Search the nature of multiphonon 2γ-band of ^{158}Dy

H.M. Mittal* and Parveen Kumari

Dr. B R Ambedkar National Institute of Technology, Jalandhar, Punjab-144011, INDIA

*email:mittal.hm@lycos.com

Introduction

Multiphonon 2γ-band in deformed nuclei has been studied experimentally and theoretically during the recent decades. In deformed nuclei, the multiphonon excitations can stipulate worthy information of nuclear structure. Zamfir and Casten [1] have reviewed a number of signatures of γ-softness versus γ-rigidity in nuclei, giving attention on the staggering properties of γ-band energies. Liao Ji-Zhi [2] studied the behavior of staggering indices S(I) in both axial and triaxial rotor model, and concluded that no zigzag behavior appeared in S(I) versus spin I plots of the axial nucleus. Brentano *et al.* [4] proposed the soft rotor energy formula (SRF) for the ground band and Bihari *et al*. [5] used this SRF to calculate the perturbed energies of γ-band produced by rotation of rigid asymmetric atomic nucleus.

The purpose of the present study is to search the nature of multiphonon 2γ-band of ^{158}Dy nucleus. In ^{158}Dy, one phonon γ and two phonon 2γ-band have been observed (see Ref.6).

Method and Calculations

The SRF formula [4] has been used

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

where J_0 is the moment of inertia parameter and α is the variable of moment of inertia parameter. The values of J_0 and α are calculated in the same way as done earlier by Bihari *et al*. [5] for γ-band. In the present paper, the energy values are calculated by fitting the odd and even spin energy sequences, using 2_3^+ and 4_3^+ energies and 3_2^+ and 5_2^+ energies for 2γ-band. Staggering indices [7] is defined as

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

which shows alternating behavior with spin I.

Results and Discussion

The energy levels for ground, γ and 2γ-bands in ^{158}Dy nucleus are plotted in Fig.1.

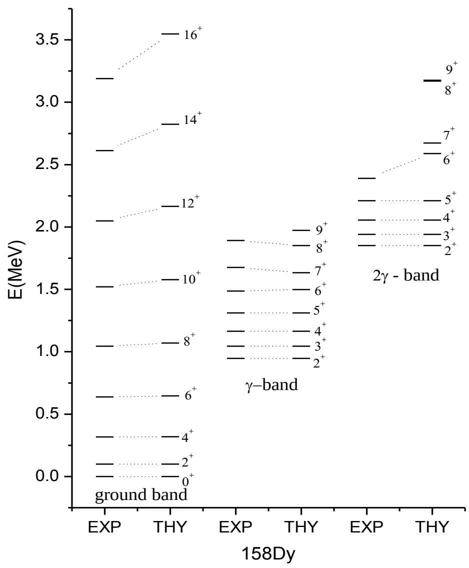

Fig.1: Comparison between experimental and calculated energy values of the ground, γ and 2γ-band using SRF formula.

For the ground band, calculated energy values show good agreement with the experimental energy up to I=12$^+$, where as in case of γ-band, the calculated energies show very good agreement with the experimental energies. In case of 2γ-band, the calculated energy values match excellently with the experimental energy values up to I=5$^+$, while a small deviation in the calculated values of energy possessing angular momentum I > 5$^+$ have been observed.

The calculated values of J_0 and α for ground (g), even and odd spin sequences for γ and 2γ-bands are listed in Table 1. For ^{158}Dy nucleus, the sign of J_0 and α are positive for ground band energies and negative for γ and 2γ-band energies.

Band	α_g	α_{even}	α_{odd}	J_0 (g)	J_0 (even)	J_0 (odd)
g	58.08			0.02		
γ		-1.20	-1.01		-4.50	-5.59
2γ		-0.99	-0.75		-3.25	-4.89

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

Davydov-Filippov energy gap relations [3] $\Delta E1[= E3_1^+ - (E2_1^+ + E2_2^+)] = 0$ and $\Delta E2[= E3_1^+ - (2E2_1^+ + E4_1^+)]$ has been used to distinguish the rigid rotor from γ-soft rotor. For γ-rigid rotor, ΔE1<<ΔE2 has been used [5] and found valid in the present study for γ-band. As studied earlier by Bihari *et al.* [8], it was also found valid.

For 2γ-band, in order to distinguish the γ-rigid rotor, the new parameters $\Delta E1[= E3_2^+ -$ E22++E23+
and $\Delta E2[= E3_2^+ - (2E2_2^+ + E4_2^+)]$ have been introduced. The parameter, ΔE1<<ΔE2 as used to distinguish the γ-rigid and γ-soft nuclei has not been found valid for 2γ- band as shown in Table 2.

For γ-band ^{158}Dy	$\Delta E1[= E3_1^+ -$ E21++E22+	$\Delta E2[= E3_1^+ -$ 2E21++E41+
	0.0	0.530
For 2γ-band ^{158}Dy	$\Delta E1[= E3_2^+ -$ E22++E23+	$\Delta E2[= E3_2^+ -$ 2E22++E42+
	-0.858	-2.007

Table 2: Experimental values of energy differences ΔE1 and ΔE2 for γ and 2γ-bands.

From the above evidences, it has been observed that this nucleus doesn't obey Davydov-Filippov energy gap relation for 2γ-band. Hence, it doesn't show triaxial region in multiphonon 2γ-band.

The variation of staggering indices S(I) with spin (I) for ^{158}Dy nuclei have been observed (see Fig.2), the spacing between odd-even spin levels in the present work show agreement with the experimental values for S(4), S(5) and the calculated values for S(6), S(7), S(8) and S(9) does not match with experimental values. For 2γ-band, the experimental values for S(I) does not changes sign rather have positive sign with small values.

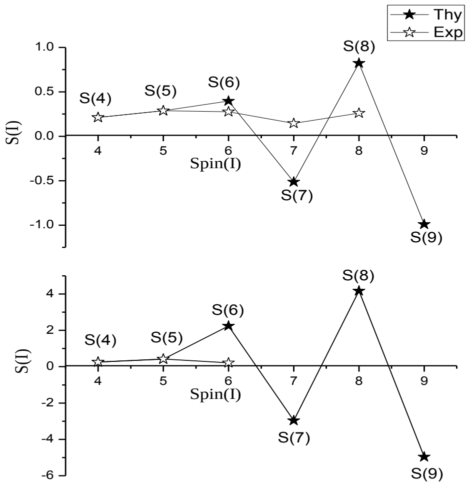

Fig.2: Staggering indices S(I) is plotted versus spin (I) in the present work and experiment for ^{158}Dy nuclei using Eq.(1) for γ and 2γ-bands.

For axial rotor, all the S(I) are positive and small in magnitude and show no zigzag behavior, but increases slowly with increasing spin I [2]. In ^{158}Dy nucleus, experimental values of S(I) have small positive values for all spins of 2γ-band. Here, it appears that at very low spin ^{158}Dy nucleus is axial but at higher spin ($I^+ = 7^+$), it may become unpredictable. Hence, we need more experimental energy values in multiphonon 2γ-band to study the nature of this nucleus.

References

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