickness, on the shielding effectiveness. Furthermore, an experimental platform for low-temperature superconducting magnetic shielding was developed, and experimental validation was carried out at 77 K. The experimental results show good agreement with the simulations, confirming the validity of the model.

This work provides valuable insights for the design of HTS magnetic shielding structures in sensitive magnetometry systems and offers a promising approach for realizing ultra-clean magnetic environments in precision measurements.

Keywords: High-temperature superconductors; Magnetic shielding; London equation; Ultralow magnetic field; Atomic magnetometry; Precision measurements

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Session Classification: Poster Session and Buffet