Structure Evolution Yb isotopes using Microscopic framework

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Introduction

The medium to heavy mass ytterbium nuclei with atomic number Z=70 are situated in the rare earth region. These nuclei are known to be well deformed and their energy spectra can be populated up to high spins [1]. With 70 protons, Yb isotopes lie far away from the proton shell closures and exhibit rotational properties in their ground-state bands. However, experimental information for the heavier Yb isotopes, even for their ground-state bands, is very limited pronouncing an existing gap of knowledge for the "east" part of the isotopic nuclear chart. This region of Segre chart has recently attracted lots of attention, both experimentally as well as theoretically.

The even–even Yb isotopes are considered as good candidates for extensive investigation of their rotational properties through calculations of various structural observables by making use of various well-established theoretical models [2-5]. Some of the previous studies have shown the presence of Triaxiality in these Yb isotopes which is an active research topic in the field of nuclear structure. The present research work is focussed on the nuclear structure elucidation of isotopic chain of Yb isotopes with mass number ranging from 160 to 178 and to have a thorough study of non-axial shapes as well as the high spin band spectra of these nuclei.

For the study of these even-even Yb isotopes, microscopic framework of triaxial projected shell model (TPSM) [6] has been used. This model has proved to be quite successful in the recent years to elucidate the structure of nuclei with axial asymmetry belonging to different mass regions. With the application of TPSM, the high spin band spectra of all the isotopes under consideration have been calculated and an excellent degree of agreement has been achieved. Also, the model has been able to predict the energy values of yrast and near yrast bands up to the spin where the experimental data was scarce.

The Theory of the Applied Model

To carry out the nuclear structure calculations for $^{160\text{-}178}$Yb nuclei, Triaxial Projected Shell Model has been used in the present work. In TPSM the configurations from 0-qp, the higher quasiparticles like 2- and 4-qp are explicitly included in the basis space. Therefore, it is considered as very useful model to study high-spin band structures and triaxial features of nuclei. In this model, the basis states include the triaxially deformed states. An explicit three-dimensional angular-momentum projection is performed for configurations built from the triaxially deformed Nilsson states. A triaxial quasiparticle configuration is an admixture of various K (projection along the symmetry axis) states, and the vacuum configuration is composed of K=0,2,4,...states in case of an even-even system. It has been shown that the angular-momentum projection from the K = 0, 2, and 4 states correspond to the ground, gamma- and gamma gamma-bands, respectively.

The TPSM calculations proceed in several stages. In the first stage, the triaxially deformed basis space is constructed by solving the Nilsson potential. In the second step, the good angular-momentum states are then obtained from the triaxially deformed basis by employing the three dimensional angular-momentum projection technique. In the third stage, the projected bases are used to diagonalize the model Hamiltonian. The set of deformation parameters, axial (ε) and triaxial (ε_4) are for all these isotopes and the corresponding triaxiality parameter has also been calculated.

Results and Discussions

The projected energies from various configurations, calculated with deformation parameters given above, are depicted in Fig. 1 for ^{160}Yb isotope studied in the present work. This diagram is known as band diagram and is very useful to extract structural information. Only the projected energies from low lying configurations are plotted as they are actively involved in the formation of lowest energy bands.

It is observed from Fig. that the projected bands from zero-quasiparticle, two-quasineutron, two quasiproton and 4-qp configurations are plotted. It can be seen from the fig. 1 that up to the spin 10^+, the (0,0) band is responsible for the formation of yrast. At spin 12^+, (1,2n) band crosses (0,0) band and becomes lowest in energy. At spin 14^+, (3,2n), (1,2p) and (3,2p) together cross the ground band and further at spin 18^+, 4-qp bands cross the (0,0) band. However, after 12^+, the lowest energy is of (1,2n) band and hence forms the yrast.

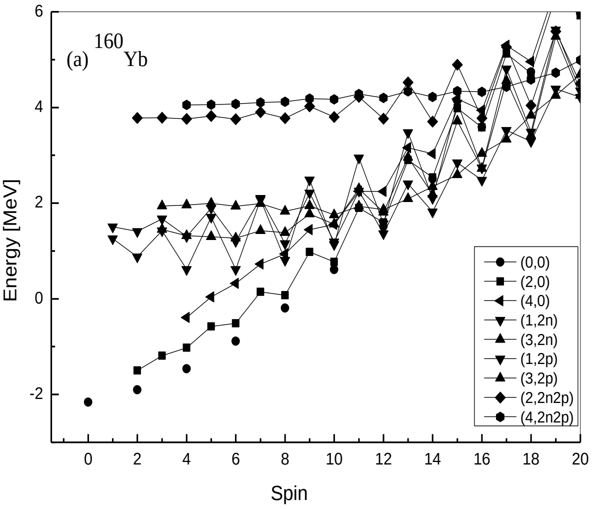

Fig. 1 Band diagrams of ^{160}Yb

The band energies, obtained after the process of diagonalization, are shown in Fig. 2 with the available experimental data. It is clear from the figure that TPSM results are in excellent agreement with the experimental energies and predicted band spectra up to high spins.

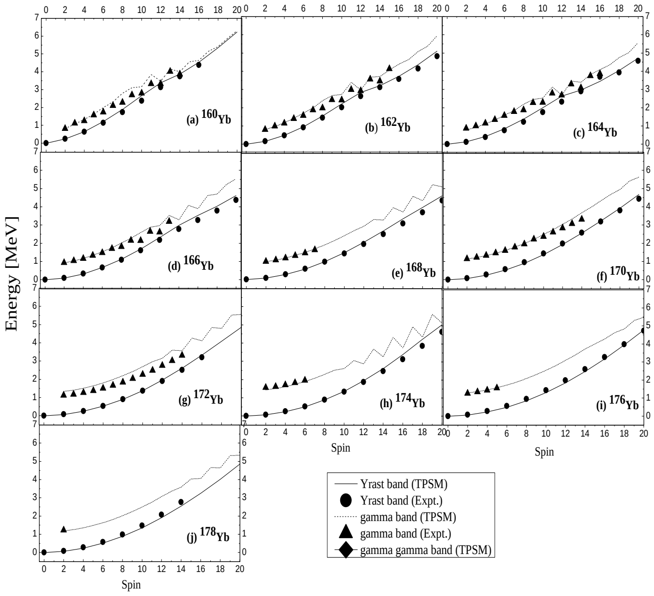

Fig. 2 Comparison of the Experimental and TPSM yrast spectra, gamma and gamma-gamma bands for $^{160-178}$Yb isotopes.

Summary

The band structure of $^{160-178}$Yb nuclei has been studied using a microscopic technique- Triaxial Projected Shell Model. The intrinsic structure of these nuclei has been interpreted in terms of multi quasi-particle configurations and useful information about the structure changes has been obtained. The calculated results are discussed along with their comparison with the available experimental data and an excellent agreement has been obtained between the two.

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