Journal of large-scale research facilities, 1, A27 (2015) http://dx.doi.org/10.17815/jlsrf-1-33

Published: 19.08.2015

DNS: Diffuse scattering neutron time-of-flight spectrometer

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Abstract: DNS is a versatile diffuse scattering instrument with polarisation analysis operated by the Jülich Centre for Neutron Science (JCNS), Forschungszentrum Jülich GmbH, outstation at the Heinz Maier-Leibnitz Zentrum (MLZ). Compact design, a large double-focusing PG monochromator and a highly efficient supermirror-based polarizer provide a polarized neutron flux of about 10^7 n cm^{-2} s^{-1}. DNS is used for the studies of highly frustrated spin systems, strongly correlated electrons, emergent functional materials and soft condensed matter.

1 Introduction

DNS allows the unambiguous separation of nuclear coherent, spin incoherent, and magnetic scattering contributions simultaneously over a large range of scattering vector Q and energy transfer E. With its compact size DNS is optimised as a high intensity instrument with medium Q- and E- resolution. The general view of DNS and instrument layout are shown in Figure 1 and 2.

New chopper, neutron velocity selector, and position sensitive detector systems have recently been installed at DNS. This is expected to largely improve possibilities for single-crystal time-of-flight spectroscopy with efficient measurements in all four dimensions of S(Q,E). With its unique combination of single-crystal time-of-flight spectroscopy and polarisation analysis, DNS is also complimentary to many modern polarised cold neutron three axes spectrometers.

Figure 1: Diffuse neutron scattering spectrometer DNS (Copyright by W. Schürmann, TUM).

2 Typical Applications

With the increased flux and efficiency delivered by the FRM II, DNS becomes ideal for the studies of complex spin correlations, such as in highly frustrated magnets and strongly correlated electrons, as well as of the structures of soft condensed matter systems, such as the nanoscale confined polymers and proteins, via polarisation analysis. The exploration of unusual magnetic properties can also be efficiently undertaken on single-crystal samples by reciprocal space mapping. In addition to the separation of magnetic cross section from nuclear and spin-incoherent ones, polarisation analysis also allows to distinguish in detail the anisotropy of spin correlations. It has also been well demonstrated that polarised powder diffraction on DNS is complementary to standard neutron powder diffraction and may be extremely useful for magnetic structure refinements, particularly in case of small moments by improving the signal to background ratio. DNS also represents a powerful instrument for the soft condensed matter community for the separation of nuclear coherent scattering from often dominating spin incoherent scattering background. The main applications can be summarised:

- **Application of polarisation analysis:**
  uniaxial-, longitudinal-, and vector-PA
- **Magnetic, lattice, and polaronic correlations:**
  geometrically frustrated magnets, strongly correlated electrons, emergent materials
- **Single-crystal and powder time-of-flight spectroscopy:**
  single-particle excitations, magnons and phonons
- **Soft condensed matters:**
  separation of coherent scattering from hydrogenous materials, polymer, liquids and glasses

3 Sample Environment

- Top-loading CCR
- Closed-cycle cold head
- Orange-type cryostat
- Cryo-furnace
- Dilution ^{3}He/ ^{4}He cryostat insert (∼20 mK)
- Cryomagnet (self-shielding, vertical field up to 5 T)

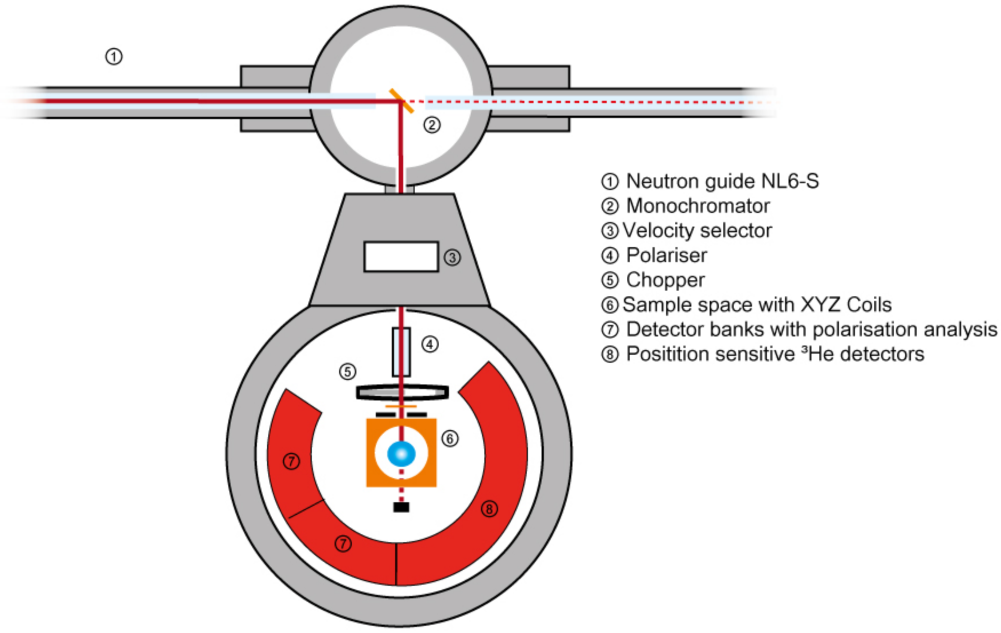

Figure 2: Schematic drawing of DNS.

4 Technical Data

4.1 Monochromator

- Neutron guide NL6-S
- Horizontally and vertically adjustable, double-focusing
- PG(002), d = 3.355 Å
- Crystal dimensions: 2.5 x 2.5 cm^2 (5 x 7 crystals)
- Wavelength range: 2.4 Å $< \lambda <$ 6 Å

4.2 Neutron velocity selector

- Minimum wavelength: 1.5 Å @ 22000 rpm
- Resolution $\Delta\lambda/\lambda$: 30 – 40 %

4.3 Chopper

- Chopper frequency $\leq$ 300 Hz
- Repetition rate $\leq$ 900 Hz
- Chopper disc: Titanium, 3 slits, Ø = 420 mm

4.4 Flux at sample

- Non-polarised: $\sim 10^8$ n cm^{-2} s^{-1}
- Polarised: $\sim 5 \cdot 10^6 - 10^7$ n cm^{-2} s^{-1} (polariser: m = 3 supermirror benders)

4.5 Detector banks for non-polarised neutrons

- 128 position sensitive ^{3}He tubes: Ø = 1.27 cm, height $\sim$100 cm
- Total solid angle covered: 1.9 sr
- Covered scattering angles in the horizontal plane: $0^\circ < 2\,\theta \leq 135^\circ$

4.6 Detector banks for polarised neutrons

- 24 detection units:
  Polarisation analysis by m = 3 supermirror benders
  ^{3}He detector tubes, Ø = 2.54 cm, height 15 cm
- Covered scattering angle in the horizontal plane:
  $0^\circ < 2\theta \leq 150^\circ$
- Q_{max}
  λ_i = 2.4 Å (E_i = 14.2 meV): 4.84 Å^{-1}
  λ_i = 6 Å (E_i = 2.28 meV): 1.93 Å^{-1}

4.7 Energy resolution

- λ_i = 2.4 Å (E_i = 14.2 meV): 1 meV
- λ_i = 6 Å (E_i = 2.28 meV): 0.1 meV