Triaxial projected shell model study of γ-vibrational bands in odd-neutron ^{105}Mo nucleus

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A unified description of nuclear excitations is one of the major research themes in nuclear structure physics. The possible modes of nuclear excitations are of single-particle, vibrational and rotational in character and in many nuclei these three modes coexist. One of the major challenges to nuclear models is to provide a unified description of these excitation modes. There is a long history of phenomenological models that were introduced to study the interplay among the three modes of excitations [1]. On the microscopic front, there are very few models capable of describing the three modes of excitations in a unified manner, in particular, at higher angular momenta. Mass $\simeq$ 110 region depicts some of the most interesting features in the nuclear periodic table. For instance, some nuclei in this region depict quite large deformation with $\beta \simeq 0.45$ and is understood as due to the reinforcing effect of proton and neutron deformed shell gaps at Z=38, 40 and N=60, 62 [2]. Further, in some nuclei in this region, well developed γ- and $\gamma\gamma$- bands have been observed up to quite high angular momenta. For instance, γ- and $\gamma\gamma$- bands have been identified in $^{104-106}$Mo isotopes [3]. In neutron-rich odd-mass $^{103-107}$Mo collective band were investigated to higher spin including yrast bands as well as some side bands built on the single-neutron orbits. Although, yrast bands in this region have been studied using theoretical approach of total routhian surface analysis, but there apppears no systematic investigation of the γ-bands in this mass region [2].

Recently, the multi-quasiparticle TPSM approach has been employed to investigate the high-spin band structures in Er-isotopes and in the mass=130 region [4, 5]. It has been demonstrated in these studies that γ-bands are built on each intrinsic configuration of the mean-filed potential and generalizes the well known surface γ-vibration in deformed nuclei built on the ground-state configuration[3]. These recent developments in TPSM approach have greatly enhanced the model predictability and may provide new insights into the observed bands with unknown structures. As a matter of fact, by using this approach, the interpretation of complicated band structures has reached a quantitative level [6]. In the present work, we have further generalized the TPSM approach to study the γ-vibration in odd-mass nuclei. A preliminary application of this new development for the odd-proton system, ^{103}Nb, has already been reported [7]. We have developed TPSM model to both odd-proton and odd-neutron systems and would like to investigate the observed γ-vibrational band structures in the mass $\simeq$ 110 region. In this mass region, γ-bands have been observed in even-even $^{102-108}$Mo and $^{108-112}$Ru nuclei, odd-neutron $^{103-107}$Mo, and odd-proton ^{103}Nb. Further, this is the only region where γ- and $\gamma\gamma$-bands have been identified in odd-mass ^{105}Mo and ^{103}Nb nuclei [8].

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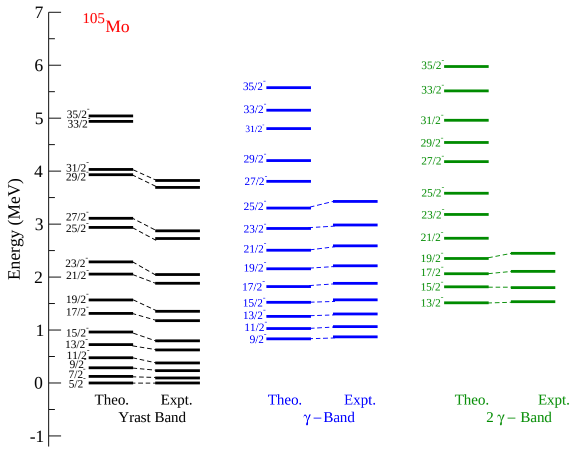

FIG. 1: The calculated yrast-, γ- and $\gamma\gamma$-bands of ^{105}Mo are compared with the corresponding experimental data [9].

For the study of odd-neutron system, our model space is spanned by the following angular-momentum-projected one- and three-qp basis $\{\hat{P}^{I}_{MK}\ a^{\dagger}_{n}\Phi,\ \hat{P}^{I}_{MK}\ a^{\dagger}_{n}a^{\dagger}_{p1}a^{\dagger}_{p2}\Phi\}$, The qp basis chosen is adequate to describe high-spin states up to $I \sim 20\hbar$ for even-even system, $I \sim 35/2\hbar$ for even-odd and odd-even nuclei considered in this work. In the present analysis we shall, therefore, restrict our discussion to this spin regime. For the self-conjugate vacuum or 0-qp state, $\kappa = 0$ and, therefore, it follows from the above equation that only $K =$ even values are permitted for this state. For 2-qp states, $a^{\dagger}a^{\dagger}|\Phi\rangle$, the possible values for K-quantum number are both even and odd, depending on the structure of the qp state. For example, for a 2-qp state formed from the combination of the normal and the time-reversed states $\kappa = 0$, only $K =$ even values are permitted. For the combination of the two normal states, $\kappa = 1$ and only $K =$ odd states are permitted. For one-qp state, $\kappa = 1/2$ $(-1/2)$, and the possible values of K are therefore $1/2, 5/2, 9/2, \ldots$ $(3/2, 7/2, 11/2, \ldots$.

In the present calculation the triaxial Nilsson mean-field Hamiltonian, which can is obtained by using the Hartree-Fock-Bogoliubov (HFB) approximation, employed is given by

$$\hat{H}_N = \hat{H}_0 - \frac{2}{3}\hbar\omega\left\{\epsilon\hat{Q}_0 + \epsilon'\frac{\hat{Q}_{+2}+\hat{Q}_{-2}}{\sqrt{2}}\right\}. \tag{1}$$

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. The monopole pairing strength G_M is of the standard form $G_M = (20.12 \mp 13.13\frac{N-Z}{A})\frac{1}{A}$ (MeV), where $-(+)$ is neutron (proton). The configuration space used is ($\pi = 3, 4, 5$ for protons and $\nu = 4, 5, 6$ for neutrons). The TPSM study has been performed for odd-neutron ^{105}Mo nucleus. The axial and non-axial deformations used in the present work are 0.300 and 0.110 respectively . Non-axial deformations have been ascertained from the PES calculations, wherever a minimum was obtained, otherwise fitted to reproduce the γ-band head energy.

The TPSM results for ^{105}Mo, Fig. 1, show a very nice agreement with the agreement with the experimental data for the yrast and as well for γ- and $\gamma\gamma$-bands. This is the only odd-neutron system in which both γ- and $\gamma\gamma$-bands have been observed upto high spin [9].

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