Excitation modes in spherical and transitional nuclei in $A \sim 130$ mass region

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Introduction

The mass A $\sim$ 130 region (with $Z \geq 50$ and $N \leq 82$) has been an important region of study in contemporary nuclear physics. This region includes the shell model orbitals $0g_{7/2}$, $1d_{5/2}$, $1d_{3/2}$, $2s_{1/2}$ and $0h_{11/2}$ for both protons and neutrons. For nuclei near ^{132}Sn (the heaviest, unstable neutron-rich doubly magic nucleus), the low-lying "single-particle excitation spectrum (angular momentum coupling of few nucleons)" can be explained using spherical shell model, with interactions known in this mass region. Such information is indispensable for the empirical estimation of the *p*-*p*, *p*-*n* and *n*-*n* matrix elements, a major component of the shell model interaction. Once these matrix elements are determined precisely from experiments, these can be used to predict and understand the proton-neutron configurations of the "vibrational (angular momentum coupling of vibrational core with valence quasiparticles)" and "rotational (angular momentum coupling of deformed core with valence quasiparticles)" bands in deformed nuclei, further away form ^{132}Sn. There are theoretical predictions that in nuclei further away from ^{132}Sn, the residual interactions among the valence nucleons in the $h_{11/2}$ orbital result in ground-state triaxial deformation of the nucleus [1, 2]. Such nuclei exhibit exotic rotational modes like *chirality* and *wobbling*, the experimental information of which is sporadic in this mass region. Hence, to explore these features, the nuclei, *viz.* ^{132}Te ($Z = 52, N = 80$), ^{130}Te ($Z = 52, N = 78$), ^{133}Cs ($Z = 55, N = 78$), ^{131}Cs ($Z = 55, N = 76$)and ^{133}La ($Z = 55, N = 76$) have been studied.

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Experimental Details

Two different experimental setups were used for performing the γ-ray spectroscopy of all these isotopes, as outlined below:

(a) Indian National Gamma Array (INGA) at TIFR, Mumbai:
The INGA array at TIFR is a clover detector array with the provision of placing 24 Compton suppressed clover High Purity Germanium (HPGe) detectors connected to a Pixie-16 Digital Data AcQuisition (DDAQ) system, the details of which can be found in the Ref. [3]. Four different experiments were carried out using this setup:
(i) ^{232}Th(^{7}Li, fission (^{132}Te)) at 38 MeV [4].
(ii) ^{130}Te(^{7}Li, 4n)^{133}Cs at 45 MeV [6].
(iii) ^{126}Te(^{11}B, 4n)^{133}La at 52 MeV [7].
(iv) ^{124}Sn(^{11}B, 4n)^{131}Cs at 55 MeV.

(b) EXOtic GAMma array-VAriable MOde Spectrometer (EXOGAM-VAMOS++) at GANIL, France:
The EXOGAM array at GANIL has the provision of accommodating 16 segmented Compton-suppressed HPGe clover detectors which is coupled to a VAMOS++ spectrometer consisting of dipole magnet, quadrupole magnets and a focal plane detection system equipped with MWPPAC, drift chambers, ionization chambers and silicon detector. The details of this setup can be found in the references Ref. [8, 9]. One experiment was carried out using this setup, the details of which is given below:
(i) ^{9}Be(^{238}U, fission (^{130,132}Te)) at 6.2 MeV/u [4].

Results and Summary

The present thesis work describes the experimental investigation of the high-spin states in various nuclei like, ^{132}Te and ^{130}Te (spherical nuclei); ^{133}Cs (vibrational nucleus); ^{133}La and ^{131}Cs (axially asymmetric deformed or triaxial nuclei) as summarized below:

(i) ^{130,132}Te: The time-stamped data obtained from the digital data acquisition system in INGA experiment allowed correlating the strongest γ rays feeding the 10^+ isomer in ^{132}Te with those depopulating it (prompt-delayed coincidence technique) and provided the angular correlation measurements for the strong transitions. The EXOGAM-VAMOS++ experiment, capable of isotopic identification of fission fragments, allowed further observation of high-spin states in ^{130,132}Te. The microscopic interpretation of these states have been carried out using the large Scale Shell Model (LSSM) calculations.

(ii) ^{133}Cs: Gamma-gamma coincidence technique, Directional Correlation of Oriented States (DCO) and polarization asymmetry measurements have been used to determine 22 new γ-ray transitions in ^{133}Cs, thus extending the existing level scheme upto an excitation energy of 5.265 MeV and spin-parity ($33/2^+$). Three one-quasiparticle $\Delta I = 2$ rotational structures arising from the $\pi g_{7/2}$, $\pi d_{5/2}$ and $\pi h_{11/2}$ orbitals and a three-quasiparticle (dipole) band due to $(\pi g_{7/2}\pi d_{5/2})^1 \otimes \nu h_{11/2}^{-2}$ configuration have been observed. These bands have been understood in terms of LSSM and Triaxial Projected Shell Model (TPSM) calculations.

(iii) ^{133}La and ^{131}Cs: The experimental confirmation of triaxial nuclei has been established in the $N = 76$ isotones, ^{133}La and ^{131}Cs, by observing the characteristic wobbling bands. This was made possible by measuring the electromagnetic properties of the interband transitions between the yrast band and the wobbling band using the INGA array. Angular distribution, DCO-ratio and polarization asymmetry measurements show that these interband γ rays are dipole transitions with a dominant electric character, hence confirming the wobbling mode. In addition, the wobbling frequency plot shows longitudinal wobbling for ^{133}La and transverse wobbling for ^{131}Cs. These phenomena have been studied using the TPSM, Quasiparticle Triaxial Rotor with Harmonic Frozen Approximation (QTR + HFA) and Tilted Axis Cranking (TAC) calculations.

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