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SPECTROSCOPY OF NEGATIVE PARITY BANDS IN ^{105}Pd*

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Excited states of the triaxially deformed ^{105}Pd have been studied. New rotational bands were identified and their configurations were determined. Some previously known bands have been extended to higher energies and spins. The main aim of this work was to search for the two-phonon wobbling band in addition to the already known one-phonon band. However, a comparison of the experimental data and the theoretical calculations revealed no evidence of a two-phonon wobbling band in ^{105}Pd.

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1. Introduction

The concept of nuclear wobbling motion was first proposed by Bohr and Mottelson [1] as a characteristic feature of triaxially deformed nuclei. In this case, the deformed nucleus rotates around the principal axis with the largest moment of inertia, and this axis executes precession about the space-fixed angular momentum vector. The related energy spectra consist of a series of rotational E2 bands, associated with the oscillation quantum number n. The yrast ($n = 0$) and yrare ($n = 1$) bands resemble signature partner bands, but the $\Delta I = 1$ transitions between them have predominant E2 character.

The first experimentally observed case was reported in ^{163}Lu [2], where both one-phonon and two-phonon wobbling bands were identified. Since then, several cases have been reported, most of which are characterized by one-proton configurations in odd-mass nuclei. Their observed characteristics were interpreted by Frauendorf and Dönau [3] and the concepts of transverse and longitudinal wobbling were proposed. Later, another interpretation, called tilted precession (TiP), was proposed by Lawrie *et al.* [4] extending the interpretation for the cases where the phenomenon cannot be described as a quantized harmonic oscillation.

In the $A \sim 100$ mass region, wobbling motion has only been observed in ^{105}Pd [5], where the one-phonon band has $\nu(h_{11/2})$ configuration with negative parity. However, the second wobbling band has not yet been observed and the experimental verification of quantized oscillation is still unresolved. For this reason, the present work searched for the possible two-phonon wobbling band by exploring all the available negative-parity bands using the same experimental data set as was used in Ref. [5].

2. Experimental methods and results

The excited states of ^{105}Pd were populated using the $^{96}\mathrm{Zr}(^{13}\mathrm{C}, 4n)^{105}\mathrm{Pd}$ fusion–evaporation reaction at beam energies of 51 MeV and 58 MeV. The EUROBALL IV spectrometer [6] was used to detect the emitted γ rays. The contaminating charged-particle reaction channels were suppressed by the highly efficient DIAMANT array [7, 8] used as a veto detector.

A total of 2×10^9 triple- and higher-fold coincidence events were collected and stored onto magnetic tapes. Approximately 7×10^8 of these events belong to the ^{105}Pd reaction channel according to the PACE calculations. Energy and efficiency calibration of the γ-ray detectors were performed using the ^{152}Eu source. Systematic errors for the calibrations are estimated to be 0.2–0.3 keV and $\sim$ 5%, respectively. The measured γ-ray energies were sorted offline into two- and three-dimensional histograms.

The level scheme of ^{105}Pd was constructed based on the triple-coincidence relations in the three-dimensional histograms using the RADWARE software package [9]. Furthermore, energy and intensity balances of the observed γ rays were also considered. The spin and parity values of the excited states were determined with the help of DCO and linear polarization analysis.

As a result, we have extended the negative-parity level scheme of ^{105}Pd. We have observed three new E2 bands and a strongly coupled band. We have also extended the previously reported bands to higher spins and energies. Figure 1 shows the E2 bands of ^{105}Pd observed in the present study. Example coincidence spectra used as a basis for placing γ rays in the level scheme are shown in Fig. 2. All sub-figures (a)–(c) show double γ-ray gated triple-fold coincidence spectra for the new bands N4, N5, and N6.

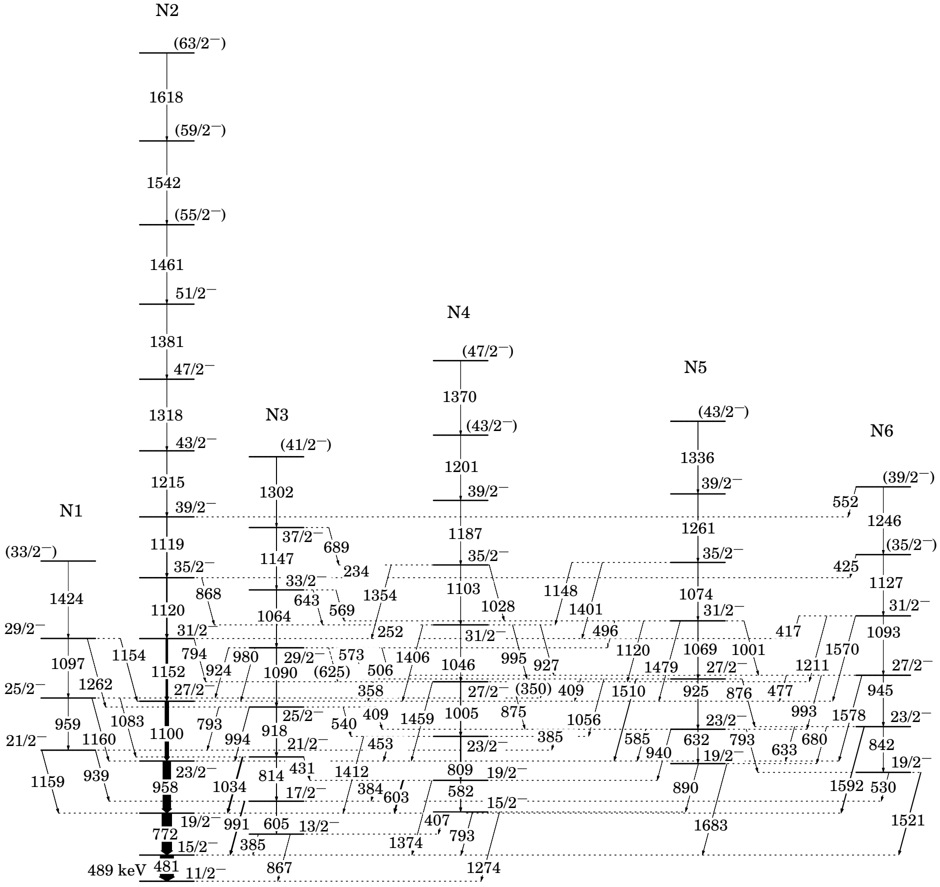

Fig. 1. Partial level scheme of ^{105}Pd obtained in the present study. The widths of the lines are proportional to the transition intensities.

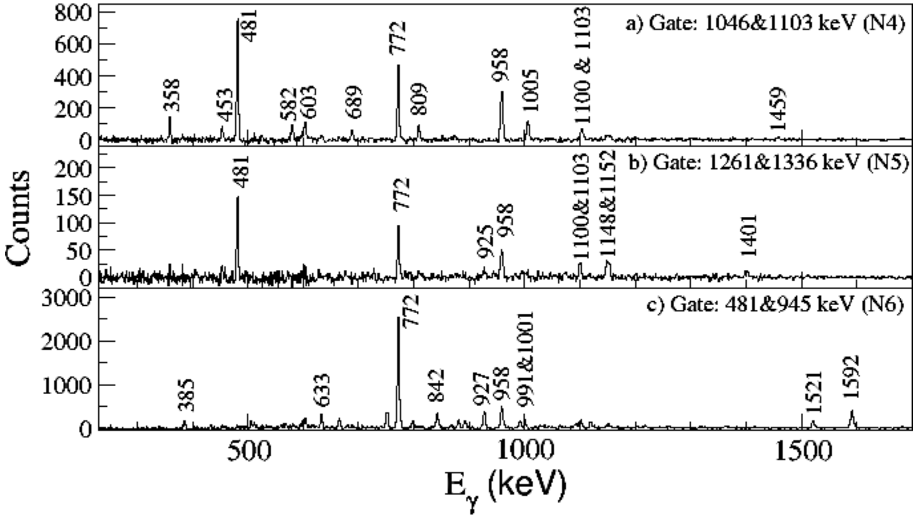

Fig. 2. The (a)–(c) $\gamma\gamma\gamma$-coincidence spectra showing the placement of bands N4, N5, and N6, respectively. The double γ-ray gates used are indicated on the panels.

3. Discussion

In order to determine the nature and quasiparticle configurations of the new bands in ^{105}Pd, we performed calculations using the constrained triaxial relativistic density functional theory (RDFT) [10, 11], as well as the quantum particle rotor model (PRM) [12, 13], and compared the experimental results with the calculated ones.

Based on its decay properties, band N4 seems to be a possible two-phonon wobbling band candidate. However, the theoretical results obtained for this scenario do not agree with the experimental data. The $B(\mathrm{M1})/B(\mathrm{E2})$ reduced transition probability ratios with the M1 transitions between bands N4–N3 and bands N4–N2, and the inband E2 transitions, are not reproduced. Also, the experimental level energies of band N4 are overestimated in the calculations. Therefore, band N4 is not the $n = 2$ wobbling band. The $B(\mathrm{E2}; I \to I)/B(\mathrm{E2}; I \to I - 2)$ ratios to band N2 (the $B(\mathrm{E2})$ ratios of the $\Delta I = 0$ and the $\Delta I = 2$ transitions from a band N4 state to the subsequent two states of band N2) are quite large, around 100. This is similar to the decay of the γ vibrational bands in even–even nuclei. This scenario is further confirmed by the fact that the experimental quasiparticle alignment of band N4 is larger by about $2\hbar$ than that of band N2, as it is seen in Fig. 3. Thus, band N4 might be the γ-vibration coupled to the $\nu(h_{11/2})$ orbital [14]. We note that very recently this band was assigned as a wobbling band [15] based on transitions which were not observed in the present study.

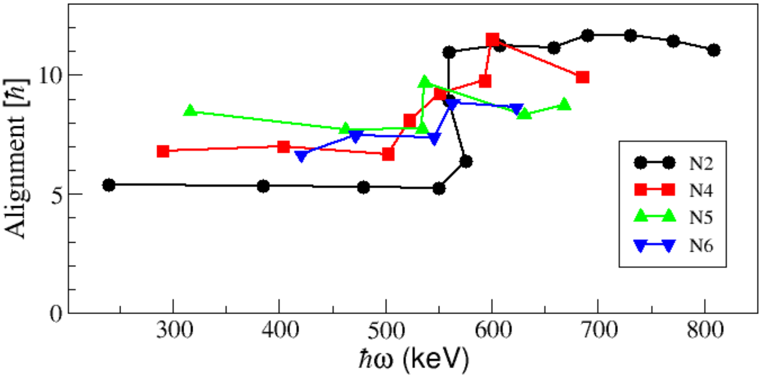

Fig. 3. The experimental alignment for bands N2, N4, N5, and N6 in ^{105}Pd.

Based on their similar alignment values, similar configurations can be expected for bands N5 and N6. This expectation has been confirmed by the results of the RDFT and PRM model calculations. Comparing the experimental and theoretical results, good agreement could be reached in the excitation energies and $B(\mathrm{M1})/B(\mathrm{E2})$ ratios assuming the following configurations. Both bands have three-quasiparticle configurations, and both of them have one neutron on the $h_{11/2}$ orbital. Additionally, band N5 has one broken neutron pair on the $2d_{5/2}$ orbital, while band N6 has one broken proton pair on the $g_{9/2}$ orbital [14].

4. Summary

Medium- and high-spin negative-parity bands of ^{105}Pd were studied using the ^{96}Zr(^{13}C,4n) reaction. The emitted γ-rays were detected using the EUROBALL IV spectrometer, which was completed with the DIAMANT charged-particle detector. Previously reported bands were observed and extended, in addition, new rotational bands were identified. No evidence could be found of the two-phonon wobbling band. Based on RDFT and PRM calculations we assigned configurations to bands N5 and N6, which are E2 rotational bands containing three quasiparticles.

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