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J-NSE: Neutron spin echo spectrometer

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Abstract: Neutron Spin-Echo (NSE) spectroscopy is well known as the only neutron scattering technique that achieves energy resolution of several neV. By using the spin precession of polarized neutrons in magnetic field one can measure tiny velocity changes of the individual neutron during the scattering process. Contrary to other inelastic neutron scattering techniques, NSE measures the intermediate scattering function S(Q,t) in reciprocal space and time directly. The Neutron Spin-Echo spectrometer J-NSE, operated by JCNS, Forschungszentrum Jülich at the Heinz Maier-Leibnitz Zentrum (MLZ) in Garching, covers a time range (2 ps to 200 ns) on length scales accessible by small angle scattering technique. Along with conventional NSE spectroscopy that allows bulk measurements in transmission mode, J-NSE offers a new possibility - gracing incidence spin echo spectroscopy (GINSENS), developed to be used as "push-button" option in order to resolve the depth dependent near surface dynamics.

1 Introduction

The neutron spin echo technique NSE uses the neutron spin as an indicator of the individual velocity change the neutron suffered when scattered by the sample. Due to this trick, the instrument accepts a broad wavelength band and at the same time is sensitive to velocity changes down to 10^{-5}. However the information carried by the spins can only be retrieved as the modulo of any integer number of spin precessions as intensity modulation proportional to the cosine of a precession angle difference. The measured signal is the cosine transform $S(Q, \tau)$ of the scattering function $S(Q, \omega)$. All spin manipulations only serve to establish this special type of velocity analysis. For details see Mezei (1980).

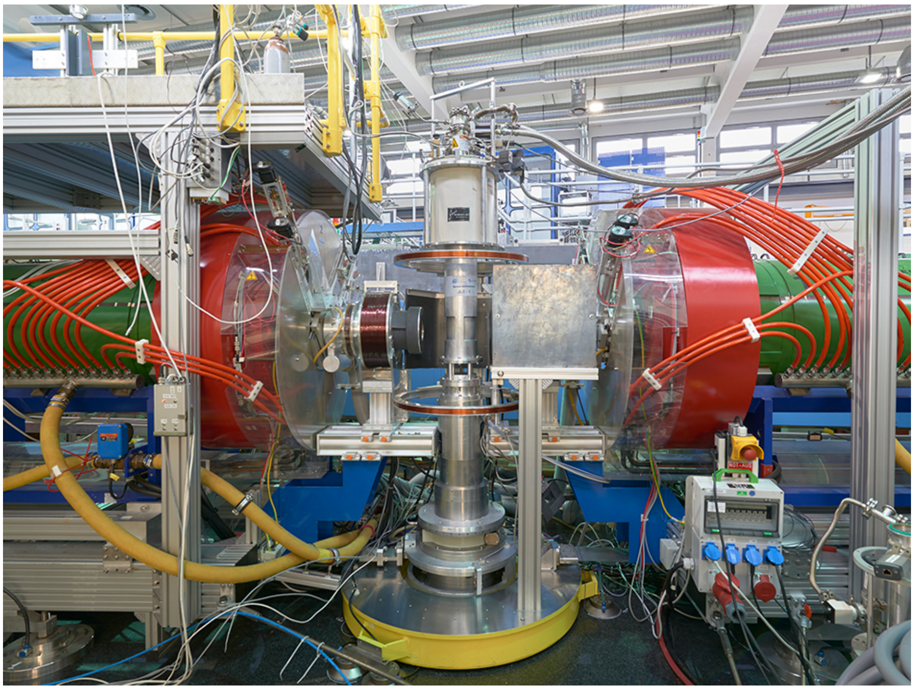

Figure 1: Sample position at the J-NSE instrument, front view (Copyright by W. Schürmann, TUM).

Due to the intrinsic Fourier transform property of the NSE instrument it is especially suited for the investigation of relaxation-type motions that contribute at least several percent to the entire scattering intensity at the momentum transfer of interest. In those cases the Fourier transform property yields the desired relaxation function directly without numerical transformation and tedious resolution deconvolution. The resolution of the NSE may be corrected by a simple division.

For a given wavelength the Fourier time range is limited to short times (about 2 ps for J-NSE set-up) by spin depolarisation due to vanishing guide field and to long times by the maximum achievable field integral J. The time is proportional to J x λ^3. The J-NSE may achieve a J = 0.5 Tm corresponding to τ = 48 ns at λ = 8 Å.

The J-NSE instrument (see Figure 1 and 2) consists mainly of two large water-cooled copper solenoids that generate the precession field. The precession tracks are limited by the $\pi/2$-flippers and the π-flipper near the sample position. The embedding fields for the flippers are generated by Helmholtz-type coil pairs around the flipper locations. After leaving the last flipper the neutrons enter an analyzer containing 60 CoTi supermirrors located in a solenoid set. These mirrors reflect only neutrons of one spin direction into the multidetector. By the addition of compensating loops the main coils and the analyzer coil are designed such that the mutual influence of the different spectrometer components is minimised.

2 Typical Applications

The spin echo spectrometer J-NSE is especially suited for the investigation of slow ($\sim$ 1 to 100 ns) relaxation processes. Typical problems from the fields of "soft matter" and glass transition are:

- Thermal fluctuations of surfactant membranes in microemulsions
- Polymer chain dynamics in melts
- Thermally activated domain motion in proteins, which is an important key for understanding the protein function

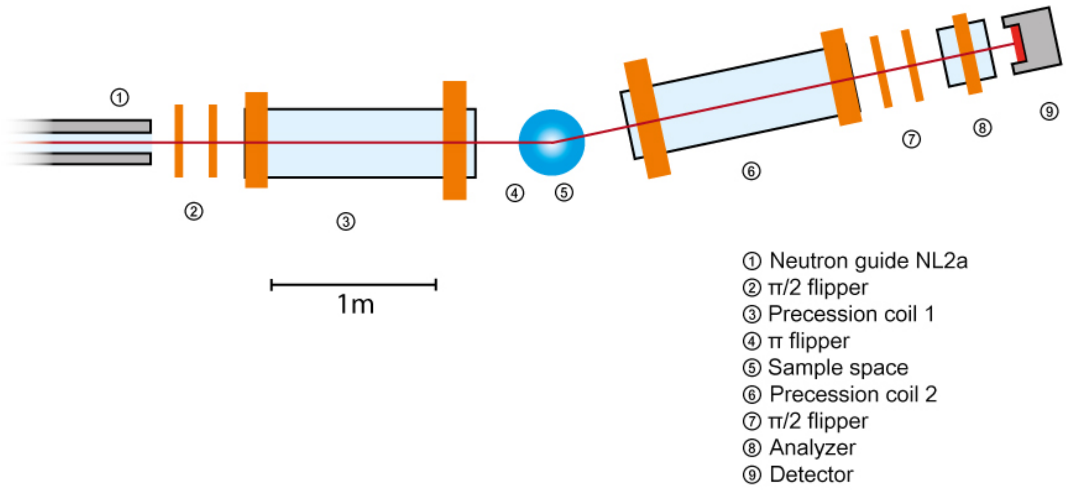

Figure 2: Schematic drawing of J-NSE set-up, top view.

3 Sample Environment

- circulation thermostat furnace (260 – 360 K)
- Cryofour (3 – 650 K)
- Furnace (300 – 510 K)
- CO_2- pressure cell (500 bar)

Other specialised sample environments are available on request.

4 Technical Data

4.1 Main parameters

- Polarised neutron flux at sample position
  7 Å: $1 \cdot 10^7$ n cm^{-2} s^{-1}
  12 Å: $6.8 \cdot 10^5$ n cm^{-2} s^{-1}
- Momentum transfer range:
  0.02 – 1.5 $Å^{-1}$
- Fourier time range:
  2 ps (4.5 Å) $< \tau <$ 350 ns (16 Å)
- Max. field integral: 0.5 Tm

4.2 Primary beam

- Neutron guide NL2a
- Polarisation:
  Short wavelength by bent section with FeSi m = 3 remanent supermirror coating
  Long wavelength by FeSi polariser at entrance of the spectrometer
- Cross section of guide:
  6 cm x 6 cm
- Max. sample size:
  3 cm x 3 cm
- Collimation:
  By source and sample size or wire collimators 0.5° x 0.5°

4.3 Analyzer

- 30 x 30 cm^2 CoTi supermirror Venetian blind

4.4 Detector

- 32 x 32 1 cm^2 cells ^3He multidetector

References

Mezei, F. (1980). The principles of neutron spin echo. In F. Mezei (Ed.), *Neutron spin echo* (Vol. 128, p. 1-26). Springer Berlin Heidelberg. http://dx.doi.org/10.1007/3-540-10004-0_16