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Measurement of Angular Correlation Changes in Double-Photon Emission Nuclides Using Ultrasound irradiation

Our group has been developing DPECT (Double Photon Emission CT) to enhance nuclear medicine diagnostics using cascade nuclides that emit multiple gamma rays simultaneously. It is possible to detect the local environment around the nuclide by examining the angular correlation of the emitted gamma rays. In this study, we investigated the effect of ultrasound to cascade gamma-ray emission and found that the angle correlation could be changed by inducing a small electric field in 111In aqueous solution by ultrasound irradiation.
Key word Nuclear Medicine, Angular Correlation, Double Photon

1. Introduction
   Our group has been developing DPECT (Double Photon Emission CT), which enhances nuclear medicine diagnosis by using cascade nuclides that emit multiple gamma rays simultaneously [1]. While it can provide highly accurate nuclear medicine diagnosis, it uses a collimator for imaging and the increase in radiation dose and degradation of image quality due to low detection efficiency are important problems. So, it is necessary to develop a method of DPECT imaging without using collimator. In this study, we focused on the angular correlation between two gamma rays emitted from cascading nuclides (Figure 1). The emission angles of multiple gamma rays from a cascade of nuclides are not random, but have a spin-dependent correlation, and this correlation depends on the local environment of the nuclide. By irradiating ultrasound from the outside and measuring the change in the angular correlation that appears due to the interaction with the nuclear spins of 111In, a two-photon coincidence emitter, we explored the possibility of a new imaging method that combines ultrasound and nuclear medicine.
2. experimental method
   As a cascade nuclide, 111InCl3, which is a SPECT tracer, was used as a point source. 8 × 8 GAGG scintillators and 8 × 8 MPPC (Hamamatsu Photonics SiPM) was used as detectors, and a dToT (dynamic time-over-threshold) circuit board was used to read out the time and energy information for all channels simultaneously and independently. The ultrasound is irradiated by a convergent ultrasound instrument with a fixed frequency of 1MHz, and the sound pressure can be adjusted by changing the input voltage value from 0 to 0.2 V. The intensity of the irradiated ultrasound, the intensity of 111In, and the experiment time are shown in Table 1. To obtain sufficient coincidence events, the experiment time was 2 hours each.
3. Analysis method
   For all channels from GAGG scintillator, we extracted the gamma-ray energies of 171 keV and 245 keV from the acquired energy spectra from 111In, and obtained the emission time difference spectra of these two gamma-rays (Figure 3). From this time difference spectrum, the coincidence time windows are set from -50 to 200 [ns], and only the events with time differences within this time window are extracted.
4. Result
   Figures 4 show the results of the experiment. Figure 4 is the result of how the angular distribution changes when ultrasound is irradiated. For the irradiated sound pressure of 0.2V, 0.15V, and 0.1V, the coincidence events around 0 degrees and 180 degrees increased about 5%, while the coincidence events around 90 degrees decreased about 2%. This phenomenon is thought to be by the induction of a small electric field by ultrasonic irradiation to the liquid [2].We derived an index of angular correlation change A_2 G_2 from the ratio of the number of counts in the 90° and 180° directions for events with a time difference of -50˜200 [ns] (time window), and calculated ω_e from this result. The frequency of this change thought to show the quadrupole interaction due to the micro-electric field induced by the

ultrasound. And from this value we also calculated the micro-electric field gradient imparted to the 111In nucleus (Table 2). This value of ω_e and V_z was consistent with the magnitude of the change in the angular distribution of the emission as previous literature focusing on small electric fields [3].

5. Summary
We found that ultrasound irradiation can change the angular correlation of 111In gamma-ray emission. This result is thought to be due to the induction of micro-electric field gradient in the aqueous solution by electroacoustic effect from ultrasonic irradiation.
As future experiments, we plan to conduct one-dimensional positioning experiments using the properties of convergent ultrasound and angular correlation changes.

Reference

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