Empirical evidence of super-rigid structure in superdeformed bands of $A \sim 190$ mass region

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Introduction

High spin phenomenon of superdeformation was anticipated many years ago to explain the fission isomers observed in the actinide nuclei [1]. Many surprising properties of SD nuclei were observed, such as the constant energy spacing between the transitions, the lack of the transition linking the yrast SD band to the normal deformed (ND) states, identical bands [2, 3] etc. The nucleon-configuration assignment of the SD bands are based on the systematic behaviour of properties like the dynamic ($\Im^{(2)}$) moment of inertia (MoI) and the transition quadrupole moments. The kinematic ($\Im^{(1)}$) and dynamic MoI ($\Im^{(2)}$) are two types of MoI explored in the SD nuclei. Since calculation of $\Im^{(1)}$ requires the knowledge of spins, $\Im^{(2)}$ is frequently studied in SD states. A smooth rise of $\Im^{(2)}$ with increasing rotational frequency ($\hbar\omega$) is observed in the $A \sim 190$ mass region which is the characteristics feature of the SD bands in this mass region. The resemblance of the yrast SD band in ^{192}Hg and ^{194}Pb nuclei suggest that the additional protons does not change the core properties of the SD bands and it was anticipated that the odd-A *Pb* isotopes might have same properties to their *Hg* isotones. However, an appealing feature of odd-A isotopes in the *Pb* is the observation of $\Im^{(2)}$ which remains nearly constant with the increasing rotational frequency (known as "flat" SD bands). Apart from *Pb* nuclei, flat SD bands are also observed in the ^{192}Tl.

Formalism

A shape fluctuation model (SF model) [4] provided a good measure to calculate the variation of the intrinsic shape in the ground-state band. The energy expression of the SF model is given as

$$\begin{aligned} E(I) &= E_0 + E^{'}\phi^{'}I + (B_0 + \phi^{'}B^{'})I(I+1), \\ &= B_0 I(I+1) + E^{'}\phi^{'}I \\ &+ B_0 + \phi^{'}B^{'}I^2(I+1). \end{aligned} \tag{1}$$

where E and B are the Hartree-Fock energy and inverse of the twice of the moment of inertia (MoI), respectively. In Eq. (1), the first term is the energy due to the rotation of the un-fluctuated core, called rotational energy (E_{ROT}). The second and third term is referred to the shape fluctuation energy (E_{SF}).

Results and Discussion

In the present paper, the flat SD bands of the $A \sim 190$ mass region in the *Tl* and *Pb* isotopes are systematically explored. Using the accurate band-head spins and the intraband $\gamma-$transition energies [5] of SD bands in *Tl* and *Pb* isotopes and employing the BFM; we have calculated the fitting parameters of SF model. We have split the intraband-γ transition energies of the SD bands in the *Tl* and *Pb* isotopes into the rotational energy (E_{ROT}) and shape fluctuation energy (E_{SF}) and its variation with the increasing rotational frequency is explored.

The analysis of E_{SF} of the SD bands in *Tl* and *Pb* isotopes reveals that for all the SD bands, the E_{SF} monotonically decreases with the increasing $\hbar\omega$ (Fig. 1). Also, the E_{SF} of all the SD bands have a high negative values throughout the rotational frequency, except

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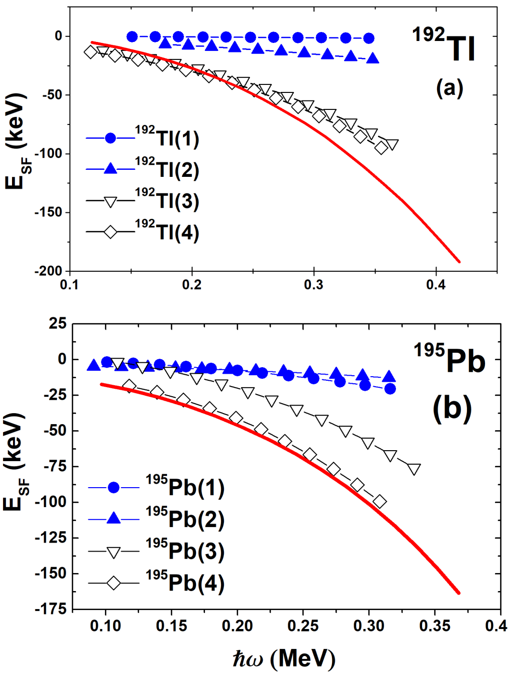

FIG. 1: The variation of the shape fluctuation energy (E_{SF}) for SD bands in the (a) Tl and (b) Pb isotopes.

for the $^{192}Tl(1,2)$, $^{193}Pb(1,2,9)$, $^{195}Pb(1,2)$ and $^{197}Pb(1-4)$. The negative sign in the E_{SF} represents the de-excitation of the core while undergoing fluctuations [4]. The fascinating feature of the SD bands $^{192}Tl(1,2)$, $^{193}Pb(1,2,9)$, $^{195}Pb(1,2)$ and $^{197}Pb(1-4)$ is that all these SD bands have nearly constant variation of dynamic MoI $\Im^{(2)}$ with the increasing rotational frequency and are known as the "flat" SD bands of the $A \sim 190$ mass region [6–11]. However, the yrast SD bands $^{192}Hg(1)$ and $^{196}Pb(1)$ have pronounced increase in the $\Im^{(2)}$ with increasing $\hbar\omega$, which is the characteristics property of the SD bands in the $A \sim 190$ mass region. For SD bands $^{192}Tl(1,2)$, the Pauli-blocking for quasi-neutron and proton was proposed to be responsible [6]. However, this cannot be invoked as a valid explanation for the flat bands of the odd-A Pb isotopes. The very small contribution of the E_{SF} to the total intraband $\gamma-$trasitions reveals that these particular SD bands are insensitive to the shape variation with the increasing $\hbar\omega$.

Conclusion

A systematic study of 45 SD bands in the Tl and Pb isotopes is made using the shape fluctuation model. We observe two trends in the SD bands of the Tl and Pb isotopes: (**I**) SD bands which follow the E_{ROT} and E_{SF} curve of the yrast SD bands ^{192}Hg and ^{196}Pb and have a pronounced increases in the dynamic MoI; (**II**) The SD bands which does not follow the E_{ROT} and E_{SF} curve of the yrast SD bands ^{192}Hg and ^{196}Pb and have nearly constant dynamic MoI . The E_{SF} of these curve reveal that they have negligible contribution to the total intraband $\gamma-$transition energies and maximum contribution is from the rotational energy term. These observations lead us to conclude that SD bands in the classification (**II**) have higher rigidity/deformation than the other SD bands within the same isotope.

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