Available online at www.sciencedirect.com
SCIENCE DIRECT®
Physica B 335 (2003) 270–273
PHYSICA B
www.elsevier.com/locate/physb

Simulations of a convergent bender as neutron polariser for NSE spectrometers

S. Manoshin*, G. Zsigmond, K. Lieutenant, F. Mezei

Hahn–Meitner-Institut, Berlin, Glienicker Str. 100, Berlin, D-14109, Germany

Abstract

Soller-type collimators with supermirror coating may be used for polarisation of neutron beams. The disadvantage of such devices is a high level of gamma background and fast neutrons in the case of pulsed neutron sources. In order to increase the neutron flux, the collimator was made convergent. Generally, benders make it possible to suppress the fast neutron and gamma background completely. The combination of a bender and a convergent Soller collimator (convergent or focusing bender) is proposed for polarisation of the neutron beam for future NSE spectrometers at the cold source of ESS. Simulations and optimisation of convergent benders as neutron polarisers for NSE spectrometers are presented. The VITESS software package proved to be a powerful tool for the optimisation of polarising devices.

Keywords: MC simulation; Convergent bender

1. Introduction

Single-channel and multi-channel bent neutron guides are used at modern neutron sources to create neutron beams practically for all types of instruments [1]. Focusing Soller-type collimators are also used to optimise neutron beams [2]. Guides and Soller collimators can be used to polarise the neutron beam. Unfortunately, each device has besides advantages some disadvantages. For example, a convergent Soller collimator does not prevent fast neutron background, but gives a significant neutron flux gain compared to normal Soller collimators. Benders give a well-polarised beam and fully suppress the background of fast neutrons and gamma rays, but do not give significant neutron flux gain, especially for benders with characteristic wavelength larger than 5 Å [2,3]. So it is necessary to combine both the devices to improve polarisation, neutron flux and to reduce background. We call such a device the "convergent" or "focusing bender". First simulations and practical realisation of the focusing benders were made for the DNS instrument (polarisation analysis for diffused neutron scattering) at FZ-Juelich [4,5]. Benders for polarisation of the neutron beams are produced at the Hahn-Meitner-Institut, Berlin [6]. A convergent bender will be proposed for high-resolution NSE at ESS as a polariser and possibly as an analyser [7]. The optimisation of the convergent bender was performed by using the "figure of merit" for the wavelength band $3\,\text{Å} < \lambda < 25\,\text{Å}$ much wider then $3.3\,\text{Å} < \lambda < 5.5\,\text{Å}$ simulated for DNS. Thus, we significantly extended the wavelength band in the optimisation for the NSE spectrometer at ESS.

*Corresponding author. Tel.: +49-30-8062-2543; fax: +49-30-8062-2523.

E-mail address: manochine@hmi.de (S. Manoshin).

0921-4526/03/$ - see front matter
doi:10.1016/S0921-4526(03)00254-0

Also, VITESS simulations of the polarisation efficiency of neutron beam at the exit of the bender were included.

2. Simulation and optimisation of convergent benders

The simulations were done by using the VITESS software package [8]. The optimisation of a convergent bender as neutron polariser is performed by calculating its "figure of merit". For optimisation, we chose $I \times P^2$ as "figure of merit", where I is the intensity of neutrons at the exit of the bender and P is the polarisation of the neutron beam, also at the bender exit. This "figure of merit" is based on the optimisation of the flipping ratio, $P^{\text{fon}}/P^{\text{foff}}$, on an instrument, where P^{fon} (P^{foff}) is the polarisation measured at the detector with the spin flipper on (off) [9,10].

During calculation of the "figure of merit", the intensity of neutron source was homogeneous at all wavelengths. According to the technical project of the high-resolution NSE spectrometer, the neutron beam extraction consists of two parts. The first part is a neutron guide with cross-section 6 cm × 6 cm, length 13.5 m and $m = 3$ supermirror coating (natural nickel coating $m = 1$). The second part is a bender or reflection polariser with length 60 cm. A wavelength band of $\Delta\lambda = 6-9$ Å within a range $3\,\text{Å} < \lambda < 25\,\text{Å}$ is selected by a disc chopper placed at a distance 6–6.5 m from the source [7]. For simulations, we chose the moderator–guide distance 6.5 m and the sizes of moderator 12 × 12 cm. The moderator and guide were situated in axial symmetry.

For a good transmission of neutrons with short wavelengths, the characteristic wavelength of the bender channels must be at least 3 Å. The geometrical characteristics of benders, which are to be considered, are given in Table 1. The thickness of the bender surface is 0.03 cm in all cases. Surface reflectivity characteristics were the following: $m = 3$ for the supermirror for spin-up reflectivity and $m = 0.25$ for spin-down reflectivity.

The first task was to choose the radius of curvature. The characteristic wavelength for channels with widths 0.15–0.2 cm and curvature radius 1500 cm have the range 2.77–3.2 Å for supermirror $m = 3$. Then the "direct line of sight" length is within the range 42–48 cm. The decrease in the radius of curvature worsens the transmission of the bender, but increasing curvature radius increases the length of "direct line of sight". As an optimum, we found that the bender with curvature radius 1500 cm completely suppresses the background of fast neutrons and has a good transmission for wavelengths larger than 3 Å.

The second task was to choose a bender with the best "figure of merit" from Table 1 with radius of curvature 1500 cm. The wavelength dependence of the "figure of merit" is shown in Fig. 1. So we conclude, that the optimal bender configuration is bender No. 2 of Table 1 with a radius of curvature 1500 cm.

As the next step in optimisation, we considered two types of coatings. First: spin-up reflectivity of $m = 3$ and spin-down reflectivity of $m = 0.1$; second: spin-up reflectivity of $m = 3$ and spin-down reflectivity of $m = 0.25$. The degree of polarisation of the neutron beam at the exit

Table 1
Geometrical data of the simulated benders

Number of benders	Curvature radius for all channels (cm)	Length of bender (cm)	Channel width at the entrance (cm)	Channel width at the exit (cm)
1	500–4000	60	0.2	0.1
2	500–4000	60	0.2	0.15
3	500–4000	60	0.2	0.2
4	500–4000	60	0.15	0.15
5	500–4000	60	0.15	0.1

The radius of curvature was changed in steps of 500 cm.

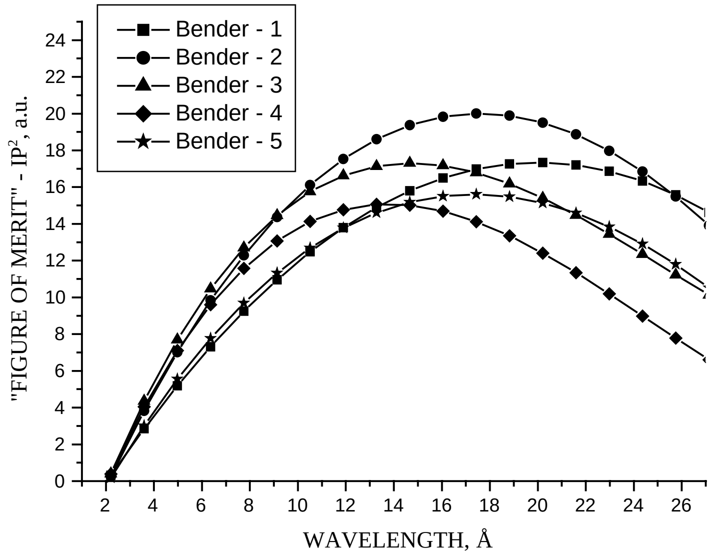

Fig. 1. The wavelength dependence of the "figure of merit" for benders from Table 1 with radius of curvature 1500 cm.

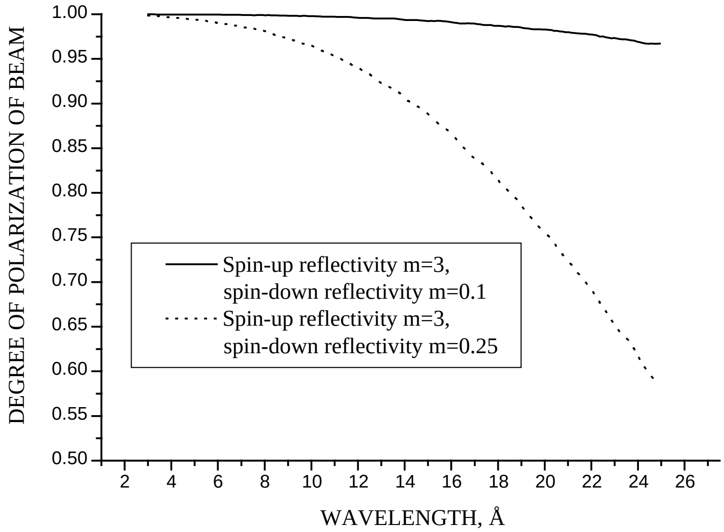

Fig. 2. The wavelength dependence of the degree of polarisation of the neutron beam at the exit of the bender polariser.

of the guide-bender system as a function of wavelength is shown in Fig. 2. It is necessary to have a neutron beam with a degree of polarisation more than 90% for all wavelengths. So we conclude that spin-down reflectivity must be less than $m = 0.25$ for a good degree of polarisation for all wavelength band. Similar benders may be used as analysers before usual or PSD detectors.

3. Conclusions

Convergent benders will be proposed as neutron polariser and a possible analyser for the high-resolution NSE spectrometer at ESS. We found an optimal configuration of the bender using $I \times P^2$ as "figure of merit". To achieve a good polarisation of the beam for the *whole wavelength band*, it would be necessary to use a coating with spin-up reflectivity $m = 3$ and spin-down reflectivity less than $m = 0.1$.

Acknowledgements

This work was carried out with the support of SCANS network under contract HPRI-CT-1999-50013.

References

[1] H. Maier-Leibnitz, T. Springer, Reactor Sci. Technol. 17 (1963) 217.
[2] R. Crawford, J. Carpenter, J. Appl. Crystallogr. 21 (1988) 589.
[3] A. Schebetov, et al., Nucl. Instrum. Methods A 432 (1999) 214.
[4] W. Hahn, W. Schweika, Physica B 234–236 (1997) 1165.
[5] W. Schweika, P. Böni, Physica B 297 (2001) 155.
[6] T. Krist, Physica B 241–243 (1998) 82.
[7] K. Clausen, et al., The ESS Project, Instrument and User Support, Vol. IV, ESS Council, Jülich, Germany, 2002, pp. 2–50.
[8] VITESS Website: http://www.hmi.de/projects/ess/vitess.
[9] L.D. Cussen, et al., Nucl. Instrum. Methods A 440 (2000) 409.
[10] W.G. Williams, Rutherford Laboratory Report, RL-73-034, 1973.