On-line test of rotating magnetic field system for β-NMR method

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The β-ray detected nuclear magnetic resonance (β-NMR) method[1)] is an efficient method to measure the nuclear magnetic (μ) moment of unstable nuclei. The absolute value of μ moments are measured for various nuclei by using β-NMR. However, the sign of μ moments are rarely measured in experiment. In the β-NMR method, a linear oscillating magnetic field (RF), which can be a superposition of a right- and left-rotating RF, is applied to invert the direction of spin polarization. Thus, only the absolute value of μ moments is estimated from the applied frequency of the linear RF. Therefore, to determine the sign of a μ moment, applying a rotating RF is necessary. A rotating RF system has been under development[2,3)] to determine the sign of a μ moment by using the β-NMR method. The rotating magnetic field is obtained using two Helmholtz-like coils with axes crossed at right angles. The experimental apparatus to produce the rotating RF is shown in Fig. 1, and a detailed description is given in Ref. 2 and 3.

In the present work, the performance of the system was studied with spin-polarized ^{20}F ($I^{\pi} = 2^{+}$, $T_{1/2}$ = 11.163 s, $\mu(^{20}\mathrm{F}) = +2.09335(9)\ \mu_N$) nuclei at the Research Center for Nuclear Physics, Osaka University. A spin-polarized ^{20}F nucleus was produced in the $^{19}\mathrm{F}(\vec{d}, \mathrm{p})^{20}\mathrm{F}$ reaction. In this reaction, the polarization of the beam particles is transferred to each nucleus. The $\vec{d}$ beam was produced using a polarized ion source[4)], and accelerated at $E/A = 10$ MeV using the AVF cyclotron. The polarized beams were impinged on a $\mathrm{CaF_2}$ crystal (0.5 mm^t) to produce the polarized ^{20}F. The crystal was placed at the center of the β-NMR apparatus (See Fig. 1.) at room temperature with a static magnetic field $B_0 = 500$ mT applied.

The β-rays emitted from ^{20}F nuclei were detected with plastic scintillator telescopes located above and below the crystal. The up/down ratio R of the β-ray counts is written as $R_0 \approx a(1+A_\beta P)/(1-A_\beta P)$, where a denotes a constant factor representing asymmetries in counter solid angles and efficiencies and A_β and P denote the β-ray asymmetry parameter and the degree of spin-polarization, respectively. A rotating RF perpendicular to B_0 is applied to ^{20}F by using the two pairs of coils. If the frequency and direction of the rotating RF correspond to the resonance values, the direction of the spin polarization is inverted ($P \rightarrow -P$) by the NMR. Thus, the up/down ratio is changed as $R \approx a(1-A_\beta P)/(1+A_\beta P)$. When the polarization is altered because of the resonant spin change, a change appears in the ratio R_0/R. The β-ray asymmetry $A_\beta P$ is written as $A_\beta P = \sqrt{(R_0/R)} - 1/\sqrt{(R_0/R)} + 1$.

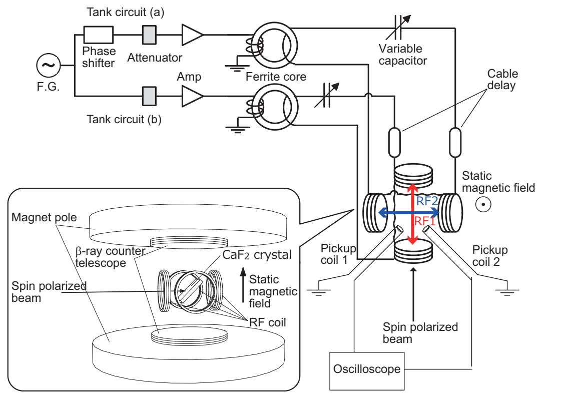

Fig. 1. Block diagram of the RF system for the rotating magnetic field and a schematic layout of the β-NMR setup.

The $\vec{d}$ beam was pulsed with beam-on and beam-off periods of 16 s and 22.02 s, respectively. In the beam-off period of a cycle, RF was applied for the first 10 ms. Subsequently, the β-rays were counted for 22 s, and in the last 10 ms of the beam-off period RF was applied again to restore the spin direction. First, we measured R_0 without RF and then, we measured R with RF. This cycle was repeated until the required measurement statistics were attained.

In this experiment, we first measured a μ moment by using β-NMR applied to the linear RF using tank circuit (a); then, measured it using another one. Figure 2 shows obtained $A_\beta P$ values. Next, we attempted to measure the sign of $\mu(^{20}\mathrm{F})$ by applying a rotating RF. Analysis of the results is in progress.

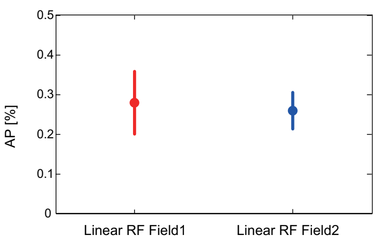

Fig. 2. Obtained $A_\beta P$ value of ^{20}F with applied linear RF field.

References
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