The HB-2D Polarized Neutron Development Beamline at the High Flux Isotope Reactor

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Abstract. The Polarized Neutron Development beamline, recently commissioned at the HB-2D position on the High Flux Isotope Reactor (HFIR) at Oak Ridge National Laboratory, provides a tool for development and testing of polarizers, polarized neutron devices, and prototyping of polarized neutron techniques. With available monochromators including pyrolytic graphite and polarizing enriched Fe-57 (Si), the instrument has operated at 4.25 and 2.6 Å wavelengths, using crystal, supermirror, or He-3 polarizers and analyzers in various configurations. The Neutron Optics and Development Team has used the beamline for testing of He-3 polarizers for use at other HFIR and Spallation Neutron Source (SNS) instruments, as well as a variety of flipper devices. Recently, we have acquired new supermirror polarizers which have improved the instrument performance. The team and collaborators also have continuing demonstration experiments of spin-echo focusing techniques, and plans to conduct polarized diffraction measurements. The beamline is also used to support a growing use of polarization techniques at present and future instruments at SNS and HFIR.

1. Introduction

Oak Ridge National Laboratory (ORNL) operates two major neutron facilities, the Spallation Neutron Source and the High Flux Isotope Reactor (HFIR). The HFIR has been operational at ORNL since 1965 [1]. It is a light water cooled and moderated, beryllium reflected reactor with a cylindrical "flux trap" core structure. Thermal neutron flux up to 2.5 x 10^{15} n/cm^{2}s is available for isotope irradiation, and the source thermal neutron flux for the beam tubes is up to 1.2 x 10^{15} n/cm^{2}s.

The HB-2 beam tube has a radial view of the HFIR core, so that both thermal and fast neutron flux, in addition to core gamma rays, are present. A cooled sapphire crystal assembly serves as a fast neutron filter. The shield assembly at the end of the HB-2 beam tube allows for installation of crystal monochromators for 4 beamlines. Neutron user instruments presently occupy three of the positions: (1) the HB-2A Powder Diffractometer [2], (2) the HB-2B Neutron Residual Stress Facility, and (3) the HB-2C Wide Angle Neutron Diffractometer. The HB-2D position has a variable angle monochromator drum, and has previously hosted the MIRROR neutron reflectometer, and the SNS detector test station. Recently, we have recommissioned HB-2D as the Polarized Neutron Development Beamline.

The monochromator drum, originally intended for a triple-axis spectrometer, is operated at a fixed angle for purposes of the present instrument. The monochromator position is 10.9 m from the end of the beam tube. The 78.6° monochromator angle yields a wavelength of 4.25 Å for a graphite monochromator, far from the approximately 1 Å spectral peak of the thermal beam tube. With a 100 mm thick Be filter at room temperature, the flux in this configuration is a modest 2 x 10^5 n/cm^{2}s. Reconfiguration for other monochromators at the same angle is straightforward. For example, we have tried, but not yet optimized for good polarization, an ^{57}Fe(Si) polarizing monochromator, which yields a primary wavelength of 2.6 Å and a flux of about 10^6 n/cm^{2}s.

Figure 1. This figure shows the HB-2D monochromator drum (upper left), and the variable height lift tables between the exit port and the beamstop.

The beamline (Figure 1) has about 4 m between the exit port and the beam stop. There are 4 variable height hydraulic lift breadboard tables, enabling rapid reconfiguration of beam components. The instrument has necessary components to operate as a polarimeter, a reflectometer, or a diffractometer, depending on requirements of the measurement.

Very recently, the instrument team has acquired two modern supermirror polarizers, which enable much better polarization performance. One is a Neutron Optics Berlin S-bender, optimized for cold neutron wavelengths. The second is a Swiss Neutronics V-cavity, which operates well at wavelengths as short as 2.4 Å.

2. Examples of component measurements.

One function of HB-2D is testing of polarization components for development or for use on other ORNL neutron instruments. It has hosted measurements of ^{3}He polarizers, including SEOP in-situ units [3], "drop-in" cells, and an experimental cell to measure the internal ^{3}He gas temperature. It has been used in a continuation of flipper development started on CG1 [4,5] with various flipper prototypes including cryoflippers, Drabkin coils, rf flippers, and dc flippers.

As an example, we show the results of an attempt to create a cryoflipper by tiling YBCO films on sapphire, using the configuration shown in Figure 2 [6]. The YBCO films were arranged in three different patterns as shown. In each case the YBCO was cooled to 90 K and translated across a 1 mm wide slit in the polarized beam. A single slab shows a uniform flipping performance across its width. With gaps between the films, the flipping effect is nearly absent within the film gaps, as expected. When the films are overlapped, there is clearly enough field leakage to compromise the flipping performance. This indicates that edge effects are a potential issue in any application using YBCO films as neutron Meissner screens.

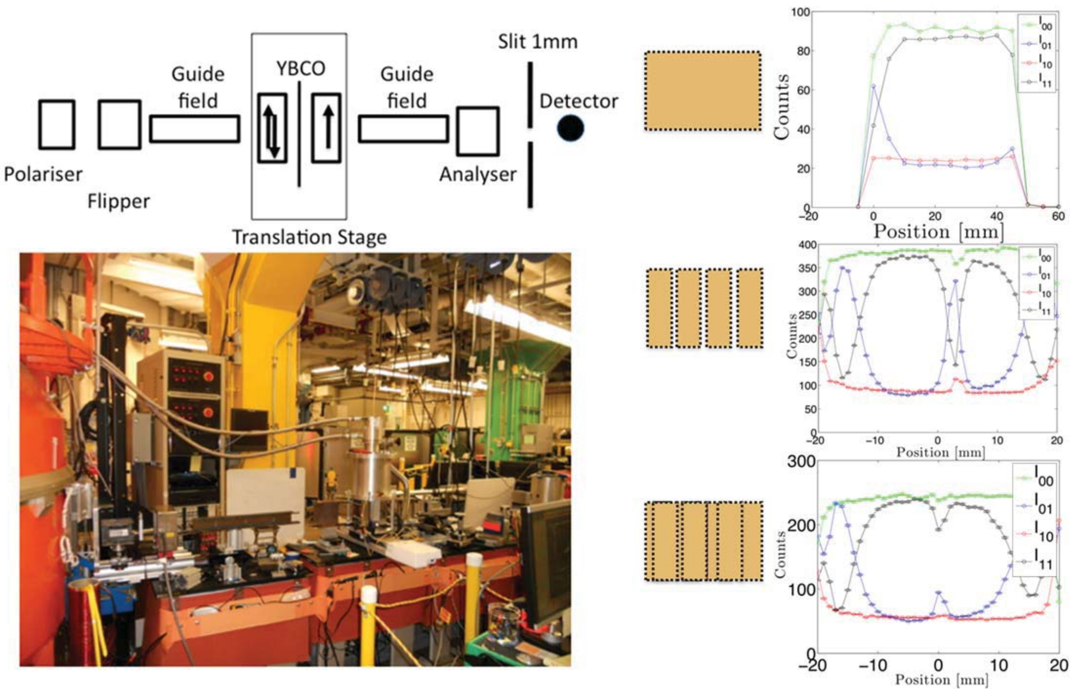

Figure 2. The schematic in the upper left illustrates the experimental arrangement for measuring the effect of gaps in YBCO assemblies used as cryoflippers. The solid slab (upper right) shows a uniform response as the film is translated across the beam. The assembly with gaps (middle right) shows that the flipping effect nearly disappears within the gaps. The assembly with overlaps (lower right) shows that even with an overlap, there is a large change due to the use of multiple slabs.

3. Tests of Spin Polarization Instrument prototypes.

HB-2D has hosted tests of spin manipulation assemblies. The polarized neutron group from Indiana University has developed a "Cryo-Cup" Spherical Neutron Polarimeter [7]. In the SNP apparatus, cooled to 20 K, the incoming and outgoing neutron polarization are controlled separately using fields generated by high-Tc coils. YBCO films serve as Meissner shields for non-adiabatic neutron spin transitions. Measurements of a 10 micron thick slab of permalloy with the easy axis in-plane showed a three-dimensional polarization matrix consistent with magnetization measurements [8].

Another device demonstrated at HB-2D is the prototype Modulated Intensity by Combined Effort (MICE) [9]. In the MICE technique, the neutron spin is encoded by rf flippers. The neutrons travel through an adjustable-current solenoid between the rf flippers; since it does not rely on a zero-field region, the performance should be robust in moderate magnetic field environments. The initial demonstration experiment, using the apparatus shown in Figure 3, clearly demonstrated time focusing, as shown in Figure 4.

Figure 3. The Modulated Intensity by Combined Effort system is shown in its initial configuration. The square coils before and after the cylindrical solenoid are rf flippers. The solenoid current is varied to conduct a scan. A neutron detector downstream detects neutrons in time-of-flight, with the time base synchronized to the coils.

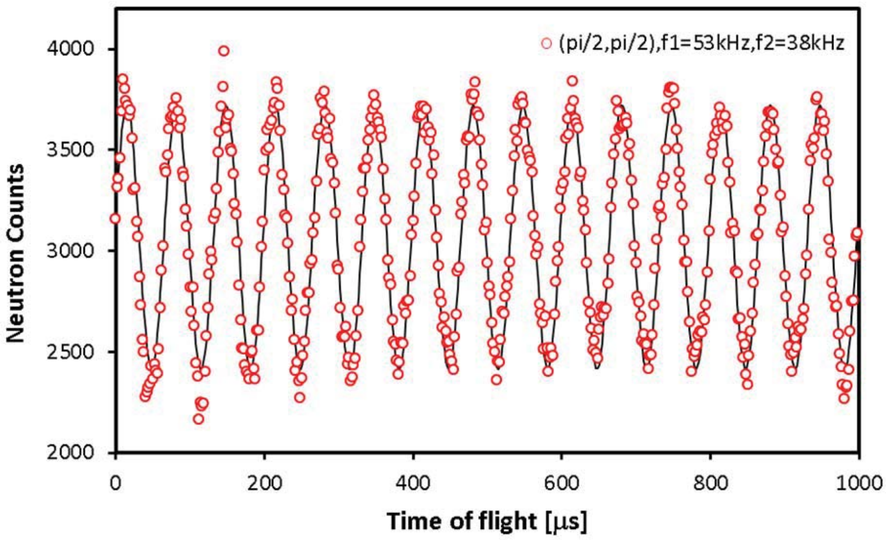

Figure 4. A typical MICE pattern is shown, with an initial coil frequency of 53 kHz and a final coil frequency of 38 kHz. The 15 fringes in 1000 μs is as predicted for this configuration.

4. Summary and future plans

Activities underway at HB-2D include continued development of the MICE technique and tests of a Wollaston prism prototype from Indiana University [10]. Measurements of components such as flippers and ^{3}He polarizers in support of other ORNL instruments will continue. The instrument now has a working diffractometer arm, which will be used in demonstration polarized diffraction measurements in the near future. The work reported here was conducted before improved polarizers were available, so the improved polarization performance will lead to better measurements.

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