ALPhA Advanced Laboratories

ALPhA's Laboratory Immersions

High T_C Superconductivity and the SQUID

Buffalo State College, July 9–12, 2017.

One set-up available

Host and Mentor

Ram C. Rai is Associate Professor in the Department of Physics at Buffalo State College. Professor Rai gained his first research experience in condensed matter physics in 1998 as a graduate student at the University of Kentucky. His research interests include the study of electronic and magnetic materials via transport, optical, electro-optical, and magneto-optical techniques. He is particularly interested in the growth and study of thin films of multiferroic complex oxides with functional properties. He has been teaching the advanced physics lab since Fall 2007 and has mentored several undergraduate students on research projects.

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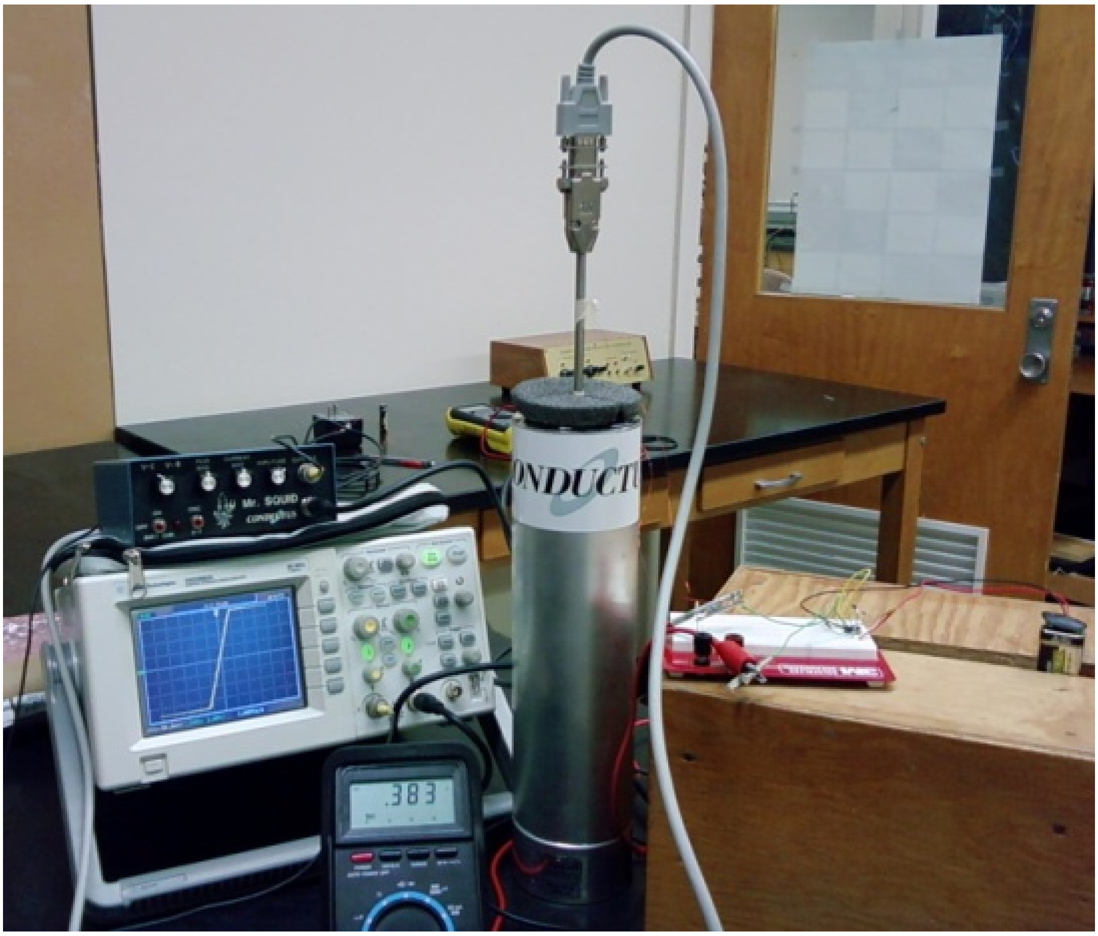
Superconductivity is one of the most fascinating phenomena in condensed matter physics. This session will focus on the study of the high T_C superconductivity of a YBCO ($Y_1Ba_2Cu_3O_7$) thin film and the superconducting quantum interference device (SQUID), which consists of a ring of superconductor containing two parallel Josephson junctions. In particular, we will study the voltage-current (V-I) and voltage-flux (V-Φ) characteristics of the SQUID (from STAR Cryoelectronics). From the V-I and V-Φ curves, we can extract superconducting parameters, such as the critical current, normal resistance, transition temperature, and the amplitude of the voltage oscillation. We will also study the ac Josephson effect of the SQUID and demonstrate a phase-locking mechanism leading to Shapiro steps in the V-I curve.



The superconducting transition of the YBCO sample can be observed in the resistance versus temperature graph. For the resistance measurement, we'll build a battery-run constant current source (∼10 μA). Since a silicon diode demonstrates a linear resistive property as a function of temperature, at least down to ∼25 K, it can act as a very reliable temperature sensor. We will use it thus, calibrating it at room temperature (∼300 K) and at liquid nitrogen temperature (∼77 K). Using these two home-made devices—the current source and the temperature sensor—we can measure the resistance of the sample as a function of temperature from room temperature down to the boiling temperature of liquid nitrogen (∼77 K). We also plan to perform the resistance measurement of superconducting pellet samples using the 4-point technique with a dc power source and digital multimeter.

The cost of the Mr. SQUID apparatus is ∼$4800. An oscilloscope is required.

Please note that the Jonathan F. Reichert Foundation has established a grant program (ALPhA webpage; Foundation website) to help purchase apparatus used in Laboratory Immersions. Limitations and exlusions apply, but generally speaking the foundation may support up to 40% of the cost of the required equipment.