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

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## Introduction

Magnetization is one of the key bulk static properties in magnetism and superconductivity. Accurate characterization of strongly correlated systems invariably requires measurements of magnetization in high magnetic fields at low temperatures. However, many techniques for these measurements suffer from heating (SQUID magnetometers, vibrating sample magnetometers), incompatibility with very high fields (SQUID magnetometers, vibrating sample magnetometers), the magnetocaloric effect (the induction method in pulsed magnetic fields), or magnetic torque (cantilever magnetometers)—except force magnetometers. With its unique design involving two pairs of crossed suspension wires and a capacitive transducer, the force magnetometer developed by Sakakibara *et al*. [1] is especially suitable for high-field low-temperature measurements, with high immunity to magnetic torque arising from sample anisotropy or shape-dependent non-uniform demagnetizing field. However, this type of magnetometer has been in use only in a small number of laboratories, none of which are high magnetic field facilities and none of which are in this country, at least to our knowledge. To rectify this situation, we have developed a force magnetometer to be used at the NHMFL DC Field Facility. Although this magnetometer has been designed for the resistive magnet with a gradient coil at the facility, the initial test was performed using SCM1, an 18 T/20 T superconducting magnet which lacks a gradient coil.

**Figure 1.** Force magnetometer. The overall diameter is 20 mm. The sample platform is at the bottom, facing down and hidden from the viewer. The two SIP connectors and the coiled leads, to which they are attached, are for a resistance thermometer and heater. Microcoaxes for the capacitor electrodes are not shown.

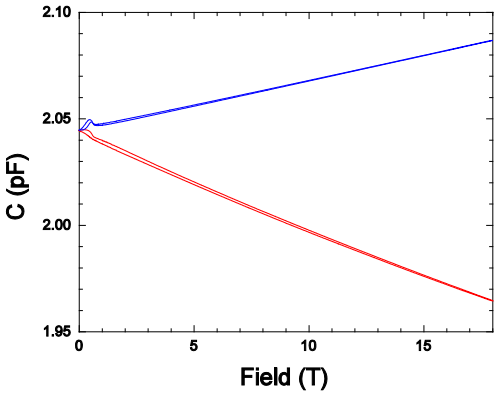


**Figure 2**. Magntometer capacitance as a function of field at 20 mK for a nickel standard placed 22.4 mm above (red) and 11.4 mm below (blue) the field center. At 18 T, field gradients at these positions are −25.4 T/m and 11.2 T/m, estimated from the magnet manufacturer's calculated field profile.

## Experimental, Results, and Discussion

**Figure 1** shows the magnetometer. A 30.62 mg nickel disk, 0.1 mm thick, was used as a sample to test and calibrate the magnetometer. The estimated saturation magnetization of the sample was 1.793 emu [2]. To obtain a field gradient required for magnetic force, the sample was placed in various positions away from the field center. As a result, the field gradient was proportional to the field for a given sample position. Results shown in **Figure 2** suggest that the magnetometer will perform well in the resistive magnet.

## Acknowledgments

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## References

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