Spin determination and role of pairing correlations in the SD bands of Hg isotopes

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Introduction

Since the discovery of first high-spin superdeformed (SD) band in ^{152}Dy by Twin *et al.* [1], many SD bands have been studied considerably in $A \sim 190$, 150, 130 and 80 mass regions. With the advancement in the γ-ray detectors, rich variety of data on SD bands is provided which mainly consists of the intraband γ-transition energies. One of the most crucial challenges in the study of superdeformation is the accurate determination of spins, parities and excitation energies of SD bands. The unavailability of discrete γ-transitions, directly linking SD states to normal deformed states makes the spin assignment of SD bands tedious. The availability of band-head spins is vital for understanding the behavior of SD bands. The moment of inertia (MoI) also proves to be a crucial quantity to study the SD rotational bands. Two types of MoI are available viz. kinematic MoI ($\Im^{(1)}$) and dynamic MoI ($\Im^{(2)}$). The spin independence of $\Im^{(2)}$ makes it the most efficient parameter to explore the SD bands. A characteristic feature of the SD bands near $A \sim 190$ region is the smooth and large increase of the dynamic MoI $\Im^{(2)}$ with rotational frequency $\hbar\omega$. The SD bands near $A \sim 190$ and 130 region display pronounced variations in $\Im^{(2)}$. The smooth rise in $\Im^{(2)}$ for SD bands in $A \sim 190$ region was attributed to the gradual alignment of higher-N orbitals in the presence of pairing correlations [2]. Dadwal and Mittal investigated the identical SD bands in $A \sim 190$ region and the role of pairing correlations was studied [3]. Recently, the flat SD bands in the $A \sim 190$ were investigated and the unusual behavior of $\Im^{(2)}$ was explored [4]. Many theoretical models are available to deduce the reliable spins of the SD bands. In the present analysis, we have deduced the band-head spins of the SD bands in Hg isotopes using the exponential model with pairing attenuation.

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Formulism

The exponential model with pairing attenuation was given by Sood and Jain [5] based on the considerations of single particle level densities. Moretto [6] identified the dependence of pairing gap on the angular momentum I as

$$\triangle(I) = \triangle_0 \left(1 - \frac{I}{I_c}\right)^{1/\nu}. \quad (1)$$

Sood and Jain [5] included the explicit spin dependence of pairing gap in addition to the the exponential dependence of moment of inertia on pairing gap and obtained the rotational energy expression as

$$E(I) = \frac{\hbar^2}{2\Im_{(Expo)}} I(I+1) e^{\left[\triangle_0 \left(1 - \frac{I}{I_c}\right)^{1/2}\right]}, \quad (2)$$

where $\Im_{(Expo)}$ and $\triangle_0$ are the parameters and I_c is adopted to be the value where the moment of inertia achieves a maximum value.

$$E_\gamma = E(I) - E(I-2). \quad (3)$$

The γ-ray transition energy E_γ obtained from the exponential model can be expressed using Eq. 2 and Eq. 3, in the following form

$$E_\gamma = \frac{\hbar^2}{2\Im_{(Expo)}} \times (I(I+1)e^{\triangle_0\sqrt{1-\frac{I}{I_c}}} - (I-2)(I-1)e^{\triangle_0\sqrt{1-\frac{(I-2)}{I_c}}}) \quad (4)$$

The band-head moment of inertia ($\Im_0$) are calculated using

$$\frac{2\Im_0}{\hbar^2} = \frac{2\Im_{(Expo)}}{\hbar^2} e^{(-\triangle_0)}. \quad (5)$$

Results and Discussion

The observed transition energies [7, 8] of the SD bands in the Hg isotopes have been fitted to the exponential model. The calculated and experimental transition energies agree extremely well whenever the correct band-head spin is assigned and the root-mean-square deviation is found to be minimum. By using the assigned band-head spins and the intraband γ-transitions, the corresponding fitting parameters viz. the band-head MoI ($\Im_0$) and the pairing gap parameter ($\triangle_0$) are calculated. The fitting parameters along with the deduced spins using the exponential model have been listed in Table I.

We observe that the band-head spins deduced using the exponential model agree well with those listed in Refs. [7, 9] except for $^{191}Hg(1)$, $^{193}Hg(5,6)$ and $^{195}Hg(3)$. The nearly identical intraband γ-transition energies obtained for the pairs $\{^{191}Hg(2)$, $^{193}Hg(2)\}$ and $\{^{191}Hg(3)$, $^{193}Hg(3)\}$ proves that they are identical SD band pairs. The $\Im^{(2)}$ are calculated after firmly assigning the band-head spins and its variation with respect to the rotational frequencies ($\hbar\omega$) is studied, and a comparison with the experiment is made.

Conclusion

In the present analysis, by using the exponential model with pairing attenuation, the band-head spins have been assigned for the SD bands in Hg isotopes and the variation of $\Im^{(2)}$ with the rotational frequencies has been investigated. The exponential model proves to be a powerful method to deduce the band-head spins and to study the general behavior of SD bands in Hg isotopes.

TABLE I: The calculated band-head spins and the corresponding fitting parameters for the SD bands in Hg isotopes using the exponential model.

		Ref. [7]	Exponential model		
SD Band	E_γ^{exp} (keV)	I_0 ($\hbar$)	I_0 ($\hbar$)	$\Im_0$ ($\hbar^2 MeV^{-1}$)	$\triangle_0$
$^{191}Hg(1)$	310.9	15.5	12.5	86.43	0.37
$^{191}Hg(2)$	252.4	10.5	10.5	91.76	0.30
$^{191}Hg(3)$	272.0	11.5	11.5	91.42	0.34
$^{191}Hg(4)$	280.9	12.5	10.5	81.90	0.39
$^{192}Hg(1)$	214.4	8	8	85.98	0.43
$^{192}Hg(2)$	241.2	10	10	90.59	0.43
$^{193}Hg(1)$	233.2	9.5	9.5	90.33	0.41
$^{193}Hg(2)$	254.0	10.5	10.5	91.28	0.31
$^{193}Hg(3)$	233.5	9.5	9.5	90.89	0.34
$^{193}Hg(4)$	254.0	10.5	10.5	90.98	0.34
$^{193}Hg(5)$	291.0	13.5	11.5	87.00	0.36
$^{193}Hg(6)$	240.5	10.5	9.5	89.42	0.24
$^{194}Hg(2)$	200.8	8	8	91.31	0.34
$^{195}Hg(1)$	294.0	12.5	12.5	90.38	0.40
$^{195}Hg(2)$	273.9	11.5	11.5	90.66	0.39
$^{195}Hg(3)$	244.0	10.5	9.5	87.26	0.36
$^{195}Hg(4)$	341.9	15.5	15.5	95.53	0.24

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