Signature Splitting in Three Quasiparticle Rotational Bands of Odd-A Nuclei

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In odd-A nuclei, for excitation energy greater than proton or neutron pairing gaps, either a proton-proton or a neutron-neutron pair can break to generate a three-quasiparticle (3qp) quadruplet, on each member of which one rotational band is formed. Rotational bands and associated high-spin phenomena are one of the important aspects of nuclear structure. The dynamics of these high-spin phenomena are influenced through the interplay between pairing interactions, moments of inertia, Coriolis interaction and particle-particle interactions. In present work, we explored one of the intriguing high-spin phenomena namely signature effects observed in 3qp rotational bands of odd-A nuclei. The signature effects refer to splitting of one rotational band ($\Delta I=1$) into two rotational spin sequences with $\Delta I=2$ and characterized as favored and unfavored branches. When the expected favored branch become unfavored at particular spin then the condition is knowing as signature inversion. To perform an extensive and systematic analysis of signature effects, we extracted the experimental data of 3qp rotational bands having strong signature effects (signature splitting and signature inversion) observed in rare-earth mass region. We found total 27 three quasiparticle rotational bands in ^{155}Dy, ^{157}Ho, ^{163}Er, ^{157,165}Tm, ^{159,163,165,167}Lu, ^{167,173}Ta, ^{165,167,179}W, ^{181}Re, ^{171,181,183,185}Os and ^{185}Pt isotopes which possess pronounced signature splitting and sometime signature inversion also. To identify the underlaying mechanism behind these phenomena, we employed the Three Quasiparticle Plus Rotor Model (3QPPRM) [1] approach which relies on the Coriolis and particle-particle band mixing among various rotational bands present in the basis space. The 3QPPRM is preferred because it is in terms of angular momentum which is a physical observable in the experiments and hence a direct comparison with the experimental data can be made. For the test case, we select the rotational band built over $3/2[521]_\nu \otimes 1/2[660]_\nu \otimes 1/2[660]_\nu$ 3qp configuration observed in ^{155}Dy [2]. This band arise due to the coupling of low-Ω and high-j orbitals and is good example to illustrate the transmission of energy staggering through Coriolis ($\Delta K=1$) and particle-particle couplings ($\Delta K=1$). For the above said 3qp configuration, there are four possible bandheads namely $K^\pi=5/2^-$, $3/2^-$, $3/2^-$ and $1/2^-$. From the available experimental indicators, it was not possible to assign to which bandhead (out of above four) the experimentally observed band corresponds. In order to resolve this problem as well as to reproduce the experimentally observed signature effects, we have carried out the complete Coriolis mixing calculations in the framework of 3QPPRM. The basis space of present calculations consists of 48 rotational bands. The single particle wave functions by using the Nilsson model [3] with deformation parameters as $\epsilon_2 =0.210$, $\varepsilon_4 =-0.02$ [4] and potential parameter $\kappa =0.0636$, $\mu =0.393$ [5]. The optimized values of crucial variable parameters such as bandhead energies, inertia parameters and Newby Shifts are obtained using Minute minimization subroutine [6] by minimizing the deviation among experimental and theoretical energies. We successfully reproduced the observed signature splitting and assigned the band under investigation as $K^\pi=5/2^-$: $3/2[521]_\nu \otimes 1/2[660]_\nu \otimes 1/2[660]_\nu$. The RMS deviation among calculated and experimental energies for spin range from $I=25/2^-$ (at 2012.3 keV) to $77/2^-$ (at 11972 keV) is found to be 82.6 keV which indicate the reliability of present calculations. The calculations of signature effects in other odd-A isotopes are in progress.

References
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