Possible Multiple Antimagnetic Rotational Bands in ^{106}Cd

C Majumder[1], S Chakraborty[1], S S Tiwary[1], P K Prajapati[1], P Banerjee[2], S Ganguly[3], R P Singh[4], S Muralithar[4], and H P Sharma[1]*
[1]Department of Physics, Banaras Hindu University, Varanasi, India.
[2]Nuclear Physics Division, Saha Institute of Nuclear Physics, Kolkata, India.
[3]Department of Physics, Bethune College, Kolkata, India. and
[4]Nuclear Physics Group, Inter University Accelerator Centre, New Delhi, India.

Introduction

The observation of rotational like band consists of strong M1 transitions in near spherical nuclei draw the attention since last two decades. Such observation was explained by introducing a new type of excitation mode, known as Magnetic Rotation (MR) [1, 2]. Later, Anti Magnetic Rotation (AMR) was also discovered, having twin shear bands, in which a pair of proton-holes combines with neutron particles and angular momentum is generated by simultaneous closure of the twin-shears [3]. In this case, the perpendicular components of magnetic moment cancel each other in a symmetric twin-shear arrangement. Therefore, there is no dipole transitions and states mainly decay via quadrupole (E2) transitions. The AMR bands have been observed in $^{105-110}$Cd [3–6] and ^{100,101,104}Pd [7–9] nuclei in A$\sim$110 mass region. From previous high spin study of ^{107}Cd nucleus, two positive parity signature partner bands having three quasi-particles configuration $\nu(g_{7/2})(h^2_{11/2})$ were known [10]. Recently, lifetime measurement were carried out for ^{107}Cd for the $33/2^+$ to $49/2^+$ and $31/2^+$ to $47/2^+$ states of these two bands [5]. These measurements show decreasing trend of B(E2) with increasing spin for these bands and also show a large $\Im/B(E2)$ ratio which confirmed the AMR character of these bands [5].Theoretical calculations were done by the semi-classical model and proposed $\pi(g^{-2}_{9/2}) \otimes \nu(g_{7/2}h^2_{11/2})$ configuration for these AMR bands [5]. In the neighbouring ^{106}Cd nucleus, a positive parity band associated with $\nu(h^2_{11/2})$ quasi-neutron structure and two negative parity bands having $\nu(h^1_{11/2})(d_{5/2})$ and $\nu(h^1_{11/2})(g_{7/2})$ configurations, respectively were known from the previous study [11]. From the lifetime measurement of 16^+ to 24^+ states of this band, a rapid decrease of B(E2) strength with spin and increase of $\Im/B(E2)$ with spin were observed.Author confirmed the AMR character of this band and suggested the coupling of $\pi g_{9/2}$ holes with the pairs of $h_{11/2}$ and $g_{7/2}$ neutron particles for this band [3].

Discussion

In present work, theoretical calculations were performed using the semi-classical model for the above mentioned AMR band having $\pi(g^{-2}_{9/2}) \otimes \nu(g^2_{7/2}h^2_{11/2})$ configuration. The semi-classical model was developed by Macchiavelli et al. [12] for magnetic rotation and later it was modified by Sugawara et al.[13] Further details of the model and explanation of various terms used in the following calculations are described elsewhere [5, 9]. In this model, the energy E(I) is given by,

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

$$+\frac{V_{\pi\nu}}{2}\frac{(3cos^2(-\theta) - 1)}{2} - \frac{V_{\pi\nu}}{n}\frac{(3cos^2(2\theta) - 3)}{2}$$

The energy minimization as a function of θ, angular momentum is given by,

$$\mathrm{I} = aj + 2jcos\theta + \frac{1.5\Im V_{\pi\nu}cos\theta}{j} - \frac{6\Im V_{\pi\pi}cos2\theta cos\theta}{nj}$$

*Electronic address: hpsharma_07@yahoo.com

Where, $j = j_\pi$, $a = \frac{j_\nu}{j_\pi}$ and $I_{sh} = aj + 2jcos\theta$. Reduced transition probability is given by: $B(E2) = \frac{15}{32\Pi}(eQ_{eff})^2 sin^4\theta$, where, Q_{eff} is the effective quadrupole moment of the core.

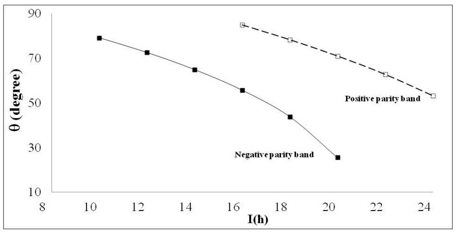

FIG. 1: Plot of spin vs shears angle θ for positive and negative parity bands.

This relations show that the B(E2) will decrease with increasing angular momentum as shown in Fig: 2, 1. In the present theoretical calculations, following parameters were used for negative parity band of ^{106}Cd taken from refs [3, 14].

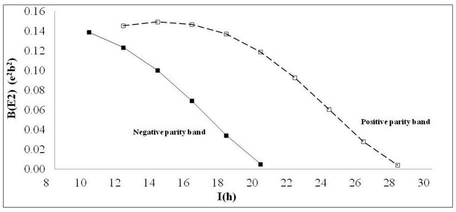

FIG. 2: Plot of spin vs B(E2) for positive and negative parity band.

$\Im|_{\theta=0} = 8.9\ \hbar^2 MeV^{-1}$, $V_{\pi\nu} = 1.2\ MeV$, $V_{\pi\pi} = 0.2\ MeV$, $(eQ)_{eff} = 1\ eb$

In the present work, the theoretical calculations have been carried out for the positive parity bands of ^{106}Cd to predict the shears angle θ (Fig.1), reduced transition probability B(E2) (Fig.2) and the ratio of $\Im$ and B(E2) (Fig.3), dynamic moment of inertia $\Im$ (Fig.4) are plotted as a function of angular momentum. These theoretical calculations agreed well with the experimental values [3] for already established positive parity AMR band.

Interestingly, these results also show decreasing B(E2) with spin (Fig. 3) and also

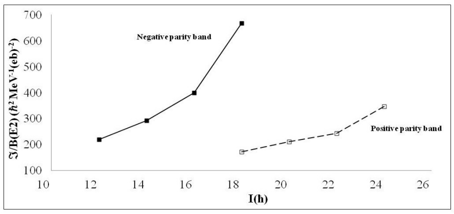

FIG. 3: Plot of spin vs $\Im$/B(E2) for positive and negative parity bands.

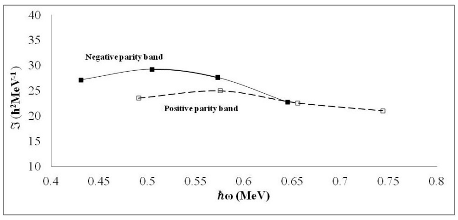

FIG. 4: Plot of frequency vs dynamic moment of inertia for positive and negative parity band.

increasing $\Im/B(E2)$ with spin (Fig. 2) which suggest the possibility of the second AMR band in ^{106}Cd.

Acknowledgment

The first author is thankful to UGC and BHU for the research fellowship provided under Ph.D. registration no. (PHY/RES/RET Qualified-2014/2014-2015/ 953)

References

[1] Frauendorf, Rev Mod Phys 73(2001)463
[2] Frauendorf, Nucl Phys A 557(1993)259
[3] Simons et al,PhysRevLett91(2003)162501
[4] Choudhury et al, Phys Rev C82, 061308(R)(2010)
[5] Choudhury et al, Phys Rev C87, 034304 (2013)
[6] Datta et al,PhysRevC71,041305(R)(2005)
[7] Zhu et al, Phys Rev C 64,041302(R)(2001)
[8] Sugawara et al,PhysRevC92,024309(2015)
[9] Rather et al,PhysRevC89,061303(R)(2014)
[10] Jerrestam et al, NuclPhysA545(1992)835
[11] Jerrestam et al, NuclPhysA571(1994)393
[12] Macchiavelli et al,PhysRevC57(1998)1073
[13] Sugawara et al,PhysRevC79,064321(2009)
[14] Roy et al, Phys Lett B694(2011) 322