$\Delta I = 4$ bifurcation in superdeformed ^{194}Hg nucleus

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Introduction

The discovery of superdeformed states in nuclei is one of the most remarkable discoveries of the 20^{th} century, since the nuclei are exposed to extreme conditions of deformation and angular momentum in order to obtain superdeformation. The existence of superdeformation was predicted by Strutinsky [1] and later confirmed experimentally by Twin *et al.* [2] in the ^{152}Dy nucleus. With the development of large $\gamma-$ray detectors, new mass regions of superdeformation have been explored. Various superdeformed (SD) bands are currently available in the $A \sim 190, 150, 130$ and 80 mass regions. Usually, SD bands are identified by transitions from equally spaced energy levels, which results in a series of $\gamma-$ray spectra. However, the spins of SD bands were not established experimentally until the discovery of $\gamma-$rays connecting states of yrast SD bands $^{194}Hg(1)$ to normal deformed (ND) states [3]. Soon after, the spins and excitation energies of many yrast and excited SD band were established in the $A \sim 190$ mass region. Besides such exceptions, the estimated spins of other SD bands in different mass regions have uncertainties of $\approx 1-2\hbar$. Many interesting phenomena such as the identical bands [4], flat bands and $\Delta I = 2$ staggering are observed in the SD bands. Many attempts have been made to describe these fascinating phenomena and explore the underlying physics behind them.

Formalism

The experimental data available for the SD bands reveal that these bands show the good rotational characteristics and can be described by the perturbed SU(3) symmetry approach. To extract the $\Delta I = 4$ bifurcation ($\Delta I = 2$ staggering), we have employed the supersymmetry scheme with many body interaction and a perturbation holding $SO(5)$(or $SU(5)$) symmetry on the rotational symmetry [5]. In this scheme, the energy of a state in the SD band can be written as

$$\begin{aligned} E = {} & E_0(N_B, N_F) \\ & + B[\tau_1(\tau_1+3)+\tau_2(_2{+}1)] \\ & + \frac{C_0}{1+f_1 I(I+1)+f_2 I^2(I+1)^2} I(I+1)) \end{aligned} \quad (1)$$

where $I = I - i, (\tau_1, \tau_2)$ is the irrep of the SO(5) group. In the practical calculation, the irrep (τ_1, τ_2) are given as

$$(\tau_1, \tau_2) = \begin{cases} ([\frac{L}{2}], 0), \\ \text{if } L = 4k, 4k+1 (k = 0, 1, ..) \\ ([\frac{L}{2}] - 1, 2), \\ \text{if } L = 4k+2, 4k+3 (k = 0, 1, ..) \end{cases} \quad (2)$$

Here $[a]$ denoted the integer part of the a and B, C_0, f_1 and f_2 are the fitting parameters. The $\Delta I = 4$ bifurcation can be obtained using the Cederwall's notation [6]

$$\begin{aligned} \Delta E_\gamma(I) = \frac{1}{16} & [6E_\gamma(I) - 4E_\gamma(I-2) \\ & -4E_\gamma(I+2) + E_\gamma(I-4) \\ & +E_\gamma(I+4)]\,. \end{aligned} \quad (3)$$

Results and Discussion

Using all intraband $\gamma-$transition energies of $^{194}Hg(1)$ [7], the fitting parameters B, C_0,

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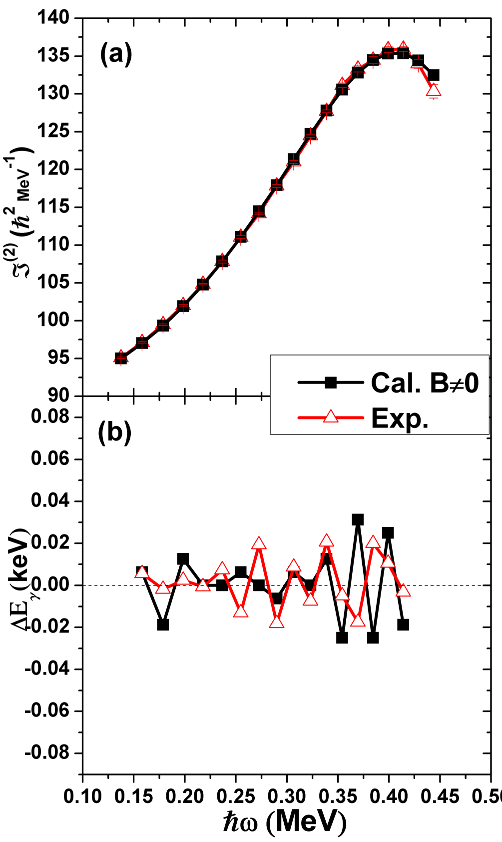

FIG. 1: (a) The variation of calculated and experimental dynamic moment of inertia with rotational frequency for the yrast SD bands $^{194}Hg(1)$ (b) The calculated and experimental results of the staggering ΔE_γ of the transition energies in the yrast SD band $^{194}Hg(1)$.

f_1 and f_2 are calculated. The best-fit parameters obtained are $B = 0.0005228$ keV, $C_0 = 5.61314$ keV, $f_1 = 7.08501 \times 10^{-5}$ and $f_2 = -6.86127 \times 10^{-9}$. With the fitting parameters obtained after the non-linear least squares fitting, we have calculated the intraband-γ transition energies of the yrast SD band $^{194}Hg(1)$. The root-mean-square deviation between the calculated and the experimental transition energies is of the order of 10^{-4}. Using the calculated transition energies, we have calculated the dynamic moment of inertia ($\Im^{(2)}(I) = 4000/[E_\gamma(I+2) - E_\gamma(I)]$) of $^{194}Hg(1)$ (see Fig. 1). It is evident from the Fig. 1 that the calculated $\Im^{(2)}$ follows the experimental $\Im^{(2)}$ quite efficiently and reproduces the downturn in $\Im^{(2)}$ at high rotational frequency. To calculate the $\Delta I = 4$ bifurcation in $^{194}Hg(1)$, we have employed the Cederwall's notation [6], illustrated in the Fig. 1. The figure displays that the $\Delta I = 4$ bifurcation can be reproduced if the $B \neq 0$, i.e. the perturbative interaction with $SO_{sdg}(5)$(or $SU_{sdg}(5)$) is taken into account.

Conclusion

A systematic study of the yrast SD band $^{194}Hg(1)$ is made using the four parameter formula. The downturn in the dynamic moment of inertia at rotational frequency ≥ 0.40 MeV is reproduced very well with the supersymmetry scheme with many body interaction and a perturbation possessing $SO(5)$(or $SU(5)$) symmetry on the rotational symmetry . The calculated results, $B \leqslant C_0/1000$, preserve the fact that the interaction with $SO_{sdg}(5)$ is indeed only a perturbation and could be the reason behind the $\Delta I = 4$ bifurcation in $^{194}Hg(1)$. Also the coefficients f_1 and f_2 obtained has different signs (f_1 positive and f_2 negative) representing that both the pairing and anti-pairing effects are present.

Acknowledgments

Financial support from Department of Science and Technology (Govt. of India) is gratefully acknowledged.

References

[1] V. M. Strutinsky, Nucl. Phys. A **122**, 1 (1968).
[2] P. J. Twin *et al.*, Phys. Rev. Lett. **57**, 811 (1986).
[3] T. L. Khoo *et al.*, Phys. Rev. Lett. **76**, 1583 (1996).
[4] A. Dadwal and H. M. Mittal, Eur. Phys. J. A **53**, 132 (2017).
[5] Y. X. Liu *et al.*, Phys. Rev. C **59**, 2511 (1999).
[6] B. Cederwall *et al.*, Phys. Rev. Lett. **72**, 3150 (1994).
[7] http://www.nndc.bnl.gov/