1. Introduction

A polarized proton solid target for RI beam experiments has been developed at Center for Nuclear Study, University of Tokyo [1]. Protons are polarized through the transfer of the electron population difference in photo-excited triplet states of pentacene molecule. By this method, proton polarization of about 20% can be obtained at a low magnetic field of 0.1 T and in high temperature of 100 K. Although this target has been successfully applied to RI beam experiments [2, 3], further improvement in proton polarization is desirable for future applications.

At present, the photon number of the photo-excited light is the bottleneck in achieving higher polarization because the photon number is fewer than the electron number of the pentacene. Simply, for increasing the photon number, the best laser light would be continuous wave. However, one problem arises that the lifetimes of the magnetic sublevels in triplet states are different. A sublevel which has the largest population decays with the shortest lifetime. Therefore, by irradiating laser light for long time the electron polarization is decreased while the photon number is increased. Thus, the photo-excited light must be pulsed. In our system, the pulse structure is determined by the rotating speed and slit width of optical chopper.

When the duty factor, which is product of width and repetition frequency of the pulse, is increased, the polarization would be decreased by expanding the pulse width. Therefore, we examine that to what extent the proton polarization is enhanced when both the duty factor and the repetition frequency are changed to increase.

2. Optical system

For the optical excitation of pentacene molecules, an Ar ion laser (Coherent TSM25) with a wavelength ranging from 454.5 nm to 528.7 nm and a total maximum output power of 25 W is used. Since the output light of this laser is continuous wave (CW), the light is mechanically pulsed by using an optical chopper (Fig. 1). The frequency of laser pulse can be changed by varying rotating speed of the optical chopper. In addition the duty factor can be easily changed by shifting the overlap of two chopper blades. This optical system enables us to change the duty factor from 5 to 50%, and the repetition frequency from 0.75 to 10.5 kHz.

3. Measurement and result

As the material to be polarized, we used a single crystal naphthalene doped with pentacene (0.001 mol%). The crystal size was 14 mm in diameter and 2.5 mm in thickness.
maximum value when the repetition frequency and the duty factor were 10.5 kHz and 50%, respectively. The polarization rate was improved by a factor of 7.5 compared with the previous works. From this result, one can expect that the polarization is enhanced by increasing the duty factor and repetition frequency.

The buildup curve of Fig.4 is represented as
\[ P(t) = \frac{A}{A + \Gamma} \left(1 - \exp\left(-\Gamma t\right)\right), \quad (1) \]
were \( A \) is proportional to polarization rate, and \( \Gamma \) is relaxation rate of polarization. The saturated polarization is described as
\[ P(\infty) \propto \frac{A}{A + \Gamma}. \quad (2) \]
Therefore, the saturated polarization is determined by the balance between \( A \) and \( \Gamma \). It is seen from the figure that the magnitude of saturated polarization with a duty factor of 50% (set-50) is improved by a factor of 4 compared with that of set-5.

4. Summary

We have studied the pulse structure dependence of proton polarization rate in order to pursue possible improvement in photo-excitation power. The proton polarization rate was measured by changing the duty factor from 5% to 50% and the repetition frequency from 0.75 kHz to 10.5 kHz. It was found that the proton polarization rate depends strongly on the pulse structure. The polarization rate was improved by a factor of 7.5 compared with the previous work by setting the duty factor to 50% and the repetition frequency to 10.5 kHz. In addition, the build up curve of polarization was measured at duty factors of 5%, 15%, 30%, and 50%. The magnitude of saturated polarization was improved by a factor of 4 compared with the previous work.

We expect that these results can be understood by considering lifetime difference among the electron photo-excited triplet states. A theoretical model which quantity deals with this polarization mechanism is now under construction.

References