**β-NQR measurement of the $^{23}$Ne ground state**


In this report, we present some results of the experimental program NP1612-RRC47. The aim of this experiment is to search for an appropriate single crystal for the β-NMR measurement of Ne isotopes and to measure its electric field gradient at the sitting site of Ne, as the first step to the nuclear electromagnetic moment measurement of neutron-rich Ne isotopes. In the present study, we applied the β-NQR method(1) to the spin-polarized $^{23}$Ne, the ground-state $Q$ moment of which has been well-studied,2) implanted into the ZnO single crystal.

The experiment was conducted using the RIKEN projectile fragment separator (RIPS). A radioactive $^{23}$Ne beam was obtained from the single-neutron pickup reaction of $^{22}$Ne at 70 MeV/nucleon on a 0.25-mm thick Be target. In order to produce spin polarization, the primary beam was injected with a tilt angle of 2° with respect to the spectrometer entrance (F0), where the Be target was located. Fragments were accepted at a finite angle $\theta = 1° - 3°$ to the primary beam direction, and at the center of the momentum distribution ($\Delta p/p \leq |\pm 25\%|$) was selected at momentum dispersive focal plane F1. A secondary beam of $^{23}$Ne with a purity higher than 90% was separated with a 321-mg/cm² thick Al wedge degrader. The intensity of the spin-polarized $^{23}$Ne was 5×10⁴ pps with a $^{22}$Ne beam intensity of 400 pna.

The spin-polarized $^{23}$Ne was implanted in a ZnO single crystal (28 mm × 20 mm × 0.5 mm, inclined at 45° to the horizontal plane), which was located at the center of the β-NMR apparatus. The $c$-axis of the ZnO single crystal was along the vertical axis. A static magnetic field of 0.5 T was applied to the crystal parallel to its $c$-axis, and an oscillating magnetic field was applied by a pair of RF coils perpendicular to the static magnetic field. The crystal was cooled to $T \sim 50$ K to achieve a longer spin-lattice relaxation time than the $^{23}$Ne β-decay half-life ($T_{1/2} = 37$ s).

The $\beta$ rays from the $\beta$ decay of $^{23}$Ne was detected through a vacuum chamber wall, made of 1-mm thick fiber-reinforced plastic, by two $\beta$-ray telescopes which were located above and below the crystal. Each telescope consists of a stack of three 1.0-mm thick plastic scintillators. The telescopes cover approximately 50% of the entire solid angle.

In the experiment, we first measured the g-factor of the $^{23}$Ne ground state with a NaF polycrystalline stopper by the β-NMR method to confirm the polarization of the $^{23}$Ne beam. In this measurement, we observed a nuclear magnetic resonance at 1653.8(5) kHz; thus, a g-factor of $g = 0.43305(14)$ was deduced. The obtained g-factor is consistent with the literature values $g = 0.432(4)$3) and 0.43268(36).4) The polarization of the $^{23}$Ne beam was also determined to be $AP = 5.0(4)%$.

After measuring the g-factor, we performed the β-NQR measurement of $^{23}$Ne by using the ZnO single crystal. Figure 1 shows the obtained β-NQR spectrum of $^{23}$Ne in the ZnO single crystal. In the figure, a clear β-ray asymmetry change is found at $\nu_y = (eqQ/h) = 1.08(5) \times 10^9$ kHz. From the obtained $\nu_y$ and the $Q$ moment [$Q = 145(13)$ emb],6) the electric field gradient $q$ was determined to be $\nu_y = 31(3) \times 10^{13}$ [V/m²]. Now, we are ready to measure the ground-state electromagnetic moments of neutron-rich Ne isotopes.

![Fig. 1. Beta-NQR spectrum of $^{23}$Ne implanted into the ZnO single crystal. The dashed line shows the least chi-square fitting result with a Gaussian function plus a constant. The horizontal error bars indicate the width of the swept frequency ($\Delta \nu_y = 1.5 \times 10^2$ kHz).](image)

References