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New Type of Neutron Polarizer for Neutron Interferometer

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A neutron polarizer based on supermirrors operating in the transmission mode is described. It does not require a high angular resolution and allows the use of a large cross-section neutron beam. The transmission of supermirrors amounts up to 80% for the selected spin state. Such polarizer provides a polarization of the neutron beam of more than 90% and a high recorded intensity on the perfect crystal interferometer output.

KEYWORDS: Polarized neutrons, Neutron Interferometry

1. Introduction

The use of polarized neutron beams in neutron interferometry is important in a number of quantum mechanical experiments[1,2] concerning the interference of the spin part of the neutron wave function. Moreover, polarized neutron interferometry can be applied for the study of magnetic phenomena in solids and ferrofluids, in thin magnetic films and also for investigations of spin-dependent effects in nuclear physics.

The results, of course, are mainly determined by the efficiency of the polarizing unit. Up to now the only construction of a polarizer used in neutron interferometry is based on magnetic birefringence, i.e., the Stern - Gerlach effect,[2] where the angular separation of neutron beams with opposite spin components (of about a few second of arc) can be achieved by the transmission of an incident neutron beam through a prism-shaped magnetic field region ($B \approx 10$ kG) due to the spin dependent index of refraction. Such beams can be resolved by a high resolution double crystal arrangement, that actually is the perfect crystal interferometer set up with a perfect crystal Si monochromator. Certainly, such high magnetic field strength can be obtained only in a small air gap; this fact limits the size of the beams used to a few square millimeters and reduces drastically the output intensity, amounting to a few neutron per second even for the high-flux reactor in Grenoble. It puts a very strong limitation to the use of polarized neutrons for neutron interferometry at medium-flux reactors. It should be also mentioned, that most of the present-day operating neutron interferometers use monochromators with considerable mosaicity (pyrolithic graphite or slightly bent perfect Si).

In this article we describe a new type of polarizer for neutron interferometry[3], which is free from the limitations in the luminosity discussed above. Unlike a prism-shaped magnetic field polarizer, the present polarizer does not require any high angular resolution of the set up, so it is suitable for the use with mosaic monochromators and allows large cross-section neutron beams.

2. Supermirror Based Polarizer

The polarizer is based on the use of high-quality neutron supermirrors, operating in the transmission mode. This fact is an important feature of the described polarizer. It means, that it does not change the angles of the propagation of neutrons between monochromator and interferometer crystals and indeed, does not violate the dispersion relation, that is automatically fulfilled in the double crystal arrangement and leads to a high luminosity of this scheme[4].

The active element of the polarizer, which has been installed at the neutron interferometer at HMI [5], has a V-form and is assembled from several 50x100 mm^2 laser cut pieces (Fig. 1). The supermirrors consist of 50 bilayers of $Co_{11}Fe_{89}$ - Si (70 - 800 Å) and were sputtered on both sides of highly polished silicon wafers with a thickness of 0.5 mm [6]. For the spin-down neutrons the scattering length density of the magnetized alloy is matched to that of Si. Thus the spin-up neutrons are reflected by the supermirror and absorbed by cadmium diaphragms. The spin-down neutrons, however, interact with a virtually pure-silicon plate. They are reflected up to the critical angle of Si and transmitted for higher angles with an absorption loss fraction of 20%. The transmitted neutron beam is 98% polarized up to the critical angle $\theta_c \approx 0.18°$ /Å (Fig. 2).

The mirrors are pressed on two 700 mm long aluminium plates, where the apex angle, i. e., twice the angle of incidence, is adjustable for different wavelengths. The angle of incidence was chosen as 0.32°, that allows the operation with a rather divergent incident beam of wavelength of 2Å. The utilizable beam size is 40 x 8 mm^2. The mirrors are magnetically saturated by permanent

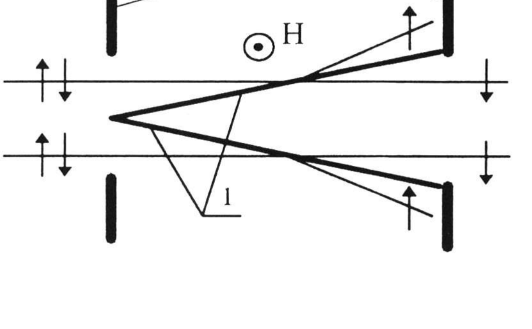

Fig.1. The polarizer layout. 1 - silicon plates double-coated with supermirrors, 2 - Cd diaphragms.

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magnets, which are fixed to a yoke, providing a field of 800 Gauss.

3. Adjustment and Results

For the procedure of adjustment we used a Brookhaven dc-flipper and a Heusler alloy crystal (Cu_2MnAl) saturated by a 2.5 kG magnetic field as an analyzer. The polarisation of the crystal was experemintally determined to be P_{an} = 92%. The position of the highest reflected intensity of the Heusler crystal was found, determining the minimum of the transmitted beam rocking curve with the unpolarized beam.

Thereafter the reflected spin-down intensity was measured both with the flipper switched off (I_{off}) and on (I_{on}). The resulting 'flipping ratio'

$$r = \frac{I_{off} - I_{bg}}{I_{on} - I_{bg}}$$

was calculated subtracting the background I_{bg}. This provides a polarization (assuming 100% flipper efficiency)

$$P_{pol} = \frac{r-1}{r+1}\frac{1}{P_{an}}$$

of the transmitted neutron beam of 90% for the beam size of (30x8) mm^2, when the best position of the polarizer was found. It increases up to P_{pol} = 98% for a beam size of (30x3) mm^2. Fig. 3 shows the polarisation and intensity over the beam width. Using this polarizer the sum of outgoing intensities of O- and H-beam of the interferometer reaches 30 n/s for 8 mm beam width; this is significantly higher than that of the ILL-perfect crystal interferometer.

4. Conclusion.

The supermirror based transmission geometry, neutron beam polarizer described in this article provides a significant increase of the luminosity of polarized neutron interferometers in comparison with the Stern - Gerlach type polarizers. Indeed, the outgoing intensities of the interferometer's beams are also significantly increased, that gives the opportunity for the polarized neutron interferometry research at medium-flux reactors. Moreover, in contrast to the Stern - Gerlach type of polarizer, it does not require any high angular resolution of the set up, so it is suitable for the use with monochromators having substantial mosaicity (pyrolithic graphite or slightly bent perfect Si). At the same time one should mention that the Stern - Gerlach type of polarizer can provide an extremely high polarization of neutron beams ($P \approx$ 99.99 %) and has up to present no alternative in the case, when such high polarization is required.

Acknowledgments.

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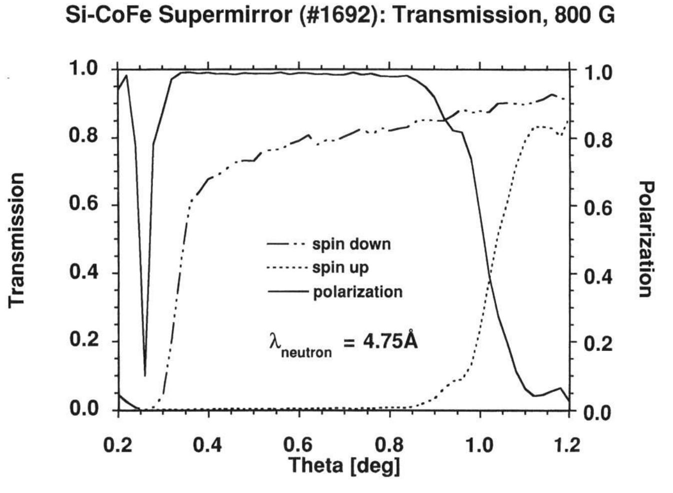

Fig. 2. Experimental transmission of Si-CoFe supermirror for spin-up and spin-down neutrons and the resulting polarization.

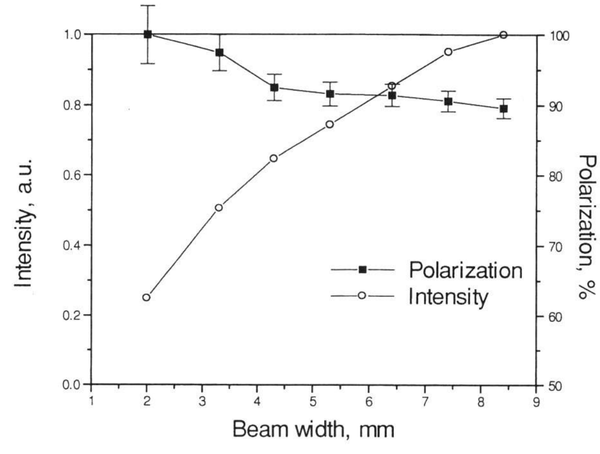

Fig. 3. Intensity and polarization vs. beam width.

1. G.Badurek, H. Rauch and D.Tuppinger: *Phys. Rev.* A 34 (1986) 2600.
2. Summhammer, G.Badurek, H. Rauch, U.Kischko and A. Zeilinger: *Phys. Rev.* A 27 (1983) 2523.
3. Mezei, Neutron Optical Devices, C.F.Majkrzak editor, *SPIE Conf. Proc*, v. 983C, (Bellingham SPIE, 1989) p.10.
4. Shull, K. W. Billmann, F. A. Wedgwood: *Phys. Rev.* 153 (1967) 1415.
5. Drabkin, A. Ioffe, S. Kirsanov, F. Mezei, V. Zabijakin: *Nucl. Inst. Meth.* A 348 (1994) 198.
6. Th. Krist, C. Pappas, Th. Keller, F. Mezei: *Physica* B 213&214 (1995) 939.