Available online at www.sciencedirect.com

SCIENCE DIRECT®

Physica B 350 (2004) 147–150

PHYSICA B

www.elsevier.com/locate/physb

The high-resolution neutron spin-echo spectrometer for the SNS with $\tau \geqslant 1\,\mu s$

M. Ohl[a,*], M. Monkenbusch[a], D. Richter[a], C. Pappas[b], K. Lieutenant[b], Th. Krist[b], G. Zsigmond[b], F. Mezei[b]

[a] *Institut für Festkörperforschung, Forschungszentrum Jülich GmbH, D-52425 Jülich, Germany*
[b] *Hahn–Meitner Institut Berlin, Glienicker Strasse 100, D-14109 Berlin, Germany*

Abstract

In the near future, the SNS will be the most powerful spallation neutron sources worldwide. The neutron instruments at these sources are being planned and many of them are currently under construction. To cover the domain of ultra-high-resolution spectroscopy a neutron spin-echo (NSE) spectrometer is foreseen. Here, we present the layout of the planned instrument with a Fourier time range that covers $\tau = 1$ ps…1 μs and high effective neutron flux. A huge field of application will be the investigation of soft condensed matter and complex fluids. However, easily accessible optional modes for a ferromagnetic and intensity modulated NSE, respectively, offers access also to magnetic samples.

Keywords: Neutron spin-echo spectrometer; SNS; Spallation source; Ultra-high resolution

---

1. Introduction

The SNS will be one of the next generation neutron sources to be built in the next decade. We propose to build an advanced neutron spin-echo spectrometer (NSE) at the cold coupled H_2 moderator of the SNS. This instrument shall be the best of its class both with respect to resolution and dynamic range. Exploiting superconducting technology and developing novel field correction elements [1], the maximum achievable Fourier time, i.e. the resolution, shall be extended to 1 μs. Utilizing wavelengths $0.25 < \lambda/\mathrm{nm} < 2.0$ an unprecedented dynamical range up to $1{:}10^6$ can be achieved. The optional easy accessible operation modes as ferromagnetic and intensity-modulated NSE will enable the detailed investigation of magnetic samples and phenomena. The design of the spectrometer will take full advantage of the recent progresses in neutron optics and polarizing supermirror microbenders [2,3], resulting in considerable gains in polarized neutron flux over a wide wavelength range as well as easy access to the intensity modulated mode.

Fig. 1 shows an artists view of the instrument with its neutron guide extending into the SNS target block.

---

*Corresponding author. Tel.: +49-2461-614203; fax: +49-2461-612610.

E-mail address: m.ohl@fz-juelich.de (M. Ohl).

0921-4526/$ - see front matter © 2004 Elsevier B.V. All rights reserved.
doi:10.1016/j.physb.2004.04.014

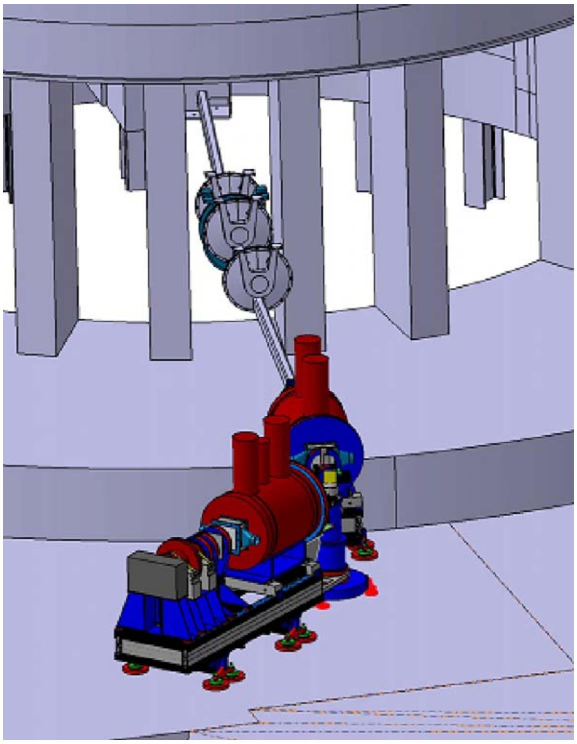

Fig. 1. The upper drawing shows the spin-echo spectrometer installed on beamline 15. Components like the superconducting main precession coils are marked in red.

2. Main features of the proposed instrument

The proposed NSE instrument is of the original generic IN11 kind, which is the technique with the largest potential to extend the resolution beyond current limits. The new instrument will possess a number of unique features:

- ultra-high resolution: $\tau_{\max} = 1\ \mu s$ ($\Delta\hbar\omega = 0.7$ neV),
- huge dynamical range extending up to $1{:}10^6$,
- position sensitive area detector,
- field compensation and magnetic shielding,
- optional intensity-modulated mode.

A moderator detector distance of 18 m yields a frame width of $\Delta\lambda = 0.366$ nm. The resolution of $\tau_{\max} = 1\ \mu s$ shall be obtained for $\lambda > 1.8$ nm ($g = 1.8$). In addition, due to the TOF λ separation the wavelength-dependent part of the Q-resolution is an order of magnitude better than at reactor instruments. Exploiting that the Fourier time $\tau \propto \lambda^3$ a subsequent use of various frames covering $0.25 < \lambda/\mathrm{nm} < 2.0$ and a variation of the magnetic field (integral) by a factor > 1000 a huge dynamical range is achieved. By automatic set-up procedures the change of wavelength frames will be a routine operation with negligible time delay. The inherent change of $Q(\lambda) \propto 1/\lambda$ fortunately complies with the usual dispersion of relaxation rates $\Gamma \propto Q^2 \ldots Q^4$. An area-sensitive fast detector of 30 cm diameter covers a solid angle of $\Delta\Omega > 4^\circ \times 4^\circ$ and assures efficient data collection rate. The magnetic stray field of the main coils is compensated down to $1\text{–}1.5 \times 10^{-4}$ T in 1.5 m distance. Thereby, it becomes possible to enclose the instrument area by a magnetic shielding which ensures a stable and reliable operation. The latter also depends on a rigid mechanical design. The thus achieved signal stability is an utterly important but often overlooked quality. Additional flippers (ferromagnetic mode) and polarizer/analysers (intensity modulated mode) will offer the unique opportunity to perform a polarization analysis of the scattering from magnetic samples, to deal with depolarizing samples [4], or separate coherent and spin-incoherent scattering.

The placement of components along the beam line is indicated in Fig. 1. The neutron guide section starts with the shutter insert at about 2.5 m distance from the cold coupled moderator. Guides shall be Ni-coated and have a cross section of 4 cm (width) × 8 cm (height). A chopper system consisting of three choppers selects the required wavelength frame. Between the first and second chopper, a short polarizing bender is located that introduces a bend of the beam line of 3.5° out of the direct line of sight. For different wavelength ranges—each covering several frames—different solid state microbenders are required. For that purpose 2–3 benders are situated in a revolver. A fourth position of the revolver serves as auxiliary shutter. After the benders a guide field in the neutron guide field preserves the polarization. Between the last (3rd) chopper the guide field is rotated from vertical to longitudinal direction. The expected flux on the sample has been determined using the VITESS Monte-Carlo code [5], the result is shown in Fig. 2. The time averaged intensity on the sample will be comparable respectively higher than the flux at the high flux ILL instrument IN11. The Fourier time of 1 μs requires the use of long wavelengths up to 1.8 nm in combination with a large magnetic precession field (1 Tm). As the intensity modulated NSE absorbs a factor of about 100 neutrons the maximum achievable wavelength with reasonable flux is limited to 0.8 nm (see Fig. 3).

The "primary" shielding sector around the neutron guide ends at about 10–11 m. The following NSE area is enclosed by a combined magnetic and radiation shielding. The functional components are located on three separate mechanical carriers: first arm, sample stage and second arm. The carriers move on air pads on a special floor (tanzboden). The main solenoids—one on each arm—consist each of two concentric cylindrical superconducting coils that provide high-field integrals in combination with compensation for lowest stray field. Flippers limit the precession paths. They are operated with current ramps that are adapted to the time varying wavelength within the selected frame. For low Q-SANS an optional converging collimator in front of the sample is foreseen.

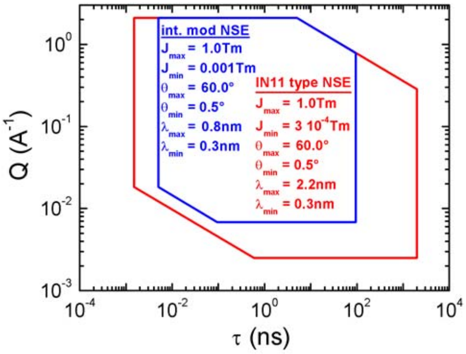

Fig. 2. The upper plot shows the Q, τ-space for the intensity modulated neutron spin-echo spectrometer (blue area determined with the parameters as listed in blue) and the generic IN11-type neutron spin-echo spectrometer (red area determined with the parameters as listed in red).

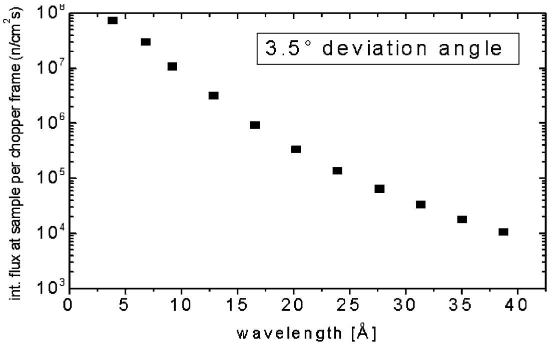

Fig. 3. Monte-Carlo flux simulation of the integrated flux of the instrument integrated over a wavelength frame of about 3.66 Å.

After traversing the last $\pi/2$-flipper the neutrons enter a combination of background suppression collimator and analyser, before those with the right final spin polarization hit the detector. The scattering arm has to be rotated around the sample position in order to realize a reasonable momentum transfer (Q) range. This determines the lateral space requirements. The instrument use has to be restricted to a maximum scattering angle of about 60° in order not to violate its sector boundaries. The thus usable Q, τ-space is shown in Fig. 3.

3. Conclusion

This novel NSE instrument will be unique and best-of-its class both in resolution and dynamic range. Compared to single detector NSE instruments it will accept a significantly larger solid angle. Therefore, the effective data rate will gain an additional factor of 5 in addition to the estimated time averaged sample flux of $10^7\,\mathrm{n/cm^2\,s}$ around $\lambda = 1$ nm. As additional and important extra quality the wavelength distribution width at any time is well below 0.5%. Thereby the resolution in momentum transfer increases significantly compared to reactor instruments with 10% or more wavelength distribution width. In summary, it will open up new experimental possibilities and qualities in soft matter research as well as in the field of magnetism.

References

[1] M. Monkenbusch, in: F. Mezei, C. Pappas, T. Gutberlet (Eds.), Neutron Spin Echo Spectroscopy, Lecture Notes in Physics, Vol. 601, Springer, Heidelberg, 2003

[2] Th. Krist, F. Mezei, Physica B 276–278 (2000) 208.

[3] B. Farago, in: F. Mezei, C. Pappas, T. Gutberlet (Eds.), Neutron Spin Echo Spectroscopy, Lecture Notes in Physics, Vol. 601, Springer, Heidelberg, 2003.

[4] B. Farago, F. Mezei, Physica B 136 (1986) 627.

[5] G. Zsigmond, K. Lieutenant, F. Mezei, Neutron News 134 (2002) 11.