Interplay of Magnetic and Collective Rotation in nuclei of A $\sim$ 100 region

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Introduction

The angular momentum in a moderately deformed nucleus is generated either through collective rotation around a principal axis (PAR) or by gradual alignment of the angular momenta of the valence neutrons and protons around an axis which is tilted with respect to the rotational axis (TAR also know as Shears Mechanism). These two modes of excitations, PAR and TAR, have been successfully described by two independent models, namely the Cranking Shell Model (CSM) and Tilted Axis Cranking (TAC), respectively. The experimental and theoretical investigations have identified some important features that distinguish these two phenomena. In case of PAR, the signature is a good quantum number and this leads to the characteristic staggering in both $I \rightarrow I-1$ transition energies and magnetic transition rates. In case of TAR, the signature is not a good quantum number. Thus, $I \rightarrow I-1$ transition energies and magnetic transition rates show a smooth increase and decrease with angular momentum, respectively.

Objective

In the thesis work, I have aimed to study neutron rich nuclei of mass 100 region. Here the Shear structure originates due to proton holes in $g_{9/2}$ orbital and neutron particles in $h_{11/2}/g_{7/2}/d_{5/2}$ orbitals. However, these nuclei also exhibit moderate deformations ($\beta_2 = 0.15$) due to higher occupation of $h_{11/2}$ orbital by the neutrons. Thus, it will be interesting to investigate whether the high spin states in these nuclei originate due to Principal Axis Rotation (PAR) or Tilted Axis Rotation (TAR) or there is an interplay between these two modes of rotations. In order to investigate this interplay, it will be essential to measure the lifetimes of the high spin levels and extract the magnetic dipole and electric quadrupole transition rates namely, B(M1) and B(E2). The above statement can be justified by the fact that B(M1) rate in this mass region is $\sim 1\mu N^2$ in case of Tilted Axis Rotation and is $\sim 3\mu N^2$ in case of Principal Axis rotation, and thus, the two different modes of rotation can be identified through lifetime measurements. Similarly B(E2) rates play the pivotal role in the identification of Antimagnetic Rotation which is another manifestation of TAR.

Summary

The interplay between the two modes has been studied in ^{109}Ag [1]. It has been demonstrated through a Projected Shell Model (PSM) calculation that the low spin states of the Ground State (GS) of ^{109}Ag originates due to Principal Axis Rotation (PAR) while the high spin states originates due to TAR. This transition was found to be associated with the rotational alignment of a pair of neutron. In contrast, the competition between the TAR and PAR has been explored in the odd-odd isotopes. The GS bands of $^{104-108}$Ag, have been found to originate due to TAR. However, ^{110}Ag has been predicted to be well deformed ($\beta_2 \sim 0.2$). The present work will report the first detail level scheme of ^{110}Ag [2], where the ground state band has been found to originate due to PAR. The phenomena of signature inversion have also been found for the first time

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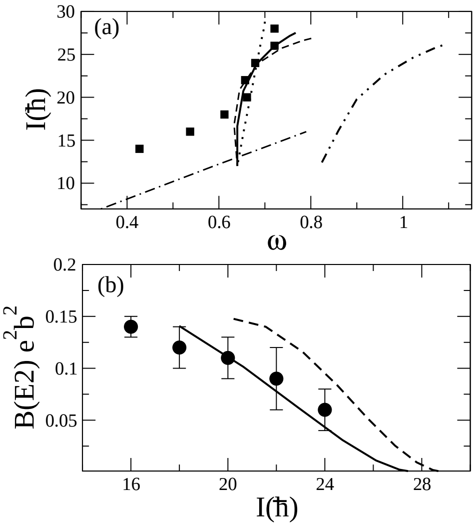

FIG. 1: The observed I(ω) plot (a) and B(E2) rates (b) in ^{110}Cd. The dot-dashed and dot-dot-dashed line in (a) represents a rotor with moment of inertia of 19.5 and 13 $MeV^1\hbar^2$, respectively. The dotted, solid and dashed lines in (a) represents the calculated routhians for $V\pi\pi$= 0, 0.15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

in this nucleus.

Further, a semi-classical model based on the geometric description of TAR has been developed to explain the energy routhians of both the Antimagnetic and magnetic bands of mass 100 region in Cd-isotopes. In this picture, the potential between the shears blades has been taken to be repulsive for hole (particle) - particle (hole) pairs and attractive for particle (hole) - particle (hole) pairs. The energy (E) - angular frequency (ω) relation has been derived by minimization of the energy for a given angular momentum (I) state, with moment of inertia ($\Im$) as the parameter. This model and it's applicability has been described in detail in this work.

In ^{106,108}Cd-isotope, antimagnetic rotation (AMR) is observed in the 6 quasi-particle configuration of these nuclei where the quasi-neutrons are aligned along the rotational axis and the quasi-protons are aligned along the deformation axis. This single particle configuration leads to the formation of a double-shear structure, which is responsible for antimagnetic rotation. In the present work, B(E2) rates (Fig. 1) in ^{110}Cd have been measured for the first time which establish the high spin states of the yrast band of ^{110}Cd originates due to AMR [3]. Similar calculations were performed to verify the presence of AMR in odd-A Cd-isotopes [4].

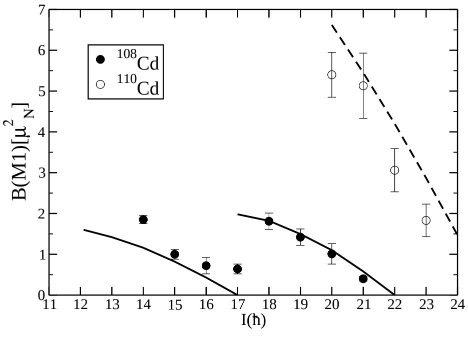

FIG. 2: Experimentally evaluated B(M1) rates as a function of angular momentum in ^{108}Cd and ^{110}Cd. The solid and the dashed lines denote the theoretical values from the semi-classical model for ^{108}Cd and ^{110}Cd respectively.

The present thesis will also report the observation of band crossing phenomenon in the shears band of ^{108}Cd (Fig. 2) [5]. This is the first observation of this kind in this mass region. This has been established through detailed level lifetime measurements.

References

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