# Nuclear Structure of the Neutron-deficient $^{132}$Ce

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**ABSTRACT**

***The present study related with a current topic of interest i.e. odd-even staggering in the gamma band of $^{132}$Ce nucleus. The experimental and theoretical details of $^{132}$Ce nucleus are discussed. The energy levels of the ground as well as gamma band have been calculated using Soft Rotor Formula. Davydov-Filippov energy gap relations are also used in order to find the nature of $^{132}$Ce nucleus. The purpose of the present work is to study the ground and gamma band of $^{132}$Ce nucleus. It is found that $^{132}$Ce is a γ-soft nucleus.***

***Keywords: Soft rotor formula, energy staggering, γ-soft nucleus.***

## 1. INTRODUCTION

The neutron deficient Cerium isotopes have the properties of rotational nuclei [1] and with increasing neutron number, the energy level structure changes very slowly and smoothly, rather than as there is a sharp shape phase transition occurs for neutron rich nuclei (N>82). The variation with neutron number N is very interesting in Cerium nuclei.

### *1.1 Experimental details of $^{132}$Ce nucleus*

In 1984, Sakai [2] illustrated the ground and few γ-band energy levels. After few years, Kortelahti et al., [1] studied the $^{132}$Ce nucleus by measuring the *γ-ray* singles and *γγ-t* coincidences in the $\beta^+$-decay and constructed the level scheme of $^{130,\ 132}$Ce nuclei, in which the ground-band was labeled up to $6^+$ spin state and γ-band was labeled up to $5^+$ spin state and another three levels (at 1497, 1734 and 2508 keV) were included without assigning spin and parity values ($I^\pi$).

Gade et al., [3] illustrated the new level scheme for $^{132}$Ce nucleus and added the excited band based on the K=$0_2^+$ state and also confirmed the three levels of Kortelahti et al., [1] cited above and assigned them spin I values of $2_3^+, 2_4^+$ and (2, 3, 4) respectively. A new level at 1932.1 keV was also reported named as $4_3^+$ state. They compared the level structure with $^{128,\ 132}$Ba and noted some similarities in their band structures and the γ-soft character.


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### *1.2 Theoretical details of $^{132}$Ce nucleus*

By using O(6) symmetry of Interacting Boson Model (IBM), Gade et al., [3] derive the interband B(E2) ratios of $^{132}$Ce. The variation of N with B(E2, I→I-2) in the yrast band was discussed by Muller et al., [4]. Gupta [5, 6] studied the Ce isotopes by using IBM-1. Recently, Gupta and Kumar [7] discussed the nuclear structure of $^{130-136}$Ce by using IBM and DPPQ model.

## 2. PRESENT WORK

Present search is related to the study of γ-band of $^{132}$Ce nucleus by using soft rotor formula. The Soft Rotor Formula (SRF),

$$E = \frac{I(I+1)}{J_0(1+\alpha I)}$$

where $J_0$ is the moment of inertia parameter and α is the variable of moment of inertia parameter. By using $2_2^+$ & $4_2^+$ gamma band energies in even sequences and $3_1^+$ & $5_1^+$ energies in odd sequence, the values of $J_0$ and α can be calculated.

Firstly, Brentano et al., [8] used this SRF for ground band and after few years Bihari et al., [9] proposed this formula for gamma band. Recently, Mittal and Kumari [10] suggested the SRF formula for the study multiphonon 2γ-band and also discussed the nature of multiphonon 2γ-band of $^{158}$Dy nucleus. Zamfir and Casten [11] suggested a number of signatures of γ-softness vs. γ-rigidity in nuclei, and they give attention in the staggering properties of γ-band. Staggering indices which may be defined as relative displacement of the odd angular momentum levels w.r.t. their neighboring levels with even angular momentum. Staggering formula written as

$$S(I, I\text{-}1, I\text{-}2) = \frac{(E_1 - E_{I-1}) - (E_{I-1} - E_{I-2})}{E_{2_1}^+}$$

and it shows alternative behavior with spin I. For even spin values, it is found to be positive and for odd spin values, it is found to be negative.

## 3. RESULTS AND DISCUSSION

The energy levels for ground and gamma band of $^{132}$Ce nucleus are plotted in Fig.1.

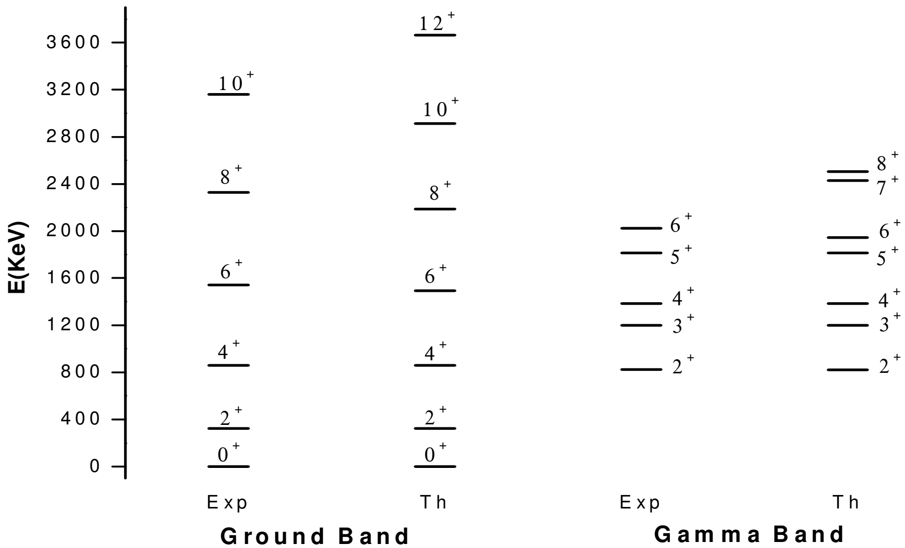


**Fig.1: Comparison between experimental and calculated energy values of the ground and γ-band using SRF formula.**

The calculated values of $J_0$ and α for ground band and for odd & even sequences of gamma band are listed in Table 1. For $^{132}$Ce nucleus, the sign of $J_0$ and α are positive for ground band energies and also for gamma band energies. This is also an indication that $^{132}$Ce nucleus is a γ-soft nucleus.

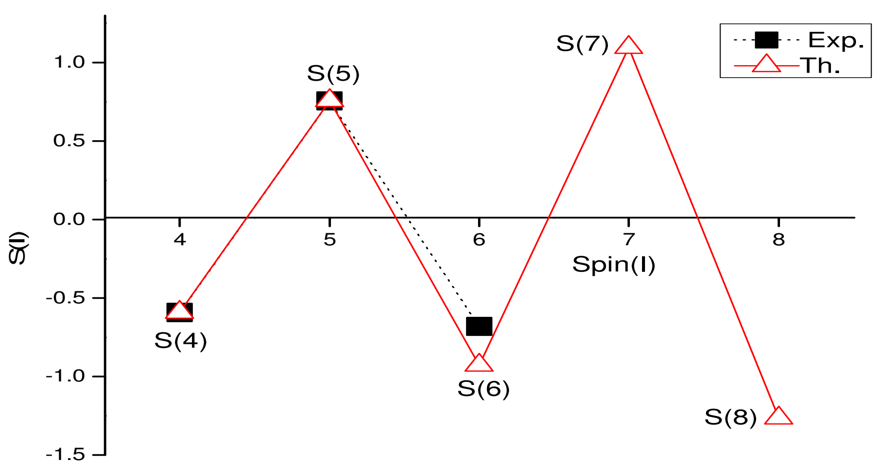


**Fig. 2: Staggering indices S(I) is plotted versus spin (I) in the present work for $^{132}$Ce nucleus using SRF formula for γ-band.**

Other points of indication of γ-soft nuclei are

- The levels of γ-band are grouped as $2^+$, ($3^+$, $4^+$), ($5^+$, $6^+$), …. in $^{132}$Ce (see Fig.1) is also a characteristic of γ-soft nucleus.
- Davydov-Filippov energy gap relations [12]

  $\Delta E1[= E3_1^+ - (E2_1^+ + E2_2^+)]$ and

  $\Delta E2[= E3_1^+ - (2E2_1^+ + E4_1^+)]$.

  These relations are mainly used to distinguish the nuclei which belong to the triaxial region and also used to recognize the difference between γ-rigid and γ-soft nuclei. Here as resulted that $\Delta E1 \gg \Delta E2$ (see Table 2), which is also a proof of γ-soft nucleus.

  The variation of staggering indices S(I) with spin I for $^{132}$Ce nucleus is shown in Fig.2. The spacing between odd-even spin levels in the present work show good agreement with experimental values for S(4), S(5), S(6) of γ-band.

- In $^{132}$Ce nucleus, the experimental values of S(I) have alternative values with spin I and S(4) is negative which shows that this nucleus is γ-soft in nature.

## 4. CONCLUSION

To summarize, here we tried to show that SRF formula is prosperous to explain the gamma band energy and also facilitative to find the new energy levels of $^{132}$Ce nucleus. The Davydov-Filippov energy gap relation is found to be applicable on this nucleus. Interestingly, on the bases of staggering indices, Davydov-Filippov energy gap relation and the value of parameters $J_0$ and α of SRF formula that $^{132}$Ce is a γ-soft nucleus.

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## TABLES

| Bands | $J_0$ | $J_{0(\text{even})}$ | $J_{0(\text{odd})}$ | α | $\alpha_{(\text{even})}$ | $\alpha_{(\text{odd})}$ |
|---|---|---|---|---|---|---|
| g-band | 0.0136 | | | 0.1767 | | |
| γ-band | | 0.0001 | 0.0002 | | 24.214 | 14.333 |

**Table 1: Fitted parameters $J_0$ and α used in present work.**

| For γ-band $^{132}$Ce | $\Delta E1[= E3_1^+ - (E2_1^+ + E2_2^+)]$ | $\Delta E2[= E3_1^+ - (2E2_1^+ + E4_1^+)]$ |
|---|---|---|
| | 51.94 | -310.19 |

**Table 2: Experimental value of energy differences ΔE1 and ΔE2 for γ-band.**


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