In-situ sample orientation at cryogenic temperatures

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The nature of magnetism changes both with temperature and applied magnetic field. Typically, for elastic and inelastic scattering on single crystals the magnetic field should be precisely aligned along either the spin direction, or one of the crystallographic axes of the crystal. Unfortunately, with our standard vertical field magnets the sample environment equipment does not allow the scientist to control the crystal alignment. Rather, the crystal would be aligned separately and then inserted in the magnet. Subsequent alignment of the scattering plane requires tilting the entire assembly and does not allow any realignment of the sample with respect to the magnetic field direction. To address this issue, we have developed a system that allows realigning the sample inside the cryostat, changing its orientation relative to the magnetic field during a neutron experiment without disrupting the experiment temperature and magnetic field conditions.

Design of such a system is a challenging problem due to the limitations for devices operated at ultra-low temperatures. The alignment device must be located inside the small space under vacuum conditions, it should produce minimal heat load to avoid interference with stable operation of the refrigerator, and it should demonstrate minimal expansion or contraction over a wide range of temperatures. Additionally, the device must not generate an electromagnetic field and must be made from non-magnetic materials. Previous designs have had both positives and negatives. Some designs used a worm-gear mechanism to mechanically connect an external room temperature motor to the sample space [1]. Another design used a piezoelectric actuator located at ultralow temperatures to achieve sample rotation [2]. However, these actuator systems were not designed for neutron measurements. Our current design for sample rotation allows 360° rotation around the axis in the horizontal plane with resolution 0.1°. The device can be used at temperatures below 1 K, magnetic fields up to 31 T, under high vacuum, and within a neutron beam. Figure 1 is a photo of the actual device.

Dimensions of this device are 98 mm high and 55 mm wide which allows it to fit inside the ^{3}He cryostat inserts operated within our facility. The dimensions are mostly defined by the size of the piezo electric rotator ANR240 (closed loop) by Attocube. The choice of this rotator was motivated by the amount of dynamic torque supplied (2 N·cm) to allow repositioning and maintaining sample position in a high magnetic field. An aluminum sample holder is attached to the bottom gear located at the neutron beam position. The piezo electric rotator and gears are supported by a

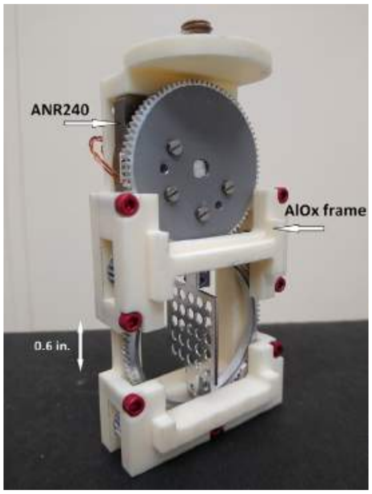

FIGURE 1: Low-temperature goniometer.

ceramic (AlO_x) frame. Figure 1 shows how the device has been designed to minimize the amount of material surrounding the sample position. The 0.6 in wide horizontal opening creates a large viewing window for undisturbed 360° sample observation. We use aluminum or copper braids to connect the sample holder and cold plate to improve thermal contact down to the ^{3}He insert base temperature (T = 0.3 K).

This sample alignment device has been successfully used in exploring the metamagnetic transition in the intrinsic antiferromagnetic topological insulator $MnBi_2Te_4$. Tilting the sample at high field and low temperature allowed researchers to access otherwise inaccessible reflections sensitive to changes in the magnetic ordering while maintaining a large component of the magnetic field along the c-axis. This alignment device is a powerful tool for researchers, allowing them to more easily search for novel relationships between scattering geometry and applied magnetic field direction.

References

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