Odd – Even staggering, a result of γ – band split

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The structure of low – lying K = 2+ gamma band in even – even nuclei represents quadrupole vibration breaking axial symmetry in unified collective model of Bohr – Mottelson [1]. It represents an anomalous rotation band in the rigid triaxial model (RTR) of Davydov and Filippov [2]. Wilets and Lean [3] used γ – independent potential V V for the collective structure, which yields a level pattern equivalent to the modified anharmonic oscillator, grouped the level of γ – band as 2_2, 3 , 4_2 , 5 , 6_2 ,……in contrast to the RTR pattern of 2_2, 3 , 4_2, 5 , 6_2, 7 ,…….. In the group theoretical approach of the Interacting bosom model (IBM) [4] the band structure can belong to one of the three limiting symmetries of U(6) algebra viz. U(5), SU(3) and O(6), corresponding to the anharmonic vibrator, deformed rotor and γ – unstable respectively.

Zamfir and Casten [5] used the odd – even staggering (OES) as a tool for the choice between RTR and the O (6) model, they examined the values of S (4, 3, 2) and S (7, 5, 4) obtained from experiment and found them matching with γ – soft predictions, showing no evidence of γ – rigidity at low spin and low energy. The evolution from U (5) (Vibrator) to SU (3) (axially symmetric rotor) in Nd, Sm, Gd and Dy isotopic chains have recently been studied by Mc Cutchan et al [6]. For each of these isotopic chains staggering index S (4, 3, 2) is always small, and evolves from negative value, passing close to zero for a single isotope along the chain and then increasing to positive value. The sudden jump in $R_{4/2}$ from 2.49 to 2.93 in $^{148-150}$Nd, 3.0 to 3.25 in $^{152-154}$Sm & 2.19 to 3.0 in $^{152-154}$Gd occurs together with a sudden jump of S (4, 3, 2) from low negative to slightly positive values. These changes occur in the neighbourhood of the N = 90 isotones ^{150}Nd, ^{152}Sm & ^{154}Gd. Thus, along the transition from vibrator {S (4) = - ve} to deformed axially rotor {S (4) = + ve}, S (4) passing through or close to zero as an indicator of a phase transition region. Adhering to historically γ – band appearance in the rotational spectrum while assigning axial asymmetry to a rotational nucleus we propose in the present work that the usual description of RTR energies which are γ – dependent and described in units of $^2/$ (J_0 is common moment of Inertia) be switched over to a new approach of having same energies but in different values of units. We assume that J_0 does not remain same as an asymmetric nucleus rotates around three different axes and generate ground, even spin and odd spin energy sequences of γ – band. The OES is the result of split of γ – band. The values of J_0 for the three energy sequences will be calculated from the model itself [7].

We present the values of $R_{4/2}$ and S (4, 3, 2) in experiment, RTR with single moment of inertia (i.e. $J_{01}=J_{02} = J_{03}$) and RTR with three different moment of inertia (i.e. $J_{01} \neq J_{02} \neq J_{03}$) for some N = 90 isotones showing phase transition region in table – I. The energies of ^{148}Nd are doubtful (given in bracket), this may be the reason of opposite sign of S (4).

^{152}Sm is well studied experimentally and therefore, the detailed description of γ – band is also given in table – II and III. In table II experimental and RTR energies of γ – band with three different moment of inertia parameters (i.e. $J_{01} \neq J_{02} \neq J_{03}$) are given for ^{152}Sm. The staggering indices -

$$S(J, J-1, J-2) = \frac{(E_J - E_{J-1}) - (E_{J-1} - E_{J-2})}{E_{2g}} \quad \text{..........(1)}$$

which are well known signature of triaxiality have also been calculated in experiment along with RTR energies upto 9^+ state for ^{152}Sm and presented in table – III. This can be seen from table III that the experimental and RTR values for three different moment of inertia parameter of S (J) are matching however, the RTR values with single moment of inertia parameter are opposite in sign.

In this work we infer that nuclei belonging to all shapes (Vibrator, rotor and transitional) are qualitatively described on assuming $J_{01} \neq J_{02} \neq J_{03}$.

Table – I

The values of $R_{4/2}$ and S (4) in experiment, RTR with single moment of inertia and RTR with three different moment of inertia for some N = 90 isotones showing phase transition region

Nucl.	$R_{4/2}$	S (4) Exp.	S (4) ($J_{01} \neq J_{02} \neq J_{03}$)	S (4) ($J_{01} = J_{02} = J_{03}$)
^{148}Nd	2.49	-0.301	+0.137	+0.46
^{150}Nd	2.93	+0.108	+0.338	+0.40
^{152}Sm	3.00	-0.083	-0.044	+0.38
^{154}Sm	3.25	+0.243	+0.158	+0.33
^{154}Gd	2.19	-0.605	-0.453	+0.40
^{156}Gd	3.01	+0.036	+0.064	+0.35

Table – II

γ – Band energies of ^{152}Sm

Levels	Exp. Value (in KeV)	ARM Value (in KeV)
2^+	108.6	108.6
3^+	123.4	123.4
4^+	137.2	130.5
5^+	156.0	162.2
6^+	172.8	171.7
7^+	194.6	183.0
8^+	(214.0)	223.6
9^+	(237.5)	239.4

Table – III

Staggering indices S (J) for γ – band in ^{152}Sm nucleus.

S (J)	Exp.	RTR ($J_{01} \neq J_{02} \neq J_{03}$)	RTR ($J_{01} = J_{02} = J_{03}$)
S (4,3,2)	-0.084	-0.044	+0.381
S (5,4,3)	+0.410	+0.120	+0.247
S (6,5,4)	-0.156	-0.052	+0.516
S (7,6,5)	+0.713	+0.125	+0.045
S (8,7,6)	-0.193	-0.049	+0.807
S (9,8,7)	+0.045	+0.125	-0.381

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