Nuclear structure of multiphonon $\gamma\gamma$-band in neutron rich $^{112}$Ru nucleus

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Introduction

The neutron rich $^{112}$Ru nucleus ($Z=44$ and $N=68$) lie within the $A=100$ deformed mass region. The experimental study of multiphonon bands was very difficult but nowadays there are many methods to measure them. Recently, Xing-Lai et al.,[1] investigate the neutron-rich $^{112}$Ru nucleus with the gamma-sphere detector array by observing prompt $\gamma$-rays of spontaneous fission of $^{252}$Cf. They proposed two-side bands, one of them was predicted as two-phonon $\gamma$-vibrational band and the another one as two-quasiparticle band. The energy ratio $R_{4/2} = \frac{E(4\gamma)}{E(2\gamma)}$ of the neutron rich $^{112}$Ru nucleus is 2.72, this shows that it lie in deformed region. Using cracked shell model, they predicted that in the ground state, the $^{112}$Ru nucleus has oblate shape deformation and posses triaxial deformation with increasing rotational frequency.

Bohr and Mottelson [2] stated that at $\gamma \geq 24^{0}$, the nuclei believed to take any shape, including triaxial. In Ref.[3], a number of $\gamma$-softness and $\gamma$-rigidity signatures in various nuclei has been reviewed and gave most of its attention to the staggering properties of $\gamma$-band energies.

In the present work, we study the nature of multiphonon $\gamma\gamma$-band in neutron rich $^{112}$Ru nucleus and also calculate the energy value of one-phonon $\gamma$-band (K=2) and two-phonon $\gamma\gamma$-band (K=4) by using Modified Soft Rotor Formula (proposed by Gupta et al.,[4]).

Method and Calculations

Brentano et al.,[5] proposed the soft rotor energy formula (SRF) for the ground band and later, Bihari et al.,[6] used this SRF to calculate the energy of one phonon $\gamma$-band. They received both the positive and negative values of moment of inertia (MoI) $\theta_0$ and also for softness parameter $\sigma$ in Ru isotopes and also in many other nuclei. Recently, Gupta et al.,[4] illustrated that it is difficult to justify the negative values of MoI and also the large values of $\sigma$. As the softness parameter is only a perturbation correction of MoI [5], so $\sigma$ is expected to be less than one and should be positive. Gupta et al.,[4] resolved the anomaly of negative MoI and the negative softness parameter $\sigma$ and also calculate the energy of one phonon $\gamma$-band of deformed and shape transition nuclei.

The Modified Soft Rotor Formula (MSRF) is given as:

$$E(I) = EK + \frac{I(I+1)}{2\theta_0(1+\sigma I)}$$

where $\theta_0$ is the MoI parameter and $\sigma$ is the variable of MoI parameter. For the detail explanation for the calculation of the energy values see Ref.[4]. Here MSRF is true for the corresponding value of $\gamma\gamma$-band MoI = $\frac{3}{E(5\gamma)-E(3\gamma)}$, for $\gamma$-band MoI = $\frac{3}{E(3\gamma)-E(2\gamma)}$ and ground MoI $\frac{3}{E(2\gamma)}$.

The staggering indices [3] given as:

$$S(I, I - 1, I - 2) = \frac{(E_I-E_{I-1})-(E_{I-1}-E_{I-2})}{E(I)}$$

shows alternative behaviour with spin I. In case of $\gamma$-rigid triaxial, the clustering of the $\gamma$-band energy levels is predicted, which resulting in an oscillating behaviour of S(I) such that it is negative for odd-spin and positive for even spin levels.

Results and Discussions

The energy levels for ground, $\gamma$ and $\gamma\gamma$-bands in the neutron rich $^{112}$Ru nucleus are available online at www.sympnp.org/proceedings
plotted in Fig. 1. The calculated energy values match excellently with the experimental energy for all spin values for ground, γ and γγ-bands. The experimental data is taken from Ref.[1].

The calculated values of $\theta_0$ and $\sigma$ for ground, γ and γγ-bands are listed in Table 1. In the neutron rich $^{112}$Ru nucleus, the calculated $\theta_0$ for γ and γγ-bands are almost equal to the calculated MoI for ground band, which is close to the corresponding rotor model values.

For axial rotor, all the staggering indices $S(I)$ values are positive and increases slowly with increasing spin I and show no zigzag behaviour [8]. The $^{112}$Ru nucleus develop a staggering pattern, here the experimental values of $S(I)$ are positive for even spin values and negative for odd spin values for γ-band. The $^{112}$Ru nucleus is predicted as γ-rigid triaxial nucleus in γ-band (see Ref.[7]). In case of γγ-band, $^{112}$Ru nucleus show the similar alternating behaviour (see Fig.2). Hence, it is recommended that the neutron rich $^{112}$Ru nucleus is γ-rigid triaxial in nature in multiphonon γγ-band.

**References**


