High Spin Spectroscopy of Nuclei in A = 135 Mass Region

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Introduction

In the last few decades a number of $\Delta I = 1$ rotational bands have been observed in almost spherical nuclei. It was discovered that these bands arise due to a new type of excitation which is represented by the rotation of a large magnetic dipole around the nuclear spin and the phenomenon was called Magnetic Rotation (MR) [1]. These MR bands were characterized by the appearance of enhanced $M1$ transitions with weak/absent $E2$ crossover transitions. Several $\Delta I = 1$ bands with strong $M1$ transitions and weak crossover $E2$ transitions built on multi-quasiparticle configurations were observed in nuclei belonging to $A \sim$ 135 mass region. Moreover, the nuclei in this mass region have a larger deformation as compared to the ones in the Pb region. Hence, it was found interesting to see if MR mechanism played an important role in the mass region A $\sim$ 135.

In the present work, ^{135}La and ^{135}Pr nuclei have been investigated for the presence of MR bands. The experimental results obtained are presented and discussed within the framework of the Tilted Axis Cranking (TAC) model.

Experimental Details

Two experiments have been performed with the Indian National Gamma Array (INGA). In the first experiment, high spin states of ^{135}Pr were populated by the reaction ^{123}Sb(^{16}O,4n)^{135}Pr using ^{16}O beam of 82 MeV from the pelletron accelerator of Inter University Accelerator Centre (IUAC), New Delhi. The target consisted of a 800 μg/cm^2 ^{123}Sb with 10 mg/cm^2 ^{197}Au backing. At the time of the experiment, the array consisted of 15 Compton suppressed clover HPGe detectors placed at 32°, 57°, 90°, 123°, and 148°. The list mode data were taken in triple and higher fold γ-ray coincidence using a CAMAC based multi-parameter data acquisition system along with the CANDLE software. To populate high spin states in ^{135}La, the reaction ^{128}Te(^{11}B,4n)^{135}La was used at beam energy of 50.5 MeV. The ^{11}B beam was provided by the Pelletron Linac Facility at Tata Institute of Fundamental Research (TIFR), Mumbai. The target consisted of 1.02 mg/cm^2 ^{128}Te on 4 mg/cm^2 ^{197}Au backing. The array consisted of 16 Compton-suppressed clover detectors at the time of the experiment. These detectors were arranged in spherical geometry with clover detectors placed at 40°, 65°, 90°, 115°, 140°, and 157° with respect to the beam direction. The online collection of data was done via XIA based triggerless Digital Data AcQuisition (DDAQ) system.

The data of ^{135}La and ^{135}Pr were sorted using MARCOS and INGASORT programs, respectively. The coincidence events were analyzed off-line using the RADWARE software package.

Results and Discussion

^{135}**La** : The level scheme has been confirmed and extended both for low and high spin states along with the observation of several new transitions [2]. Among lower spin states, a new positive parity band ($\Delta I = 2$) has been observed. It has been seen that the energy level spacings in this band are similar to those in the even - even core nucleus ^{134}Ba. Hence, this band has been identified as a decoupled band. Two negative parity dipole bands ($\Delta I = 1$) have been established. In one of the band, referred to as band 6 (see [2]) $E2$ crossover transitions have been identified for the first time. Band 6 has

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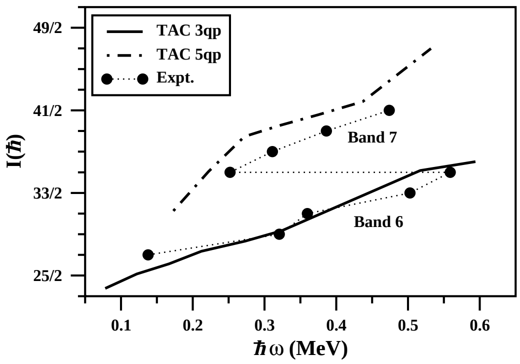

FIG. 1: I($\hbar$) vs $\hbar\omega$ of bands 6 and 7 for ^{135}La.

been extended to a spin of $37/2^-$ and excitation energy of 6028 keV. From the experimental plots of I($\hbar$) versus $\hbar\omega$ and E versus I($\hbar$), a band crossing has been observed between the negative parity dipole bands 6 and 7 at $\hbar\omega \approx 0.41$ MeV and $I \approx 35/2^-$. Theoretical calculations (TAC calculations) have been performed for bands 6 and 7 by taking their configurations as $\pi(h_{11/2})^1 \otimes \nu(h_{11/2})^{-2}$ and $\pi(h_{11/2})^1(g_{7/2}/d_{5/2})^2 \otimes \nu(h_{11/2})^{-2}$, respectively. The 3qp configuration assigned for band 6 and the 5qp configuration assigned for band 7 resulted in a minimum in the total energy at deformation of $\epsilon_2 = 0.120$, $\gamma = 58°$, average tilt angle $\theta = 31.1°$ and deformation of $\epsilon_2 = 0.116$, $\gamma = 60°$, average tilt angle $\theta = 29.8°$, respectively. The calculations were in good agreement with the experimental data (I versus $\hbar\omega$ (Fig. 1) and E versus I values) which supports the choice of the assigned configurations and suggest MR features for bands 6 and 7. It has been observed that the transitions 376- and 380-keV belonging to band 8 have Directional Correlations of Oriented states (DCO) ratios and polarization asymmetry values which are not consistent with $E2(\Delta I = 2)$, $E1$ and $M1$ character. Hence, these transitions have been assigned $\Delta I = 0$ character. The structure of the two $15/2^-$ states from which these transitions decay can arise from the coupling of one proton in $g_{7/2}/d_{5/2}$ orbitals with two neutrons in $h_{11/2}$ and $d_{3/2}$, respectively.

^{135}**Pr** : The partial level scheme consisting of only negative parity states was studied. In the negative parity level structure, several new transitions have been identified and placed. Among higher spin states, the $M1(\Delta I = 1)$ nature of band 3 [3] has been established by $R_{\rm DCO}$ and polarization measurements. The crossover $E2$ transitions in this band have been observed for the first time. From the experimental behaviour of I($\hbar$) versus $\hbar\omega$ a band crossing has been seen at $\hbar\omega \approx 0.37$ MeV. For the TAC calculations, a 3qp configuration $\pi(h_{11/2})^1 \otimes \nu(h_{11/2})^{-2}$ and a 5qp configuration $\pi(h_{11/2})^1(g_{7/2})^2 \otimes \nu(h_{11/2})^{-2}$ have been considered for the lower and upper part of the band, respectively. The minimum in the total energy was obtained at deformations $\epsilon_2 = 0.14$, $\gamma = 62°$, $\theta = 31.6°$ and $\epsilon_2 = 0.14$, $\gamma = 60°$, $\theta = 26.9°$ for the 3qp and 5qp configurations, respectively. A good agreement has been seen between the I versus $\hbar\omega$ experimental data and theoretical calculations. This supports the proposed configuration assignments to band 3.

Acknowledgments

I would like to acknowledge the support provided by the staff members of the Pelletron Linac facility at TIFR and Pelletron facility at IUAC, financial support of the Department of Science and Technology (DST), UGC-DAE-Kolkata centre and Council of Scientific and Industrial Research (CSIR).

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