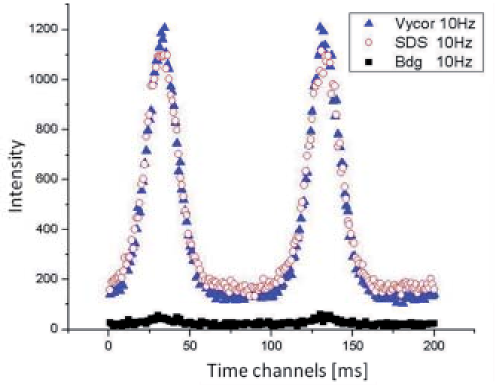

figure 4: *Time dependent intensity at 10 Hz beam modulation, for Vycor (blue) and SDS micelles (red) and background (black).*

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

Y. Hasegawa (1), H. Lemmel (1,2)

(1) Atominstitut, Vienna University of Technology, Austria
(2) Institut Laue-Langevin, Grenoble, France

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.

Since our perfect-crystal interferometer is sensitive particularly to thermal and vibrational disturbances, we suspect that the instability of temperature in the experimental area is largely responsible for the phase instability. In order to carry out measurements with higher precision and further meticulous quantum optical experiments, 0.1 degree phase-stability over several days is required. Such a high stability can only be achieved by proper thermal insulation of the environments around both the interferometer and the monochromator in addition to an isolation from thermal and vibrational disturbances of the experimental floor.

Building a new setup in addition to the existing one allows optimization for the new needs while preserving the high flexibility of the old setup, including USANS. Thus not only the interferometry but also the USANS community with industrial impact will profit from the increased beam time.

Description of the current instrument

Both the interferometer setup and USANS setup consist of two perfect crystals in non-dispersive configuration. The first crystal serves as monochromator and is situated directly in the beam line. Both crystals have to be stabilized against each other better than 0.01 arcsec and are therefore mounted on a common optical bench. The bench is suspended on springs for vibrational isolation and reaches through the radiation shielding up to the neutron guides.

Interferometer Option	*USANS Option*
A set of various silicon interferometers are available in various shapes and sizes to optimize for visibility, sample space and other requirements. The Bragg angle can be tuned smoothly but we usually use either 30° (wavelength of 1.9Å) or 45° (wavelength of 2.7Å). While the former gives highest intensity on the thermal beam line, the latter is needed with very large interferometers for geometric reasons. A third axis is available for a momentum and polarization analysis of the beams leaving the interferometer.	Two triple bounce crystals (as monochromator and as analyser) form a so-called Bonse-Hart camera. The 6-fold reflection and the so-called Agamalian-cut give a peak to background ratio better than 10^5. The instrument covers a Q-range $2.10^{-5}<Q<5.10^{-2}$ Å^{-1} which allows a clear overlap with standard pinhole SANS.
Monochromator type: perfect crystal silicon	channel-cut perfect crystal silicon
Reflecting planes: [111], [220], [113], [331]	[220], [331]
Wavelength range: 0.6 Å < λ < 4 Å	1.6 Å < λ < 2.9 Å
Flux: 7000 n cm^{-2} s^{-1}	10000 n cm^{-2} s^{-1}
Visibility: 60% to 90%	10^5 (signal to background)
Resolution: 0.5° phase resolution	0.1arcsec angular resolution $1.5.10^{-5}$ Å^{-1} momentum resolution

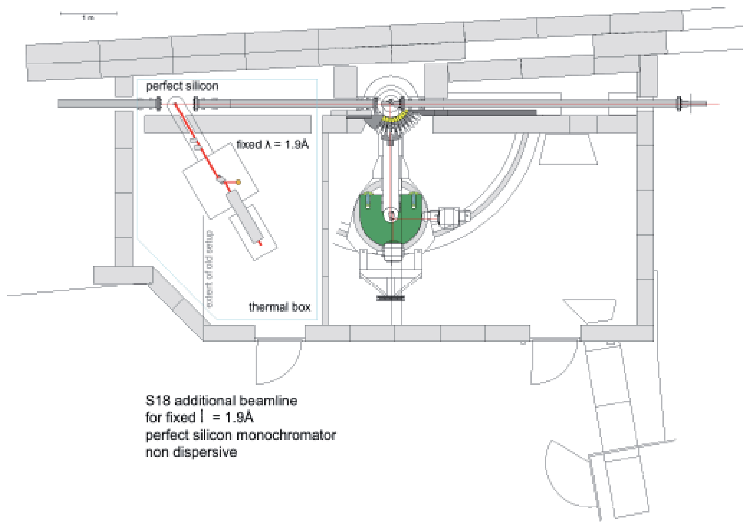
Polarized neutrons can be made available for both options by inserting two magnetic prisms between monchromator and second crystal. The prisms allow a beam cross section of 1x1cm² and create a polarization better than 99.5%.

Description of the proposed instruments

Vibrational disturbance and the temperature instability of both monochromator and interferometer are considered as the main obstacles to phase instability. In particular we have found experimental and theoretical evidence that the phase drift originates in temperature changes not only around the interferometer but also around the monochromator. Therefore the new setup should include the following changes compared to the old one.

- The concrete blockhouse around the experiment will be replaced by thermally insulating walls and ceiling.
- The pavement on the gravel below will be replaced by a thermally insulating floor. A Tanzboden surface will allow the new optical bench to be moved.
- The suspension on springs will be replaced by a state-of-the-art vibration damped optical bench, which would give more room on top for experimental setups.
- The new walls and floor will contain also the monochromator region, i.e. the whole section of the beam guide and the shielding blocks.
- We will restrict the new setup to Bragg angles of 30° and 45°. This feature simplifies the shutter system and radiation shielding, thereby enabling a compacter setup.

A sketch of the new setup besides the old one is shown below. This draft would extend the space requirements of S18 by about 1.5m to the left (upstream towards the reactor).



We expect total costs in the order of 1.5M€. We would ask the ILL to bear the costs for the beam guide, shutter system, shielding blocks and the new floor. The air conditioning and the instrument itself would be financed by our own sources.

Main research topics

Interferometer Option

- Measurement of basic quantum physics laws
- Measurement of neutron-nuclei scattering lengths
- Phase tomography imaging and measurements
- Decoherence, dephasing and de-polarisation experiments
- Experiments with non-classical neutron states

See [1-6] for recent results

USANS Option

- Pore structure of geological and composite materials
- USANS from artificially structured materials
- Polarized USANS experiments
- Studies of micro structures of light and heavy water hydrated calcium sulphates, fuel materials like bituminous coals[7,8].

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8. HIFI - a dedicated HIgh-FIeld diffraction and spectroscopy instrument

P. Steffens (1), **M. Enderle** (1), M. Böhm (1) and S. Roux (1)

(1) Institut Laue Langevin, Grenoble, France

Abstract

The outstanding scientific impact of single-crystal neutron diffraction and spectroscopy in steady state vertical magnetic fields up to 15 T (17 T without dilution fridge) is reflected in numerous high-profile publications, e.g. [1-5]. 30 T – 35 T in vertical geometry allow to address enigmatic questions without equivalence at lower fields. The constraints implied by such magnetic fields demand a specially designed dedicated instrument. Since the vertical field geometry is crucial for single-crystal diffraction as well as spectroscopy, the solid angle of scattered neutrons is restricted, and a high-flux reactor is best suited to host a corresponding instrument. We propose a world-wide unique versatile instrument for diffraction and spectroscopy in vertical steady fields of 30 T.

Scientific case

A magnetic field of 15 T, converted to an energy scale, compares and overcomes dipolar interactions, but only reaches the lowest range of magnetic superexchange, double exchange and direct exchange interactions. 30 T – 35 T allow to access an interaction range relevant for a wide range of modern condensed matter science: high-T_C and unconventional superconductors (re-entrant and field-induced), heavy fermions, colossal-magnetoresistance materials, multiferroics, rare-earth compounds, frustrated magnetism, quantum magnetism, with applications in nano- and molecular magnetism, material science, liquids, as well as soft and biological matter. Neutron scattering in a vertical field of 30-35 T enables one to address enigmatic questions that have no equivalence at lower fields, for example:

- normal state of high-T_C superconductors,
- nature of the hidden order in URu_2Si_2,
- static and dynamic correlations in true Bose-Einstein condensates like Han purple,
- nature of the plateau phases of the two-dimensional Shastry-Sutherland lattice $SrCu_2(BO_3)_2$,
- static and dynamic correlations in quadrupolar spin-nematic Luttinger liquids,
- the origin of electric polarisation changes at 20-30 T in certain multiferroics,
- the evolution of the magnetic order near the charge order melting in $Na_{0.5}Co_2$ near 30 T.

The vertical field geometry is crucial for single-crystal diffraction as well as spectroscopy to measure different energy and momentum transfers Q at the same field direction with respect to the crystal. This is impossible in a horizontal field geometry.