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POLARIZED EPITHERMAL NEUTRON SPECTROMETER AT KENS

M. Kohgi
Department of Physics, Tohoku University, Sendai 980, Japan

ABSTRACT

A spectrometer employing a white, epithermal, polarized neutron beam is under construction at KENS. The neutron polarization is achieved by passage through a dynamically polarized proton filter (D.P.P.F). The results of the test experiments show that the D.P.P.F method is promising in obtaining polarized epithermal neutron beam. The basic design of the spectrometer is described.

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1. INTRODUCTION

A spectrometer employing a white, epithermal, polarized neutron beem is now under construction at KENS. The neutron polarization is planned to be achieved by passage through a dynamically polarized proton filter (D.P.P.F)[1]. This Polarized Epithermal Neutron Spectrometer (PEN) will be used for the wide purposes ; for example, the study of the process of the dynamical polarization of protons itself, the magnetic structure determination of the amorphous magnets, the observation of high energy magnetic excitations in the ferromagnets, as well as the nuclear physics problems.

Prior to the installation of the PEN spectrometer, we performed some test experiments (Pre - PEN experiments). The results are briefly summarized below. The basic design of the PEN spectrometer is shown in the last section.

2. PRE-PEN EXPERIMENTS

The aim of the Pre-PEN experiments was twofold. One was to establish the technique for cooling a large area filter by liquid ^{3}He and another was to examine the geometrical dependence of the neutron polarization cross section by polarizing longitudinally the neutron beams and comparing the results with those obtained by Hiramatsu et al.[1] and Lushchikov et al.[2] where the neutrons were polarized in the transverse directions.

The Pre-PEN machine consists of a horizontally mounted coaxial superconducting magnet with a ^{3}He cryostat in it[3], a Drabkin type spin flipper, a goniometer to install the Fe_8Co_{92} analyzer crystal and a detector rotating around the goniometer. Because of the testing nature of the Pre-PEN experiments, the machine was constructed by assembling the existing apparatuses[3) which were not necessarily optimized for the present purpose. The neutron beam was tightly collimated to 15 x 15 mm^2 so that no neutrons bypassing the filter were monitored by the detector. The polarizing filter was made with a polycrystalline sample of ethylene glycol with stable Cr^V complex[1). The filter was cooled to ca. 0.5 K in a cryostat by pumping on liquid ^3He. Since ^3He has a large neutron absorption cross section and the cryostat was mounted horizontally, a protection of neutron beam path from liquid ^3He constitutes the most difficult part of the experiment.

The protons of the filter were polarized by a dynamic method at a frequency of 70 GHz in a magnetic field of 25 KG applied in the direction of the neutron beams (longitudinal polarization). The proton polarization was detected by analyzing the height of NMR signal from the filter. The neutron polarization was determined by two methods ; either directly by Bragg reflection from a saturated Fe_8Co_{92} at discrete energies or indirectly by analyzing the intensity of the transmitted beams.

The filter configuration which was used in the early stage of the experiments is shown in Fig. 1(a). Using this type of filter (case (a)), the high enough polarization of neutrons was observed at the low energy side (for example, over 90% at 50 meV, 80% at 100 meV). However, it was found that in this configuration the leakage of unpolarized neutrons through the Cd shield was unavoidable at the high energy side because of the lowering of the liquid ^3H level.

The finally adopted filter configuration which made the bypass leakage of neutrons as small as possible is shown in Fig. 1(b) (case(b)). In this case, the beam size was significantly reduced and we were obliged to decrease the filter thickness to 10 mm in order to increase the counting statistics. The neutron polarization is, therefore, reduced in case (b) compared with the case (a), but the energy dependence of the polarization could be determined with less ambiguity.

The results of polarization of the white neutron beams with the polarized proton filter of case (b) is shown in Fig. 2, where the polarization determined by Bragg reflection (open circles) are corrected for the efficiency of the spin flipper.

The neutron polarization, P_N, obtained after passage thgough a filter of proton polarization P_p is given by

$$P_N = \tanh (P_p \sigma_p Nt), \tag{1}$$

where σ_p is the polarization cross section ($=1/4(\sigma_s-\sigma_t)$),N the number of protons per cm^3 and t the filter thickness. The solid line in Fig. 2 is calculated by eq. (1) using the data for σ_p of Lushchikov et al.$^{2)}$, while the closed circles are the results of analysis from the transmission intensity T. The transmission T is given by

$$T/T_o = \exp(P_p^2 \sigma_1 Nt) \cosh(P_p \sigma_p Nt),^{2)} \tag{2}$$

with T_o the transmission of the unpolarized target. σ_1 which is the cross section depending on the materials is assumed to be zero for the present analysis. The overall agreement among the values of polarization estimated by three different methods was obtained as shown in Fig. 2. Note that the neutron polarization determined by the transmission agrees well with that of Lushchikov et al. above 400 meV where σ_1 is expected to disappear.

Several important conclusions could be derived from the Pre-PEN experiments which are summarized below.

(i) The epithermal neutron beam with neutron energies extending beyond 10 eV could successfully be polarized by the polarized proton filter method.

(ii) In case of (a) (t=15mm, 45% proton polarization) an 80% polarization was achieved at typical neutron energy of 100 meV.

(iii) The longitudinal polarization has the same polarization cross section as the transverse one$^{1,2)}$ within the accuracy of the experiments as was anticipated by Hoshizaki et al.$^{4)}$.

(iv) The downward deviation of the open circles from the closed circles in Fig.2 in the high energy side is presumably due to the depolarization which would occur between the spin flipper and the analyzer. The distance between them was found not enough to satisfy the adiabatic condition.

(v) The upward deviation of the closed circles from the solid line can be attributed to σ_1 in eq. (2).

Further experiments would, however, be necessary before we conclude that σ_p in eq. (1) is completely the same for both LMN (Lushchikov et al.) and ethylene glycol (Pre-PEN).

3. DESIGN OF PEN SPECTROMETER

In contrast to the Pre-PEN machine, we adopted the transverse polarization scheme in PEN ; The He^3 cryostat is vertically inserted in the Helmholtz type superconducting magnet with the magnetic field in the vertical direction. This configuration was selected because of its advantage over the Pre-PEN machine for the neutron scattering experiments ; the neutron scattering experiments can be performed for the dynamically polarized material, the distance between the filter and sample can be made shorter, the level of liquid He^3 can be kept stable, the consumption of liquid He^4 can be significantly reduced, etc. The superconducting magnet was specially designed so as to produce 25 KG with a homogenuity of 5×10^{-5} over a dimension of 30 x 40 x 20 mm^3 and with no zero field in the neutron beam path. The magnet as well as the shield house to accomodate it have already been installed in H8 beam hole. The designing of the proton filter configuration is now in progress taking account of the results of the Pre-PEN experiments. The neutron detecting system of the PEN spectrometer is scheduled to be divided into three groups. The first is used for the observation of the scattering from the dynamically polarized materials or others set on the proton filter position. The scattered neutrons from the center of the proton filter system are observed through several small windows open on its shield. The ^3He detectors with their shield boxes are placed in front of the windows. The second group is used for the magnetic total scattering. An assembly of a sample table, ^3He detectors and their shield is placed just after the polarized neutron exit of the proton filter system. The position of the assembly is variable along the incident neutron path. A electric magnet can be settled on the sample table. The third group is used for inelastic scattering (mainly magnetic). It is composed of a small detector bank and its shield. The detectors look the center of the second scattering assembly. The flight path between the sample table and the detector bank as well as the scattering angle is variable. This configuration was selected taking account of its flexibility for controlling the resolution and choosing the scattering condition.

The first part of the neutron detecting system described above has already been constructed. The final designing of the other parts is now in progress.

In conclusion,the D.P.P.F. method is promising in obtaining polarized epithermal neutron beams. Since the various factors will be optimized in designing PEN, including an effort to increase the total neutron intensity, PEN will become a powerful polarized epithermal neutron beam facility at KENS.

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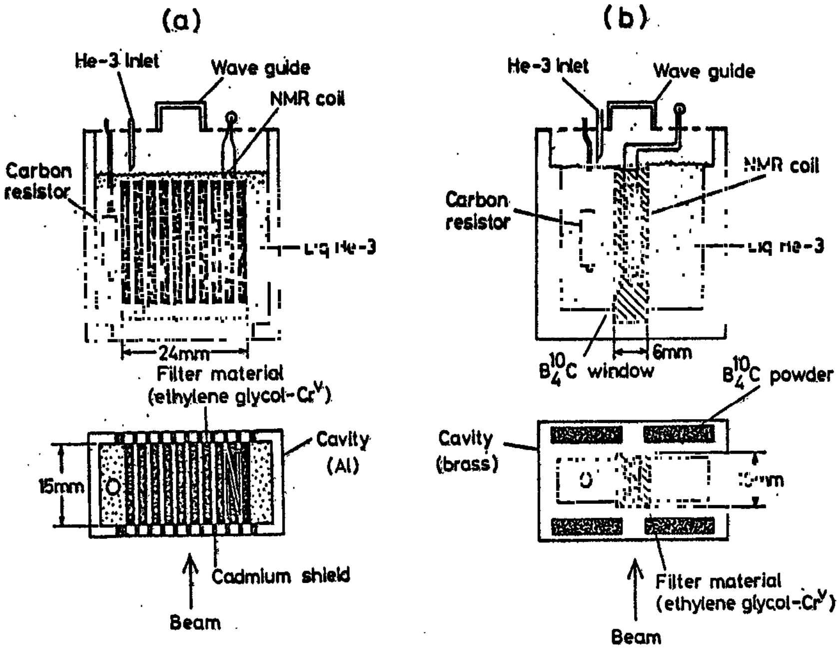

Fig.1 Proton filter configuration for Pre-PEN experiments

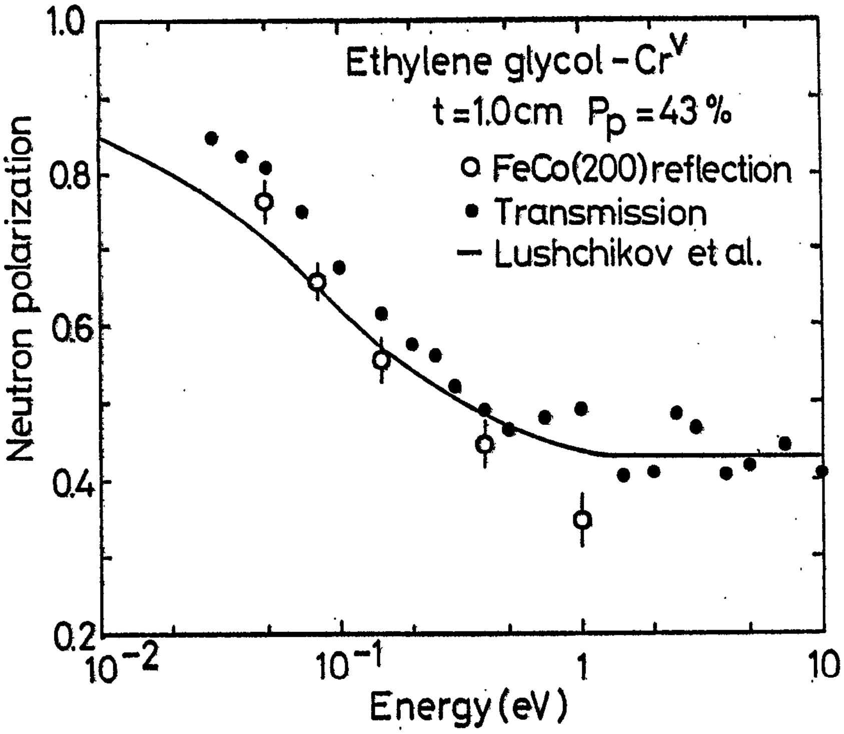

Fig.2 Neutron polarization by D.P.P.F with the configuration shown in Fig.1(b)