Development of the GAGG(Ce) calorimeter for the cluster knockout reaction measurement

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A new project named "ONOKORO" was recently launched to investigate the cluster formation phenomena in nuclei and nuclear matter with cluster knockout reactions.[1)] In this project, we plan to perform systematic measurements for various stable and unstable nuclei at the following accelerator facilities: RIBF, RIKEN, RCNP, Osaka University, and HIMAC at QST. At RCNP, we will measure the knockout reactions from fixed targets of stable nuclei with proton beams at 200–400 MeV. The experimental technique is already established with double-arm high-resolution magnetic spectrometers. At RIBF and HIMAC, the knock-out reactions with inverse kinematics will be measured with stable and unstable heavy-ion beams on liquid or solid hydrogen targets. For this measurement, we have proposed a new detector telescope, named TOGAXSI,[2)] consisting of silicon strip detectors (SSD) and GAGG(Ce) calorimeters. In this paper, we report the results of the performance test of the GAGG(Ce) calorimeters.

We chose the GAGG(Ce) scintillator to measure the kinetic energies of the recoil protons and knockout clusters (100–250 MeV/nucleon) because it has good scintillation properties compared to other standard scintillators such as NaI(Tl) and CsI(Tl). Figure 1 shows a photograph of the GAGG(Ce) crystal with a size of $40 \times 40 \times 120$ mm^3. In the ONOKORO experiments, high counting rates up to 100 kcps are expected; therefore, a good time response is required as well as a good energy resolution. To detect the scintillation photons, we prepared several photo sensors of PMT (R7600U, R11265U-20), APD (S8664-1010) and PD (S3584-08) produced by Hamamatsu. The PMT has a fast time response and a high gain, but low photo efficiency at ~500 nm compared to APD and PD. Because APD and PD have small gains, we newly designed a fast amplifier circuit with a high-speed operational amplifier (Analog Devices, AD8000).

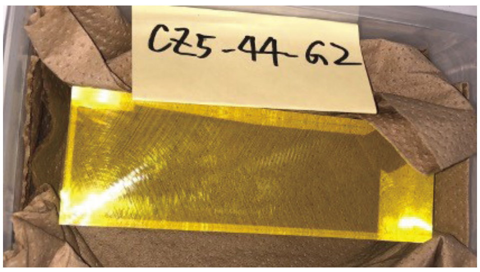

Fig. 1. The GAGG(Ce) crystal ($40 \times 40 \times 120$ mm^3).

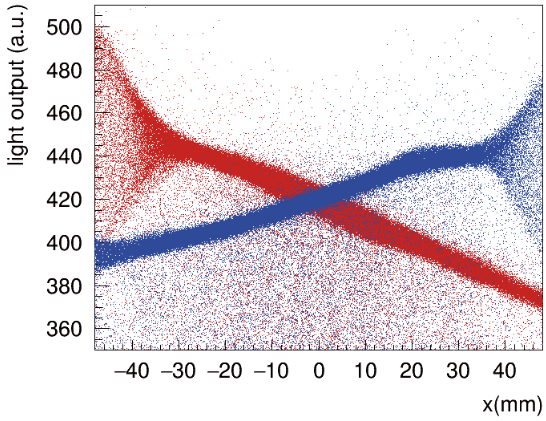

Fig. 2. Position dependence of the light outputs of the right (blue) and left (red) sensors located at $X = \pm 60$ mm.

To check the performance of the GAGG(Ce) calorimeter for high-energy charged particles, we performed a test experiment using p and α beams at 75–230 MeV/nucleon at HIMAC. We tested several detector configurations, but we briefly report the results of one setup: two photo sensors (PMT/APD/PD) were attached on both sides of the crystal, and p and α beams at 75 and 100 MeV/nucleon were impinged on the long side. The energy resolutions are <1% and <0.6% for the 100 MeV/nucleon proton and α beams focused on the center of the crystal, respectively. We also used defocused beams to check the position dependence by tracking the beam trajectories with SSDs. Figure 2 shows the correlation of the light outputs of the left and right sensors versus the horizontal position of the beam (X). On the far side from the sensor, attenuation effects can be clearly seen, but the signals are widely spread where the beam is close to the sensor. This is because the solid angle of the sensor drastically changes depending on the vertical (Y) positions as well as X. We applied a correction of the X and Y position dependences, and finally, a good energy resolution of 0.3–0.6% for 100 MeV/nucleon α beams was obtained in the wide range of the crystal. The result is good enough to achieve a separation energy resolution of ~2 MeV in rms.

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References

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2) T. Uesaka *et al.*, RIBF Construction Proposal, NP2112-SAMURAI72 (2021).