Production of polarized ^{3}He with meta-stability exchange method

E. Ihara[1], T. Wakasa[1], M. Dozono[1], and Y. Sakemi[2]
[1] *Department of Physics, Kyushu University, Fukuoka 812-8581, Japan*
[2] *Cyclotron and Radioisotope Center, Tohoku University, Miyagi 980-8578, Japan*

Recent progress in the development of high intensity infrared ytterbium-doped fiber lasers enables us to produce highly polarized ^{3}He nuclei by the meta-stability exchange method. We have investigated the relation between the relaxation time and the nuclear polarization in high pumping rate region [1].

The nuclear polarization of ^{3}He can be obtained by measuring the circular polarization of an optical line at 668 nm ($3^1\mathrm{D}_2 \to 2^1\mathrm{P}_1$). An isolation of 668 nm light is performed using a Thorlabs laserline filter FL670. The circular polarization of the isolated light is measured using a Thorlabs polarization analyzing system PAX5710VIS. Figure 1 shows the typical ^{3}He nuclear polarization deduced from the circular polarization of 668 nm light as a function of time. The laser was tuned for the C_8 transition, and was irradiated from $t = 30$ to 130 s with an RF discharge frequency of $f = 8.3$ MHz. The measurements were performed for several RF discharge intensities which resulted in 668 nm light powers of $-54 \sim -48$ dBm on the system. The nuclear polarization P reaches its saturation value with an effective laser power of $\sim$400 mW on the cell, and it is insensitive to the applied RF frequencies. The time dependence of P is expressed [2] as $P_0[1-\exp(-t/\tau)]$ where P_0 is the final polarization for $t \to \infty$ and τ is the effective pumping time constant, and the solid curves in Fig. 1 are the results of fitting. The effective pumping time τ was short as 1–6 s, which is an unique feature of the meta-stability exchange method. The maximum nuclear polarization of $P_0 = 72\%$ was obtained in -54 dBm case. The relaxation of P after stopping the laser irradiation is expressed [2] as $P_0[\exp(-t/\tau_r)]$ where τ_r is the relaxation time, and the dashed curves in Fig. 1 are the results of fitting. Note that both τ and τ_r are functions of RF discharge intensity as seen in Fig. 1, and they are controlled by the applied RF power. The relaxation time τ_r was long as 3–19 s compared with the effective pumping time τ.

The relation between τ_r and P_0 for $f = 9.6$ MHz is shown in Fig. 2. The Caltech data [3] for a 0.3 Torr cell with $f = 10$ MHz are also represented in the large τ_r region. It is found that in the whole τ_r region, the C_8 transition is the better choice to obtain higher polarization P_0. The nuclear polarization P_0 can be expressed [2] using τ_r as

$$P_0 = P_\infty \frac{1}{1+\tau_p/\tau_r} , \tag{1}$$

where τ_p is the pumping time constant and P_∞ is the maximum polarization for $\tau_r \to \infty$. The solid curves in Fig. 2 are the results of fitting with Eq. (1) with constant τ_p, which reproduce the measured data reasonably well.

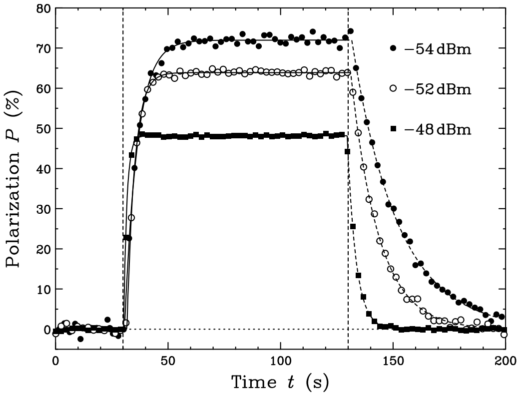

Figure 1: Build-up and relaxation of nuclear polarization P as a function of time.

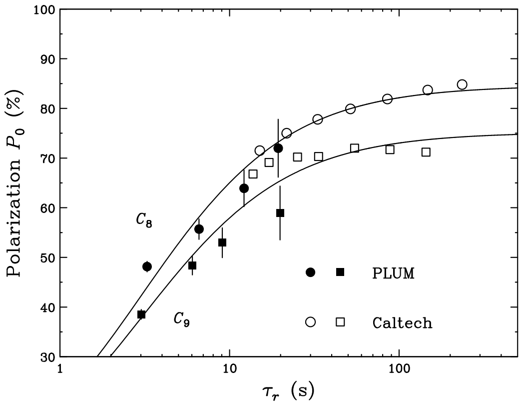

Figure 2: Nuclear polarization P_0 as a function of relaxation time τ_r for C_8 and C_9 transitions.

References

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