Study of Nuclear Shapes in even mass region A~100

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Asymmetry in even transional nuclei is a well established phenomenon. The question, whether an asymmetric atomic nucleus is γ-soft or γ-rigid has been a ongoing and active issue in nuclear structure physics for over half a century. Bohr and Mottelson had commented earlier that of $\gamma \geq 24$ nuclei are no longer to be considered deformed in the original sense and the nucleus is expected to take any shape, including triaxial [1].The examples of collective excitations resulting in both oscillations and rotations are well established in the form of γ-soft by Wilet and Jean and γ-rigid by Davydov & Filippov [2,3].The comparison of a γ-rigid rotor and γ-soft model are similar for ground band energies but, a clear distinction arises in the γ-band. The levels of γ-band are grouped as 2^+, (3^+, 4^+) ,(5^+,6^+),……….in γ-soft and as (2^+,3^+), (4^+,5^+),……in γ-rigid.

The relative displacement of odd angular momentum levels with respect to their neighboring even angular momentum levels named as odd-even staggering (OES) in the γ-band. The staggering indices S(I,I-1,I-2) defined as-

$$S(I, I-1, I-2) = \frac{(E_I - E_{I-1}) - (E_{I-1} - E_{I-2})}{E(2_1^+)} \quad .....(1)$$

Have been used as a signature to distinguish the γ-soft and γ-rigid shapes. Zamfir & Casten examined the values of the staggering indices S(4, 3, 2) & S(6,5,4) obtained from the experimental data and found them to be matching with γ-soft predictions showing no indication of γ- rigidity at substantial asymmetry [4].

Mani et.al; [5] used Lipas ansatz for evaluating perturbed energies due to rotation- vibration interaction in the asymmetric rotor model with the plea that interaction of even spin of the γ-band with the counterpart of the odd spins of the yrast band in the Davydov- Filippov model were limited and the wider space is necessary to take the full account of rotation- vibration interaction.

We propose in the present work to extend the earlier approach (Mani et.al;) to test the triaxiality in the nucleus belonging to mass region A~100 of nuclear chart. The Ru isotopes with N>50 lie in a region of structural change that has long been a challenge to theoretical interpretations. In the present work we have taken the $^{102-110}$Ru nuclei in A~100 mass regions for the structural determination in the light of signature indices. In table I, the asymmetry parameter (γ), $\beta A^{2/3}$, ΔE_1 & ΔE_2 are tabulated for $^{102-110}$Ru isotopes. For all the nuclei, the asymmetry parameter is $22.5<\gamma< 24.2$ and $5< \beta A^{2/3}<7$. ΔE_1 & ΔE_2 is the signature for γ- rigid & γ- soft potentials which can be calculated as-

$$\Delta E1 = E3_1^+ - (E2_1^+ + E2_2^+) \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

$$\Delta E2 = E3_1^+ - (E4_1^+ + 2E2_1^+) \ldots\ldots\ldots\ldots\ldots\ldots(3)$$

From table-I, it is inferred that for all the nuclei ΔE_1 is small & ΔE_2 is very large, which hits the γ- rigid potentials for these nuclei. Further, it is not sufficient to distinguish γ- soft and γ- rigid potential on the basis of $\Delta E1$ and $\Delta E2$ therefore; we have been taken staggering indices test for these nuclei.

Table – I

Nucleus	$\beta A^{2/3}$	γ^0	ΔE1	ΔE2
^{102}Ru	5.33	22.5	57	535
^{104}Ru	6.06	24.5	9	362
^{106}Ru	6.04	22.7	29	164
^{108}Ru	6.71	22.8	24	175
^{110}Ru	6.95	24.2	6	285

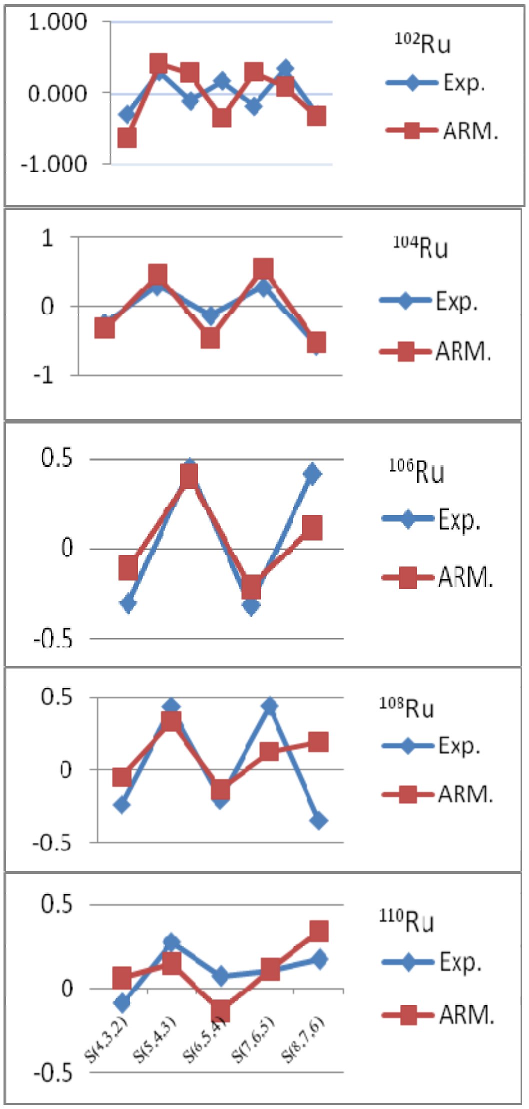

Fig.-1. Staggering indices for even – even Ru-isotopes

The energy sequence in quasi *γ*-band is well known to be sensitive to the triaxiality of a nucleus. The type of triaxiality can be qualitatively established by inspecting the relative positions of even- spin part versus the odd- spin part of a quasi *γ*- band [6] It has been shown that *S(I,I-1,I-2)* for even *I* can clearly distinguish between *γ*-soft and *γ*-rigid potentials. For instance *S(4,3,2)* = +1.67 for rigid triaxial rotor (γ = 30^0) and -2 for γ-soft rotor. The experimentally observed staggering *S(I,I-1,I-2)* along with rigid triaxial rotor have been calculated using eq. (1) and shown in figure -1. Experimental staggering in ^{102}Ru nucleus does not follow the rigid triaxial rotor trend. Thus, it is inferred that this nucleus is γ-soft. At the same time, it should be mentioned here that S. Lalkovski et. al; [7] discarded the rigid triaxiality for ^{102}Ru which supports our predictions. However, in case of $^{104-110}$Ru isotopes the rigid triaxial rotor staggering almost matches with experimental one which indicates the rigid triaxiality in these nuclei.

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