Systematic study of signature inversion and shape coexistence at high spin states in medium heavy nuclei

-Study of Magnetic Rotation in ^{140,141}Sm-

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Abstract: As a part of the systematic study of signature inversion and shape coexistence at high spin states in medium heavy nuclei, lifetime measurement for the rotational bands in ^{140,141}Sm has been performed using GEMINI-II in JAEA via the ^{80}Se(^{64}Ni,xn)^{141,140}Sm reaction at a beam energy of 235 MeV. Due to a lower melting point of the ^{80}Se target, the beam intensity was limited at ~0.5 pnA, and a total of 70 millions γ-γ coincidence events were accumulated in a machine time of 4 days. We aimed at extracting the lifetimes of the energy levels through lineshape analysis for γ transitions of our interest. The data analysis is in progress.

Keywords: In-beam γ-spectroscopy, magnetic rotational bands, lifetime, lineshape analysis

1. Purpose

Magnetic rotation (MR) phenomenon, observed more than a decade ago, has generated great interests in the nuclear structure community. These regular sequences of M1 transitions show rotation-like bands in almost spherical nuclei [1]. In the contrary to normal deformed (ND) and super-deformed (SD) rotational bands, the dipole MR bands exhibit strong intraband magnetic dipole transitions whereas the crossover E2 transitions are either weak or almost absent. This rotational behavior has been difficult to understand in terms of the rotational model because of the rather small deformation. Frauendorf proposed an explanation for the MR bands in terms of a shears mechanism and interpreted these sequences using the tilted-axis-cranking (TAC) model [2]. A coupling of high-j proton particles (holes) in low (high) Ω orbital and high-j neutron holes (particles) in high Ω orbital leads to a nearly perpendicular coupling of angular momentum vectors. The neutron and proton angular momentum vectors represent the two blades of a shear which close with increasing angular momentum and energy. Consequently, the total angular momentum axis does not coincide with one of the principal axes of the nucleus. The perpendicular coupling of the particle-hole orbitals, each with high j, results in a large transverse component of the magnetic moment vector and creates the enhanced M1 transitions between the shears states. Experimental proof for the shears mechanism are the decreasing B(M1) values with increasing spin and the termination of the bands when the shears are closed. These have been confirmed in many MR bands. In the A=130~140 mass region, magnetic rotations are expected where high-j nucleons are available and the deformation is small. Up to now, MR bands have been found, e.g. in ^{136}Ce, ^{137}Pr, ^{139}Sm, ^{141}Eu. In 2008, we have carried a conventional in-beam γ-spectroscopy experiment in the tandem accelerator laboratory in CIAE in order to search for such magnetic rotation in ^{139}Pm [3]. Positive result from this experiment encourages us to make a lifetime measurement for the so-called M1 bands in ^{140,141}Sm utilizing the advantages of heavier-ion beams and high-efficiency detector system GEMINI-II in JAEA. The lifetime of the energy levels provides strong evidence for the shears mechanism of such magnetic rotation.

2. Methods

The experiments have been performed in the Japan Atomic Energy Agency (JAEA). The ^{80}Se(^{64}Ni,xn)^{140,141}Sm reaction was used to populate the high-spin states of ^{140,141}Sm. The ^{64}Ni beam with 235 MeV and 0.5 pnA intensity was provided by the tandem accelerator in JAEA. The γ-ray detector array GEMINI-II [4] composed of 12~19 Compton suppressed Ge detectors was used. A total of 7.0×10^7 γ-γ coincidence events was accumulated. These coincidence events were sorted into a symmetric and a non-symmetric matrices for off-line analysis. We aimed at extracting the lifetimes of the energy levels through lineshape analysis for some specific γ transitions de-exciting the M1 bands.

3. Results

The experiment was successfully performed in JAEA. However, due to a lower melting point of the ^{80}Se target, the beam intensity was limited at ~0.5 pnA, and a total of 70 millions γ-γ coincidence events were accumulated in a machine time of 4 days. This statistic is lower in comparison to our previous experiments. Further analysis of the experiment data is still in progress.

4. Discussions

Dipole bands in ^{140,141}Sm [5,6] could be associated with a small oblate deformation of the nucleus due to alignment of neutrons. For this shape $h_{11/2}$ proton states with large Ω values and $h_{11/2}$ neutron-hole states with small Ω values contribute to the configurations of the dipole bands. Considering an alignment of the spins of the particle states along the symmetry axis and of the hole states along the rotation axis, angular momenta of 25/2 and 33/2, respectively, are expected for the bandheads. A similar M1 bands in neighboring nucleus ^{141}Eu has been attributed to the shears mechanism through lifetime measurements. Though, the present experiment is still in the process of data analysis, we hope that continuous efforts and accumulation of the experimental data may provide important contribution to clarify the concept of shears mechanism in the A=130~140 mass region.

Acknowledgement: This work was performed under the Common-Use Facility Program of JAEA.

5. References

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