Study of multiphonon $\gamma\gamma$-band in ^{110}Ru

Parveen Kumari and H.M. Mittal
Department of Physics,
Dr. B. R. Ambedkar National Institute of Technology,
Jalandhar 144011, Punjab, India

Introduction

The ^{110}Ru nucleus with $Z = 44$ and $N = 66$ lie within $A \sim 100$ mass region, having various phenomenon like chiral band and back-bending phenomena. The isotopes of Ru have been studied widely using various experimental and theoretical techniques. In ^{110}Ru nucleus a band with bandhead (10^+) at 3193.3 keV and the doubling of the ground band above the 8^+ level were proposed by Zhuo *et al.* [1] and the three side bands were also observed. A new doubling of the one-phonon quasi-gamma band above 8^+ level in ^{110}Ru nucleus was observed and high spin states of Ru isotopes were also reinvestigated by Zhu *et al.* [2].

The present work is to discuss the excitation energies and odd-even staggering patterns in one-phonon $(K = 2)$ and two-phonon $(K = 4)$ of ^{110}Ru nucleus using Modified Soft Rotor Formula (MSRF). The calculations of the present work are compared with experimental data of ^{110}Ru nucleus taken from Ref. [1].

Theory

The Soft Rotor Formula (SRF) proposed by Gupta [3] used the concept of increasing Moment of Inertia (MoI) with increase in spin I. Brentano *et al.* [4] used SRF formula in calculations of excitation energies and can be written as:

$$E(I) = \frac{\hbar^2 I(I+1)}{2\theta(1+\sigma I)}, \quad (1)$$

where I is spin of each state and σ is softness parameter. Bihari *et al.* [5] used the SRF formula for γ-band to calculate the excitation energies and they got both the positive and negative values of MoI. Gupta *et al.* [6] resolved the matter of negative value of MoI and large values of σ by modifying the SRF formula. We further extend the search of MSRF by applying it to multiphonon $\gamma\gamma$-band, MSRF can be written as:

$$E(I) = EK + \frac{\hbar^2 I(I+1)}{2\theta(1+\sigma I)}. \quad (2)$$

where EK is constant energy term. Recently, the multiphoon $\gamma\gamma$-band in Mo isotopes and ^{112}Ru nucleus have been studied by Kumari and Mittal [7].

Results and Discussions

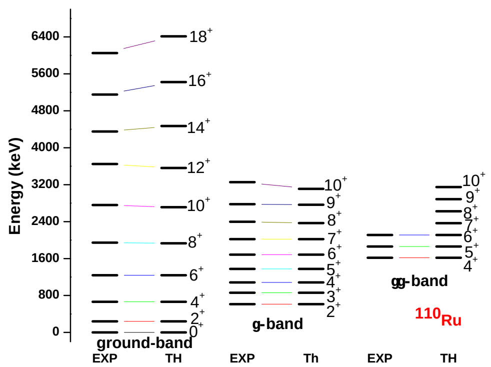

FIG. 1: Comparison between experimental and theoretical values of the ground, γ and $\gamma\gamma$- bands energy using Modified Soft Rotor formula.

The excitation energies of ground-band, γ-band and $\gamma\gamma$-band are calculated using the softness parameter σ and moment of inertia θ of MSRF formula in ^{110}Ru. The comparison of experimental values with calculated values

TABLE I: The softness parameter σ, MoI $\theta_{ground-band}$, $\theta_{\gamma-band}$ and $\theta_{\gamma\gamma-band}$ (keV^{-1}) from MSRF. The rotor model $\theta_{grnd} = \frac{3}{E(2_1^+)}$ for ground band, $3/(E(3\gamma) - E(2\gamma))$ for γ-band and $3/(E(5\gamma\gamma) - E(4\gamma\gamma))$ for $\gamma\gamma$-band are listed for comparison.

^{110}Ru nucleus	Theoretical MoI	Expt. MoI	σ	EK
Ground band	$\frac{3}{E(2_1^+)} = 0.012$	0.012	0.062	30.24
γ-band	$3/(E(3\gamma) - E(2\gamma)) = 0.012$	0.012	0.067	447.91
$\gamma\gamma$-band	$3/(E(5\gamma\gamma) - E(4\gamma\gamma)) = 0.021$	0.006	0.317	849.14

using MSRF formula is presented in Fig. 1 for ^{110}Ru. The calculated data shows very good agreement with experimental data for all the three bands.

The MoI values of rotor model for all K-band serve as the reference point. The value of MoI of γ-band is almost equal to the MoI of ground band for the same nucleus [8]. We find that the experimental MoI values of $\gamma\gamma$-band is almost equal to half of the experimental MoI values of γ-band and ground-band for ^{110}Ru nucleus. The values of θ, σ and EK for ground, γ and $\gamma\gamma$-bands using MSRF formula are written in Table I.

Staggering Indices

Staggering indices $S(I)$ [9] are defined as relative displacement of odd spin w.r.t. even spin levels (for details of calculation of $S(I)$ in γ- and $\gamma\gamma$-bands see Ref. [7]). The $S(I)$ of experimental energy levels of $\gamma\gamma$-band can be expressed as :

$$S(6\gamma\gamma) = \frac{(E_{6\gamma\gamma} - 2E_{5\gamma\gamma}) - (E_{4\gamma\gamma})}{E(2_1^+)}. \quad (3)$$

In Fig. 2, the $S(I)$ of γ-band have positive value for odd spin members and negative value for even spin members. Therefore, we can say that the neutron rich ^{110}Ru nucleus show triaxial behaviour in γ-band. The calculated $S(I)$ values show decreasing positive values for even and odd spin members of $\gamma\gamma$-band.

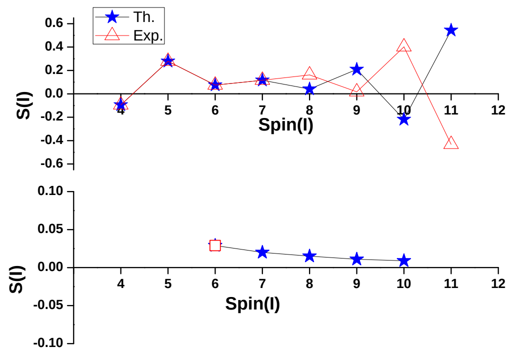

FIG. 2: Plots of Staggering indices $S(I)$ versus spin I using experimental and theoretical values for ^{110}Ru nucleus for γ- and $\gamma\gamma$-bands.

Conclusion

The MSRF provides good perspective to study the multiphonon K=4 $\gamma\gamma$-band. The neutron rich ^{110}Ru nucleus shows triaxial behaviour in γ-band. In order to get full information about the nature of ^{110}Ru nucleus in $\gamma\gamma$-band, more experimental data is required.

References

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