Advanced Neutron Tools

^{3}He Neutron Spin Filters

Polarised ^{3}He gas is now available for many ILL instruments. The polarised gas acts as a neutron spin-filter (NSF) both for creating the polarisation of the incident beam and for analysing the polarisation after the sample. Now available in sufficiently large quantities for several instruments to be supplied every day via the Tyrex central facility ***(Fig. 1)***, ^{3}He NSFs are becoming an attractive solution for neutron beam polarisation over large solid angles and for the whole range of neutron wavelengths.

The principle

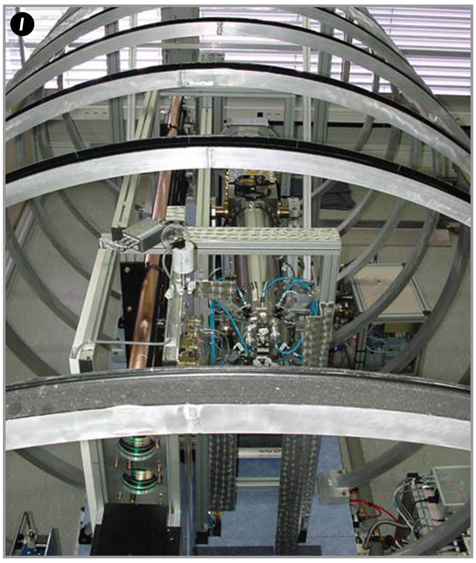
^{3}He has a very large 1/v absorption cross-section and only absorbs neutrons in the opposite spin state to that of the ^{3}He nucleus. The cross-section for scattering is very small and essentially isotropic. These two features make polarised-^{3}He NSFs a very efficient and also a very "clean" technology for neutron beam polarisation; the filters are optically neutral in contrast to other polarisation methods, which invariably modify the angular and/or wavelength distribution and can also produce spurious effects, such as off-specular or small-angle scattering (supermirrors) or multiple or higher-order Bragg scattering (polarising crystals). The beam polarisation obtained with an NSF is perfectly homogeneous over the beam profile and there is no γ-background created by the absorption of the neutrons in the NSF.

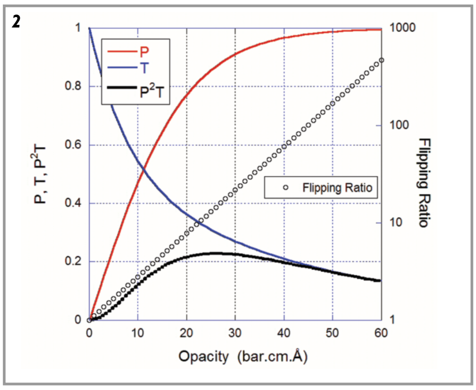
Optimisation

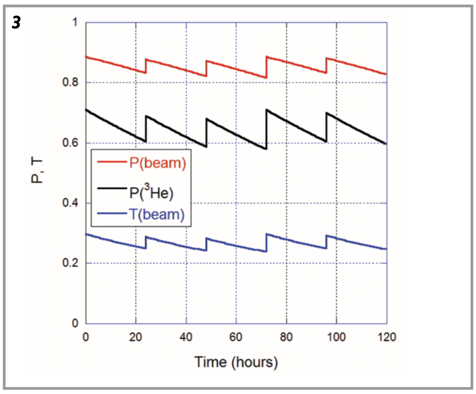
As the gas is never 100% polarised, it is very important to optimise the trade-off between beam polarisation ("flipping ratio") and transmission ***(Fig. 2)***. This is determined by the opacity of the NSF, which is proportional to the product of the cell length, the gas pressure and the neutron wavelength. As the opacity is increased, the flipping ratio also increases, but the transmission goes down and therefore the counting statistics are no longer as good. There is an optimum opacity which depends on the counting rate and the type of measurement that the experimental team is seeking to perform. In case of doubt, please contact the ^{3}He group.

Performance of ^{3}He NSFs at the ILL

The level of gas polarisation is the critical parameter for the performance of the NSF. The Tyrex central filling station typically provides ^{3}He gas at a polarisation of 70% on the neutron instrument. After being polarised on Tyrex, the ^{3}He gas will inevitably start to depolarise with a characteristic depolarisation time T_1. The main relaxation contributions typically arise from the material of the NSF cells and magnetic field gradients. Relaxation times at the moment are of the order of 100 hours, which means that the NSF gas is typically replaced on the instrument once every 24 hours ***(Fig. 3)***. The polarisation decays in a regular and predictable way, allowing for accurate data correction.







1 - The Tyrex central filling station

2 - Performance of an NSF as a function of opacity for a ^{3}He polarisation of 70%. Neutron beam polarisation (P) and transmission (T) of an unpolarised beam are shown, as is the standard figure of merit P^2T, which displays a maximum at the optimum opacity. The flipping ratio (defined as (1+P)/(1-P)) is shown on the right-hand logarithmic axis.

3 - The variation of polarisation and transmission during a typical neutron experiment, showing the effect of relaxation. The NSF cell is replaced every 24 hours. The relaxation curves are straightforward exponentials.

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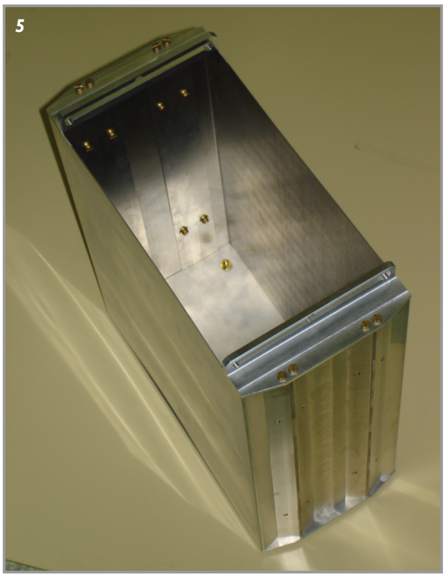

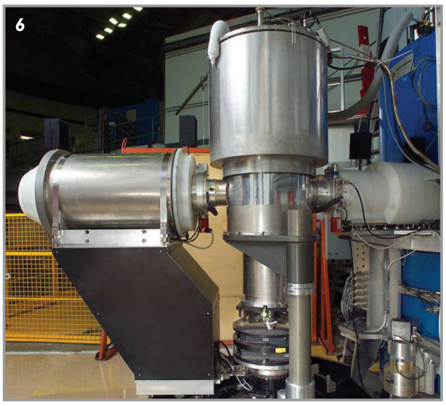

*4 - **(a, b, c)** examples of NSF cells: standard cylindrical (D3-type) cell, banana cell for large-solid-angle polarisation analysis, Si-window cells for reflectometry and SANS.*

5 - Magic box transporter, using permanent magnets.

6 - Decpol being used with the new Cryopad on D3.

Gas delivery

An appropriate NSF container is filled with gas at a pressure decided upon with the experimental team and transported to the instrument in a magnetically shielded transporter. When possible, the NSF cell is transferred directly from the transporter into the neutron beam. Alternatively, when access to the neutron beam is difficult, the NSF can be left permanently in the beam and filled from the transporter via a capillary.

NSF cells

The material and shape of the NSF cell is adapted to the instrument. Typical cells are shown in ***Fig. 4***. Glass cells can go to high pressure and/or cover large solid angles, while single-crystal Si-window cells can be used to further minimise parasitic scattering.

Magnetostatic cavities

These are designed to maximise the relaxation time of the NSF by delivering the best possible magnetic-field homogeneity and efficiently screening external fields. Three types are currently available:

a) Magic boxes. So-called because when first built they performed better than predicted by finite-element calculations! They use mild steel and μ-metal to screen external fields and simultaneously act as pole pieces, creating a transverse field ***(Fig. 5)***. Several of these exist, using coils or permanent magnets to create the field, depending on the application.

b) Cryopol. Uses Meissner screens to allow operation near large superconducting magnets. Developed in collaboration with the CEA-Grenoble.

c) Decpol. Dedicated to D3 and developed for use with Cryopad. Coils and μ-metal together produce a homogeneous longitudinal field ***(Fig. 6)***.