Band moment of inertia of yrast and excited SD bands of even-even nuclei in A=150 mass region

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Introduction

The superdeformed (SD) shapes whose existence was predicted first by V.M. Strutinsky [1] have been observed experimentally by Twin et al., [2]. A large number of SD bands have been observed in the mass region A=60, 80, 130, 150, 190 [3, 4]. Also Ideguchi et al., [5, 6] observed SD bands in A=40 mass region. It may be pointed out that a lack of knowledge of the spins assignments has led to an emphasis on the study of dynamical moment of inertia of SD bands and the systematics of the kinetic moment of inertia have not been examined in a detailed manner. Sharma and Mittal [7] have studied that all the excited SD bands in even-even nuclei are signature partner SD bands because the J_0 value of each signature partner SD band is almost identical. The J_0 values obtained from fitting of SD bands in A=190 mass region exhibit spread in many cases which point towards the presesnce of structural effects in these SD bands [8].

In this paper, we extract the band moment of inertia J_0 of all the known yrast and excited SD bands in A=150 mass region corresponding to 2:1 deformation and present their systematics.

Results and Discussion

First of all, we classify the bands into yrast and excited SD bands of even-even nuclei in A=150 mass region by using the feeding intensities from the experiments and reported in ref. [3, 4]. We have calculated the band moment of inertia J_0 by fitting the E2 gamma ray energies of all the yrast and excited SD bands of even-even nuclei in A=150 mass region [3, 4] by using a 4-parameter formula [9]. In these bands, some kind of spin assignments are available. The fits are very good because the SD bands are very good rotors. The root mean square deviation has been calculated and shown in the results for each band. For a prolate ellipsoid, the transition quadrupole moment (Q_t) can be related to the major-to-minor axis ratio, x, by

$$Q_t = \frac{2}{5} Z R^2 \frac{x^2 - 1}{x^{2/3}} \times 10^{-2} eb. \qquad (1)$$

So, the axes ratio can be estimated from Q_t in this way. For a prolate ellipsoid which give rigid rotation, it is possible to estimate the rigid body moment of inertia as [10]

$$J_{prolate} = \{\frac{A^{5/3}}{72} \frac{1 + x^2}{2x^{2/3}}\}[\hbar^2 MeV^{-1}]. \qquad (2)$$

Higher order shape degrees of freedom and effect of triaxiality or necking have been ignored here.

We have compared the fitted values of J_0 of yrast and excited SD bands of even-even nuclei in A$\sim$150 mass region with the rigid rotor values of moment of inertia obtained from the measured-Q_t values. Those SD bands in which the Q_t measurements are not available, we have compared the fitted J_0 values with those obtained from the corresponding prolate shape of the SD nuclei. It is to be noted that all the SD nuclei of A=150 mass region correspond to the 2:1 shape of the nuclei. In a significant finding, we noted that fitted values of J_0 of yrast SD bands of even-even nuclei i.e. $^{148}Gd(1)$ and $^{152}Dy(1)$ are larger than that of the measured Q_t-values. These bands are termed as "super-rigid" SD bands.

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On the other hand, it is highly interesting to note that J_0 values of all the excited SD bands of even-even nuclei are almost identical. It means all the excited SD bands of even-even nuclei in A=150 mass region are signature partner SD bands. The J_0 values of all the signature partner SD bands of A=190 mass region are found to be the same [11]. Among all these excited SD bands, J_0 value of $^{150}Gd(4)$ is found to be larger than that observed from the measured Q_t-value. This band is found to be super-rigid in nature. Except these super rigid SD bands, all the yrast SD bands and excited SD bands of even-even nuclei in A=150 mass region have J_0 value smaller than those obtained from the measured Q_t - values. The reason behind the smaller values of J_0 is that the pairing correlations have not quenched sufficiently in these bands; presence of pairing leads to a decrease in the moment of inertia.

Conclusion

The 4-parameter formula has been used to obtain the band moment of inertia J_0 for the yrast and excited SD bands of even-even nuclei in A=150 mass region. In a significant finding, we found that the value of J_0 of yrast SD bands of even-even nuclei i.e., $^{148}Gd(1)$ and $^{152}Dy(1)$ is larger than the rigid rotor value obtained from the measured Q_t values. We termed these bands as super-rigid rotor bands. It is very interesting to note that the excited SD bands of even-even nuclei in A=150 mass region are signature partner SD bands as the J_0 values of all the excited SD bands of even-even nuclei are almost identical. Among all the excited SD bands of even-even nuclei of A=150 mass region, $^{150}Gd(4)$ is found to be super-rigid rotor band as the value of band moment of inertia J_0 of this band is larger that of the measured Q_t value.

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References

[1] V. M. Strutinsky Nucl. Phys. A **122**, 1 (1968).
[2] P.J. Twin et al., Phys. Rev. Lett. **57**, 811 (1986).
[3] B. Singh, R. Zywina and R. B. Firestone, Table of superdeformed Nuclear Bands and Fission Isomers, Nuclear Data Sheets **97**, 241 (2002) and references therein.
[4] Evaluated Nuclear Structure Data File (ENSDF) and Experimental Unevaluated Nuclear Data List (XUNDL) databases maintained at the National Nuclear Data Centre, Brookhaven National Labortary, Upton, NY.
[5] E. Ideguchi et al., Phys. Rev. Lett. **87**, 222501 (2001).
[6] E. Ideguchi et al., Phys. Lett. B **686**, 18 (2010).
[7] Neha Sharma and H.M. Mittal, Int. J. of Mod. Phys. E **24**, 1550054 (2015).
[8] Neha Sharma and H.M. Mittal, Int. J. of Applied Engineering Research **9**, 11 (2014).
[9] Neha Sharma, H.M. Mittal, A.K. Jain, Phys. Rev. C **87**, 024322 (2013).
[10] R. M. Clark, P. Fallon and R. Wadsworth, Phys. Rev. Lett. **87**, 202502 (2001).
[11] H.M. Mittal and Neha Sharma, Int. J. Nucl. Energy Sci. and Tech. **7**, 368 (2013).