Systematics of antimagnetic rotation in even-even Cd isotopes

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Introduction

In nearly spherical nuclei, bands with regularly spaced energy levels originate due to Shears mechanism where the particle and hole angular momenta form the two blades of the shears structure [1–3]. The various observed features of these bands can be described in terms of the angle between the two blades namely, the Shears angle (θ) [3].

An interesting consequence of the shear structure has been pointed out by S. Frauendorf [2]. It is possible to have a symmetric double shears structure, where each hole in the time reversed orbit, combines with the particles whose angular momentum vector is along the rotational axis. Thus, the angle between the two hole vectors is 2θ. The higher angular momentum states in this scenario, will be generated by simultaneous closing of the two shears and is represented by, $I = j_p + 2j_h \cos\theta$. In this specific case, the two perpendicular components of the dipole moments cancel each other due to the symmetry of the structure which leads to the absence of M1 transitions. This coupling scheme has been termed as antimagnetic rotation (AMR) due to it's similarity with anti ferro-magnetism [2]. In this model, the electric quadrupole transition rate (B(E2)) is proportional to $\sin^4\theta$ [3].

Therefore, as the two shears close symmetrically, the B(E2) rates will show a characteristic drop with increasing angular momentum, which distinguishes a AMR band from a band arising due to collective rotation.

In the present work the lifetime of the yrast band of ^{110}Cd have been measured and the extracted B(E2) rates exhibits a steady fall with increasing angular momenta beyond I $\sim$ 18$\hbar$ (see Fig. 1(b)). The close similarity in the nature of the measured B(E2) rates with the lower mass even-even Cd isotopes indicates to a possibility of AMR mechanism in ^{110}Cd. However, the high spin alignment behavior of ^{110}Cd is completely different from already known antimagnetic rotor nuclei, ^{106}Cd [4] and ^{108}Cd [5].

This puzzling fact have investigated in the light of two-particle-plus-rotor model [3]. For the Cd-isotopes, the two symmetric shears are formed between $j_h{}^{(1)} = j_h{}^{(2)} = j_\pi$ and $j_p = j_\nu = a j_\pi$, where a is the ratio of the magnitude of proton and neutron angular momenta.

In this model the energy E(I) is given by [6],

$$E(I) = \frac{(\boldsymbol{I} - \boldsymbol{j_\pi} - \boldsymbol{j_\nu})^2}{2\Im} + \frac{V_{\pi\nu}}{2}(\frac{3\cos^2\theta - 1}{2}) + \frac{V_{\pi\nu}}{2}(\frac{3\cos^2(-\theta) - 1}{2}) - \frac{V_{\pi\pi}}{n}(\frac{3\cos^2(2\theta) - 3}{2}) \quad (1)$$

where the first term is the rotational contribution and the rest of the terms are the shears contribution. The repulsive interaction between the neutron particles and proton

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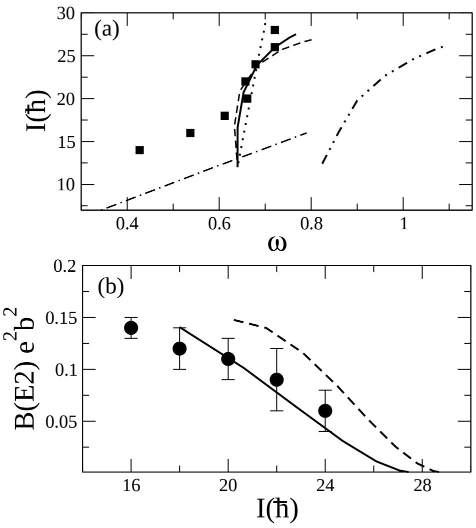

FIG. 1: The observed I(ω) plot (a) and B(E2) rates (b) in ^{110}Cd. The dot-dashed and dot-dot-dashed line in (a) represents a rotor with moment of inertia of 19.5 and 13 MeV$^{-1}\hbar^2$, respectively. The dotted, solid and dashed lines in (a) represents the calculated routhians for $V_{\pi\pi}$= 0, 0.15 and 0.30 MeV, respectively and eQ_{eff} = 1.1 eb. The solid and the dashed lines in (b) represents the calculated B(E2) values for AMR+rotation and pure AMR, respectively.

holes is $V_{\pi\nu}P_2(\theta)$ (2^{nd} and 3^{rd} term), where $V_{\pi\nu}$ is the interaction strength [3]. The hole-hole (proton-proton) attractive interaction is $V_{\pi\pi}P_2(2\theta)$ (4^{th} term) and has been assumed to be of the same form [3] with the additional boundary condition that it vanishes for $\theta = 0$ [6]. 'n' is the scaling factor between $V_{\pi\nu}$ and $V_{\pi\pi}$.

The corresponding total angular momentum can be evaluated by imposing the energy minimization condition as function of θ.

For a band, originating solely from AMR, the rotational frequency (ω_{sh}) can be computed through ($\frac{dE_{sh}}{d\theta}/\frac{dI_{sh}}{d\theta}$) and is given by,

$$\omega_{sh} = \left(\left(\frac{1.5V_{\pi\nu}}{j}\right) - \left(\frac{6V_{\pi\pi}}{nj}\right)\cos 2\theta\right)\cos\theta \quad (2)$$

In ^{110}Cd the expected configuration for the high spin states is $\pi g_{9/2}{}^{-2} \otimes \nu h_{11/2}{}^2$, since the alignment plot does not support the alignment of $g_{7/2}$ neutrons. Thus, for this configuration there are four neutron-proton combinations (n=4) and j_p= 10$\hbar$ i.e. a= 2.22. For the calculation, the band head has been assumed to be 12$\hbar$, since the $h_{11/2}$ neutron alignment takes place around 10$\hbar$ which is essential for the formation of the double shear structure. Thus, the angular momentum (I) is to be calculated from the minimization of energy and the frequency ω will be given by,

$$\omega = \omega_{rot} - \omega_{sh} \quad (3)$$

where, ω_{sh} is given by Eq. 2 and $\omega_{rot} = \frac{1}{2\Im}(2I+1)$ is the core rotational frequency and $\Im$ is the core moment of inertia.

The calculated values have been plotted as dotted, solid and dashed lines in Fig. 1(a) for $V_{\pi\pi}$= 0, 0.15 and 0.30 MeV, respectively. It is evident from the figure that the experimental I(ω) beyond 0.65 MeV is well reproduced for $V_{\pi\pi}$= 0.15 MeV and it has a definitive effect on the curvature of the routhian. The effect of $V_{\pi\pi}$ becomes appreciable in ^{110}Cd since, there is one hole-hole shear combination and four particle-hole combinations, while in $^{106,\,108}$Cd there are eight. Thus, the present calculation suggests that AMR mechanism is active in the even-even ^{106,108,110}Cd isotopes.

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