# Low-lying Positive-parity Band Structure in $^{150}$Nd

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## Introduction

The stable N = 90 isotones $^{150}$Nd, $^{152}$Sm, and $^{154}$Gd lie in a region of rapid shape change and can be expected for displaying complex collective structure. Although the level structure of $^{152}$Sm and $^{154}$Gd were studied quite extensively in the recent past [1, 2], the knowledge of the low-lying level structure of $^{150}$Nd is found to be surprisingly poor. The results from our previous investigations [3] for the negative-parity states in $^{150}$Nd are suggestive of the enhanced $B(E1)$ strengths (of ms order) for the transitions decaying from the $K^\pi = 0_1^-$ to the $K^\pi = 0_1^+$ band. Also, a complex coupling between the members of the $K^\pi = 2_1^-$ and the $K^\pi = 2_1^+$ bands was observed. The present report highlights the new results related to the positive-parity band structure of $^{150}$Nd, obtained from a series of $\gamma$-ray spectroscopic experiments involving measurements of excitation functions, angular distributions, and $\gamma - \gamma$ coincidences using the $(n,n'\gamma)$ reaction.

## Experimental Procedure

The experiments were carried out at the University of Kentucky Accelerator Laboratory using nearly mono-energetic neutron beams. Neutrons were produced via the $^3$H$(p,n)^3$He reaction with pulsed and time-bunched beams of protons. Gamma rays produced by inelastic neutron scattering from a 31.15-g sample of $Nd_2O_3$, enriched to 96.17% in $^{150}$Nd, were detected with a single Compton-suppressed HPGe detector. Gamma-ray excitation function measurements were carried out by varying the neutron energy in steps of 100 keV (with an energy spread typically around 60 keV) between 1.2 and 3.0 MeV with the detector placed at 125° with respect to the proton beam. Angular distributions of $\gamma$ rays were obtained at neutron energies of 1.2, 1.4, 2.05, and 2.7 MeV by rotating the detector through angles between 40° and 155°. A modest $\gamma$-$\gamma$ coincidence measurement was carried out using an array of four HPGe detectors at a neutron bombarding energy of 3.2 MeV. The detectors were placed $\sim$ 5 cm from the $^{150}$Nd sample. Attempts were made to measure the level lifetime by considering the Doppler shifts of the $\gamma$ ray(s) decaying from the level as a function of emission angle, using the methodology described in Ref.[4]. Except for the $2_2^+$ level at 1061-keV and the $3_1^+$ level at 1200-keV, the lifetimes of the rest of the positive-parity levels are found to be too long to be determined by the present DSAM method. The measured lifetimes for the aforementioned $2^+$ and $3^+$ levels are $1210^{+370}_{-240}$ and $1150^{+420}_{-250}$ fs, respec-

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tively. The lifetimes are just at the limit of sensitivity of the present measurement.

## Experimental Results

Fig. 1 illustrates the comparison of the low-lying positive-parity band structure (partial) of $^{152}$Sm with that of the newly established structure of $^{150}$Nd. Our preliminary results for $^{150}$Nd indicate that although the regular structure for the bands built upon the first and second $0^+$ states apparently look to be similar to that in $^{152}$Sm, the band built on the $0_3^+$ state appears to be somewhat irregular in nature. The E2 strength of the transitions (wherever possible) decaying from the levels of the $K^\pi = 2_1^+$ band to those of the $K^\pi = 0_1^+$ band are highlighted in Table I. It is found that the presented $E2$ strengths in some cases deviate from the predicted values based on the Alaga rules by a factor of four in $^{150}$Nd, suggesting the significant mixing of the underlying bands.

TABLE I: Comparison of the relative $B(E2)$ values (in W.u.) for a few transitions decaying from the $\gamma$-band to the ground state band of $N = 90$ isotones with the theoretical values obtained using the Alaga rules. One transition is normalized to 100 for each initial state to make the comparison with that of the Alaga rules feasible.

| $J_i^\pi$ | $J_f^\pi$ | Alaga | $^{150}$Nd | $^{152}$Sm | $^{154}$Gd |
|---|---|---|---|---|---|
| 2 | 0 | 70 | $47^{+13}_{-12}$ | 39(5) | 46(4) |
| 2 | 2 | 100 | $100^{+30\,a}_{-27}$ | 100(14) | 100(8) |
| 2 | 4 | 5 | $21^{+1.1}_{-0.8}$ | 8(1) | 14(1) |
| 3 | 2 | 100 | $100^{+33}_{-30}$ | $100^{+22}_{-16}$ | |
| 3 | 4 | 40 | $125^{+44\,b}_{-38}$ | $106^{+24}_{-16}$ | |
| | | | $0.6^{+1}_{-0.5}$ | | |
| 4 | 2 | 34 | | $10^{+7}_{-4}$ | |
| 4 | 4 | 100 | | $100^{+57}_{-43}$ | |
| 4 | 6 | 9 | | $13^{+9}_{-6}$ | |

[a]As the mixing ratio could not be measured, the quoted transition rate is obtained without the use of a mixing ratio value and hence should be treated as an upper limit.

[b]The quoted $B(E2)$ values correspond to the two possible mixing ratio values as obtained from the present measurement.

Further experimental data is needed for the refinement of the uncertainties quoted in Table I and addressing the other underlying issues. In this regard, additional proton and alpha scatterings experiments are planned.

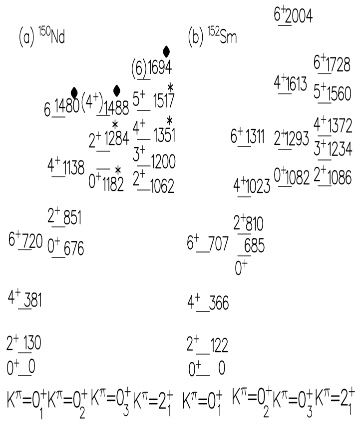


FIG. 1: Low-lying positive-parity band structure of (a) $^{150}$Nd (left) and (b) $^{152}$Sm (right). The lowest three $K^\pi$=$0^+$ bands and the yrast $K^\pi$=$2^+$ band are shown. The new levels and new spins in $^{150}$Nd established from the present investigation have been marked with • and $*$, respectively.



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