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Three-axis spectroscopy with remanent benders

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Abstract

Recent developments in sputtering techniques allow the production of polarising supermirrors with a significant in-plane magnetic anisotropy that leads to a pronounced remanent and coercive field along the easy axis of magnetisation. The magnetic layers can be magnetised by a field pulse of $B_p \simeq 20$ mT either parallel or anti-parallel to a guide field $B_g \simeq 1$ mT. We show that polarising benders using remanent supermirrors are a versatile means to perform polarisation analysis with a three-axis spectrometer. The major advantages of remanent benders are: (i) no need for spin flippers, (ii) no cross-talk between neutron polarisation and magnetic fields at the sample position, and (iii) ideal for white beam applications. © 2001 Published by Elsevier Science B.V.

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1. Introduction

The standard method for polarised neutron spectroscopy was introduced in the late 1960s by Moon et al. [1]. In the usual setup for uniaxial polarisation technique, the production and analysis of a polarised beam is performed by Heusler monochromators, and the spin eigenstate is selected by means of spin flippers. However, difficulties arise from cross-talk between the magnetic field \mathbf{B} at the sample position and the fields used for the spin flippers. This problem is specially crucial for experiment requiring a horizontal magnetic field. In this situation, \mathbf{B} follows the scattering vector \mathbf{Q} , there-

fore the flipping ratio can be modified significantly, even within an inelastic scan. The ideal solution would be to modify the currents in the spin flippers for each configuration accordingly, but it would require tedious alignment procedures that are difficult to perform. More recently, a new polarising technique was developed using ^3He spin filters [2]. These devices have a good transmission and are easy to install on a spectrometer. Moreover, they are suited for white beam measurements or large angular beam acceptance (e.g. full polarisation analysis on SANS). Despite many evident advantages, the lifetime of such filters (≈ 100 h) is short when compared to standard polarising devices. Moreover, the need of a large filling station facility requires large manpower and financial investment. We present in this contribution, a technique that uses remanent benders. During the development phase of this new type of polarising devices

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significant care was taken to overcome the above mentioned difficulties.

The conventional benders are already known for more than two decades. The basic idea results from the observation that the reflectivity of artificial magnetic multilayers depends on the spin polarisation [3].

The improvement of sputtering techniques over the 20 past years has allowed to increase significantly the critical angle of total reflection of supermirrors, while keeping an excellent transmission over the whole range of useful wavelengths [4,5]. In addition, low coercive field and pronounced remanent magnetisation can be achieved by the use of anisotropic sputtering conditions [6]. These essential properties allow to implement in a single optical device the polarisation of the neutron beam as well as the possibility to select its spin eigenstate. The transmission characteristic of such devices indicates that they can provide reasonable performance in the wavelength range from 1.6 Å to 8.0 Å, with a polarisation larger than 92% [6].

2. Remanent benders

The remanent benders consist of curved polarising supermirrors (FeCoV/TiN_x) that have been sputtered on a glass substrate. They are then mounted together, separated by aluminum spacers. An additional layer of $\text{Ti}_{1-x}\text{Gd}_x$ was sputtered on the glass for absorbing the non-reflected neutron spin eigenstate. Detailed information about these devices can be retrieved in a previous publication [6]. The transmission of these devices was observed to be up to $\simeq 35\%$ in the cold and thermal neutron spectrum, depending on the experimental arrangement. Due to the curvature of the bender, the beam is deflected by about 1.35° with respect to the optical axis. The direction of magnetisation of the benders can be selected by applying a field pulse of $B_p \simeq \pm 20$ mT. The problem of cross-talk between spin selection and sample environment is eliminated, because the polarisation is not achieved by Larmor precession type of flippers. Therefore no extra \mathbf{B} is necessary for manipulating the spins during the measurement. This latter property is particularly fruitful for neutron spin echo spec-

trometers that are extremely sensitive to magnetic field perturbations or inhomogeneities [7,8]. In addition, the way the spin direction is selected in the bender makes the selection independent of the neutron wavelength.

3. Polarised neutron setup

In Fig. 1, we present a polarised beam setup including remanent benders on a three-axis spectrometer. The surfaces of the mirrors at the exit of the first bender are parallel to the optical axis of the instrument, so that the beam is not displaced with respect to the unpolarised setup. The deviation at the entrance can be easily corrected by adjusting the translation and the two-theta angle of the monochromator, that does not affect the energy of the reflected neutrons. In the particular case of TASP, a special insert has been installed after the monochromator, that allows the easy installation of a bender or of a collimator. The insert is equipped with a permanent guide field of about $B_g \simeq 1$ mT and an electromagnetic system for switching the magnetisation of the bender. The second bender is arranged with the optical axis pointing towards the analyser. The deviation of the beam is, however, small enough (1.35°) so that the full beam reaches the detector, therefore no adjustment is necessary. The polarisation of the neutron beam is defined by the direction of the magnetisation \mathbf{M} with respect to \mathbf{B}_g that is always kept fixed (see Fig. 2).

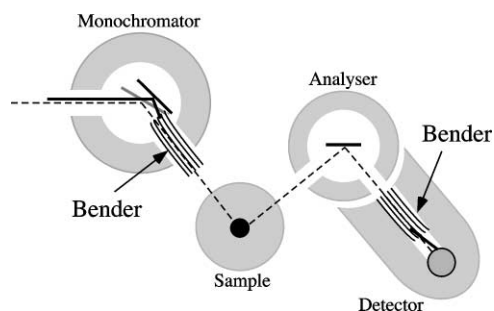


Fig. 1. Layout of the polarised beam spectrometer TASP using remanent benders. The neutron path in the non-polarised setup is presented as a dashed line. The plain line shows the deviations caused by the benders.

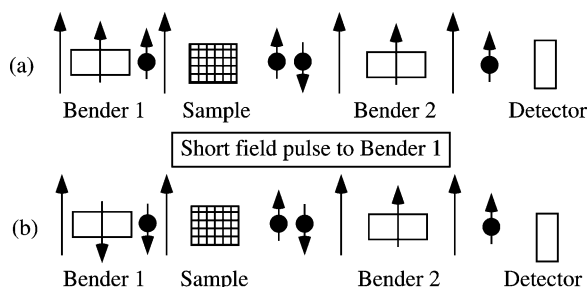


Fig. 2. Principle of polarised neutron scattering using remanent benders. The four cross sections $(++)(-+)(--)$ and $(+-)$ can be consecutively measured by switching the magnetisation of the supermirrors before and after the sample. The setup for the channel $(++)$ and $(-+)$ is shown in the layout (a) and (b), respectively.

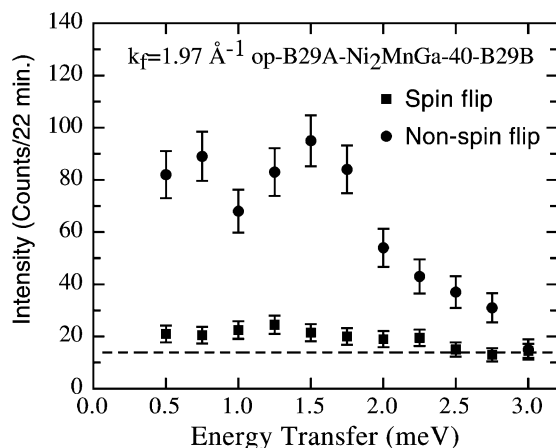


Fig. 3. Inelastic neutron experiment with polarised beam in a Ni_2MnGa Heusler alloy [9]. No corrections have been applied to the data. The flipping ratio is $R \approx 10$. The non-spin-flip channel is due to a soft phonon. The dashed line indicates the background of the spectrometers, that appears in both channels. No (magnetic) excitation is seen in the spin-flip channel, which is mainly composed of background. The additional intensity is due to the contamination of the non-spin-flip channel, because of the finite value of the flipping ratio.

An example of a polarised neutron experiment is shown in Fig. 3 [9]. The characteristics of the remanent benders that have been used are listed in

Table (1) and shown in Fig. (4) of Ref. [6]. The soft phonon is observed to appear in the non-spin-flip channel, whereas the signal in the spin flip channel is strongly reduced. Most of the signal of the spin-flip scattering is due to the background of the spectrometer (≈ 0.7 count/min). The finite flipping ratio is $R \approx 10$ explain the additional intensity due to the contamination of the non-spin-flip signal.

4. Conclusion

We have shown that remanent benders offer a convenient means to perform uniaxial polarisation analysis on a three-axis spectrometer.

The advantages of this technique are the following: (i) no need of spin flippers and their tedious alignment; (ii) no cross-talk between spin flippers and fields of the sample environment; (iii) spin selection independent of the neutron wavelength, therefore well suited for white beam application.

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