B (E2) values of transitions from $K^{\pi} = 0^{+} \rightarrow 2^{+}$ vibrational bands in some well deformed heavy nuclei

M. Singh[1], Mani Varshney[2], Chhail Bihari[3], Yuvraj Singh[4], A.K.Varshney[5],
K.K.Gupta[6] and D. K. Gupta[2]
[1]*S. S. L. D. Varshney Girls Engineering College, Aligarh-202001, (U.P.), INDIA*
[2]*S. V. College, Aligarh-202001, (U.P.), India*
[3]*Bon Maharaj Engg. College, Vrindavan, Mathura, (U.P.), India*
[4]*Govt. College, Dharamshala, (H.P.), India.*
[5]*Pt. Sant Ram Govt. Degree College, Baijnath-176125, (H.P.), India*
[6]*Govt. College, Dhaliara – 177103, (H.P.), India*
Email: singh.moti@gmail.com

Experimentally collective $K^{\pi} = 0^{+} \rightarrow 2^{+}$ excitations with energy about 1 MeV have been known for a long time, and are termed beta vibrations from the interpretation $K^{\pi} = 0^{+}$ as component of the quadrupole shape oscillations. Using Asymmetric Rotor Model *(ARM)*, Davydov and Rostovsky derived expression for computing *E2* reduced transition probabilities for transitions from levels of the beta vibrational band to the ground state rotational band. Zawische et al; interpreted that beta vibrational character comes from the coupling of the low-lying pairing vibrations like $K^{\pi} = 0^{+} \rightarrow 2^{+}$ levels with the high lying beta vibrations like resonances. Therefore, there is simultaneous reduced *B (E2)* values of low-lying $K^{\pi} = 0^{+} \rightarrow 2^{+}$ states, indicating a beta vibration like structure as well as the two particle transfer cross – section which suggest a pairing vibration like character and interpreted that low–lying $K^{\pi} = 0^{+} \rightarrow 2^{+}$ resonance are classical beta vibrations [1]. Recently, similar doubts about the origin of beta vibrations from surface oscillation have also been published [2].

The mass coefficients (B_{β}, B_{γ} & B_{rot} for β, γ-and ground state band respectively) play an important role for the description of nucleus and *E2* transition probabilities between the *β*- & *γ*-vibrational and ground state band [3]. The Bohr Hamiltonian uses one common mass coefficient to calculate E2 transition probabilities of rotational, *β* & γ-vibrational modes. Jolos and Brentano have calculated *B (E2)* values using the well known Davydov - Chaban procedure to solve approximately the Bohr Hamiltonian with three different mass coefficients.

Their calculations indicate that the Grodzins products (P_g, P_{γ}, P_{β}; given by equation 1, 2 & 3 and tabulated in table I) for the yrast band and the vibrational band are inversely proportional to the mass coefficients which in hydrodynamic approach are slowly varying functions of the mass number *A* and charge number *Z* [3].

$$P_g = E(2_g^+)B(E2;0_g^+ \rightarrow 2_g^+)Z^{-2}A^{2/3} \ldots\ldots\ldots (1)$$

$$P_{\gamma} = E(2_2^+)B(E2;0_g^+ \rightarrow 2_{\gamma}^+)Z^{-2}A^{2/3} \ldots\ldots\ldots (2)$$

$$P_{\beta} = E(2_{\beta}^+)B(E2;0_1^+ \rightarrow 2_{\beta})Z^{-2}A^{2/3} \ldots\ldots (3)$$

Table I: Parameters used in the present work

Nucleus	P_g	P_{γ}	P_{β}	B_{γ}/B_{rot}	B_{β}/B_{rot}
^{154}Sm	*2.63*	*0.83*	*0.20*	*3.17*	*6.40*
^{156}Gd	*2.94*	*0.96*	*0.13*	*3.06*	*11.7*
^{162}W	*2.47*	*0.75*	*0.20*	*3.29*	*6.05*

Table II: Intraband transition ratios

Nucleus	*Exp.*	$B(E2;2_{\beta} \rightarrow \frac{4_g}{0_g})$ $B_{\gamma} = B_{\beta} = B_{rot}$
^{182}W	*0.070*	*0.126*

The intraband *E2* reduced transition probabilities have been calculated under the assumption that $B_\beta=B_\gamma=B_{rot}$ (table II) which are in good agreement with the experiment. But, under this assumption the calculated *E2* transition probabilities have the hindrance/ enhancement factor 5 or 6 with the experiment in case of interband *E2* transition probabilities. The interband *E2* transition probabilities calculated under the assumption $B_\beta \neq B_\gamma \neq B_{rot}$ are tabulated in table III which are very close to the experiment. Thus, the assumption that B_β, B_γ & B_{rot} have different values is important only for the calculations of the interband *E2* transition probabilities. ^{154}Sm, ^{156}Gd and ^{182}W are the representative of the well deformed even nuclei in heavy mass region and the experimental values of the Grodzins type products in the unit of $KeV.e^2b^2$ and the values of the ratios B_γ/B_{rot} and B_β/B_{rot} calculated using the relation

$$\frac{B_\gamma}{B_{rot}}=\frac{P_g}{P_\gamma}\ \&\ \frac{B_\beta}{B_{rot}}=\frac{P_g}{P_\beta}\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

Adiabatic approximation in Davydov - Filippov model [4] is unacceptable but the results obtained by this rigid rotor model are very close to experiment as far as *(E2)* ratios & intruder values are concerned.

The Davydov–Rostovsky model [5] in which the freedom of β & γ has been introduced, the results of *B (E2)* ratios deviates from experiment and this was the reason why this genuine model could not get its proper place while explaining nuclear structure. We, therefore, for the first time attempt to revive the half century old Rostovsky model considering the different mass coefficients for different modes of rotation and vibrations. Few known *B (E2)* ratios in ^{154}Sm, ^{156}Gd and ^{182}W have been considered in *DR* model and the results of B_β, B_γ and B_{rot} which were large have reduced and come closer to the experiment. On taking $B_\beta \neq B_\gamma \neq B_{rot}$ nuclei considered are well deformed in heavy mass region possess the smaller value of asymmetry. Therefore, the low-lying $K^\pi=0^+$ oscillations do belong to pure beta character, ^{154}Sm nucleus which primarily was embraced by Zawische et. al [1] is now backing to the asymmetric rigid rotor regime [5].

Table III: Interband transition ratios

Nucleus	$B(E2;\frac{0_g\to 2_\beta}{0_g\to 2_\gamma})$			$B(E2;\frac{0_g\to 2_\beta}{0_g\to 2_g})$		
		DR			*DR*	
	Exp.	$B_\gamma = B_\beta = B_{rot}$	$B_\gamma \neq B_\beta \neq B_{rot}$	*Exp.*	$B_\gamma = B_\beta = B_{rot}$	$B_\gamma \neq B_\beta \neq B_{rot}$
^{154}Sm	*0.28*	*1.1*	*0.55*	*0.003*	*0.04*	*0.006*
^{156}Gd	*0.15*	*0.91*	*0.20*	*0.002*	*0.05*	*0.004*
^{182}W	*0.60*	*0.94*	*0.50*	*0.012*	*0.05*	*0.009*

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