Systematic study of some universal features of superdeformed nuclei

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The phenomena of superdeformation was first experimentally observed in the ^{152}Dy which led the study of superdeformed (SD) bands at the forefront of nuclear structure. The superdeformation is now studied widely in other mass regions such as $A \sim 190, 150, 130$ and 80. Presently, a very enormous data about the SD bands is available. However, this experimental data essentially consist the intraband $\gamma-$energies. This is because of unavailability of discrete $\gamma-$transition linking SD states to normal deformed (ND) states.

The aim of this thesis was to systematically study the universal features of the superdeformed nuclei in the various mass region with the help of different phenomenological rotational energy formulae/ models. All 20 SD bands of $A \sim 80$ mass region have been analysed with the VMI model, *ab* formula and Harris ω^2 expansion [1]. Out of these formulae/models, the band head spin obtained from the two-parameter *ab* formula found to be close to the experimental spin in the axial-symmetric SD bands. For triaxial SD bands in the ^{86}Zr, the band head spin obtained from the VMI model agrees with the available experimental results [2]. The band head moment of inertia calculated of all these SD bands are close to each other, $\Im_0 \sim (23 \pm 6)\hbar^2 MeV^{-1}$. Further, the calculated band head spin of $^{86}Zr(4)$ is $1\hbar$ higher than $^{86}Zr(2)$ and the band head MOI of these two bands are very close to each other. This is in favour of the conjecture that $^{86}Zr(4)$ and $^{86}Zr(2)$ are signature partner SD bands.

Next, we have for the first time employed the soft rotor formula (SRF) to deduce the band-head spin of the 17 SD bands in Tl isotopes in the $A \sim 190$ mass region. The SRF formula provides very promising results, making it an alternative formula to study various properties of the SD bands [3]. According to the band head MoI $\Im_0$ values obtained by using SRF, the SD bands of Tl isotopes may be classified into two groups, i.e., odd-odd (even-A) nuclei and odd-even (odd-A) nuclei. The band-head MoI's for odd-odd nuclei, ^{192}Tl and ^{194}Tl are highest ($\Im_0 \sim 97 \pm 6 \quad \hbar^2\text{MeV}^{-1}$) among other isotopes. Also, $\Im_0$ obtained for the bands $^{192}Tl(1)$ and $^{192}Tl(2)$ is exceptionally large for which occupied high-j intruder orbitals are responsible. The $\Im_0$ obtained for ^{193}Tl is $\Im_0 \sim 85 \quad \hbar^2\text{MeV}^{-1}$, while for ^{191}Tl a value of $\Im_0 \sim 75 \quad \hbar^2\text{MeV}^{-1}$ is obtained. This decrease in $\Im_0$ of about 10% for ^{191}Tl could be due to increased neutron pairing as one departs from secondary shell gap at $N = 112$.

We presented a reliable phenomenological analysis of identical bands SD bands using two parameter soft rotor formula, semiclassical particle-rotor model (PRM) and exponential model with pairing attenuation. A total of 12 identical SD band pairs available in $A \sim 190$ mass region of Hg, Tl and Pb isotopes [4] and 4 pairs in the $A \sim 150$ mass region relative to the yrast SD band in the ^{152}Dy nucleus are analysed [5]. Since all the energy expressions depend explicitly upon the assigned spins of the SD bands, hence the band-head spins of identical pairs in the $A \sim 150, 190$ mass region are deduced using nuclear softness (NS) formula. A reliable phenomenological analysis of 24 identical SD bands of the $A \sim 190$ mass region using NS formula and exponential model shows that the identical SD

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band pairs have similar band-head MoI. For the $A \sim 150$ mass region, reliable analysis of the 4 pairs of identical bands using the NS3 formula, semiclassical-PRM and modified exponential model with pairing attenuation reveal that the band head MoI, average MoI, and MoI in zero pairing limit is very similar.

The semiclassical PRM reveal very significant results for identical bands. For all the identical SD bands of the $A \sim 190$ mass region, the calculated average alignment (i) has the negative value which may have quantized nature. The semiclassical PRM in our calculations reveals that just as the alignments should be quantized, similarly, the anti-alignment of spin is also expected to give integer or half-integer values. The similar systematics are obtained for the identical SD bands $A \sim 150$ mass region. This result is consistence with the "pseudospin alignment" concept of the Stephens *et al.* [6] which accounts for the natural/unnatural quantized spin alignments in the $A \sim 190, 150$ mass region.

Our calculations also reveal similar effective pairing Δ_0 parameter for identical band pairs, which correspond to the similar residual nucleon-nucleon correlations, results in the similarities of intraband $\gamma-$transitions energies and hence the dynamic moment of inertia. In summary, we have shown that the identical SD bands of the $A \sim 150$, 190 mass region have similar band-head MoI and effective pairing parameter. Also, the identical bands may have quantized spin alignments as proposed by Stephens *et al.* [6]. The present systematic study of the identical SD bands thus provided the evidence of the unified descriptions of the identical SD bands in the various mass regions.

Next, a systematic study of flat SD bands in the Tl [3] and Pb [7] isotopes is made using the shape fluctuation model [8]. The shape-fluctuation energy E_{SF} of these results reveal that they have a negligible contribution to the total intraband $\gamma-$transition energies and maximum contribution is from the rotational energy term. The results obtained from the SF model further lend support from the calculation of the minimal vibrational distortion factor $\Im^{(2)}_{vib}$ for $^{192}Tl(1,2)$ and $^{195}Pb(1,2)$. The negligible value of the softness parameter and alignments obtained from the NS formula and semiclassical PRM reveals that the deformation is higher and the alignments are negligible for the flat SD bands. Taking these evidence into consideration, it seems that the flat SD bands have a very minimal contribution from shape variation and most of the energy corresponds to the rotational energy having higher deformation and minimal effective pairing parameter. This observation gives support to our proportion that the flat SD bands are "super rigid" SD bands.

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References

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