Multi-faceted study of the nuclear structure of deformed nuclei

Poonam Jain*
Amity Institute of Nuclear Science and Technology, Amity University, Uttar Pradesh-201303, India

Introduction

The deep understanding of internal structure and the properties of atomic nucleus has become a versatile issue in the field of nuclear physics. The thesis deals with two important areas of nuclear physics; Normal Deformed (ND) and Super-Deformed (SD) nuclei. The nuclei having collective motion along with the single particle motion are called Normal Deformed [1–5] and those nuclei which are very far from spherical shapes, forming an ellipsoidal shape with axes ratio approximately 2 : 1, are called Super-Deformed. The nuclei in SD states are highly rigid and unstable so they last only for fraction of seconds and they emit γ-rays and their study is also very useful to explain the various features of SD nuclei [6, 7]. The theoretical modelling is the only way to explain various features and properties of SD band as transition energies are the only information available experimentally [8]. Due to the non-linkage to low lying states and very short life time of SD nuclei it is difficult to provide spin parity assignment experimentally. A new finding in the SD region is the discovery of Triaxial Super-Deformed (TSD) bands [9, 10]. These nuclei have an additional degree of freedom for rotational motion in comparison to axially symmetric deformed nuclei and its rotational angular momentum is distributed among three different axes. This thesis work is one of the important step to deal with some fascinating and challenging features of Normal Deformed and Super-Deformed nuclei in the actinide [11, 12] and rare earth regions respectively. The work on Newby shift and n-p residual interaction using TQPRM approach has been done for odd-odd nuclei in actinide region. We also focus on one of the striking property i.e. existence of identical bands in SD nuclei. Also, in this thesis, we focus on the spin assignment of TSD bands mainly available in the rare-earth region. Finally, this thesis deals with the theoretical explanation of ND bands in $K = 0$ odd-odd actinides using TQPRM model and the properties of SD and TSD bands in rare-earth region using modified VMI model.

The thesis is organized in **six** chapters. A brief description of the chapters to present the overview of findings are given as follows:

In **Chapter 1**, we review briefly the basic theoretical ingredients relevant for Normal and Super-Deformed bands.

In **Chapter 2**, we append the brief history of some phenomenological models the "Two Quasiparticle plus Rotor Model (TQPRM)" and the modified "Variable Moment of Inertia (VMI) Model" in Nuclear physics which we use as present models.

In **Chapter 3**, we revisit the role of n-p residual interaction and the Newby shift in $K = 0$ bands in the actinides. We present an analysis of all the experimentally known $K = 0$ bands in the deformed odd-odd actinide nuclei. By using the TQPRM model, we have obtained the value of Newby shift for these $K = 0$ bands. The Newby shift so obtained is expected to be free from the Coriolis mixing effects. A total of 11 bands of ^{238}Np, ^{234}Pa, $^{240-244}Am$ and ^{250}Bk have been analyzed. We find that the staggering pattern in all the cases is properly reproduced. We also examine the validity of an empirical rule to obtain the sign of the Newby shift. We find that for the 8 cases when $\Omega_n = \Omega_p \neq 1/2$, the rule predicts correct sign but the rule

*Electronic address: poonam.jn1@gmail.com

does not work in rest of the 3 cases when $\Omega_n = \Omega_p = 1/2$. As an important outcome, we propose the spin parity assignments and level energies of the $K = 0$ and $K = 5$ G-M partner bands in ^{240}Am, $\{5/2[523]_p \otimes 5/2[622]_n\}$. We resolve the tentative nature of the assignment and present a unique level scheme. Also, we predict the band-head energy of $K = 0$ bands in four cases, namely three $K = 0$ bands of ^{238}Np and one $K = 0$ band of ^{240}Am, where the band-head energy is not known experimentally. These results may be useful for future experiments.

In **Chapter 4**, We use modified VMI model to explore the TSD bands. The band-head spin (I_0) of TSD bands mainly available in rare earth region are predicted by using the model. Quantitatively good results of the γ energies and the spins of the TSD bands for Tm, Lu and *Hf* isotopes are obtained. The calculated and observed transition energies are agreed well when an accurate band head spin (I_0) is predicted. This method brings comprehensive interpretation for spin assignment of TSD bands which could help in designing future experiments for TSD bands. We have verified the obtained band-head spin by plotting ratio of transition energies over spin (RTEOS) $E_\gamma/2I$. The total of 44 TSD bands are reported in literature for Er, Tm, Lu and *Hf*. In this chapter, we have predicted the band head spin for 20 Triaxial Super-Deformed bands which are known experimentally. Out of 20 bands, the band-head spin is assigned correctly for 16 TSD bands using VMI equations and for the rest 4 TSD bands the spin predicted is either higher or lower than the observed values. Overall, we are able to predict the spins of TSD bands firmly. The results of calculations are close to experimental value and helpful for the theoretician for further study in this area.

In **Chapter 5**, we further extended our idea to explain Identical Bands (IBs) in the Super-Deformed region. We applied the modified VMI model to extract the band-head and level spins of Super-Deformed bands. The calculated transition energies, level spins and dynamic moment of inertia are systematically examined. A total of 16 pairs of IBs are identified in the SD region. Further, in the framework of VMI model, the kinematic and dynamic moment of inertia have been calculated for these identical pairs. Secondly, the N_pN_n scheme is applied to verify the existence of IBs in the Super-Deformed nuclei. The parameters like structure factor, saturation parameter, p-factor etc. deduced from N_pN_n scheme are also in well agreement. A quite good agreement is found between experimental data and theoretical calculations.

In **Chapter 6**, we present a summary and conclusions drawn from this thesis work and provide some insights in this area for future research work.

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