In-beam γ-ray spectroscopy of ^{140}Sm

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Introduction

The nuclei with Z > 50 and N < 82 are known to have some of the largest ground-state deformations in the nuclear chart [1]. The phenomenon of shape coexistence is expected to occur in nuclei of mass region A $\approx$ 140. In the even-even nuclei with mass number A $\approx$ 140, the alignment of both neutron and proton quasiparticles in the $h_{11/2}$ orbital generates low-lying 10^+ state which is an isomeric state [2]. These excitations have been localized in the N = 78 ^{140}Sm and ^{142}Gd nuclei [3]. The ^{140}Sm nucleus belongs to a transitional region where the nuclear shape changes rapidly with neutron number from a spherical shape at the N = 82 shell closure to a relatively large deformation for the most neutron-deficient Sm isotopes at neutron mid-shell. The two distinct 10^+ states of single-particle nature are due to the coupling of two aligned proton particles or two aligned neutron holes in the $h_{11/2}$ orbital with configuration $\pi(h_{11/2})^2$ and $\nu(h_{11/2})^{-2}$, respectively. Isotopes of Sm (Z = 62) in the vicinity of the ^{146}Gd (Z = 64, N = 82) core have been subjects of many spectroscopic investigations for a long time. The present work pertains to the in-beam gamma spectroscopy of ^{140}Sm with the spin-parity assignment to a dipole band and several new gamma transitions are also observed.

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Experimental details

The high-spin states of ^{140}Sm were populated with the ^{116}Cd(^{28}Si, 4n)^{140}Sm heavy ion fusion evaporation reaction using ^{28}Si beam at 128.7 MeV provided by the TIFR-BARC Pelletron LINAC facility at TIFR, Mumbai. An isotopically enriched ^{116}Cd (1 mg/cm^2) was evaporated on Au foil (6 mg/cm^2) to form the target. The de-exciting γ-rays were detected by using the Indian National Gamma Array (INGA) comprising of 19 Compton suppressed Clover detectors at seven different angles of -23°, -40°, -65°, 90°, 65°, 40° and 23°, with respect to the beam direction. Two and higher fold γ-γ coincidence data were recorded in a fast digital data acquisition (DDAQ) system [4] in the list mode format.

Data Analysis and Results

The multipolarities of the γ-ray transitions have been determined from an angular correlation analysis using the method of directional correlation of oriented states (DCO) ratio. Data were sorted by using the MARCOS program developed by TIFR group and a γ-γ asymmetric matrix was created with the angles 157° and 90° on x-axis and y-axis, respectively. RADWARE software was used to analyze the asymmetric matrix to obtain the DCO ratio.

The DCO ratio can be calculated from the intensities of γ-rays (I_γ), at two angles 157° and 90°, as

$$R_{DCO} = \frac{I_{\gamma 1}\ at\ 157^\circ\ gated\ on\ \gamma_2\ at\ 90^\circ}{I_{\gamma 1}\ at\ 90^\circ\ gated\ on\ \gamma_2\ at\ 157^\circ}$$

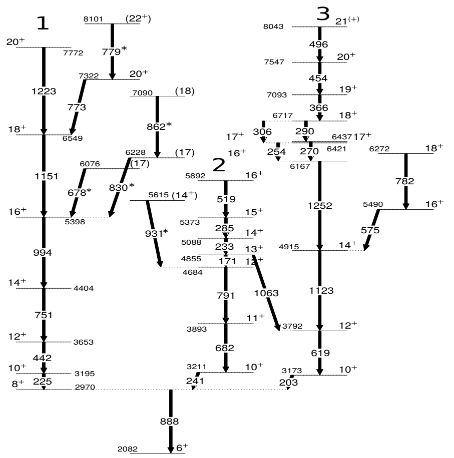

FIG. 1: Partial level scheme of ^{140}Sm.

For a gated stretched dipole transition, the DCO ratio was found to be ≈ 1 (≈ 2) for stretched dipole (quadrupole) transition. Furthermore, for a gated stretched quadrupole transition, the DCO ratio was having value ≈ 1 (≈ 0.5) for stretched quadrupole (dipole) transition. Parities can be assigned from the measurement of the integrated polarization asymmetry (IPDCO) ratio from the parallel and perpendicular scattering of γ-ray photon. The IPDCO ratio measurement give the qualitative idea about the type of transition (electric or magnetic). The experimental IPDCO asymmetry parameter can be defined as

$$\Delta_{IPDCO} = \frac{a(E\gamma)N_{\perp} - N_{\parallel}}{a(E\gamma)N_{\perp} + N_{\parallel}}$$

where $N_{\parallel}$ and $N_{\perp}$ are the counts for the actual Compton scattered γ-rays in the planes parallel and perpendicular to the reaction plane, respectively. The factor a(Eγ) is asymmetry parameter defined by $N_{\parallel}/N_{\perp}$, denotes the correction and having value close to unity. Spin and parity are assigned for the transitions above 16^+ state and having excitation energy $\sim$ 6.1 MeV. Fig. 1 shows the partial level scheme of ^{140}Sm nucleus. The information about spin and parity assignments is included in Table 1.

In the partial level scheme, three bands are shown having 5 new γ-transitions (marked with asterisk). Band 1 is electric quadrupole having configuration $\pi(h_{11/2})^2$, band 2 is magnetic dipole and band 3 is also electric quadrupole having configuration $\nu(h_{11/2})^{-2}$ upto 16^+ level and magnetic dipole after 16^+ with some mixed transitions as shown in table 1.

Present angular correlation measurement confirms the dipole nature of γ-transitions in band 3 above 16^+. Spin of 5 different states has been confirmed for the band 3. Polarization result confirms the magnetic dipole with some mixed transitions. Δ_{IPDCO} value could not be measured for 306 and 496 keV transitions. Further analysis is in progress and results will be presented and discussed in detail during the symposium.

TABLE I: γ-rays transition (in keV), level energy (in keV), DCO ratio (after gating on quadrupole transition) and Multipolarity in ^{140}Sm.

E_γ	E_{level}	R_{DCO}	*Multipolarity*	$J_i^\pi \rightarrow J_f^\pi$
254	6421	0.42±0.03	M1	$17^+ \rightarrow 16^+$
270	6437	0.54±0.02	M1	$17^+ \rightarrow 16^+$
290	6727	0.63±0.04	M1/E2	$18^+ \rightarrow 17^+$
366	7093	0.50±0.02	M1/E2	$19^+ \rightarrow 18^+$
454	7547	0.49±0.02	M1/E2	$20^+ \rightarrow 19^+$
496^a	8043	0.52±0.04		$21^{(+)} \rightarrow 20^+$

^{a}Polarization values could not be calculated.

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