Evidence of increasing deformation with particle number for superdeformed shapes

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Historically, the spherical magic numbers have played a key role in the development of nuclear physics and nuclear models [1]. Many pieces of empirical evidence support the existence of spherical magic numbers (N or Z = 2, 8, 20, 28 etc.); prominent among these are the behavior of the neutron separation energies and the binding energies, number of isotones and isotopes for a given N and Z respectively, the excitation energies of the first 2^+ states and the ratio of the first 4^+ to 2^+ level energies in the even – even nuclei. The idea of magic numbers has since been generalized to non – spherical shapes, and the relationship of shapes and shell structure has played a vital role in the development of nuclear structure physics [2-5]. It is now well known that the shell closures at the 2:1 axes ratio in the deformed oscillator potential lead to a good understanding of the phenomenon of high spin super-deformation and the fission isomers. Hundreds of superdeformed (SD) bands in different mass regions [6] and the fission isomers in the heavy mass nuclei have been observed. Their understanding in terms of the shell correction based models, testify to the success of the shell correction based approaches. For detailed discussion on SD bands we refer the reader to Ref. [7,8]. In the past, much attention has been paid to the SD bands in A=150 mass region where ^{152}Dy (Z=66, N=86) has been used as a doubly magic core to obtain some of these unique features like the incremental alignment and the identical band nature of the SD bands [9-12]. An empirical analysis of the SD bands [13], based on the dynamical features of a semi-classical analysis of the cranking and the particle rotor models [14, 15], also pointed out many general features like the rigid body nature of the moment of inertia and a negative alignment. It was suggested that the SD bands are unique structures located around twin stable fixed points in a sea of chaos. A detailed numerical analysis of the semi-classical model in the non-linear regime and a comparison with the experimental data was then carried out to obtain features like the $\Delta I=2$ staggering [16].

In searching for the SD configurations and their theoretical ramifications, Ragnarsson *et al.* [4], in 1978, pointed out the existence of chains of particle numbers for superdeformed configurations by using the harmonic oscillator potential and also the modified oscillator potential. Later on, Bengtsson *et al.* [17] and Dudek *et al.* [18] pointed out the same with the Woods-Saxon potential. It was also pointed out [4] that the increasing mass number A leads to increasing deformation of the SD bands, which was later established by several calculations in the mass region A~110 to A~150 [17-22]. We have given the direct empirical evidence, by using the simple premise as mentioned above for the spherical magic numbers, to confirm these predictions [23]. Sufficient data on SD bands allowed us to carry out such an analysis in many ways. We presented many types of empirical evidence and reconfirm many of the previous theoretical predictions [4, 17-18]. We observed that the SD configurations occur for chains of the particle numbers, and that the deformation increases with the particle number. In doing so, we identified the most probable SD magic numbers.

On the basis of the various kinds of evidence [23], we identified Z = 30, 38-41, 46, 58, 59, 62 and N= 30, 36, 42-46, 59, 60, 72-75 as the most favored magic numbers for the 1.5:1 shape. Similarly, we identified Z = 64, 80-82 and N = 80, 111-115 as the most favored magic numbers for the 1.7:1 shape. The most favored magic numbers for the 2:1 shape are obtained as Z = 64-66 and N = 86.b Finally, we plot in Fig. 1, the measured deformation of only those SD bands which have a magic number of protons or, neutrons as a function of the mass number A. The plot confirms the theoretical finding that increasing particle number leads to increasing deformation [4, 19]. We are able to confirm this feature in all the mass regions, right from A~ 80 to A~ 190.

Acknowledgement

Author (NS) thank the Chairman, CT Group of Institutons for providing the facility do the research work.

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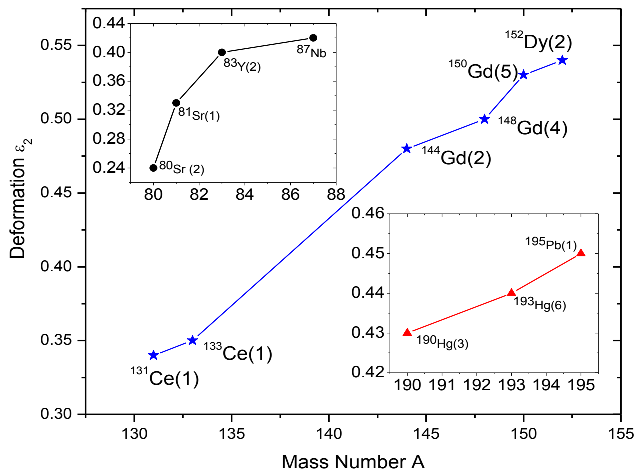

Fig. 1. (color online). Plot of the measured deformation vs. mass number for the SD bands corresponding to the magic numbers of protons/neutrons from A=80 to A=190.

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