Observation of the nearly degenerate doublet bands in ^{143}Sm nucleus: Violation of the chiral symmetry

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Introduction

In nuclear structure studies, chirality is the mostly studied phenomena in triaxial nuclei during the last decade. Chirality is a direct consequence of the perpendicular coupling of the angular momentum vectors from the valence proton and neutron occupying high-j particle-like and high-j hole-like orbitals aligned along the short and long axes, respectively, and the angular momentum vector due to the triaxial core rotation oriented along the intermediate axis [1]. In such a case the projections of the angular momentum vector on the three principal axes can form either a left- or a right- handed system and thereby making the system chiral. Since the chiral symmetry is dichotomic, its spontaneous breaking by the axial momentum vector leads to a pair of degenerate $\Delta I = 1$ rotational bands, called chiral doublet bands [2].

Several candidates for chiral nuclei have been reported experimentally in the $A \sim 80$, 100, 130, and 190 mass regions [2, 3]. The nearly degenerate energy levels of the same spin and parity and the spin independent energy staggering which is indicative of the three mutual perpendicular angular momentum vectors of the triaxial nuclei are the necessary signatures to identify the ideal chiral bands. The electromagnetic signature due to the chiral symmetry breaking sets up the almost equal $B(E2)$ values for the chiral twin bands. Correspondingly, the $B(M1)$ values should exhibit odd-even staggering. This means that the $B(M1)/B(E2)$ ratios also exhibit the odd-even staggering for the both partner bands.

Recent work on ^{143}Sm has provided the evidence of a dipole cascade with a bandhead energy at 8.4 MeV [4]. The present investigation reveals another dipole band almost degenerate in energy with the previously observed dipole sequence. The crossover $E2$ transitions for the yrast and side bands confirmed the placement of the transitions in the bands. In $A \approx 140$, nuclei are predicted to be gamma soft due to the excited nucleons and become triaxial at high spin regime. It is thus imperative to investigate possible existence of chirality in the ^{143}Sm nucleus and if the same exist for the multiquasiparticle configuration.

Experimental details

High spin states in ^{143}Sm have been populated using the reaction ^{124}Sn (^{24}Mg, 5n) at $E_{lab} = 107$ MeV. The ^{24}Mg beam has been obtained from the Inter University Acceleration centre (IUAC), New Delhi. The beam was incident on 0.8 mg/cm^2 of ^{124}Sn target on a 13 mg/cm^2 thick Au backing. The de-exciting γ-rays were detected by the Indian National Gamma Array (INGA) array [5] which consisted of 18 Compton suppressed clover detectors placed at four different angles.

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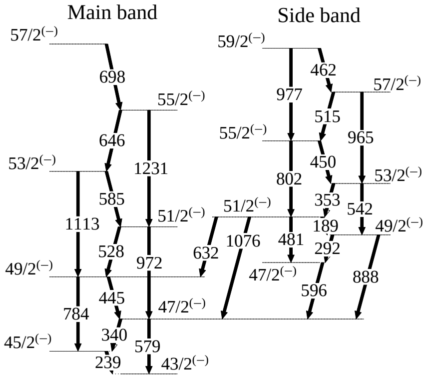

FIG. 1: The partial level scheme of ^{143}Sm (degenerate doublet bands) obtained in the present work.

Results and discussion

The partial level scheme of ^{143}Sm (Fig. 1) has been established from the coincidence relationships, relative intensity (I_γ) and R_{DCO} measurements. The previously reported γ-transitions of the yrast dipole structure have been confirmed and modified in the present investigation. The yrast structure has been extended upto the $57/2^{(-)}$ state by placing 528, 585, 646 and 698 keV transitions above 445 keV transition. The observation of 972, 1113, 1231 keV crossover $E2$ transitions confirmed

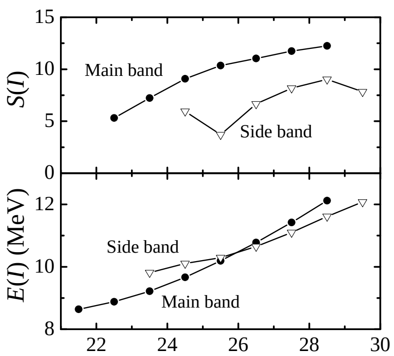

FIG. 2: The experimental energy $[E(I)]$ and energy staggering $[S(I) = (E(I) - E(I-1))/2I]$ values for the main band and side band in ^{143}Sm.

the placement of these dipole transitions. Another dipole cascade constituting with 292, 189, 353, 450 and 462 keV dipole transitions connected to the yrast sequence by the 632, 1076, 888 and 596 keV γ transitions has been observed first time in the present experiment.

The excitation energy $[E(I)]$ and the energy staggering $S(I)$ values for the two bands in ^{143}Sm are plotted as a function of spin (Fig. 2). The absence of staggering of the $S(I)$ values for both the bands indicates weak Coriolis interactions resulting from perpendicular angular momenta coupling of the single particle to that of the core. The energy degeneracy (Fig. 2) shows almost identical behavior indicating the strong influence of the core rather than the valence particles. Such observations strongly indicate that these bands are chiral partners owing to their characteristics, irrespective of their origin. The proposition needs to be stringently tested in the light of the electromagnetic properties of the observed bands. The observation of this doublet structure in near shell closure nucleus ^{143}Sm reveals breakdown of a symmetry with resemblance to chirality. The detailed calculations will be presented to unravel the intrinsic stucture of the nearly degenerate doublet bands.

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