Polarized ^{3}He by metastability exchange with a laser

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Both "nuclear" polarized $^3\overrightarrow{\mathrm{He}}$ atoms and $^3\overrightarrow{\mathrm{He}}^+$ ions can be produced simultaneously by the metastability exchange method [1], which is a unique feature compared with the spin-exchange method. We are especially interested in $^3\overrightarrow{\mathrm{He}}^+$ ions because they can be used as a $^3\overrightarrow{\mathrm{He}}^+$ beam by extracting and accelerating them. Thus we have started the construction and the development of a ^{3}He polarizer by this method.

Figure 1 shows the configuration of our experimental apparatus. A ^{3}He (0.3–2.0 Torr) gas is sealed in a Pyrex glass cell with a size of 3 cm$^\phi\times$ 5 cm^t. This ^{3}He cell is set in a uniform magnetic field (∼13 G) generated by a Helmholtz coil in order to keep the polarization. In the metastability exchange method, first ^{3}He atoms are excited to the metastable $2^3\mathrm{S}_1$ state by applying an RF field ($f \simeq$ 1–10 MHz). Secondly, ^{3}He atoms in $2^3\mathrm{S}_1$ are optically pumped to the $2^3\mathrm{P}_0$ state with ∼1083 nm infrared light produced by a fiber laser module. By using left-handed circularly polarized light, only two sublevels of $M_F = -3/2$ and $-1/2$ out of four sublevels of $M_F = \pm 3/2$ and $\pm 1/2$ in $2^3\mathrm{S}_1$ are concerned with the optical pumping, which results in "electronic" polarization for ^{3}He atoms in the metastable $2^3\mathrm{S}_1$ state. Finally, this electronic polarization is transfered to the nuclear polarization through the hyper-fine interaction, and $^3\overrightarrow{\mathrm{He}}$ atoms in $2^3\mathrm{S}_1$ are de-excited to the ground state by metastability exchange collisions.

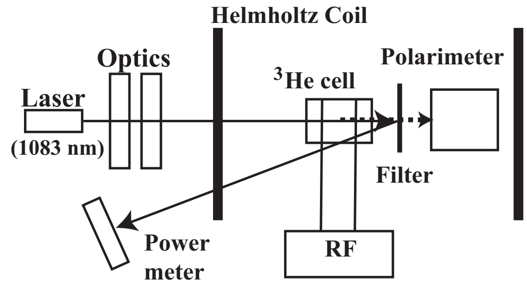

Figure 1: Schematic view of the ^{3}He polarizer.

The nuclear polarization of ^{3}He can be obtained by measuring the circular polarization of an optical line at 668 nm ($3^1\mathrm{D}_2 \to 2^1\mathrm{P}_1$ [3,4]). Figure 2 shows the ^{3}He nuclear polarization in a 0.3 Torr cell as a function of time for the C_9 line from $2^3\mathrm{S}_1$ to $2^3\mathrm{P}_0$ with 3.5 W laser power and a RF discharge frequency of $f = 6.5$ MHz. The measurements were performed for several RF discharge intensities which resulted in 668 nm light powers of $-57 \sim -52$ dBm. In this figure, the cell was irradiated by the laser between 30 to 100 s. The pumping time was about 10 s, and the nuclear polarization became maximum of $\simeq$ 50%. The relaxation time was long as 10–40 s compared with the pumping time.

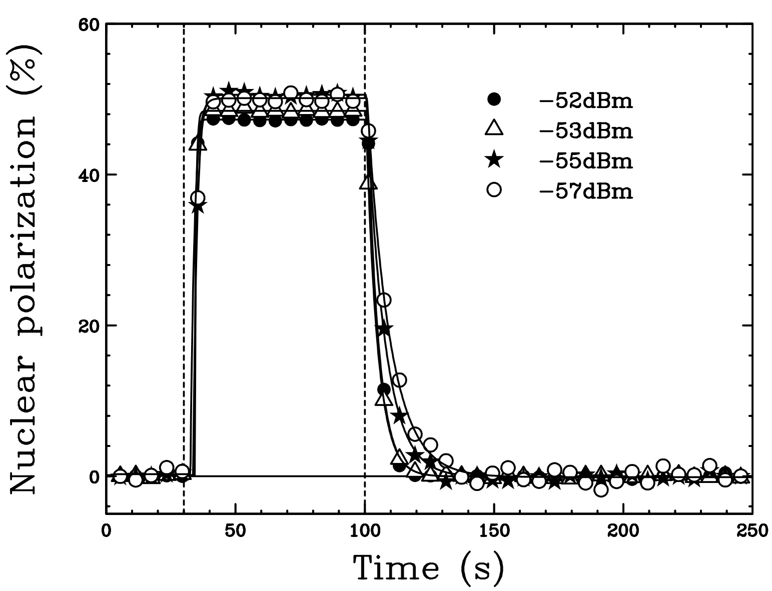

Figure 2: The ^{3}He nuclear polarization in a 0.3 Torr cell as a function of time. The pumping laser with 1083.327 nm radiated the ^{3}He cell between 30 to 100 s.

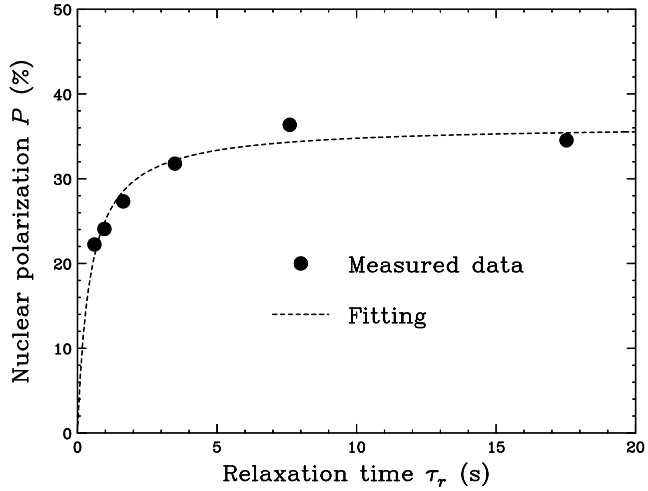

Figure 3: The relation between the relaxation time and the ^{3}He nuclear polarization.

The relation between the relaxation time and the nuclear polarization is shown in Fig. 3. The measurements were performed for a 1.0 Torr cell by using the C_9 line with 3.5 W laser power and a RF discharge frequency of $f = 9.6$ MHz. It is found that the nuclear polarization is increased as the relaxation time is increased. The nuclear polarization P can be expressed by using the relaxation time τ_r as [3]

$$P = P_0 \frac{\tau_r}{\tau_r + \tau_p}, \tag{1}$$

where P_0 is the maximum polarization for $\tau_r \to \infty$ and τ_p is the pumping time. The dashed curve in Fig. 3 is the result of fitting with Eq. (1) which reproduces the measured data reasonably well.

The direct measurement of the ^{3}He nuclear polarization by NMR is now in progress.

References

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