Multi-phonon γ-vibrational bands in ^{108}Mo nucleus

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Introduction

In the study of nuclear structure, the multi-phonon γ-vibrational bands are very important subjects. The multiphonon excitations in deformed nuclei can provide valuable information of the nuclear vibrational collectivity. However, to experimentally observe the multi-phonon bands is difficult. So far, considerable efforts have been made to search for the multi-phonon bands i.e., γ- and $\gamma\gamma$-bands in even-even and odd-mass nuclei. If the K is a band-head quantum number of a quasiparticle band, for the γ-states, there exist two states with K^{+2} and K^{-2}. For the $\gamma\gamma$-states, there may exist three states with K^{-4}, K and K^{+4}. It is also expected that the K^{+2} for γ-state and the K^{+4} for $\gamma\gamma$-state may be easy to be observed, and others may be difficult. Several low lying $K^{\pi} = 4^{+}$ two-phonon $\gamma\gamma$-bands have been identified, such as in ^{166,168}Er, ^{164}Dy and ^{232}Th. In A $\sim$ 110 neutron-rich nuclear region, the one-phonon γ- and $\gamma\gamma$-bands have been observed in even-even ^{104,106,108}Mo and ^{108,110,112}Ru [1]. For the odd-A nuclei, the study of the $\gamma\gamma$-bands is scarce. Recently, in A $\sim$ 110 neutron-rich region, a first $\gamma\gamma$-band in an odd-A nucleus has been observed in ^{105}Mo, ^{107}Tc and ^{103}Nb nuclei.

On the microscopic front, however, there are very few models capable of describing the multi-phonon excitations in a unified manner, in particular, at higher angular momenta. Nuclei around A $\sim$ 110 exhibit some of the most interesting features in the nuclear periodic table. For instance, some nuclei in this region depict quite large deformation with $\beta \sim 0.45$ and is understood as due to the reinforcing effect of proton and neutron deformed shell gaps at Z=38, 40 and N=60, 62 [5] Since, in some nuclei in this region, well developed γ- and $\gamma\gamma$-bands have been observed up to quite high angular momenta. But although, yrast bands in this region have been studied using theoretical approach of total routhian surface analysis [5], but there appears no systematic investigation of the $\gamma-$bands in this mass region.

The multi-quasiparticle TPSM approach has been employed to investigate the high-spin band structures in Er-isotopes and in the mass $\sim$ 130 region [6]. It has been demonstrated in these studies that $\gamma-$bands are built on each intrinsic configuration of the mean-field potential and generalizes the well known surface γ-vibration in deformed nuclei built on the ground-state configuration. Recently, multi-quasiparticle triaxial projected shell model (TPSM) approach has been developed and it has been shown to provide a coherent and accurate description of yrast-, γ- and $\gamma\gamma$-bands in transitional nuclei [7] Quite recently, we have further generalized the TPSM approach to study the γ-vibration in odd-proton nuclei and a preliminary application of this new development for ^{103}Nb has already been reported [8].

TPSM Results

For the even-even system, the TPSM basis are composed of 0-qp vacuum, two-proton, two-neutron and the four-quasiparticle con-

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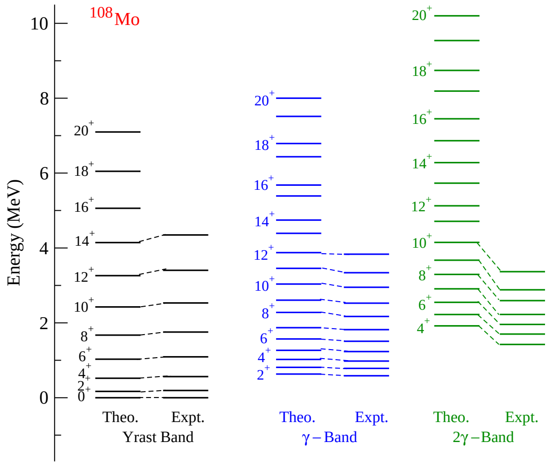

FIG. 1: (Color online) Comparison of experimental and the calculated band energies for ^{108}Mo. (Data is taken from ref. [1]).

figurations. As in the PSM calculations, we use the pairing plus quadrupole-quadrupole Hamiltonian [9].

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

The corresponding triaxial Nilsson mean-field Hamiltonian, which can is obtained by using the Hartree-Fock-Bogoliubov (HFB) approximation, is given by

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

where $\hat{H}_0$ is the spherical single-particle shell model Hamiltonian, which contains the spin-orbit force. The second, third and fourth terms in Eq. (1) represent quadrupole-quadrupole, monopole-pairing, and quadrupole-pairing interactions, respectively.

The TPSM band structures obtained after band mixing are compared with the known experimental data for the even-even ^{108}Mo nucleus in Fig. 1. The experimental data for ^{108}Mo is quite rich with both γ- and $\gamma\gamma$- bands known up to quite high angular-momenta. It is quite evident from the comparison that TPSM reproduces, yrast-, γ- and $\gamma\gamma$- bands surprisingly well. However, there appears a discrepancy between the theory and the experimental band head energies for the $\gamma\gamma$-band. This problem has also been noted in the TPSM study of ^{103}Nb [8].

In the present work the study of the band structures observed in neutron-rich ^{108}Mo nucleus has been performed using the recently developed multi-quasiparticle TPSM approach. The advantage of the TPSM approach is that it provides a unified description of the collective and the quasiparticle excitation modes. In this mass region, rich band structures have been observed and this is one of the few regions where γ- and $\gamma\gamma$-bands have been observed up to quite high-spin. It has been demonstrated that, in general, TPSM results are in good agreement with the available experimental data for the energies. However, there appears to be a problem to reproduce the band head of the $\gamma\gamma$-band for studied nucleus and this problem was also noted in our earlier investigation for ^{103}Nb [8]. At this stage, there is no simple explanation for this discrepancy and more investigations are needed to understand it.

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