Triaxial projected shell model study of Multi-phonon γ-band in ^{165}Ho nucleus

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Atomic nuclei are among the most fascinating quantum many-body systems that depict a rich variety of shapes and structures [1]. Most of the nuclei are known to have axially-symmetric, dominantly quadrupole, deformed shape in the ground-state. However, there are also regions in the nuclear periodic table, referred to as the transitional regions, where axial-symmetry is broken and a triaxial mean-field description is appropriate to characterize the properties of these nuclei [2, 3]. For the comprehensive understanding of the triaxial nuclei having rich experimental high spin band structures a history of theoretical models have proposed to study these band structures with varying degrees of success. Like The quasiparticle phonon nuclear model (QPNM), the multiphonon method (MPM), the dynamic deformation model (DDM), algebraic models including the extended version of the interacting boson (sdg-IBM) and pseudosymplectic models have also been employed to study the γ-excitation modes and these predict high collectivity for the double-γ vibration. We would also like to add that a considerable effort has been devoted in understanding the γ-excitation mechanism by using the random phase approximation (RPA) approach. The advantage of the triaxial projected shell (TPSM) model is that it describes the deformed single-particle states microscopically as in QPNM, MPM, and DDM, but its total many-body states are exact eigenstates of the angular momentum operator.

Recently, TPSM approach has been generalised to study the γ-vibrational band structures in odd-mass nuclei. It has been demonstrated that TPSM provides an excellent description of the γ-vibrational bands observed in ^{103}Nb, ^{105}Mo [4–6]. In particular, TPSM study provided a theoretical support for the first observation of $\gamma\gamma$-band in an odd-mass nucleus like ^{105}Mo. For the study of odd-neutron system, our model space is spanned by (angular-momentum-projected) one- and three-qp basis, i.e., $\hat{P}^I_{MK}\ a^\dagger_n\,|\,\Phi>$, $\hat{P}^I_{MK}\ a^\dagger_n a^\dagger_{p1} a^\dagger_{p2}\,|\,\Phi>$ and $|\,\Phi>$ represents the triaxially-deformed qp vacuum state. The qp basis chosen in our model space includes the configurations of two-proton quasiparticle states built on the one-quasineutron states. The basis, with one- and three-qp configurations included, has proven adequate to describe the high-spin states in odd-mass systems.

As in the earlier PSM calculations, we use the pairing plus quadrupole-quadrupole Hamiltonian

$$\hat{H} = \hat{H}_0 - \frac{1}{2}\chi\sum_\mu \hat{Q}^\dagger_\mu \hat{Q}_\mu - G_M \hat{P}^\dagger \hat{P} - G_Q \sum_\mu \hat{P}^\dagger_\mu \hat{P}_\mu,$$

Here $\hat{H}_0$ is the spherical single-particle Hamiltonian, which contains a proper spin-orbit force. The interaction strengths are taken as follows : The QQ-force strength χ is adjusted such that the physical quadrupole deformation ϵ is obtained as a result of the self-consistent mean-field HFB calculation.

In the present calculation, we take $G_1 = 20.12$ and $G_2 = 13.13$, which approximately reproduce the observed odd-even mass difference in the studied mass region. This choice of G_M is appropriate for the single-particle space employed in the model, where three major shells are used for each type of nucleons $(4, 5, 6(3, 4, 5)$ for neutrons (protons)). TPSM calculations have performed for ^{165}Ho nucleus with deformation parameter $\epsilon = 0.220$ and $\epsilon' = 0.145$. The axial parameter ϵ is normally chosen from the measured quadrupole moment of the system, wherever available, or

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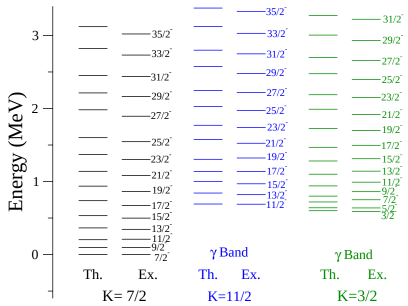

FIG. 1: (Color online) Comparison of experimental and the calculated band energies for ^{165}Ho nucleus. Data taken from [7].

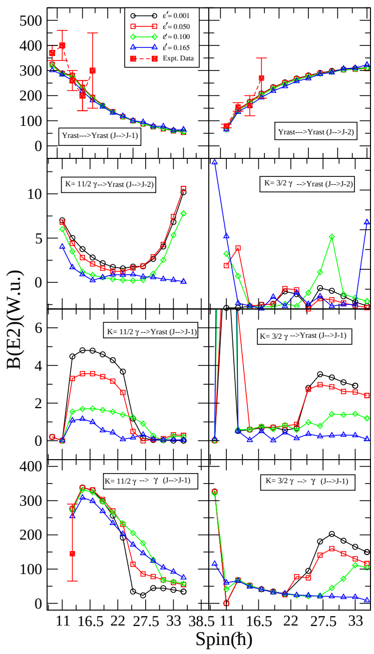

FIG. 2: (Color online) Comparison of experimental and the calculated B(E2) (W.u) for different values of γ for ^{165}Ho nucleus.

the tabulated values using the phenomenological potential models. The value of ϵ' is, preferably, chosen from the minimum of the potential energy surface (PES) of the nucleus, or, the value of ϵ' is chosen in such a manner to reproduce the γ-band head energy. To compare theoretical energies with the experimental data, we plot the experimental and theoretical level energies in Fig. 1 for the yrast-band and ($K^\pi=7/2^-$), ($K^\pi=11/2^-$) and ($K^\pi=3/2^-$) γ-bands. The agreement between the TPSM and the experimental energies for the yrast- and the γ-bands is exceedingly good.

Using the TPSM wave functions and standard $E2$ effective charges ($e_n = 0.5e$ and $e_p = 1.5e$) we have evaluated the inter and intra band transition probabilities along the yrast line and the γ-bands of the studied ^{165}Ho nucleus, see Fig. 2. The overall behavior of the transition probabilities is reproduced quite well by the TPSM approach. The decrease in B(E2)'s for Yrast band from (J→J-1) and increase of B(E2)'s for Yrast band from (J→J-2) is reproduced quit well. Figure 2 also shows the TPSM predictions for B(E2) of Yrast → $K^\pi=11/2^-$ γ-band and Yrast → $K^\pi=3/2^-$ γ-band for both configurations of (J→J-1) and (J→J-2) at $\epsilon' = 0.001, 0.050, 0.100$, and 0.165. It is seen that the best reproduction of experimental data is obtained at the optimum value of $\epsilon' = 0.165$.

In conclusion, the observed band structures in ^{165}Ho have been investigated using the TPSM approach. It has been shown that excited observed bands are, indeed, the γ-bands based on the one-quasiparticle configurations as proposed in the experimental work. Further, the electromagnetic transition probabilities using the TPSM wavefunctions and the standard expressions for the yrast band ($K^\pi=7/2$) are in good agreement with available data.

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