Precision measurement of ground-state electric quardrupole moment for neutron-rich ^{21}O

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The anomalous nuclear properties had been experimentally indicated for the neutron-rich ^{23}O isotope, such as the formation of halo structure[1)] and the presence of the new neutron magic number at neutron number[2)] $N = 16$. This originates the interest in the shell evolution in this region of neutron-rich oxygen isotopes. Such information can be directly provided by the knowledge about the nuclear properties of neighboring isotopes, such as ^{21}O.

Previously, we have conducted the measurements of the electromagnetic moments of ^{21}O[3)] and the ground-state magnetic moment has been successfully determined. However, due to RF tank circuit limitations, the obtained spectrum for the quadrupole moment (Q-moment) measurement was insufficient to make firm conclusions and required further study. Since then, the experimental setup was improved and the Q-moment has been successfully measured.

The present experiment was carried out using the RIPS separator at the RIBF facility. A spin-polarized beam of neutron-rich ^{21}O was produced in the projectile fragmentation reaction of a ^{22}Ne beam at 70 MeV/nucleon on a 185-mg/cm^2 Be target. To ensure polarization, the momentum window and emission angle of the secondary fragments were selected to be $p_F = p_0 \times (0.97 \pm 0.03)$ and $\theta_F > 1.5°$, respectively. Here, p_0 is the fragment momentum corresponding to the projectile velocity. The secondary beam of ^{21}O was then purified by the momentum and momentum-loss analyses and delivered to the β-ray detected nuclear magnetic resonance (β-NMR) apparatus installed downstream the beam line. The well-established method of β-NMR[4)] in combination with adiabatic fast passage technique[5)] was applied to measure quadrupole moment.

The obtained nuclear quadrupole resonance (NQR) spectra are shown on Fig. 1. It consists of the two series of measurements. The black circles represent the measurement with ±44 kHz modulation of quadrupole coupling constant $\nu_Q = eqQ/h$, where q, Q and h denote the electric field gradient of the stopper material, the Q-moment and the Planck's constant, respectively. The spectra are plotted with $A_\beta P$ values measured as a function of deviation from the peak frequency ν_Q^{peak}, where $A_\beta P$ is the β-decay asymmetry parameter, and P the ^{21}O nuclear spin polarization. A resonant peak formed by the β rays emitted from ^{21}O stopped at the substitution site of TiO_2 is clearly identified in Fig. 1. Due to the improvement in polarization detection, the signal-to-noise ratio was greatly increased and a less pronounced additional NQR effect was detected at a lower Q-moment region.

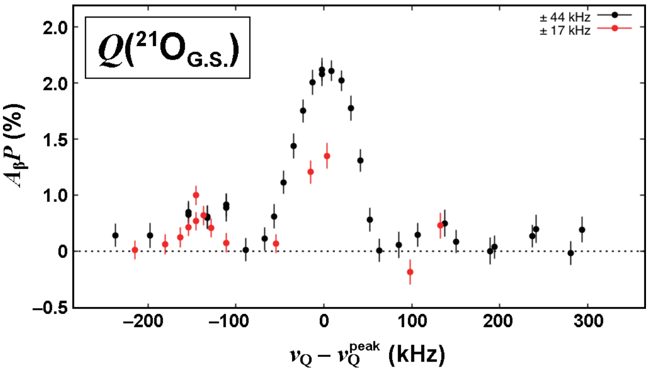

Fig. 1. β-NQR spectra of ^{21}O in TiO_2 single crystal. The figure shows the results of two series of measurements with ν_Q modulation of ±44 kHz (black circles) and ±17 kHz (red circles) are shown.

In order to investigate this minor peak in more detail, a measurement with narrower scan width of ±17 kHz was conducted. The result of this measurement is represented on Fig. 1 by the red solid circles. The centroid position of the small peak is consistent with the previous nuclear quadrupole resonance (NQR) measurement of ^{21}O at RIPS in 2016.[3)] The origin of the additional lower-amplitude peak is under analysis. In overall, the two NQR measurements confirmed the existence of a major peak at higher Q-moment region that could not be detected in 2016 due to several experimental limitations. The Q-moment value of ^{21}O can be then firmly assigned based on the obtained results. The uncertainty assignment based on the peak shape analysis and the discussion of the results in terms of ^{21}O nuclear structure are work-in-progress.

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