Improvement in Cross-Polarization System for Radioisotope Polarization

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II. 1. Improvement in Cross-Polarization System for Radioisotope Polarization

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We have proposed a new technique to polarize unstable nuclei by a cross polarization method[1)]. The aim of this study is to find a possibility to produce a polarization of unstable nuclei better than 10%. The highly polarized unstable nuclei would be useful in the study of nuclear structure as well as material science.

As the first step, we constructed a proton polarizing system[1)] which contains a permanent-magnet with variable field strength. The magnet can continuously change the field strength and polarity by rotating cylindrical permanent-magnet rods. The maximum field strength was 326 mT. The field uniformity, however, was a few percent over a volume of 10 mm diameter and was insufficient to observe an NMR signal of polarized protons. We have thus performed a calculation of magnetic field to attain field uniformity better than 10^{-3} over the volume. The magnetic field was calculated by changing a dimension of a shim using the Poisson/Superfish code. Based on the results of calculations, we have modified the magnet with the shim of $128 \times 90 \times 15$ mm^3.

By using the modified magnet, we have performed an experiment to polarize protons by means of a cross polarization[2,3)]. The magnetic field was 58 mT, and the temperature was 305 K. To confirm an enhancement of proton polarization by the cross polarization, we are using a pulsed NMR technique with a quadrature detection. Figure 1 shows a measured NMR signal of polarized protons. In the figure, we also plot a NMR signal observed before polarizing protons as a background. We have clearly succeeded in polarizing protons.

We have also measured polarizations in a buildup and a relaxation processes to evaluate a polarization rate. The proton polarization, P_p, in the buildup process can be written as

$$P_p = P_e \frac{A}{A+\Gamma}\left\{1-\exp\left[-\left(A+\Gamma\right)t\right]\right\} \quad , \qquad (1)$$

while that in the relaxation process can be written as

$$P_p = P_p(0)\exp\left(-\Gamma' t\right), \qquad (2)$$

where P_e is an electron population difference in the photo-excited triplet state[4,5], A is the polarization rate of protons, G is a relaxation rate of protons, and G' is a measured relaxation rate of protons. Figure 2 shows a result of the proton polarization as a function of time in the buildup process. By fitting the data with Eq. (1), the buildup time, $1/(A+G)$, was derived as 3.6(9) min. Figure 3 shows a decrease in proton polarization as a function of time. The measurement was performed after stopping the polarization buildup process. From the measurement, the relaxation rate, $1/G$', was obtained as 4.0(4) min by fitting the data using Eq. (2). The relaxation rate in the buildup process is now assumed to be almost same as the measured relaxation rate, i.e., G= G'. We then obtain A as 0.03(7).

The evaluated value of polarization rate is very small to attain proton polarization of better than 10%. This small value is mainly caused by a reflection of laser light at a surface of the crystal. To avoid the reflection, we will irradiate the laser light onto a cleavage plane of the crystal. We are also planning to optimize the power and duty rate of the laser to increase the polarization rate.

References

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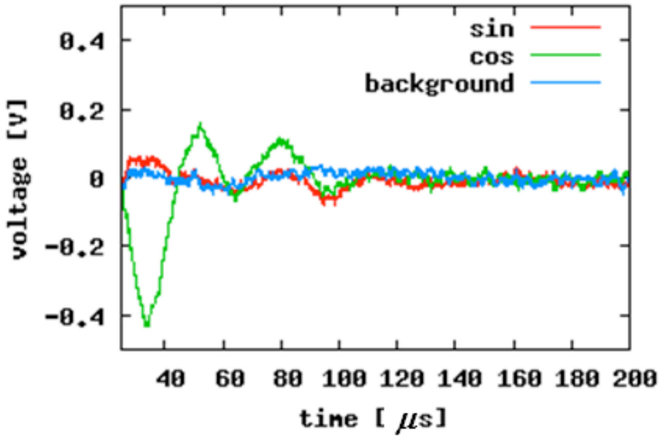

Figure 1. NMR signals of polarized protons in a p-terphenyl crystal. The red line is an NMR signal on the x axis of the rotating frame and the green one is that on the y axis of the rotating frame. The blue line is an NMR signal observed before polarizing protons

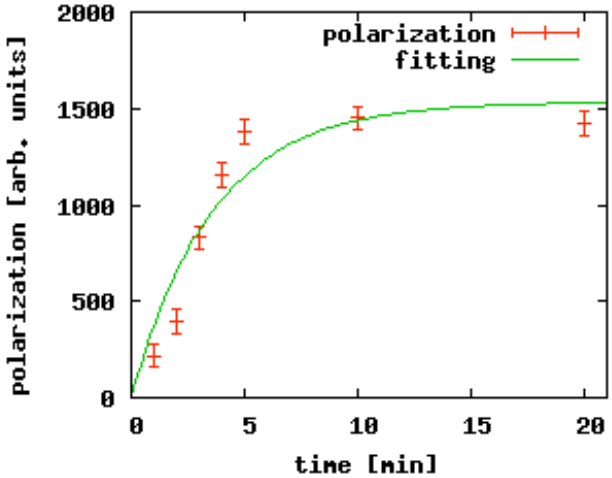

Figure 2. Proton polarization as a function of time in the buildup process. The red points are amplitude of NMR signals. The green line is the fitting line using Eq. (1).

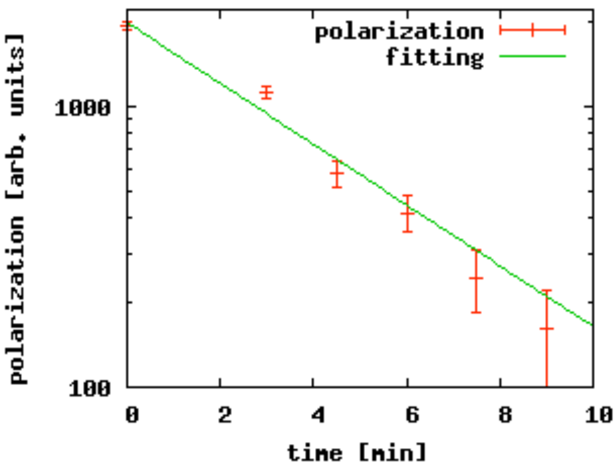

Figure 3. Decrease in proton polarization as a function of time. The red points are amplitude of NMR signals. The green line is the fitting line using Eq. (2).