Nuclear structure of ^{158}Dy from interacting boson model-1

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Introduction

The rotational and vibrational characteristics of the g-, β-, γ- and other higher bands of even Z and even N nuclei in the rare earth region have been studied extensively both in experiment and theory (Bohr and Mottelson,1975). With the advent of in-beam γ-ray spectroscopy and sophisticated experimental and data analysis techniques, vast information on the lower and higher lying excited states have become available. The proton rich $^{154\text{-}160}$Dy isotopes which is on midway between Z= 50-82 major shell closures span the spherical to the well-deformed region.

Chuu and Hsieh (1988) used IBM-1 and reproduced the energy spectra of the Dy isotopes but only the ground-band transition rates were calculated. Gupta et al., (1992) analyzed the six K-bands of ^{158}Dy by using the DPPQ model (Kumar, 1975). The present work represents an extensive analysis of the positive parity level structures in ^{158}Dy using IBM-1(Iachello & Arima, 1987).

Level Energies from the IBM-1

The PHINT package (Scholten, 1979) is used to study the energy spectrum of ^{158}Dy isotope and optimized values of boson- boson interacting parameters are obtained. The level energies and K-band groupings from the IBM-1 calculation (fourth row) are compared with experiment (first and second row) and the DPPQ calculation (third row) (Gupta et al., 1992) in Table 1. Somewhat reduced g-band spacings and extended energy levels spacing in the β- and γ-bands are general features of DPPQ calculations. The correct K-band structure in ^{158}Dy is reproduced using IBM-1.

The $I^\pi = 4^+$ level in the $K^\pi = 4^+$ band was found to be lower than the 4^+ level of the $K^\pi = 2_2^+$ βγ-band. The observed values of energy for $I^\pi = 4^+$ level in the $K^\pi = 4^+$ band is 1895 keV compared to 1884.8 keV in IBM-1.

Table1. The experimental values (in KeV) are compared with DPPQ and present IBM-1 calculations.

K^π Band[d]	Spin→	0^+	2^+	3^+	4^+
0_1^+	EX[a]	0	99		317
	EX[b]	0	98.9		317.1
	DPPQ[c]	0	99		282
	IBM-1	0	88.6		295.3
2_1^+	EX[a]		946	1045	1164
	EX[b]		946.3	1044.6	1163.8
	DPPQ[c]		1262	1390	1500
	IBM-1		952.2	1040.8	1158.8
0_2^+	EX[a]	991	1086		1280
	EX[b]	990.5	1085.6		1280
	DPPQ[c]	1119	1376		1660
	IBM-1	976.7	1065.4		1272.2
4_1^+	EX[a]				1895
	EX[b]				
	DPPQ[c]				2473
	IBM-1				1884.8
2_2^+	EX[a]		1852	1941	2055
	EX[b]		1852	1940.8	2055.4
	DPPQ		2290	2613	2695
	IBM-1		2314.1	1868.0	1948.6
0_3^+	EX[a]	1710	1840		2383
	EX[b]	1269[e]	1362[e]		
	DPPQ[c]	2097	2595		2895
	IBM-1	1654.0	1846.5		

[a] Lee, (1980). [b] Helmer, (2004). [c] Gupta et al., (1992). [d] The notation 0_1^+ means the first $K^\pi = 0^+$ band, 41+ means the first $K^\pi = 4^+$, etc.
[e] Helmer, (2004) observed 0^+ and 2^+ states of $K^\pi = 0_3^+$ band at 1269 keV and 1362 keV respectively. No transition from these two states was observed.

Absolute B(E2) Values And Static Moments

The B(E2, $0^+g \rightarrow 2^+$) values are available for various 2^+ states as observed from the coulomb excitation work (Ronningen et al.,1982). The DPPQ (Gupta et al., 1992) and present IBM-1 calculation does reproduce the large B(E2, $0_1 \rightarrow 2_1$) value and values smaller by an order of magnitude for the 2_γ^+ (= 2_2^+) and 2_β^+ (= 2_3^+) states, although the last two values differ in magnitude by a factor of two from experiment (see Table 2). The B(E2) values which are much smaller are obtained for the higher 2^+ states in IBM-1 calculation. The IBM-1 value of quadrupole moment $Q(2_1^+)$ is in agreement with experiment. The calculated B(E2; $4_g^+ \rightarrow 2_1^+$)/B(E2; $2_g^+ \rightarrow 0_1^+$) ratio is very close to experimental value indicating that ^{158}Dy lies on SU(5) to SU(3) transition, because its SU(5) limiting value is 2.

Table 2. The absolute B(E2) values (in $e^2.b^2$), quadrupole moments and B(E2) ratios for (g→g) transitions.

Quantity	Expt[a]	IBM-1	DPPQ[d]
B(E2; $0_g^+ \rightarrow 2_1^+$)	4.67(4)	4.6435	3.92
B(E2; $0_g^+ \rightarrow 2_2^+$)	0.149(8)	0.017	0.069
B(E2; $0_g^+ \rightarrow 2_3^+$)	0.053(8)	0.001	0.118
B(E2; $0_g^+ \rightarrow 2_4^+$)		0.0002	$2x10^{-5}$
$Q(2_1)$ (e.b)	-1.96(2)[c]	-1.9516	-1.79
$Q(2_2)$ (e.b)		1.7602	
$Q(2_3)$ (e.b)		-1.7227	
$Q(4_1^+)$ (e.b)		-2.4721	
$Q(4_2^+)$ (e.b)		-0.8819	
$Q(4_3^+)$ (e.b)		-2.1835	
$Q(4_4^+)$ (e.b)		2.7853	
B(E2; $4_g^+ \rightarrow 2_1^+$/ $2_g^+ \rightarrow 0_1^+$)	1.35[b]	1.4095	1.48

[a] Ronningen et al., (1982). [b] Lee, (1980). [c] Rotor model value. [d] Gupta et al., (1992).

Result and Conclusion

The energy levels of various bands of ^{158}Dy are calculated using the interacting boson model-1. There was agreement between experiment and the present IBM-1 calculation. The analysis was extended up to six K-bands with $I^\pi \leq 4^+$. The energy levels of various bands, absolute B(E2) values and B(E2) ratios for inter- band and inter-band transitions are calculated from interacting boson model-1. The theoretical values of interacting boson model-1 are compared with dynamic- pairing- plus – quadrupole model. The interacting boson model-1 results are in agreement with experimental and dynamic-pairing- plus – quadrupole model results.

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