A counter-rotating multi-slit double chopper deserves individual beams simultaneously. Considerable gains in intensity are obtained by large frame overlap. In the MIEZE technique a polarised neutron beam passes through two spin-flippers (RF) running at different frequencies ωe and ωs and separated by a zero field flight path of length L_1 followed by an analyser. When the time dependent MIEZE signal is produced at the sample (L_2) which now is subjected to a periodic modulation of the contrast, microsecond responses are probed in a static detector.

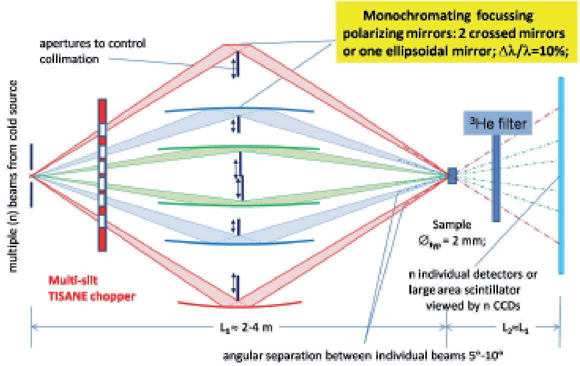

Figure 1: *Focussing multiple SANS with multi-slit TISANE chopper for fast stroboscopic measurements.*

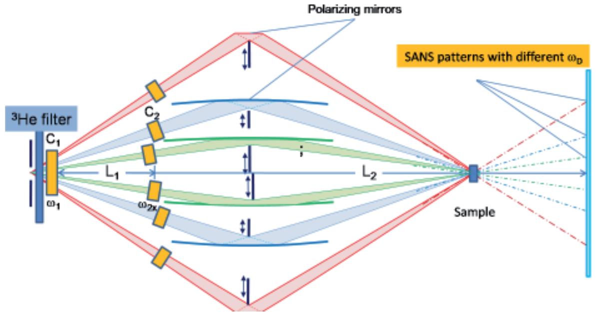

Figure 2: *MIEZE encoding of multiple SANS RF flippers C_1 and C_2 are separated by L_1 and produce time dependent signals at detector at L_2 for frequency encoding.*

Avoiding cross talk

Scattering of neutrons resulting from a given incident beam will partly be detected in a neighbouring detector when beams are close to each other. Cross talks between nearest neighbour beams can be avoided when the TISANE) chopper with n/2 slits will open at the same time every second nearest neighbour beams.Alternatively, the MIEZE technique allows Fourier filtering to label beams when different RF-coils C_2 for each individual beam but one common RF-coil C_1 are used (Figure 2). Optionally, spatial encoding can be performed with 2 magnetic prisms (or RF-coils) with different fields. An analyser converts the Larmor precession angle into a spatially modulated pattern the amplitude of which depends on SANS contrast. No separation between individual beams is required which produces extremely high intensity.

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6. Compact High Resolution SANS using very cold neutrons (VCN-SANS)

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Abstract

SANS is a popular method for elucidation of nanoscale structures. However science continually challenges SANS for higher performance, prompting exploration of ever-more exotic and expensive technologies. We propose a compact high resolution SANS, using very cold neutrons, magnetic focusing lens and a wide-angle spherical detector. This system will compete with modern 40 m pinhole SANS in one tenth of the length, matching minimum Q, Q-resolution and dynamic range. It will also probe dynamics using the MIEZE method. Our prototype lens (a rotating permanent-magnet sextupole), focuses a pulsed neutron beam over 3-5 nm wavelength and has measured SANS from micelles and polymer blends.

Motivation

Small angle neutron and X-ray angle scattering (SANS and SAXS) have become invaluable tools for nano-scale structure determination in a broad range of scientific disciplines. Although SAXS is less expensive and more accessible, SANS is advantageous in specific applications, due to the unique characteristics of the neutron interaction. These advantages included: sensitivity to light elements such as hydrogen and to isotopes (providing the H/D contrast method), the neutron magnetic dipole moment which allows study of magnetic structure and dynamics, the neutron energy is low does and does not damage delicate biological samples.

Consequently SANS features particularly in the biological and polymer sciences, and has found a niche in materials science and condensed matter physics. The most popular form, the pinhole SANS, has become a mainstay at all the leading neutron sources around the world. The big challenge lies in the balance between ‘‘instrument resolution’’ (small Q_{min} and good Q-resolution), and instrument speed (beam current).
With cold neutrons (wavelength from ~0.5-1 nm), long instruments (~40 m) and large detectors (1 m^2) with high-resolution (5 mm pixels), we often access the length scales of interest (~1-500 nm), but there are a growing number of applications where larger (and smaller) scales are required, and where simultaneous access to a wide Q-range is necessary (e.g. for hierarchical systems or for irreversible reactions).
The limit in instrument length was reached in the 1970's with D11 (80 m), but no new instrument since then is more than ½ that length.

We must advance the technological limits; in detector resolution and size, in source spectrum and with novel beam optics to address these emerging applications. Such advances may come at an enormous expense; (e.g. vacuum tanks and detectors alone are becoming prohibitively expensive). Recently focusing optics (refractory material, magnetic lens and ellipsoidal mirrors) has emerged, providing gains in length scale by factors of two or more. Variants such as ultra-SANS, extending the length scales by another order of magnitude (~ 10 μm) are also finding a niche (albeit with losses in dimensionality and dynamic range). We propose a different approach, with a very cold neutron (VCN) source, and a variable strength magnetic sextupole lens [1] that can focus a broad spectral band from ~3 to 6 nm. This approach gains a factor of 10 or more in compactness (so that an instrument less than 4 metres in length could compete with modern 40 m SANS). It also lends itself to addition of capability for dynamics measurement (over time scales from nSec to μSec) correlated directly with spatial information [S(Q,ω)]. This can be achieved without any physical change to the configuration with the MIEZE method [2] if we use the magnetic lens as polarization analyser.

Description of instrument

The basic VCN-SANS instrument configuration is shown in Fig. 1. It begins with an unpolarized VCN beam pulsed through a pair of disc choppers, and polarized with a polarizing supermirror. Thereafter polarization must be maintained with magnetic guide fields up to the rotating sextupole lens (and beyond to the sample for studies of magnetic materials). The polarized pulsed beam passes through the source aperture and into the lens where it is focused onto the plane of the detector. A combination of disc choppers facilitates variable time resolution (typically 1–5 %), and elimination of frame overlap over the full wavelength range (λ_{min} to λ_{max}) while allowing maximization of time-averaged flux. If the distance from source aperture to lens equals the distance from lens to detector then $\lambda_{max} \leq 2.\lambda_{min}$ for full focusing of the beam. The instrument is of fixed length (~3 – 4 m). Ideally sample and detector would be spherical to minimise optical aberrations, and the detector area should approach 4π steradian. An annular sample ≤ 1 mm thick would minimize multiple scattering. With source aperture size range of 1 – 2 mm, sample size range of 2 - 4 mm, detector pixel size ≤ 1 mm and wavelength range from 3 to 6 nm, the dynamic Q range would be ~5 x 10^{-4} Å^{-1} to 0.4 Å^{-1}. Gravitational aberrations (which can be serious at these wavelengths), are avoided simply by placing the instrument on a vertical axis. In principle, upwards trajectory spreads the wavelength spectrum and downwards trajectory compresses it, although the effect is quite small over this distance.
The MIEZE RF coils are also shown in Fig. 1. These coils modulate the beam polarization at high frequency (kHz range). MIEZE mode uses the sextupole lens as polarization analyser, and can accept the full VCN wavelength range. In MIEZE mode the advantage of VCN is that the energy resolution varies as λ^{-3}, therefore gain factors of order 100 times are accessible, compared to cold neutron wavelengths.

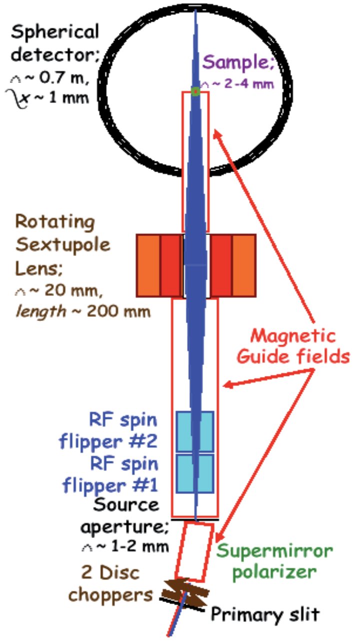

Figure1: *VCN-MIEZE SANS configuration*

We have performed preliminary VCN-SANS measurements on the PF2 VCN beam line at ILL, with a prototype rotating magnetic sextupole lens (made at Kyoto University) and flat ^{3}He area detector (courtesy of ILL detector group). In these experiments the sextupole lens produced an image of the same size as the source (≈ 3 mm) over a wavelength range of 3.0 to 4.8 nm with focal length of 1.14 m [3]. The key results are illustrated in Fig. 2 for a tri-block copolymer (Pluronic F127) [4], and in Fig. 3 for stretched polymer blends (Shish-Kebab) [5]. The experimental arrangement was far from ideal, with only 100 mm between sample and detector, and scattering angles up to ~50° onto the 10 mm thick Aluminium detector window. Nonetheless, we see in Fig. 2 that the peak resolution from Pluronic micelles is sharper than seen on SAND at IPNS. The VCN-SANS measurement time was less than the SAND measurement time, even though the sample volume was smaller.

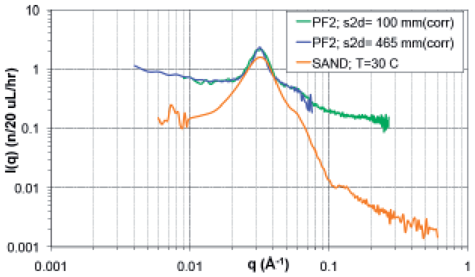

Figure 2: *VCN-SANS for 15 wt% Pluronic in D_2O (28C°), compared with SAND @ IPNS.*

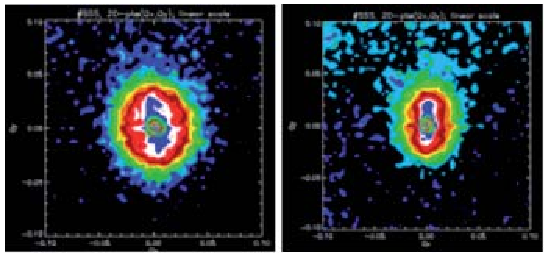

Figure 3: *VCN-SANS plots for unstretched (left) and stretched (right) polymer blend.*

We have also demonstrated the viability of the MIEZE mode of operation with a modified MIEZE test mea-surement [6], at wavelength of 4.4 nm ($\delta\lambda/\lambda$ ~17 %). The results were very encouraging, with breathing modes in aqueous sodium dodecyl sulphate (SDS) micelles being detected in quasielastic broadening of the SANS, although not spatially resolved [7]. This is illustrated in Fig. 4, where we see the SDS sample has reduced contrast between flipper on & flipper off states compared to Vycor glass (which is porous, giving SANS peaks at similar Q to SDS but no energy broadening.

The only available location for this instrument is the PF2 beam-line on level D of the ILL reactor. We have not fully prototyped the instrument yet, so our cost estimates are rather rudimentary.

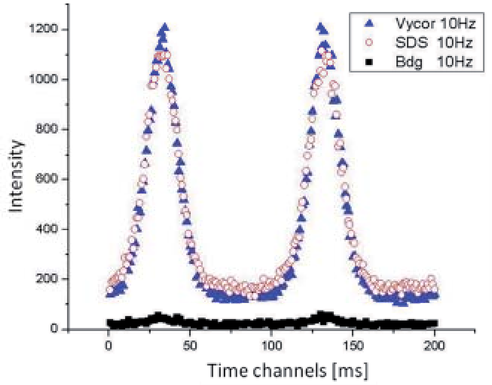

figure 4: *Time dependent intensity at 10 Hz beam modulation, for Vycor (blue) and SDS micelles (red) and background (black).*

Given the complexity of the detection system, the rotating sextupole lens, and sample cells, the need for disc choppers, polarizer, RF flippers and high quality radiation shielding we suggest a ballpark cost between 3M€ & 5M€.

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7. High precision neutron interferometer setup S18b

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Abstract

The present setup at S18 is a multi purpose instrument. It is used for both interferometry and a Bonse-Hart camera for USANS (Ultra Small Angle Neutron Scattering) spectroscopy with wide range tunability of wavelength. Some recent measurements demand higher stability of the instrument, which made us to propose a new setup dedicated particularly for neutron interferometer experiments requiring high phase stability. To keep both options available, we suggest building the new setup in addition to the old one. By extending the space of the present setup by 1.5m to the upstream, both setups can be accommodated side by side.

Motivation

Although predictions of quantum mechanics (QM) are verified in a variety of experiments, the interpretation of QM, namely explanations of what is really going on in a quantum system, is bizarre. From the very beginning, neutron interferometer experiments are established as one of the most useful tools to investigate quantum mechanical phenomena on a fundamental basis and the interferometer setup S18 at the ILL has gained excellent reputation. Although consequences of the non-relativistic Schrödinger equation for matter-waves can also be studied with other particles, like electrons, atoms, ions, and molecules, many features of neutron interferometry are unique, such as macroscopic-scale experiments, high detector-efficiency, low decoherence-rate, and high-efficiency manipulation rate. In addition to fundamental experiments, neutron interferometry is used in more applied fields like the precise measurement of coherent neutron scattering lengths which are frequently required for other neutron scattering spectroscopy.

The main construction of the present setup was carried out in 1980s and some minor revisions have followed afterwards. The major drawback experienced so far is the unpredictable and uncontrollable drift of the interference pattern over the measurement time. This phase instability sets an accuracy limit on measurements data, like coherent scattering length data. In addition, larger interferometers, expected to allow multi-loop setups, enlarged sample spaces etc., meet difficulties due to higher sensitivity to environmental disturbances.

Lately, we made a rough estimation of the instability and suggest possible causes as well as solutions for our instruments. During stable weather (temperature in the experimental hall is more or less stable in this condition), typical phase drift is about 5 degrees in 12 hours. In contrast, at a change of weather (may be accompanied by rapid change of temperature in the experimental hall by up to 10 °C), the phase drifts often exceed several tens of degrees in several hours.