- high-pressure cells and gas handling systems for H_2, CO_2, etc. sorption analyses
- non-magnetic pressure cells and clamps for magnets, spin-echo spectrometers,…
- vertical and horizontal high-field magnets for TOF and SANS spectrometers
- when feasible the implementation of focusing optics to allow the investigation of very small samples

Further to this list, we propose to build a specific Cryopad that would contribute to the investigation of the effects violating parity and time reversal invariance or the quest to the determination of the neutron electric dipole moment. The availability of a non-magnetic cradle cooled inside a cryogen-free cryostat – i.e. a cryocradle - would also greater facilitate the determination of complex antiferromagnetic arrangements in zero-field polarimeters. To complete these equipments, we propose to supply laboratory space to allow users to prepare and characterize their samples. Users could bring their own equipment or use the ILL devices. We also propose to combine neutron scattering measurements with ac-susceptibility or resistivity measurement techniques among many others.To succeed with this program considerable efforts will be required from both the Science and Project & Technique Divisions. The pay-off in terms of scientific quality would be considerable and of value to the whole user community. Partnerships with industrial companies would be envisaged, as would collaborations with other neutron centres – perhaps through a future NMI3 initiative. Such an investment is estimated to be at least 6M€.

21. IN5 POlarisation OPtion (IPOP) and HIgh FIeld Magnet Option (HIFIMO) for the IN5 time-of-flight spectrometer

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Abstract

The new secondary spectrometer for the cold neutron time-of-flight (ToF) instrument IN5 was built of non-magnetic material, keeping in mind the upgrade option of polarisation analysis (PA) and the possibility of applying high continuous magnetic fields. The refurbished instrument has a high incident flux and elevated count-rate and offers a unique opportunity for applying polarised neutron methods for high resolution inelastic scattering, including single crystal investigations. This proposal outlines the case and what is needed to bring PA and high magnetic fields to this instrument.

Motivation

(i) Polarisation analysis:
Despite significant advances in instrumentation over the last 30 years, with larger detector solid angles and increased angular resolution as well s the development of multi-chopper systems coupled to either tapered supermirror guides or focusing monochromators, the use of polarised neutrons on ToF instruments is still very much in its infancy. At present only D7 at ILL offers the possibility of performing inelastic ToF measurements with PA and cold neutrons ($\lambda > 3$ Å), although at only moderate energy resolutions. However, plans for PA on forthcoming cold ToF instruments are omnipresent. The rebuilt IN5 with its greatly improved flux at the sample and the large position sensitive detector solid angle is the instrument of choice to explore the best compromise between spectrometer performance and the most demanding sample environment devices.

On IN5 the polarised option would use the PASTIS concept [1] of three sets of compact perpendicular coils (see the PANTHER proposal) allowing XYZ-PA and a ^{3}He analyser banana. Such a development would open up a large field of applications, from biophysical and molecular spectroscopy through functional materials to fundamental magnetism. It would enable the direct separation of coherent and incoherent scattering allowing, inter alia, the separation of collective (nuclear pair-correlation related to coherent scattering) and single-particle (self-correlation related to incoherent scattering) dynamic contributions. It can provide an unambiguous identification of phonon and magnetic excitations, greatly enhances the potential for studying magnetic systems, high-T_c superconductors, itinerant magnetism, multiferroic systems, and more.

(ii) Magnetic fields:
Applied magnetic fields provide a key means of controlling the collective behaviour of a wide range of magnetic systems, accessing new phases and phenomena, or testing the theories that rationalise their behaviour.

The higher the field, the greater the range of phases and phenomena that can be explored so there is a strong demand for magnets in the range 10-15 Tesla for the examination of themes such as molecular magnetism, low dimensional and/or frustrated spin systems, heavy fermion materials and quantum critical phenomena. To date, this community has used diffraction and triple-axis instruments at ILL extensively to study field-dependent phenomena, but ToF instruments have been poorly exploited by such scientists, in part because of the lack of supporting infrastructure.

Description of instrument/infrastructure

(i) Polarisation devices

Incident beam: Two methods can be considered for polarization of the incident beam: there is enough space available in front of the sample chamber to host either a polarizing guide section or a compact ^{3}He polarizing chamber.

An S-shaped polariser, in order to keep the beam axis to the sample area, might lose its transmission because of the rather high beam divergence with the tapered guide. Alternatively a converging supermirror polariser could be used, but has the potential drawback to reduce the flipping ratio significantly. Another shortcoming for these types of polarising guide is that they are optimised for a narrow wavelength band only, reducing the advantage of the flexibility in spectrometer setup inherent to the chopper technique. If a ^{3}He polarizing cell is used instead, such problems with the beam divergence and incident wavelength range do not occur. However, such a device would have to be equipped with a continuous external recirculating system to maintain the polarisation of the gas because it sits in the main chamber vacuum, and retrieval of the entire device would be very inconvenient. Development of such a filling station would be performed at ILL using in-house expertise in this area, and probably serving other instrument projects. A guide field has to be installed from the polariser to the sample area up to the π-flipper.

Polarisation analysis: the only reasonable way of covering the wide angle detector is to do the polarisation analysis with a ^{3}He banana spin filter cell [2] placed inside the non-magnetic sample chamber in the large space (800 mm diameter) for sample environment.

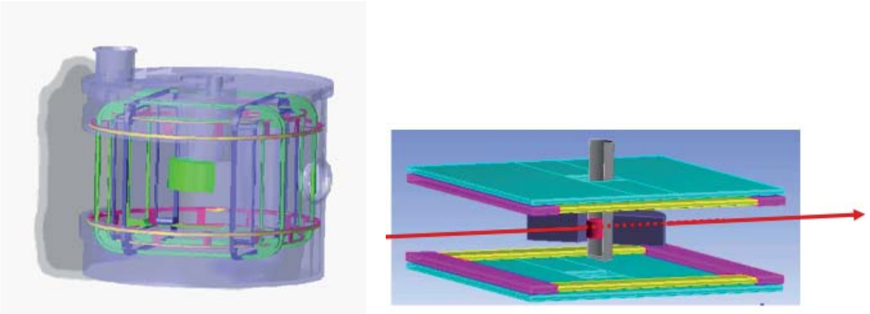

Figure 1 (left): *The PASTIS concept: by using compact coils and a ^{3}He analyser (centre in green), XYZ-PA can be installed in the existing IN5 sample chamber. (right) The shielded magnetostatic cavities device. The 3He analyser can be seen behind the sample in gray.*

The chamber has to be kept free from any magnetic perturbation (such as remanent fields due to high field magnet operation, see below) that could hinder XYZ polarization analysis.

Polarisation coil geometry

The PASTIS type crossed coil geometry shown in Figure 1 (see also [1]) appears as the most efficient system when it comes to covering the wide scattering angle of the detector bank. There will be some shadow cast by this device on the detector, but thanks to the PSD elements, this is easily masked in the data analysis. The shielded magnetostatic cavities (Figure 1) place no material in the equatorial plane but are less attractive due to the imposed small vertical acceptance that does not cover the full detector height. A PASTIS prototype already exist at the ILL that would fit in the sample chamber but is far from being fully optimised. The development and design of a compact device optimised for IN5 (e.g. for the detector shadow) has to be included in the project. An additional cost to take into account is the test periods required on the instrument. Mounting and dismantling the installation, optimisations and tests are time consuming, requiring at least a full reactor cycle time divided into bunches of 10 to 15 days over the period of the project. Some scientific manpower dedicated to the project and to the operation of the polarisation option might also be required in order to relieve the workload of the instrument scientists for the other operation mode.

(ii) High magnetic fields

A magnet suitable for ToF instruments must place a minimal amount of material in the incoming and outgoing beams and provide a large asymmetric view towards the detectors. An homogeneous field area of about 20 mm diameter over 30 mm height is also required. There is a size constraint set by the 800 mm diameter sample chamber and the optimal angular acceptance towards the detectors is -12° /+ 135° in the equatorial plane and +/- 22° in the vertical direction. The maximum field obtainable will probably be set by the acceptable limits of stray fields, noting that there is a magnetically suspended chopper 1.0 m from the sample space. Effort must also be expended on minimising interference between the polarisation operation and possible remanent fields in the surrounding elements such as heavy concrete shielding, chopper mounting support or H15 guide support. Some development of asymmetric coil magnets for ToF operation, such as the 9 T asymmetric coil on MERLIN at ISIS, already exists. Nevertheless a specific development for the optimized configuration on IN5 is necessary and relying on the only external company (Oxford Instruments) that has experience with such magnets should provide a result at minimal cost and risks.

Budget and other required resources

HIFIMO: Magnet- rough estimate ~ 800 k€ (Oxford Instruments);
IPOP:polarisation device: 120 to 150 k€; manpower to optimise design;
commissioning time ~ 1 reactor cycle.

References

[1] J.A. Stride et al., Physica B 356 (2005) 146
[2] W. Heil et al., Nucl. Inst. Meth. Phys. Res. A 485 (2002) 551.