A novel approach for a spin–exchange high density ^{3}He target.

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Abstract. In the past decade high density polarized ^{3}He fixed targets based on spin–exchange with optically pumped Rb have been used successfully in electron scattering experiments at MIT/Bates and SLAC, as a neutron polarizer, and with proton and pion beams at TRIUMF. In the near future similar targets will be used in physics programs at TJNAF and as neutron polarizers at Los Alamos. Until now, the typical spin exchange target was a sealed design, however there are several advantages to target cells that can be evacuated and filled with a variable pressure of polarized ^{3}He. We have begun development of such an actively filled target, based on technology recently developed for NMR/MRI with hyperpolarized noble gases. The benefits and difficulties of constructing such a "flowing" high density ^{3}He target system are discussed.

INTRODUCTION

For a neutron spin filter, the optimum ^{3}He thickness depends on both the neutron wavelength and the ^{3}He polarization. Neutron polarization is given by the following equation :

$$P_n = \tanh(n_3\sigma_\alpha l P_3). \tag{1}$$

The ^{3}He density is indicated by n_3, the velocity dependent neutron absorption cross–section by $\sigma_\alpha = \frac{v_o}{v}5327$ barn, $v_o = 2200\frac{m}{s}$, the column depth of the spin filter by l, and the ^{3}He polarization by P_3. For experiments at neutron spallation sources, a broad spectrum of wavelengths is available. The variable ^{3}He pressure allows for optimization of the polarizer to specific conditions and experimental parameters such as neutron wavelength. Another advantage of the actively filled cells is that leaks can be tolerated. Target materials containing strong neutron absorbers (e.g. ^{11}B in most conventional glasses) strongly attenuate long wavelength neutrons due to $(1/v)$ cross–sections. Materials such

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as quartz have been shown to have favorable properties for ^{3}He polarization in addition to neutron transmission. However, quartz has a high leak rate for helium. The leaking gas can easily be replenished in the actively filled cells. Also, leaky seals such as those between dissimilar window and target cell materials would no longer be a problem.

VARIABLE PRESSURE CELL SET-UP

A variable pressure ^{3}He polarization cell was constructed. The cell was manufactured with Corning 7056 glass, a borosilicate. The cell has a 2.5 cm diameter and is approximately 10 cm long. During operation the cell is held in a cylindrically shaped Pyrex oven. The oven has a diameter of 4 cm and a length of 14 cm. Hot air is used to raise the temperature of the oven; for these tests the cell was operated at 170° C, controlled with a RTD and Omron temperature controller device. A metallic valve is used to control the pressure of the cell; the valve is connected to the main body of the cell with a Pyrex capillary tube. The capillary has an inner diameter is 0.05 cm and a length of approximately 10 cm. Assuming that the valve is 100% depolarizing and that no polarization gradient exists transverse to the axis of the capillary, the effective relaxation time, T_1, is given by :

$$\frac{1}{T_1} = \frac{1}{T_1'} + \frac{SD}{LV}. \tag{2}$$

The intrinsic cell relaxation time is T_1'. The capillary cross-sectional area is given by S and the length by L. The ^{3}He diffusion constant in the capillary is given by D (at the appropriate temperature and density). The volume of the cell is given by V. Figure 1 illustrates the optical pumping cell.

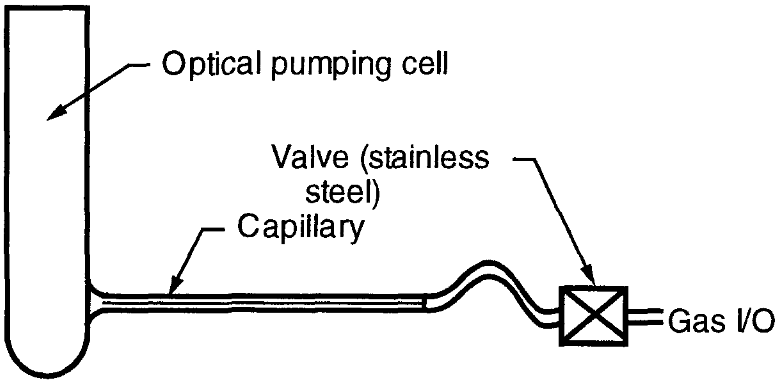

FIGURE 1. Variable pressure optical pumping cell.

RESULTS

We have tested the cell under two conditions : 1) a fill pressure of approximately 1 atmosphere (atm) and 2) a fill pressure of approximately 2.5 atm. In addition to the helium, a small partial pressure of nitrogen was included, about 60 torr. Each cell was optically pumped with approximately 2.3 watts of 795 nm circularly polarized light provided by an argon ion pumped Ti:sapphire laser. Relaxation measurements were made over the course of many hours using the method of *adiabatic fast passage*. Polarization data along with exponential fits are shown in Figure 2. Plot **A** shows the spin–down for the 1.0 atm. fill. The 2.5 atm. fill spin–down is shown in plot **B**. The capillary serves

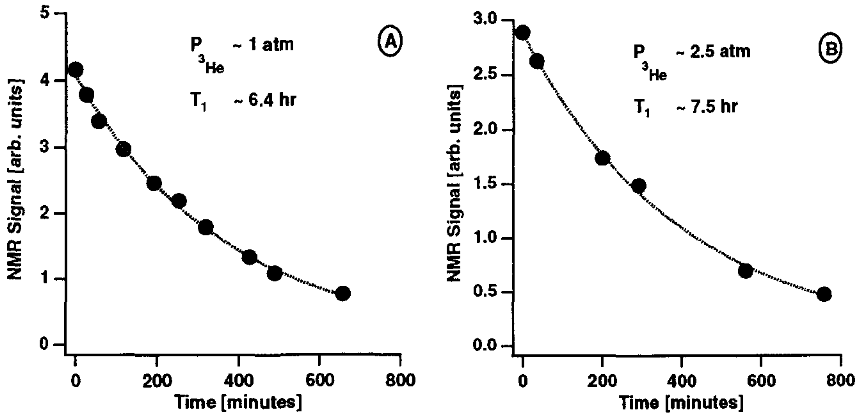

FIGURE 2. Spin-down curves for variable pressure cell. (A) Approximately 1 atm. pressure of ^{3}He. (B) 2.5 atm. pressure of ^{3}He. Lines indicate the exponential fits.

the purpose of isolating the bulk polarized ^{3}He from the depolarizing effects of the stainless steel valve. However, the relaxation times are not sufficiently long for use in neutron spin filter applications. We expect to run further tests to diagnose the performance of the cell.

CONCLUSIONS

A variable pressure cell has been successfully tested with promising results. We expect to conduct further tests with this cell to verify the performance. We have plans for constructing quartz cells and cells with glass valves instead of metal. In the near future we have plans to test two chamber cells, in which the optical pumping cell can accomodate high ^{3}He density and can thus take advantage of pumping with laser diode arrays due to pressure broadening of the Rb line. The secondary chamber would then be filled with polarized gas from the first chamber. We expect to make large quartz secondary cells applicable for use as neutron polarizers.