Systematic study of vibrational mode on dynamic moment of inertia in superdeformed nuclei in Hg isotopes

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Introduction

The superdeformation (SD) phenomenon is considered as an important tool to study the nuclei at an extreme deformation. The superdeformed bands are long and regular cascades which are connected by electric quadruple E2 transitions and deviated from spherical shape to an ellipsoidal with an axis ratio around 2:1 [1]. The similar characteristics of bands are observed in A ~190 mass region in Hg isotopes having an average dynamic moment of inertia $J^{(2)}$ around 110 $\hbar^2$MeV^{-1} and an axis ratio of ellipsoidal around 1.65:1 [1]. The variation of $J^{(2)}$ with rotational frequency in SD bands in Hg show rise with increasing rotational frequency. There are two main reasons which justified above conclusion: reduction in pairing correlations and combined alignment of high N = 6 quasi-protons of $j_{13/2}$ intruder orbital and N = 7 quasi-neutrons of $i_{15/2}$ intruder orbital in the presence of pairing [2-4]. The dynamic moment of inertia $J^{(2)}$ not only influenced by pairing correlations and combined alignment of high N intruder orbitals but also by vibrational mode at high spins on SD bands. In this manuscript, we have studied the variation of vibrational mode on $J^{(2)}$ in SD bands in Hg isotopes by employing Semi-Classical Vibration Distortion Model [5]. The analysis of vibrational mode on $J^{(2)}$ in A ~150 mass region has been already executed by S. Roy [5] and similar analysis has been done in lower mass region in SD bands in Zn [6].

Brief Review of model and Methodology

We have employed the semi-classical vibration distortion model (VDM) to study the impact of vibrational mode on dynamic moment of inertia in SD bands in Hg. The model studies the extent to what rigid rotors are deviated from ideal rotor behaviour and also explain the influence of vibration mode on SD bands at high spin. The energy expression of ground state for VDM model can be written as

$$E = (B_V - D_V I(I+1))(I(I+1)). \qquad (1)$$

Here, B_V, (vibrational frequency-dependent moment of inertia) and D_V, (centrifugal distortion factor) are two fitting parameters which are obtained by least square fitting of experimental gamma transition energies E_γ^{expt} reported from chart of nuclides available at nndc website [7-8] and I is the spin.

A. Dynamic moment of inertia

The following expression is used to calculate experimental dynamic moment of inertia using experimental gamma transition energies E_γ^{expt} is

$$J^{(2)} = \frac{4000}{E\gamma(I) - E\gamma(I-2)}. \qquad (2)$$

Using the energy expression Eq. (1), the moment of inertia can be obtained, which shows dependence on vibrational and rotational modes. Therefore $J^{(2)}$ in terms of vibration dependence is written as\

$$J^{(2)} = J_c^{(2)} \pm J_{vib}^{(2)}\left(1 - \frac{\omega}{\omega_{max}}\right)^2. \qquad (3)$$

Here, $J_c^{(2)}$ is constant dynamic moment of inertia and $J_{vib}^{(2)}$ is vibration dependent dynamic moment of inertia, which are two fitting parameters, obtained by least square fitting of experimental dynamic moment of inertia obtained using Eq. (2). The rotational frequency $\hbar\omega$ is obtained by using the following expression

$$\hbar\omega = \frac{E_\gamma(I) + E_\gamma(I-2)}{4000}. \qquad (4)$$

The ω_{max} is the maximum value of frequency acquired by SD bands in respective Hg isotopes. The $J_{vib}^{(2)}$ depends on ω, i.e. they show non-linear relation with one-another. At $\omega = \omega_{max}$, the $J_{vib}^{(2)}$ approaches to zero,

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which signifies there is minimum deviation from ideal rotor behaviour. It is also seen from Eq. (3) that $J_c^{(2)}$ and $J_{vib}^{(2)}$ can couple positively or negatively depending upon the direction of vibration in the plane of rotation.

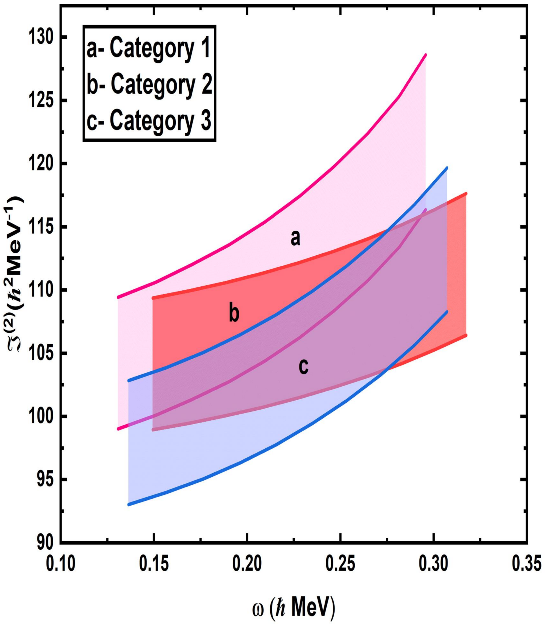

Fig.1 The $J^{(2)}$ vs. $\hbar\omega$ for three categories based on the value of this ratio $J_c^{(2)}/J_{vib}^{(2)}$, category 1 ($J_c^{(2)}/J_{vib}^{(2)}$) ~ 1.5 (pink curve), category 2 ($J_c^{(2)}/J_{vib}^{(2)}$) ~ 4.5 (orange curve), and category 3 ($J_c^{(2)}/J_{vib}^{(2)}$) ~ 10 (blue curve).

Results and Discussion

We have studied the effect of vibrations on dynamic moment of inertia for SD bands in Hg isotopes. For this, we have categorized SD bands in Hg isotopes in three different categories on the basis of this ratio $J_c^{(2)}/J_{vib}^{(2)}$ (ratio of categories: 1.5, 4.5, and 10 respectively). In all three categories, the dynamic moment of inertia found to rising with rotational frequency as expected. At lower frequency range, all three categories seem to partially overlapping with one-another because their average value of dynamic moment of inertia is around 110 $\hbar^2$MeV^{-1} and also in all categories, the $J^{(2)}$ rises with rotational frequency along increasing spin with different extent. As they are partially overlapping, which signifies they have different band moments of inertia. Whereas, at higher frequency range, the $J^{(2)}$ of every category does not separate distinctly as observed in A ~ 150 mass region [5]. This is because all the SD bands in A ~ 190 mass region except ^{192}Hg, show regular behaviour between dynamic moment of inertia and rotational frequency i.e. the dynamic moment of inertia rises with rise in rotational frequency but not in A ~ 150 mass region. There is some distinct feature observed in A ~ 190 mass region but not in A ~ 150 mass region is that SD bands in A ~ 190 mass region show band crossing, a structural change which is due to small constant spacing between gamma transition levels. The Fig. 1 , where all three categories show different trend for moment of inertia found with rotational frequency is due to crossing of levels of intruder orbitals.

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