Signature Reversal in $K_- = 2^-$, $\{h_{11/2} \otimes d_{5/2}\}_p$ band of ^{170}W

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Introduction:

The experimental data on two quasiparticle rotational bands of even-even rare earth nuclei [1] have been examined and reveal significant signature dependence in both $K_+ = (\Omega_1+\Omega_2)$ and $K_- = |\Omega_1-\Omega_2|$ bands [2]. These bands show more complexities as compared to rotational bands of doubly odd nuclei [3, 4]. A systematic of rotational bands in deformed doubly even nuclei have been studied in detail and exhibit a number of interesting features like odd- even staggering [2] and signature reversal [5]. We found the phenomenon of signature reversal in $^{162}_{66}Dy$, $^{170}_{70}Yb$ and $^{170}_{74}W$ in doubly even nuclei in rare earths. Earlier the phenomenon of signature reversal is well reproduced in ^{170}Yb by Goel et al. [5]. In the present paper we show TQPRM calculations for ^{170}W, having two quasiproton configuration which represents the reverse pattern of staggering i.e. signature reversal.

Input Parameters:

We have explained signature reversal within the framework of two quasiparticle plus axially symmetric rotor model [6] which is modified to perform calculations for doubly even nuclei. The TQPRM calculations involve many parameters which were taken from Nilsson model. The standard Nilsson parameters were used $\kappa_p = 0.0620$ and $\mu_p = 0.614$ [7] with a deformation of $\epsilon_2 = 0.208$ and $\epsilon_4 = 0.020$ [8] to obtain the single particle energies and $\langle j+ \rangle$ matrix elements. The quasiparticle energies were obtained by using a fixed value of pairing gap Δ = 1Mev and Gallagher splitting was assumed to be about 300keV in all the cases. The Inertia parameter ($\hbar^2 / 2\Im$) is taken as 10.0keV and 10.5keV for K_+ and K_- bands respectively and adjusted during the fitting process. The calculations require mixing of many 2qp experimentally known and unknown bands; so estimated energies of experimentally unknown bands is obtained by using semi-empirical formulation [9].

Results and Discussion:

The rotational bands of even - even nuclei exhibit odd – even staggering and the favored signature is given by:

$$\alpha_f = 1/2(-1)^{j_1 - (1/2)} + 1/2(-1)^{j_2 - (1/2)} \; ..... (1)$$

where j_1 and j_2 represents that both the particles are now identical. For $\alpha_f = 0$, even spins are favored and $\alpha_f = 1$, odd spins are favored. On the other hand empirical rule proposed by Frisk gives favored spin I_F in a K= 0 band to be

$$I_F = (j_1 + j_2 - 1) \bmod 2 \; ...... (2)$$

Which is opposite to the odd – even shift of K = 0 bands in doubly odd nuclei.

According to rule, in ^{170}W, for $K_-=2^-$ band, with two quasi proton configuration $\{9/2[514]_p \otimes 5/2[402]_p\}$, $\alpha_f = 0$ i.e. even spins should lie lower in energy throughout the staggering pattern. Generally, the levels with α_f are expected to lie lower in energy, but in the experimental data we note that favored signature states lie higher in energy than the unfavored states. This abnormal feature is called signature reversal. In Fig. 1 we plot the ratio ΔE (I→I-1) /2I in (keV) vs. spin I for the $K_-=2^-$ band in ^{170}W; the experimental data is shown by the solid line.

A schematic model calculations for two quasi proton configuration $\{(h_{11/2})_p \otimes (d_{5/2})_p\}$ with the inclusion of $g_{7/2}$ proton orbital were carried out to reproduce the observed energies of ^{170}W. A total of 16 rotational bands were included, of which only the $K_-= 2^-$ band is experimentally known. The abnormal behaviour of $K_- = 2^-$ band is arising from the ultimately coupling through a chain of $K_- = 0^-$ and 1^- band. There is a strong mixing between $K_- = 0^-$, $\{5/2[532]_p \otimes 5/2[402]_p\}$ and $K_- = 1^-$, $\{7/2[523]_p \otimes 5/2[402]_p\}$ band. Both the $K_- = 0^-$ and $K_- = 1^-$ band favors odd spin throughout the pattern. The signature dependence of $K_- = 0^-$ and $K_- = 1^-$ band is transmitted to the $K_- = 2^-$ band through Coriolis coupling. The Newby Shift of $K_-=0$ band plays an important role in explaining reversal feature in $K_- = 2^-$ band of ^{170}W. The value of Newby Shift for K=0, $\{5/2[532]_p \otimes 5/2[402]_p\}$ band is -215.16 KeV (fitted value), which is supported by Frisk rule. The obtained staggering is in good agreement with the experimental staggering pattern. Our calculations successfully reproduce the magnitude of staggering at higher spin region although the magnitude of staggering is less at lower spin region as shown in Fig.1.

Conclusion:

The feature of signature reversal in 2qp, $K_- = 2^-$, $\{9/2[514]_p \otimes 5/2[402]_p\}$band of even – even nucleus ^{170}W is well reproduced by TQPRM calculations and is of similar nature to the signature inversion observed in odd –odd nuclei. It is well shown that signature reversal is due to the Coriolis effect arising due to strong mixing of $K_- = 0^-$ and 1^- band. The Newby Shift of $K_- = 0^-$ band is also playing an important role to obtain the required magnitude of staggering. The calculations to reproduce signature reversal in ^{162}Dy are in progress.

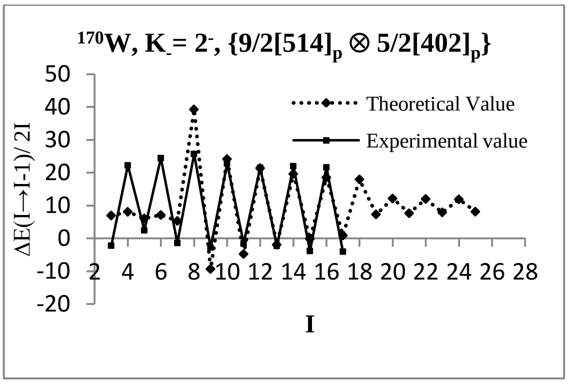

Fig.1: Odd - even staggering plot for the experimental data (solid line) of $K_-= 2^-$ band in ^{170}W showing the signature reversal. Results of TQPRM calculations are shown by dashed line.

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