Study of Nuclear Shape Coexistence in A ≈ 140 Region Using In-beam Gamma Spectroscopy

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In mass 140 region, the light rare earth nuclei have drawn considerable attention due to the interplay between collective rotation and single particle motion. Depending on the configurations of the valence quasiparticles, various structural characteristics can be seen in nuclei in this region which in turn gives us information about nuclear shapes, shape coexistence, nonaxial deformation etc. The present thesis is aimed at probing different structural aspects like shape coexistence of nuclei in the vicinity of mass 140 region.

In nuclei for this region, both protons and neutrons are at the same high j shell, i.e. $h_{11/2}$ orbital which gives us an opportunity to study the role of p-n interaction and its influence on both collective rotation as well as single particle motion.

The generation of angular momentum for weakly deformed systems in this mass region also evokes considerable interest in recent years. This is because at low energy, these nuclei are expected to exhibit single particle behaviour due to the proximity of the shell closure. However the proton can occupy the intruder high spin orbit $h_{11/2}$, thus leading to a moderately high spins at low energy. Moreover, due to availability of particles and holes in the high j orbital ($h_{11/2}$) phenomena like magnetic rotation is expected in this mass region and in fact magnetic rotational bands have been observed in many nuclei in this region.

In the present work I have studied the nuclei $^{138}\mathbf{Pr}_{59}$, $^{139}\mathbf{Nd}_{60}$ and $^{141}\mathbf{Nd}_{60}$ by using the technique of in-beam gamma spectroscopy with a view to observe the complex interplay between collective motion and single-particle degrees of freedom.

For the present work three multi-detector arrays i.e. Gamma Detector Array (GDA), Indian National Gamma Array (INGA) and EUROBALL have been used.

In all the experiments data have been collected in list mode and the coincidence data have been sorted to produce matrices and cubes and finally analysed with standard software packages like INGASORT & RADWARE. The multipolarities of the observed γ-rays are determined from DCO ratios. Shell model, relativistic mean field model and CNS formalism have been used to interpret the observed levels in these nuclei.

Levels of doubly odd ^{138}Pr

The main motivations behind the present work are: i) to study in a more extensive way the level scheme of ^{138}Pr with a larger array of HPGe detectors and ii) to determine the relevant experimental data (i.e. branching ratio and B(E2)/B(M1) values) for a meaningful comparison with the theoretical work done earlier within the framework of Particle Rotor Model (PRM). The level properties of ^{138}Pr are studied using the GDA of eight detectors through the reaction ^{128}Te(^{14}N,4n) at a beam energyof 55-65 MeV obtained from the 15UD Pelletron Accelerator at the IUAC, New Delhi. The experimental details, our measurement results and theoretical comparisons are reported in the work [1]. The level scheme of ^{138}Pr contains a total of 87 transitions of which 53 are newly observed. Several new level sequences have been established in this nucleus and the present work confirms, to an extent, with the earlier report on the three primary bands. However, it has been possible to find out a number of new in-band and inter-band transitions in these bands. Three additional structures are also being proposed. The level properties of the yrast band have been compared with theoretical calculations performed within PRM. The theoretical branching ratios and B(M1)/B(E2) values suggest an oblate core for yrast band. Comparing other similar Pr nuclei, probable configurations of other bands are also suggested [1].

Collective structures of ^{139}Nd

In this article [2] we report on spectroscopy of high spin states in ^{139}Nd using the EUROBALL spectrometer. High-spin states in ^{139}Nd have been populated in the reaction ^{96}Zr(^{48}Ca,5n) with a 195 MeV Ca beam from the Vivitron tandem accelerator at IReS, Strasbourg. The level scheme has been extended considerably and most of the information of earlier works has been confirmed. An interesting feature of the level scheme at low energy is the presence of several M1 bands. Of these bands, C, E and H are completely new. The quadrupole band J is another new addition. We have also added a few linking transitions from the known bands to the lower excited states, modified the placement of the band F and modified the sequence of gamma transitions of band I. We confirm all the transitions placed in the two bands 1 & 2, extend them up to $81/2^-$ and $89/2^-$ respectively and observe one new rotational band (band 3) at high spin. In addition the bands 1 and 2 have now been connected to bands G and B, respectively [2]; which was earlier unobserved. The decay transitions from the band 3, and hence exact spin and parity assignments to the states could not be established. However, DCO ratio measurements show that the band consists of transitions of quadrupole nature. Relativistic Mean Field calculations have been utilized to investigate the configuration of the dipole bands. Calculations based on the Cranked Nilsson Strutinsky formalism have been used to assign configurations to the high-spin quadrupole bands. These low deformed bands have been interpreted as triaxial structures.

High spin states of ^{141}Nd

The earlier studies on ^{141}Nd reported levels up to about 3 MeV in excitation energy and 17/2 in spin. No study of ^{141}Nd using heavy ion fusion-evaporation reaction was published. The neighbouring odd A-isotope ^{139}Nd shows a triaxial shape at low spin, while at high spin magnetic rotational bands are observed in the light of TAC calculation. This work is initiated with the motivation to extend the level scheme of high spin states of ^{141}Nd and also to look for any possible occurrence of magnetic rotation in this nucleus. High spin states of ^{141}Nd nucleus are studied in two separate experiments. Using the GDA set-up with 10 detectors the primary experiment employs the ^{130}Te(^{16}O,5n) reaction utilizing the ^{16}O beam from 15UD Pelletron Accelerator at IUAC, New Delhi. High spin states of ^{141}Nd are also populated in a second experiment in the reaction ^{124}Sn (^{24}Mg, α3n) at a beam energy of 107 MeV using the INGA array stationed at IUAC, New Delhi. The partial level scheme of ^{141}Nd [3] contains 30 new transitions and almost all the earlier known transitions. Apart from placement of a number of new gamma transitions and some rearrangement at the low energy section of the scheme, the principal new findings are the structures identified as A, B, C and D in the level scheme, all of which were completely unknown previously. Band B is observed to be an M1 band while the sequence C is a bifurcation of it. The sequence of transitions D consists mainly of quadrupole transitions. The level scheme clearly exhibits a single particle character for most of the levels. The nucleus ^{141}Nd has 10 valence protons and 1 valence neutron hole, both lying in the 50-82 shell. The shell model code ANTOINE along with unrenormalized Bonn-A interaction for 50-82 shell has been employed in studying the negative parity states up to approximately 6 MeV in excitation energy and $31/2^-$ spin. We also investigate the configuration of the M1 band B using a particle hole calculation in the relativistic mean field approach using the blocked BCS method

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References

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