Skyrme-RPA calculation for octupole vibrations of rotating superdeformed nuclei

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The superdeformed (SD) shell structure is significantly different from that of normal deformation. Each major shell at the SD shape consists of about equal numbers of positive- and negative-parity levels. This is a favorable situation for the appearance of negative-parity vibrations. In fact, low-frequency octupole vibrations have been predicted by random phase approximation (RPA) calculations with the Nilsson potential[1)] and discovered in several experiments for SD nuclei in Dy and Hg-Pb regions.

One of the central issues concerning the collective motions of SD nuclei is the octupole instability (appearance of the static shape) depending on angular momentum. Several authors have already demonstrated the importance of the Coriolis force at low-spin band head states of octupole vibrational bands.

Recently, SD bands were discovered in ^{36,40}Ar, ^{40}Ca, and ^{44}Ti. In this mass-number region, we can expect rich experimental information on the collective modes of SD nuclei because the observation of rotational bands starting from the 0^+ state and the linking transition between the SD bands and low-lying normal deformed bands are unique features characterizing the SD states in the region around mass number $A \sim 40$ (for example, see Ref.[2)]).

In this study, we investigate the rotational effect on the ocutpole vibrations of SD states in the $A \sim 40$ region. We have already demonstrated the low-frequency octupole vibrations of the 0^+ SD states through RPA calculations with the Skyrme force (Skyrme-RPA)[3)]. For the excitations from the SD yrast bands, on the other hand, the Skyrme-RPA calculation has not yet been performed owing to computational limitations.

We develop a new framework of the Skyrme-RPA calculation. The single-particle Hamiltonian describing independent-particle motion in the triaxially deformed particle–hole potential that is uniformly rotating with rotational frequency ω_{rot} about the x-axis is adopted; $h' = h - \omega_{rot} j_x$. The Skyrme SkM* interaction is employed for the h. The particle–hole residual interaction is derived from the Skyrme force through the Landau–Migdal approximation:

$$V_{ph}(\mathbf{r},\mathbf{r}') = N_0^{-1}\left[F_0 + F_0'\tau\cdot\tau' + (G_0 + G_0'\tau\cdot\tau')\,\sigma\cdot\sigma'\right]\delta(\mathbf{r}-\mathbf{r}').$$

The single-particle wave functions φ_k and the two-particle wave functions $\Psi_{kk'} = \varphi_k^\dagger \varphi_{k'}$ are represented by the Fourier-series expansion method in order to effectively treat the configurations involving unbound single-particle states.

We show the isoscalar octupole transition strengths for $K^\pi = 0^-$ and 1^- excitations of the triaxial SD state of ^{44}Ti in Figs. 1 and 2. The results with $\omega_{rot} = 0.0$ and 0.6 MeV/$\hbar$ are compared.

In the $K^\pi = 1^-$ case, an octupole instability of the SD yrast states toward a reflection-asymmetric shape (banana-like shape) is suggested to take place at $\omega_{rot} > 0.6$ MeV/$\hbar$ (corresponding to the total angular momentum $I > 5\hbar$) because of the Coriolis effect.

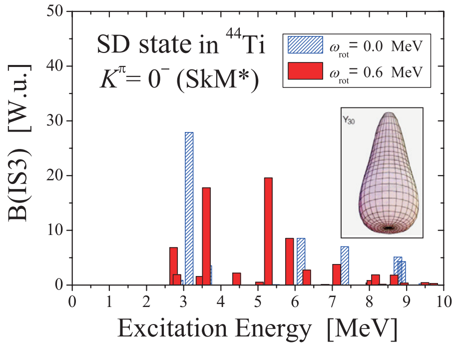

Fig. 1. Isoscalar octupole transition strength for $K^\pi = 0^-$ excitation of the SD state in ^{44}Ti. The results with $\omega_{rot} = 0.0$ and 0.6 MeV/$\hbar$ are compared. The deformation is almost constant at $(\beta_2, \gamma) = (0.58, 9.4°)$ in both cases. $B(IS3)$ is shown in Weisskopf units (W.u.).

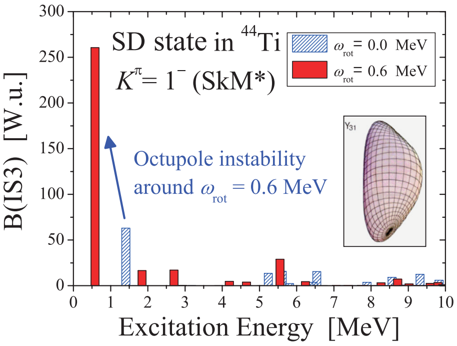

Fig. 2. The same as Fig. 1 but for $K^\pi = 1^-$ excitation.

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