

# High precision depolarisation measurements with an opaque test bench

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**Abstract.** We present a tool to investigate neutron depolarisation effects with  $10^{-4}$  precision. The test bench consists of two opaque  $^3\text{He}$  cells with in-situ adiabatic fast passage flipping of the helium spin. The cells polarise a neutron beam to more than 99.99 % and analyse its polarisation with high accuracy. For depolarisation studies, a sample can be inserted between the two cells and its effect on a primarily highly polarised beam is analysed. The test bench has been validated at the cold neutron beam PF1B at Institut Laue-Langevin, France. We present here preliminary results for the wavelength range from 5 Å to 7 Å. Polarisation with super mirrors is limited to about 99.7%. Direct evidence of depolarisation in the order of  $10^{-3}$  in polarising super mirrors was found by the test bench.

## 1. Introduction

High precision in polarisation of large neutron beams to this day has been of the order of  $10^{-3}$ , mostly produced by high performance polarising super mirror benders. The best polarisation obtained with super mirrors is of 99.7 % [1], using the crossed X-SM geometry. We present a tool to measure depolarising effects in samples to an accuracy level of  $10^{-4}$ . On our test bench, we use  $^3\text{He}$  for both polarisation and polarisation analysis. The transmission  $T$  through a cell of polarised helium to a degree of  $P_{\text{He}}$  for neutrons of wavelength  $\lambda$  with spins parallel (+) and antiparallel (-) to the helium's spin can be described by:

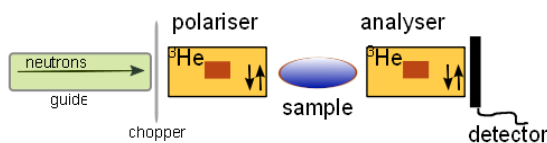
$$T_{\pm} = \frac{1}{2} \exp^{-(1 \mp P_{\text{He}})O} \quad (1)$$

$$O = \frac{0.0733}{\text{bar} \cdot \text{cm} \cdot \text{Å}} (p \cdot l \cdot \lambda) \quad (2)$$

where  $p$  is the helium pressure and  $l$  refers to the cell's length. The letter  $O$  is called the cell's opacity. The resulting polarisation can hence be given as:

$$P = \frac{T_+ - T_-}{T_+ + T_-} = \tanh(P_{\text{He}}O) \quad (3)$$

For details, see [2]. An adequate choice of the cell opacity by driving its parameters to appropriate values results thus in high neutron spin polarisation in the theoretical description of the cell, see Eqn. (3). As an example, neutrons of 5 Å wavelength are polarised to 99.99 % after crossing a cell of 15 cm of length, He polarised to 75 % at a pressure of 1.4 bar.



**Figure 1.** Set-up of the test bench as used on PF1B in November 2010.

## 2. Set-up

A sketch of the test bench is shown in Fig. (1). The test bench consists of a polarising and an analysing helium cell contained in so-called magic boxes [3]. A neutron detector follows directly after the second magic box. The sample is placed between the two cells. Wavelength resolution is provided by a chopper in front of the first magic box and time of flight. Measurements are taken in two different cell configurations: The  $^3\text{He}$  polarisations in two cells are either parallel (count rate  $N_+$ ) or anti-parallel (count rate  $N_-$ ) alignment to the  $^3\text{He}$  spin. Thus, the product of the polarising power  $P$  and the analysing power  $A$  is:

$$A \cdot P = \frac{N_+ - N_-}{N_+ + N_-} \quad (4)$$

As both polariser and analyser cell do have the same shape and were filled with  $^3\text{He}$  of the same pressure and initial polarisation, the product  $A \cdot P$  can be estimated via Eqn. 3 as :

$$A \cdot P = \tanh(P_{\text{He}}O) \cdot \tanh(P_{\text{He}}O) = \tanh^2(P_{\text{He}}O) \quad (5)$$

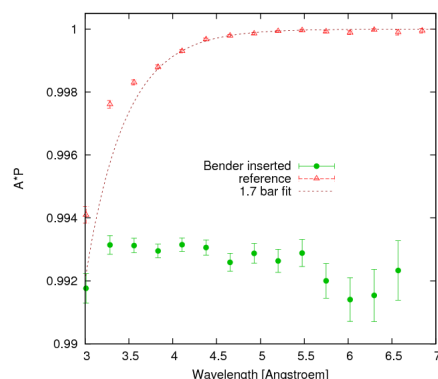
The experiment took place at the high flux instrument PF1B of Institut Laue-Langevin, Grenoble [4]. Measurements were taken for cells with 1.7 bar pressure and an initial Helium spin polarisation of 75 %. The cells' relaxation times were found to be longer than 140 hours and measurements were performed within the first five hours after the filling of the cells. Flipping of the  $^3\text{He}$  polarisation took place in situ; polarisation loss in  $^3\text{He}$  was less than  $10^{-5}$  per flip so that we could safely neglect the number of spin flips for the cells' performance. Between the Helium cells, a guiding field was installed. With no sample present, the resulting polarisation was higher than 99.99 % (see red triangular data points in Fig. 2) for wavelengths longer than 5 Å. For wavelengths longer than 7 Å, the transmission (see also Eqn. (1)) was too low to provide good statistics. Data were treated assuming a constant background and were dead-time corrected. Data points were fitted to Eqn. (5) using the helium polarisation as free parameter and taking into account the finite wavelength resolution (dominated by the chopper).

## 3. Depolarisation In Polarising Supermirror Bender

We introduced on the sample site a Co-Ti Schaerpf Bender [5] in a magnetizing field of 0.04 T. In Fig. 2, the polarisation of the two  $^3\text{He}$  cells only is compared to the final polarisation obtained in a set-up with cell-bender-cell. Clearly, polarisation of the latter is several times  $10^{-3}$  smaller than for the other configuration. Hence, the highly polarised neutrons coming out of the polariser cell undergo depolarisation when subject to a super mirror bender. Depolarisation effects by the bender's housing were excluded.

## 4. Conclusion

We have shown a possibility to measure depolarisation effects of neutrons with an accuracy of  $10^{-4}$  by the use of an opaque test bench. The sample is placed between two helium



**Figure 2.** Product of polarisation and analysis power versus wavelength. Plot shows both a reference case without a sample (red triangles, with fit in dark red performed) and the case with the sample of a super mirror bender (green dots).

spin filters. Under ideal conditions, i.e. a sufficiently homogeneous high flux neutron beam, the cells' parameters can be chosen in a way that polarisation of 99.99 % and the required experimental sensitivity are achieved. When applied to a supermirror bender, depolarising effects were observed. The test bench may find application in neutron scattering processes to closely investigate depolarisation effects as well as in particle physics to develop highly performant polarisation devices.

## 5. Acknowledgement

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## 6. References

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