Level spin for superdeformed ^{195}Hg nucleus

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Introduction

Superdeformation was first discovered in ^{152}Dy [1], since then many superdeformed (SD) bands were observed in $A \sim 190, 150, 130$ and 80 mass region. Nowadays a rich variety of experimental data is available on SD bands. However, experimental data on superdeformation only consist of intraband energies because of unavailability of linking transition to normal deformed states. Superdeformation spectroscopy provided us with much information regarding the behaviour of moment of inertia in SD nuclei. Superdeformation in $A \sim 190$ mass region is of particular interest because vast majority of SD bands in this mass region show similar behaviour of dynamic moment of inertia ($\Im^{(2)}$) with rotational frequency ($\hbar\omega$). This is accounted for the gradual alignment of pairs of nucleons occupying high-N intruder orbitals [2, 3] in the presence of pairing correlations. Spin assignment of most of the SD bands has an uncertainty of $\approx 1-2\ \hbar$. Level spin determination of SD states is crucial of understanding the physics behind them. Features like small axial asymmetry, very large quadrupole deformation and super-rigidity makes SD bands a perfect candidate to test various rotational energy formulae. Currently many theoretical models like Bohr-Mottelson's $I(I+1)$ expansion [4], Harris ω^2 expansion [5], ab expression [6], variable moment of inertia model [7] are available which provide a reliable way of spin assignment. In present approach, the spins of ^{195}Hg superdeformed bands are determined using least-squares fit of dynamic moment of inertia in Harris three parameter ω^2 expansion. Dynamic moment of inertia and rotational frequency are not directly measured quantities, hence they are only estimated using experimental transition energies.

Rotational Formulae

Harris [5] represent that the nuclear rotation energy E can be expanded in even power series of rotational frequency ω rather than $I(I+1)$.

$$E(\omega) = \alpha\omega^2 + \beta\omega^4 + \gamma\omega^6 + \delta\omega^8 + ... \quad (1)$$

here we have restricted ourself to only three parameters. Hence we can write

$$E(\omega) = \alpha\omega^2 + \beta\omega^4 + \gamma\omega^6 \quad (2)$$

using relation between energy E and spin I

$$\frac{dE}{d\omega} = \frac{dE}{dI}\frac{dI}{d\omega} = \hbar\omega\Im^2 \quad (3)$$

hence the dynamic moment of inertia $\Im^{(2)}$ takes the form

$$\Im^{(2)} = 2\alpha + 4\beta\omega^2 + 6\gamma\omega^4(\hbar^2 MeV^{-1}) \quad (4)$$

The Eq.(4) can be rewritten as

$$\Im^{(2)} = A + B\omega^2 + C\omega^4 \quad (5)$$

since $\Im^{(2)} \approx \hbar\frac{dI}{d\omega}$, Hence using Eq.(5) spin can be obtained by integrating $\Im^{(2)}$ with respect to ω.

$$I = A\omega + (B/3)\omega^3 + (C/5)\omega^5 + i_0 \quad (6)$$

where i_0 is the constant of integration. It is known as aligned spin which results from the alignment of high-j particles. For odd-A nuclei, i_0 can take either zero or half value in 190 mass region.
Dynamic moment of inertia and rotational frequency (MeV) can be estimated from following relations, respectively [8];

$$\Im^{(2)}(I) = 4126/[E_\gamma(I+2) - E_\gamma(I)]$$

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and

$$\hbar\omega(I) = [E_\gamma(I) + E_\gamma(I+2)]/4126 \quad (7)$$

where $E_\gamma(I)$ is energy difference between $(I+2)^{th}$ and $(I)^{th}$ level.

Results and Discussion

Observed transition energies [9] of $^{195}Hg[1,2,3,4]$ are used to obtain dynamic moment of inertia using expression in Eq.(7). Here $1, 2, 3$ and 4 in parenthesis represent band 1, band 2, band 3 and band 4, respectively. However, tentative transitions have been ignored in the discussion. Harris expansion coefficients α, β and γ are obtained by least-squares fitting of proposed dynamic moment of inertia in Eq.(5). Using such expansion coefficients, level spin of SD rotational bands is calculated from Eq.(6). Bandhead spins calculated using different

TABLE I: Harris expansion coefficient (α, β, γ) obtained using least-squares fitting. E_γ represents lowest observed transition and is given in keV. I_c, I_0 corresponds to calculated and established bandhead spin respectively. Comparison with other theoretical work and experimental data is also presented.

SD band	E_γ	$I_c(\hbar)$	$I_0(\hbar)$	Ref.[9]	Ref.[10]
$^{195}Hg[1]^a$	333.9	12.37	12.5	12.5	17.5
$^{195}Hg[2]^b$	273.9	11.46	11.5	11.5	13.5
$^{195}Hg[3]^c$	284.5	11.96	12.0	10.5	14.5
$^{195}Hg[4]^d$	341.9	15.42	15.5	15.5	17.5

$^a\alpha = 45.371\ \hbar^2MeV^{-1}$, $\beta = 128.55\ \hbar^2MeV^{-3}$, $\gamma = -189.91\hbar^2MeV^{-5}$.

$^b\alpha = 45.53\ \hbar^2MeV^{-1}$, $\beta = 128.04\ \hbar^2MeV^{-3}$, $\gamma = -182.52\ \hbar^2MeV^{-5}$.

$^c\alpha = 55.01\ \hbar^2MeV^{-1}$, $\beta = -79.40\ \hbar^2MeV^{-3}$, $\gamma = 613.69\ \hbar^2MeV^{-5}$.

$^d\alpha = 48.24\ \hbar^2MeV^{-1}$, $\beta = 74.71\ \hbar^2MeV^{-3}$, $\gamma = -103.76\ \hbar^2MeV^{-5}$.

fitting parameters are given in Table I. The results obtained from the Harris three parameter formula agrees well with experimental data except in $^{195}Hg[3]$ where predicted value is 10.5 $\hbar$. Since transition energies of band 1 lies very close to midpoint energies of consecutive transitions of band 2, it was proposed [11] that they could be signature partner bands. The bandhead spin of $^{195}Hg[1]$ comes out to be 1 $\hbar$ higher than $^{195}Hg[2]$ which is consistent with the observation that these two are signature partner bands.

Conclusion

Using three expansion coefficients in Harris formula bandhead spin of ^{195}Hg SD band is assigned. The bandhead spin agrees well with experimental data.

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