THE HYSPEC POLARIZED BEAM SPECTROMETER AT THE SNS

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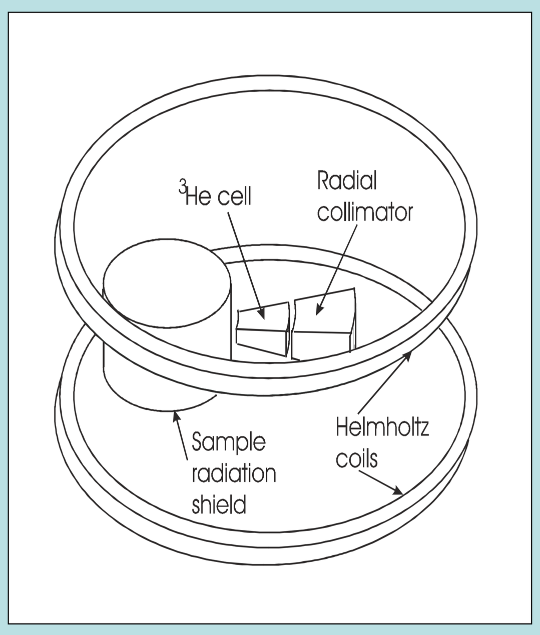
Abstract

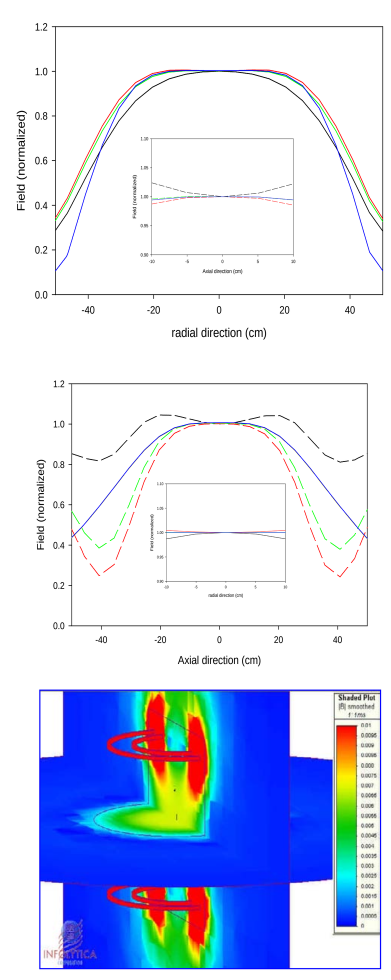
The HYSPEC instrument, currently under construction at the SNS is a direct geometry time of flight spectrometer that utilizes Bragg focusing optics to obtain a high intensity at the sample position for neutron energies in the range 3.6 < E_I<90 meV. HYSPEC will also have the capability to perform full polarization analysis in inelastic mode. The layout of the HYSPEC beamline and the concepts for implementing polarization on HYSPEC are outlined on this poster.

^{3}He Filter Analyzer

We propose to use two high efficiency wide angle polarization analyzers on HYSPEC. For cold neutron experiments we will use a supermirror array and for the thermal energy range a nuclear spin polarized ^{3}He filter analyzer of the PASTIS type. A sketch of our porposed set up is shown to the right along with preliminary field calculations.



2 pairs of coils with diameter 400 mm & 350 mm separated by 400 mm. By applying appropriate currents to the coils, field uniformity similar to a pair of 400 mm diameter Helmholtz coils can be obtained.



Neutron Spin Filter

The absorption cross-section σ for polarized ^{3}He is highly spin dependent. For neutrons with wavelength λ=1 Å, anti-aligned neutrons see a thick absorption target:, $\sigma_{\uparrow\downarrow}$=5931 barns, and aligned neutrons see a thin target: $\sigma_{\uparrow\uparrow}$~5 barns. The transmission T_n and analyzing power P_n are

$$T_{n\uparrow\uparrow} = T_e e^{-(1-P_{He})n\sigma_0 \lambda l}$$

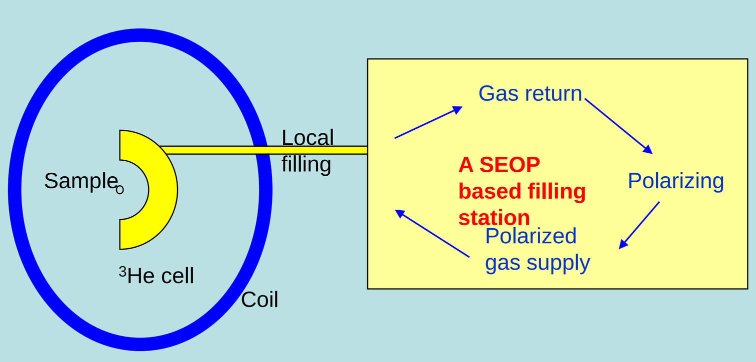
$$T_{n\uparrow\downarrow} = T_e e^{-(1+P_{He})n\sigma_0 \lambda l}$$

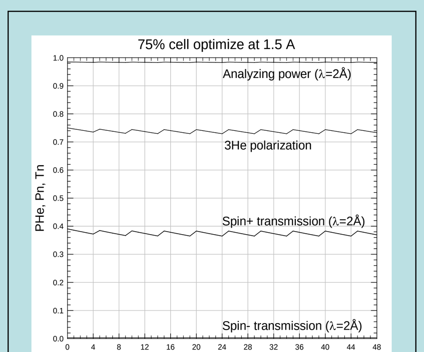
$$P_n = \tanh(P_{He} n\sigma_0 \lambda l)$$

$\sigma_0 = \sigma_{\uparrow\downarrow}$ since $\sigma_{\uparrow\downarrow} >> \sigma_{\uparrow\uparrow}$
T_e = neutron transmission through glass cell
P_{He} = ^{3}He polarization
l = cell length
λ = neutron wavelength
n = number density of ^{3}He

SEOP Filling Station

The Spin Exchange Optical Pumping (SEOP) method (see box) for polarizing ^{3}He gas produces a high polarization of the ^{3}He. However the large cell proposed for the HYSPEC filter analyzer is too large to directly pump via SEOP. Instead we propose to develop a "filling station" of smaller SEOP cells whose output can be accumulated to refill the filter cell. Some preliminary rate calculations for the filling station are shown below.





Optical pumping may be difficult due to the shape of the cell. Refilling may be the solution.

Filling station example:

Max ^{3}He polar. =0.75, optimized at 1.5 Å. T1=200 hours, refill 75% volume every 5 hours. (Plot: for 2 Å neutrons)

Spin-Exchange Optical Pumping

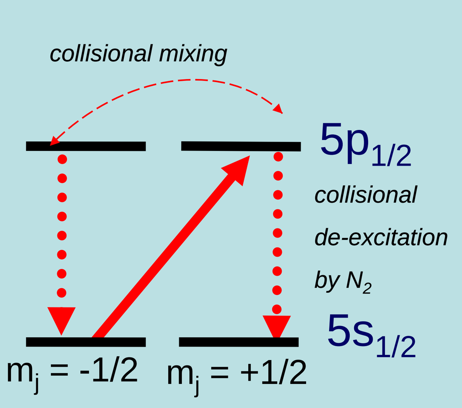
^{3}He nuclei are polarized in a 2-step process. First Rb atoms are polarized by optical pumping. Then spin is transferred from the Rb electron to ^{3}He nuclei during collisions.

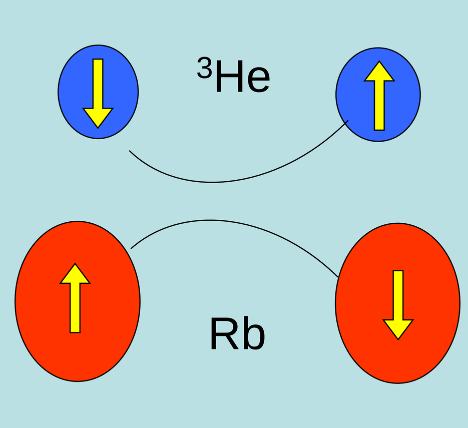
Optical Pumping

- pump Rb D1 line with circularly polarized light (795 nm)

Spin-Exchange

- spin is transferred between Rb electron and ^{3}He nucleus during collisions

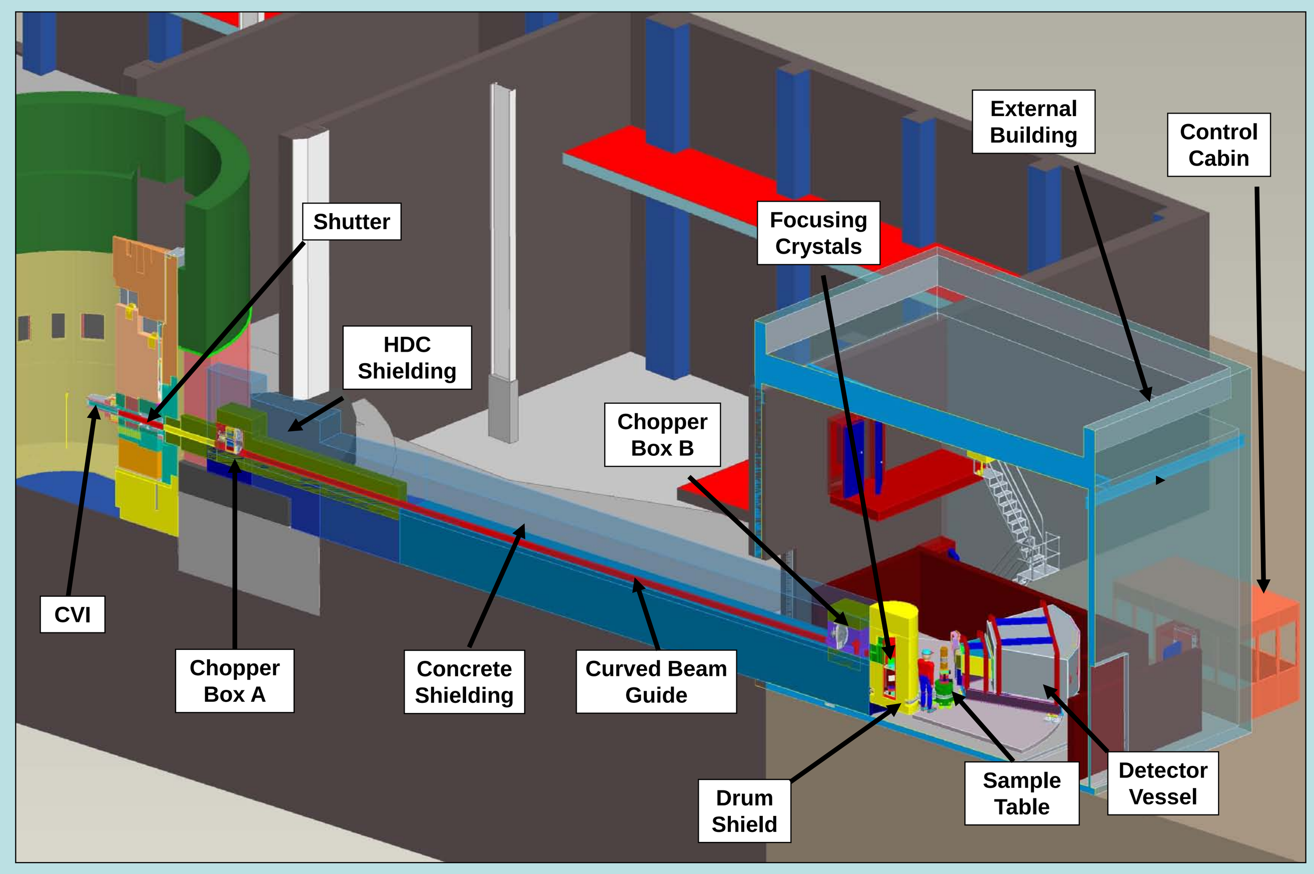




$$P_{He}(t) = \frac{\gamma_{SE} P_{Rb}}{\gamma_{SE}+\Gamma}\left[1-e^{-(\gamma_{SE}+\Gamma)t}\right]$$

P_{He} – ^{3}He polarization
P_{Rb} – Rubidium polarization
γ_{SE} – spin-exchange rate
Γ – ^{3}He relaxation rate

HYSPEC



The Hybrid Spectrometer (HYSPEC) is currently under construction at the Spallation Neutron Source, Oak Ridge National Laboratory, U,S.A. It is a direct geometry spectrometer intended for the measurement of excitations in small single crystal specimens. A rendering of the beamline layout is shown above, Neutrons are carried from the bottom down stream cryogenic coupled H_2 moderator of the SNS out to the experimental area, located in a building external to the SNS target hall, via supermirror neutron guides. They are conditioned by various choppers and focused onto the sample position by Bragg scattering from an array of crystals.

CVI and Shutter

The neutrons exit from the face of the 100mm wide x 120mm tall moderator through the Core Vessel Insert (CVI) which does not contain guide but is tapered to allow the beam to expand vertically. In the shutter and target monolith wall the neutrons are transported by m=3 supermirror guide, which continues to vertically expand up to a height of 150mm tall at 6.4m from the moderator. Beyond this the guide is constant at 150mm tall and 40mm wide.

Chopper box A

In the region known as chopper box A two neutron choppers are located. A vertical axis T0 chopper of the same design as used for the ARCS and Sequoia beamlines at SNS operating at 30 or 60Hz is located at 8.5m. This chopper reduces the high energy component of the neutron beam. The second chopper is a 60Hz frame overlap disk chopper located at 9.33m which removes the very low energy component of the beam.

Curved guide

Following chopper box A there is a 24m long curved guide, with a radius of curvature of 2.56km, with m=3 supernirror on the top, bottom and outer curved surface and m=2 supermirror on the inner curved surface. At the end of the curved guide is the secondary shutter and then chopper box B. The curved guide, the disk chopper in chopper box A, the secondary shutter and the two choppers in chopper box B share a common (windowless) vacuum.

Chopper box B

In chopper box B there are two choppers, a 60Hz disk chopper that is used for order suppression and frame overlap, and a short straight bladed Fermi chopper. The Fermi chopper can operate between 60Hz and 540Hz in 30Hz intervals and is used to monochromate the neutron beam. After the Fermi chopper he neutrons continue up to the drum shield where the guide ends.

Focusing crystals

The neutron beam from the Fermi chopper is vertically focused onto the sample using one of two arrays of crystals. One such array consists of highly oriented pyrolitic graphite (HOPG) crystals with a mosaic spread of ~48' (ZYB). The other is an array of Heusler crystals as described in the box below.

Detector vessel

The sample is mounted on a goniometer for orientation and around the sample axis the detector vessel can be rotated. The detector vessel is filled with Ar gas and contains 160 vertically oriented LPSD tubes at a distance of 4.5m from the sample.

Heusler Focusing Crystal Array

In order to polarize the incident beam on HYSPEC we propose to use an array of vertically focusing Heusler (Cu_2MnAl) crystals. The flux gain from vertical focusing on HYSPEC is much greater than the flux gain from horizontal focusing and thus using a vertically focusing array is much the better choice. This does mean that the polarization will need to be rotated between the Heusler crystals and the sample but this will not be a problem. On the right we show a photograph of the IN22 Heulser monochromator which is very similar to the sort of device we propose to use..