Continuous wave nuclear magnetic resonance with a vector network analyzer for the polarization monitoring of room-temperature polarized solid proton target

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A polarized solid proton target based on the triplet dynamic nuclear polarization (triplet-DNP) has been developed for measuring deuteron-proton elastic scattering. The aim is to investigate the spin dependence of three-nucleon forces.[1)] In the triplet-DNP, the polarization of the photoexcited triplet electrons is transferred to the protons via microwave irradiation and field sweep. Fourier transformation nuclear magnetic resonance (FT NMR)[2)] is utilized with an OPENCORE NMR spectrometer[3)] to monitor the polarization. Although FT NMR provides high-sensitivity measurements, it has a limitation in that the changes in signal intensity do not exactly correspond to polarization changes. This limitation is attributed to dead time, which is the transient response of the NMR resonator to strong pulse irradiation, which causes FT NMR to overestimate polarization with an increase in proton polarization. Therefore, we introduced a continuous wave (CW) NMR[4)] system to properly evaluate target polarization.

CW NMR is implemented by introducing a vector network analyzer (VNA) and is used to examine the high-frequency property of a circuit by conducting a frequency sweep and observing the reflected and transmitted signals. CW NMR requires the same procedure, and therefore, a VNA is additionally installed. Further, as shown in Fig. 1(a), a photo relay is installed in the monitoring system to control a laser that initiates the triplet-DNP. Both the triplet-DNP and its monitoring are performed by operating the devices with Python-based code on a PC. The same code also includes signal processing.

To this end, triplet-DNP was performed under conditions of 0.3 T and 293 K. The target was a *p*-terphenyl single crystal doped with 0.01 mol% deuterated pentacene. CW NMR was conducted with a sweep power of −20 dBm and duration of 0.2 s, and the result was the average of ten consecutive sweeps. Figure 1(b) shows the signal processing and extracted signal after 10 min of triplet-DNP. The signal was processed with the following steps: (1) subtracting before-DNP data from after-DNP one, and (2) applying the fifth-order polynomial fitting to the baseline outside the polarization signal.

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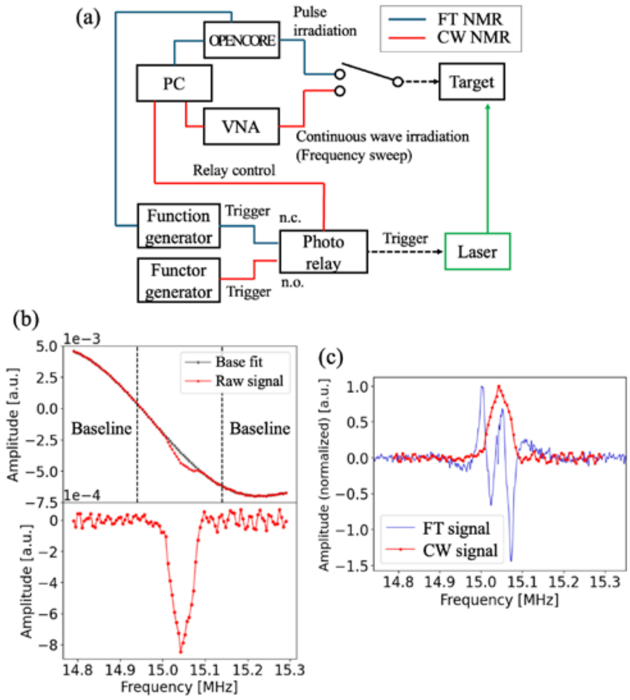

Fig. 1. (a) Structure of the polarization monitoring system. FT and CW NMR lines are indicated in blue and red, respectively. (b) Signal processing (upper: difference of before- and after-DNP data (gray) and the fitting curve of the baseline (red), lower: subtracted signal). (c) FT (blue) and CW NMR signal (red). They are normalized for comparison.

The FT and CW NMR signals are compared, as shown in Fig. 1(c). Although the FT signal showed a deformed spectrum because of the dead time, the CW monitoring measurement provided the complete polarization signal. In addition, CW monitoring only exhausted 1% of the polarization. The signal-to-noise ratio of CW NMR was ∼25, which is acceptable but needs to be improved. From the above, our CW NMR system can be applied for the polarization monitoring of room-temperature polarized solid proton target. Further improvements are underway.

References
1) Y. Saito, PhD. thesis, to be submitted.
2) G. Reicherz *et al.*, Nucl. Instrum. Methods Phys. Res. A **526**, 96 (2004).
3) K. Takeda, J. Magn. Reson. **192**, 218 (2008).
4) G. Reicherz, F. Grimm, PoS (PSTP2022), 017 (2022).