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8.24 Polarized Target Facility for Neutron Physics Experiments*

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We have constructed a cryogenic polarized target facility for the brute force nuclear orientation of bulk metallic samples. The target was developed for use with the polarized neutron beam facility at TUNL and is presently being used to study spin-spin effects in neutron scattering.

The polarized target consists of a dilution refrigerator and a superconducting magnet, together capable of cooling metallic samples to temperatures between 10 and 20 mK in magnetic fields up to 7 T. At these temperatures and magnetic fields brute force nuclear orientation (BFNO) occurs for a variety of nuclei ranging from hydrogen to bismuth. The technique is conceptually straightforward but has only recently been technologically feasible following the development of reliable high cooling power refrigeration in the 10 mK region.[1] Fig. 1 summarizes the vector polarizations attainable via BFNO at 0.7 T/mK. Convenient cryogenic materials are aluminum, copper, niobium and bismuth. Our first experiments have been with aluminum.

Spin-spin terms in the neutron nucleus optical potential contribute to the total cross section for polarized neutrons incident on polarized nuclei. Their contribution can be determined from asymmetry measurements made with different neutron and target spin orientations.[2] The spin-spin cross section is given by

$$\sigma_{ss} = \varepsilon/2P_n f_1 t$$

where ε is the neutron asymmetry at 0° for neutron and target spins parallel and anti parallel, P_n is the neutron polarization, f_1 is the target polarization, and t is the areal target thickness. Recent calculations by Thompson et al.[3] indicate that σ_{ss} is typically less than 20 mb. The expected asymmetries are therefore small, less than 10^{-3} for our experimental configurations.

The central and tensor contributions to the spin spin potential can be separated if asymmetry measurements are made with[4]

1) neutron and target spins transverse to the beam direction,
2) neutron and target spins parallel to the beam direction.

The polarized target assembly is shown in Fig. 2. The dilution refrigerator is an SHE model 430 cryostat with a cooling power of 1.48 μW at 10 mK. The magnet is a NbTi split coil solenoid from American Magnetics, rated at a maximum field of 7 T at 85 A of current. The magnet has four 90° access ports and a homogeneity of 0.1% over a 1 cm diameter spherical volume. By rotating the mounting the magnetic field can be aligned parallel or horizontally transverse to the neutron beam.

The sample is mounted at the end of a cold finger made of a bundle of OFHC copper wires. The Al target is 1.8 cm wide, 1.8 cm thick and 5 cm high and is attached to the cold finger by a threaded insert.

The sample temperature is measured via nuclear orientation with a 2 μC ^{60}Co(Co) single crystal source from Oxford Instruments. The crystal is mounted on the bottom of the sample with its axis parallel to the magnetic field. The warm to cold anisotropy is measured with an 11.5% efficient intrinsic germanium detector. In order to prevent breakdown inside the germanium detector we operate it 36 cm from the sample, where the magnetic field is less than 0.2 T. At this distance the count rate is about one event per second.

The performance of the refrigerator has been very satisfactory. In the first test run the aluminum sample was cooled to 11.3 mK. This corresponds to a polarization of 36%, a factor of four better than the best previous reported value for polarization of aluminum.[5] We are currently improving the operating characteristics of the target, as well as working on the development of stabilized beam transport and neutron detection systems.

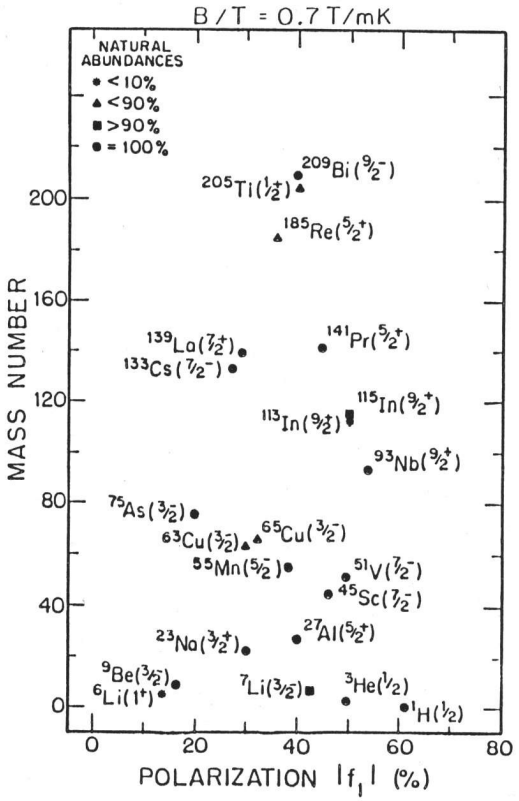

Fig. 1. BFNO polarizations

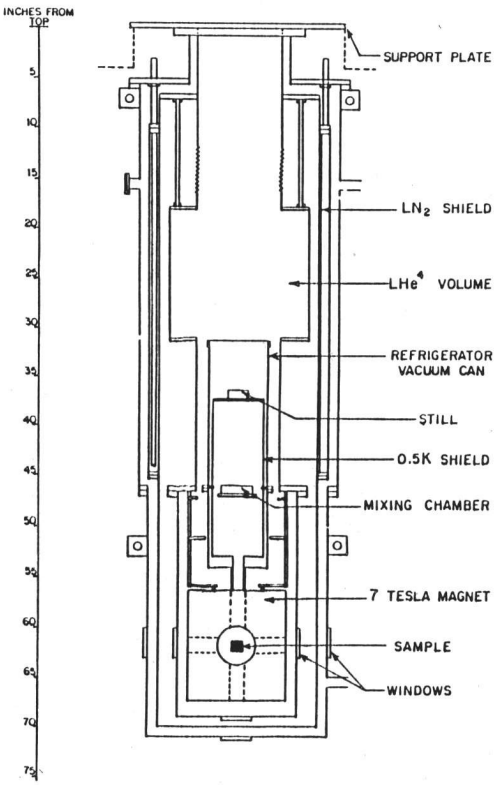

Fig. 2. Polarized target

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