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Polarized beam operation of the hybrid spectrometer at the pulsed spallation neutron source

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Abstract

The concept of a neutron hybrid spectrometer (HYSPEC) combines the time-of-flight spectroscopy with the focusing Bragg optics and incorporates a polarized beam option. Here, we describe the polarization analysis scheme proposed for HYSPEC and quantify its performance via the Monte-Carlo simulations. We find that the broadband supermirror-bender transmission polarizers provide reasonably good polarization analysis capability within a ~8–10 meV energy window for scattered neutron energies in the thermal range, up to ~25 meV.

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1. Introduction

The neutron polarization analysis (PA) [1] is broadly recognized as an important tool in neutron scattering studies. It allows distinguishing between the spin excitations and phonons, separating magnetic scattering from background and uncontrolled structural features (''Braggons'', ''spurions'', etc.), studying magnetic critical dynamics, etc. Recently, PA was successfully applied to the doped strongly correlated oxides, [2,3] quantum magnets, [4,5] studying phase transitions and novel ordered phases in complex systems [6,7].

Traditionally, polarized neutron studies were performed on the crystal (mainly triple axis) spectrometers at steady-state neutron sources and by employing the polarization-dependent Bragg reflectivity of the Heusler-alloy (Cu_2MnAl) crystal. The time-of-flight (TOF) spectroscopy in many cases offers significant advantages by surveying neutron scattering events in a wide range of angles and energy transfers in a single measurement. The superiority of the TOF approach is overwhelming at the pulsed (spallation) neutron sources, where

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the incident neutron beam is inherently time-modulated. However, development of the PA techniques for the TOF instruments is still in its infancy and presents an area of the expected future growth.

The main problem of using the traditional PA techniques in the TOF setup is posed by the contradictory requirements of a large angular acceptance on the one hand, and of the well-collimated beams on the other. Indeed, a beam collimation is required both in the Heusler crystal PA setup [1,8] and in the PA setup with the supermirror-bender transmission polarizers (SBTP) [9]. One venue for the PA on the TOF instruments is opened by the recent progress in developing the polarized ^{3}He transmission cells [10]. However, while the great potential of this approach is unquestionable, it has not yet been established as a reliable technique where the large angular apertures are required. An alternative approach consists in using the multi-channel setup by replicating the traditional, collimated-beam PA devices covering the large range of scattering angles. Such scheme is currently employed on the D7 spectrometer at the ILL [10]. Here, we describe the multi-channel PA setup with the transmission polarizers proposed for the hybrid spectrometer (HYSPEC) at the pulsed spallation neutron source (SNS) [11].

2. The polarized beam setup on HYSPEC

HYSPEC is a direct-geometry, crystal/TOF hybrid spectrometer designed for the SNS [11]. It will operate in the thermal and sub-thermal neutron range [2.5, 90] meV, have a resolution comparable to that of a reactor-based triple axis spectrometer, or better, and will have a polarization analysis capability. HYSPEC combines the TOF spectroscopy with the focusing Bragg optics by using the TOF for selecting the neutron energy and the vertically curved crystal monochromator for concentrating the neutron flux on sample. In this setup, a particular incident neutron polarization needed for the PA can be selected by using the (1 1 1) Bragg reflection from a Heusler crystal. This reflection has the property that the nuclear and magnetic scattering lengths are equal so only one spin state is reflected. Studies indicate that the polarization in excess of 95% is achievable when the Mn moments are aligned, and the Bragg reflectivity can approach that expected for an ideal mosaic crystal such as PG [8].

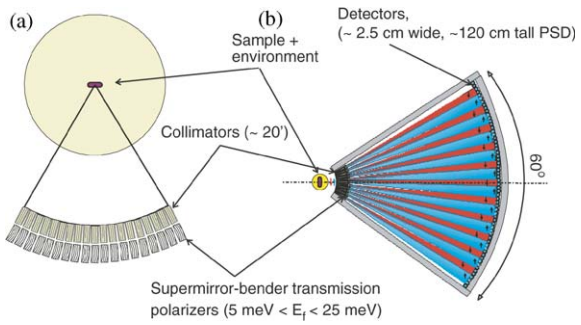

Fig. 1. Schematics showing: (a) geometry of the HYSPEC's multi-channel setup for the scattered beam polarization analysis; and (b) the operation of the analyzer in the polarized beam mode. Shading and arrows illustrate how the supermirror-benders split scattered neutrons into beams with opposite polarizations.

Large angular acceptance of the HYSPEC's analyzer (a 60° horizontal coverage is currently planned) does not allow using a Heusler crystal for determining the polarization of the scattered neutrons. Therefore, a multi-channel array of equivalent, broadband SBTP is envisioned for the polarization analysis of the scattered beam, Fig. 1(a). Nineteen-to-twenty benders could be positioned in front of the analyzer vessel, at a distance $\approx$0.5 m from the sample axis, and within the 60° angle subtended by the detector array. For each PA channel this allows a $\approx$3° sector, or a $\approx$24 cm long segment on the detector bank at 4.5 m from the sample, containing 8–10 detector tubes.

3. Performance and optimization of the transmission polarizer

Supermirror-bender polarization analyzer is a short, multi-channel curved guide with magnetically aligned, polarization-sensitive Fe–Si supermirror films on the channel walls. In practice, each channel is made of a thin, supermirror-coated