Development of a Force Magnetometer for the NHMFL DC-Field Facility

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Introduction

Aside from the vibrating sample magnetometer (VSM), the capacitively-detected force magnetometer is presently the only instrument that accurately measures magnetizations at fields above 8 T at low temperatures. Originally developed by Sakakibara *et al*. [1], this magnetometer has a crucial advantage over the VSM: it can be used at temperatures below 1.5 K, a practical limit above which a VSM can be reliably used without often uncontrollable frictional heating produced by the driven motion of the sample and the sample probe.
After our successful testing of a force magnetometer last year in SCM1, an 18 T/20 T superconducting magnet at the DC-Field Facility, we have made several improvements to make the magnetometer fit inside the 15.5 mm-diameter space available inside a ^{3}He refrigerator for the 31.2 T magnet (Cell 7) at the facility. Unlike the superconducting magnet, this resistive magnet has a separate gradient coil, capable of producing field gradients up to 4.3 T/m along the magnet axis. This feature in principle can significantly improve the accuracy and sensitivity of the magnetometer.

Experimental, Results, and Discussion

A 31.71 mg nickel disk, 0.1 mm thick, was used as a sample to test and evaluate the performance of the magnetometer. All measurements were made in the Cell 7 magnet at fields up to 25 T at 4.2 K. As shown in Fig. 1a, a commercial automatic capacitance bridge could not detect a change in the magnetometer capacitance caused by a force exerted on the sample by a static field gradient, because of noise due to mechanical vibrations caused by the cooling water of the magnet. An AC response of the magnetometer to a 1 Hz AC field gradient was successfully detected up to about 11 T by a double-lockin technique, as shown in Fig. 1b. Above this field the signal dropped rapidly, however, because of electromagnetic noise from the magnet power supply. To make the magnetometer work properly in the harsh environment of the resistive magnet, improvements to the vibration isolation of the cryostat and grounding for the electronic instruments are planned.

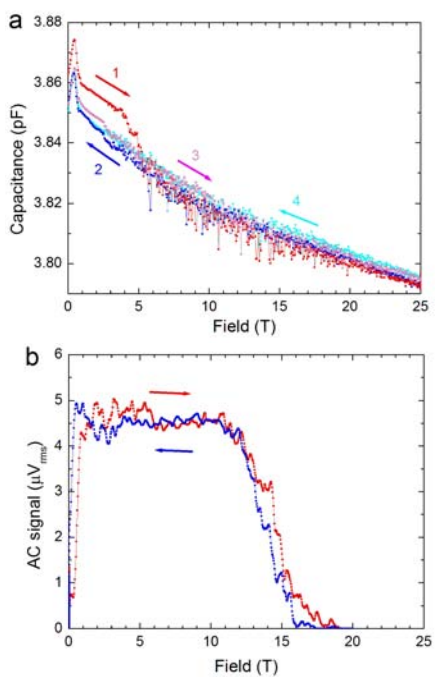

FIG 1. (a) Magnetometer capacitance as a function of field for the nickel standard, measured with an Andeen-Hageling 2700 A capacitance bridge. During field sweeps 1 and 2, a 1.6 T/m field gradient was imposed, whereas the gradient was turned off for sweeps 3 and 4. (b) AC variation of the magnetometer capacitance detected by a double-lock in technique. A 1.6 T/m field gradient was driven by a 1 Hz AC power supply, while a ratio-transformer capacitance bridge was driven with a 10 V_{rms} excitation at 1 kHz. The 1 kHz off-balance signal of the bridge was detected by a PAR 124A lockin amplifier, whose output was fed to a Stanford Research SR830 lockin amplifier, which in turn detected the 1 Hz signal due to the force exerted on the sample by the AC field gradient. For all measurements, the magnetic field was ramped at a rate of 2 T/min.

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References

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