Spectroscopy of ^{154}Tb

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Introduction

The study of level schemes of odd-odd deformed nuclei has always been challenging due to multiple band interactions and the existence of low-lying isomeric states. The light rare-earth region is where the rotational deformations begin. One of the features of this region is the existence of isomer triplets [1] in lighter rare-earths of which many have not been fully characterized. One such nucleus, ^{154}Tb (Z=65), is a case where two low-lying isomeric states, other than the gs, have been found experimentally [2] but lack definite assignments. The band structure and spin-parity assignment of the levels in the existing level scheme is based on comparison with the neighbouring isotopes and isotones. Except the three known low-lying isomeric states, the spin parity values of the rotational bands are all tentative. The parity of the I=0 gs state has also not been experimentally established. Earlier studies on the level structure of ^{154}Tb have mostly focused on expanding the level scheme to higher spin states [3,4] without much experimental observations on the lower members of the band structures. With an aim to resolve the ambiguity and characterize the low-lying level structure of ^{154}Tb, in-beam gamma spectroscopic studies were carried out. We report here the preliminary results of this experimental study.

Experimental Details

The excited states of ^{154}Tb were populated using the ^{152}Eu(α, 2n) reaction at E_{lab} = 39 MeV. The target was nat-Eu, in oxide form, of 6.5 mg/cm^2 thickness on mylar backing. The Indian National Gamma Array (INGA) at the Variable Energy Cyclotron Center (VECC), Kolkata, was used for gamma spectroscopy. During the experiment, the array consisted of 12 Compton-suppressed HPGe clover detectors positioned at three different angles; two detectors at 40º, six at 90º and three at 125º. The digital data acquisition system principally consisted of PIXIE-16 (XIA LLC) 12-bit 250 MHz digitizer modules running on a firmware that was conceptualized by the UGC-DAE CSR, Kolkata Centre [5]. Data were acquired under the condition of at least two Compton suppressed detectors firing in coincidence.

Data Analysis

The IUCPIX [5] software package, also developed at the UGC-DAE CSR, Kolkata Centre, was used to process the obtained data and generate the symmetric and asymmetric coincidence matrices. The asymmetric matrices were used to determine the directional correlation and the polarization of the observed γ-ray transitions. The Ratio of Angular Distribution from Oriented Nuclei (R_{ADO}), Ratio of Directional Correlation from Oriented Nuclei (R_{DCO}) and Polarization Asymmetry were calculated for the transitions in ^{154}Tb. Low-energy gammas which were known to be E2 transitions were gated to obtain the gammas belonging to the rotational bands of ^{154}Tb. The R_{ADO} and R_{DCO} were calculated at detector angles of 90º and 125º. The ratios thus obtained are plotted in Figs. 1-3.

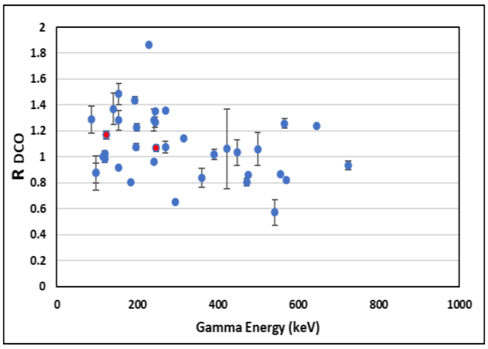

Fig 1: R_{DCO} vs gamma energy. The reference R_{DCO} values of ^{154}Gd gammas are in red

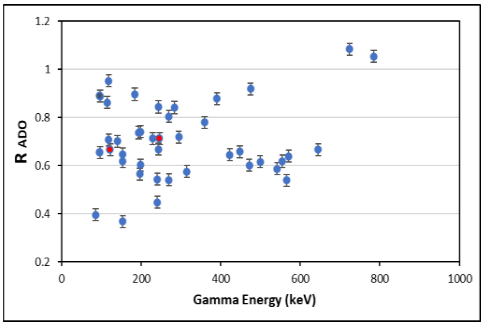

Fig 2: R_{ADO} vs gamma energy. The same reference gammas used in R_{DCO} are used here.

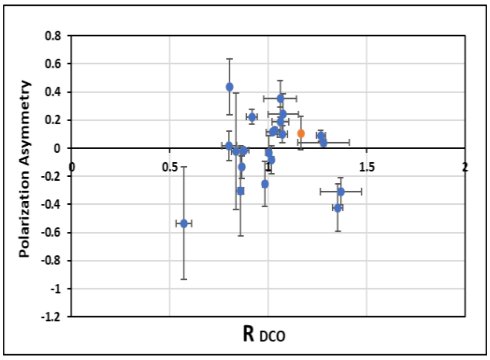

Fig 3: Polarization asymmetry vs R_{DCO}. The reference R_{DCO} and corresponding asymmetry value of ^{154}Gd gamma is highlighted in red.

Results

This is the first time these experimental ratios have been calculated for the ^{154}Tb gammas. The range of R_{ADO}, R_{DCO} and Polarization asymmetry values give an understanding of the nature of the gamma transitions.

It can be seen in fig. 1 that, the observed ^{154}Tb gammas mostly have a R_{DCO} value in the range 1–1.5. Taking the R_{DCO}=1.155±0.04723 of observed gammas of ^{154}Gd as reference for stretched E2 transitions in stretched E2 gates, we can infer that most of the ^{154}Tb gammas exhibit stretched E2 character [2]. Similarly, with the same ^{154}Gd gammas, a reference value of R_{ADO}= 0.6895±0.0223 can be fixed to signify E2 character. Most gammas of ^{154}Tb have R_{ADO} values within the E2 reference range, as seen in fig 2. The polarization asymmetry plot in fig. 3 helps in identifying the polarization of the transition. From the plot, it is seen that most of the γs have a positive asymmetry value and a R_{DCO} value ~1, again indicating stretched E2 behaviour. The negative asymmetry values for a few gammas may denote admixture of magnetic multipoles.

We conclude from this study that the nature of the ^{154}Tb γs is predominantly stretched E2. This inference has been made from the R_{ADO}, R_{DCO} and polarization values of the ^{154}Tb gammas obtained in the experiment. This is in agreement with the tentative spin-parity assignments for the levels in previous studies [3,4]. Further analysis of the coincidence spectra is currently underway for constructing the low-lying level scheme with the aim to unambiguously assign spin-parity to the gs of ^{154}Tb nucleus, as pointed out in our earlier study [1].

Acknowledgement

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