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SU(3) DYNAMICAL SYMMETRY AND ODD-EVEN ($\Delta L = 1$) STAGGERING IN HEAVY DEFORMED NUCLEI

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We propose that the odd-even staggering (OES) in the γ- bands of heavy deformed nuclei, which is traditionally considered in terms of a plot of the moment-of-inertia parameter versus the angular momentum L, can be reasonably characterized by the quantity:

$$Stg(L) = 6\Delta E(L) - 4\Delta E(L-1) - 4\Delta E(L+1) + \Delta E(L+2) + \Delta E(L-2)\ , \qquad (1)$$

which is the discrete approximation of the fourth derivative of the function $\Delta E(L) = E(L+1) - E(L)$, i.e. the fifth derivative of the γ- band energy $E(L)$. This expression is introduced by analogy with the $\Delta L = 2$ staggering observed in superdeformed nuclei and diatomic molecules [1]. We have shown that it provides a well developed $\Delta L = 1$ staggering pattern (zigzagging behavior of the function $Stg(L)$) in all nuclei for which the gamma band is long enough ($L \geq 10$), ^{156}Gd, ^{156,160,162}Dy, $^{162-166}$Er, ^{170}Yb and ^{228,232}Th.

We show that OES can be interpreted reasonably as the result of the interaction of the γ band with the ground (g) band in the framework of a Vector Boson Model (VBM) with SU(3) dynamical symmetry. In the VBM the two bands are coupled into the same (λ, μ) multiplet of SU(3) [2, 3]. For the multiplets of the type $(\lambda, 2)$ the model provides a simple expression for the γ- band energy levels:

$$\begin{aligned} E^{\gamma}(L) &= 2B + AL(L+1) \\ &+ B\left[\sqrt{1 + aL(L+1) + bL^2(L+1)^2} - CL(L+1) - 1\right]\left(\frac{1+(-1)^L}{2}\right)\ , \qquad (2) \end{aligned}$$

where the quantities A, B, C , a and b are determined by the effective model interaction. The last factor in Eq. (2) switches over E^{γ} between the odd and the even states and thus gives a natural possibility to reproduce the parity effects in the γ-band structure. It is important to remark that such a result is a direct consequence of the SU(3) dynamical symmetry mechanism.

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Eq. (2) reproduces successfully the zigzagging of the quantity $Stg(L)$ in all considered nuclei. The experimental and the theoretical staggering patterns obtained for the nuclei ^{164}Er and ^{166}Er are illustrated in Fig. 1.

We established that for the considered nuclei the $\Delta L = 1$ staggering amplitude varies in rather wide range. For example, for $L = 8$ the absolute value of the quantity $Stg(8)$ is observed in the limits $0.01 - 0.5$ MeV

The analysis of the staggering patterns in rare earth nuclei shows that the amplitude generally decreases towards the midshell nuclei. The best example is the group of the three Er isotopes, ^{162}Er (with $Stg(8) = 0.425$ MeV), ^{164}Er ($Stg(8) = 0.251$ MeV) and ^{166}Er (with $Stg(8) = -0.013$ MeV) (See Fig. 1).

This observation is consistent with the general behavior of the nuclear rotational properties in the limits of the valence shells. It is well known that towards the midshell region these properties are better revealed so that any kind of deviations from the regular rotational band–structures should be smaller. In this respect the weaker $\Delta L = 1$ staggering effect observed in the midshell isotopes of rare earth nuclei is quite natural.

On the other hand, such a behavior of the staggering effect can be reasonably interpreted in terms of the ground–γ band interaction. It has been shown in the SU(3) dynamical symmetry framework that the mixing of the two bands systematically decreases towards the middle of a given rotational region [4]. This is associated with the corresponding increase in the energy separation between them. In terms of dynamical symmetry one has an increase in the splitting of the SU(3) multiplet. So, the weaker mutual perturbation of these two bands in the midshell region is consistent with the respectively good rotational behavior of the γ-band.

The above consideration is consistent with the recently suggested possibility [3, 4] for a transition from the g–γ band coupling scheme of the VBM, which is more appropriate near the ends of the rotational regions, to the Interacting Boson Model classification scheme [5] with β–γ band coupling, which is more relevant in the midshell nuclei.

Further, it has been established that for the nuclei under study the experimental staggering amplitude generally increases with the increase of the angular momentum L up to $L = 12 - 13$ (For instance see Fig. 1 (b)). This result is well reproduced by the theoretical expression Eq. (2) which provides a monotonous increase of the function $Stg(L)$.

Interesting behavior of the staggering amplitude is observed in the nucleus ^{164}Er (Fig. 1 (a)). In this case the amplitude initially increases up to $L = 8 - 10$ and then begins to decrease. Further, at $L = 14$, an irregularity in the alternative signs of the quantity $Stg(L)$ occurs. Actually, at this angular momentum the structure of the γ-band of ^{164}Er is changed due to a crossing with another band and a backbending effect is observed. It is remarkable that the experimentally determined quantity $Stg(L)$ gives an excellent indication for the presence of bandcrossing effects.

The results presented show that the use of the fourth derivative of the odd-even ($\Delta L = 1$) energy differences gives a rather accurate quantitative measure to estimate the magnitude of the OES effect in the γ- bands of heavy deformed nuclei. Hence one is able to assess this effect for a given angular momentum or given region of angular momenta. In such a way the role of the band-mixing interactions could be correctly taken into account. Moreover, the well determined staggering amplitudes together with the clearly established alternating signs pattern allow one to provide various quantitative analyses of the fine structure of nuclear collective bands as a whole.

The approach suggested gives a rather general prescription to study the fine effects based on various band mixing interactions in nuclei. It allows relevant tests and detailed comparison of different band coupling schemes with SU(3) dynamical symmetry.

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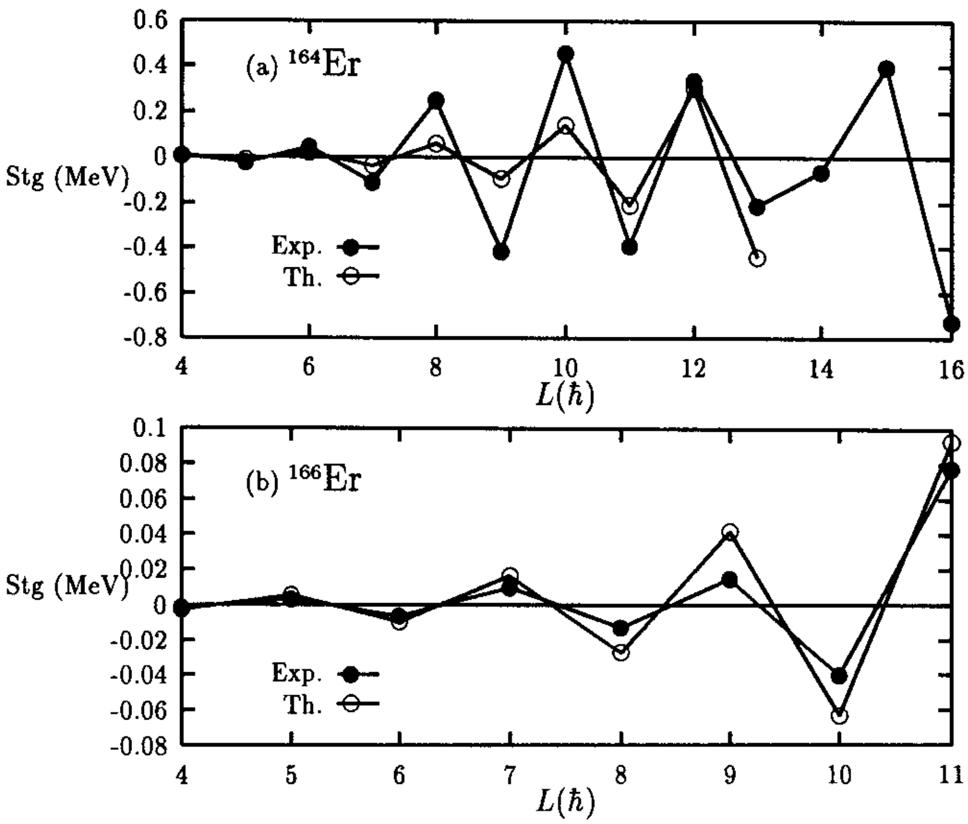

Fig. 1. $\Delta L = 1$ staggering pattern for (a) ^{164}Er and (b) ^{166}Er (data from [6]).

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