Onset of triaxiality in Dy nuclei around $N = 88$-92

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Introduction

Transitional rare earth nuclei around $N =$ 88 - 92 are very special as they are the ones which were experimentally studied upto the highest spin states, both in normal- and super-deformed states. These nuclei exhibit exotic high spin phenomenon such as, shape coexistence, super-deformation, band termination etc. One of the interesting features of these nuclei is prolate to oblate shape evolution. Isotopes of Dy (Z = 66) around $N =$ 88 - 92 were studied extensively [1–3], both theoretically and experimentally, in recent years. The heavier isotopes show prolate deformation at low spin and becomes oblate at high spin. Where as, the transitional lighter isotopes show gamma softness. However, the questions on shape evolution and the onset of deformation still remain. Recently, from the lifetime measurements of the states in ^{157}Dy [2] it was interpreted that the extra neutron in ^{157}Dy stabilizes the shape of the soft core of ^{156}Dy. In the present work, we have performed Total Routhian Surface (TRS) calculations to find out the shape evolution in the transitional Dy isotopes with rotational frequency.

Theoretical basis

The total Routhian surface (TRS) calculations were performed for the even-even Dy nuclei with $N =$ 86-94 and also for the odd-A ^{157}Dy nucleus. In these calculations, Woods-Saxon potential was used with BCS pairing to calculate the single particle energies. The TRSs were calculated using the Strutinsky shell correction method for several values of the deformation parameters β_2, γ and β_4 at different rotational frequency $\hbar\omega$. The β_2 and γ values corresponding to the minimum of the TRS have been taken as the deformation of a nucleus. The TRS code of Nazarewicz *et al.*[4, 5] was used for the calculations. In this code $\gamma = 0°$ ($\gamma = \pm 60°$) corresponds to a prolate (oblate) shape. Any intermediate values of γ correspond to a triaxial shape. The detailed procedure has been described in Refs. [6, 7].

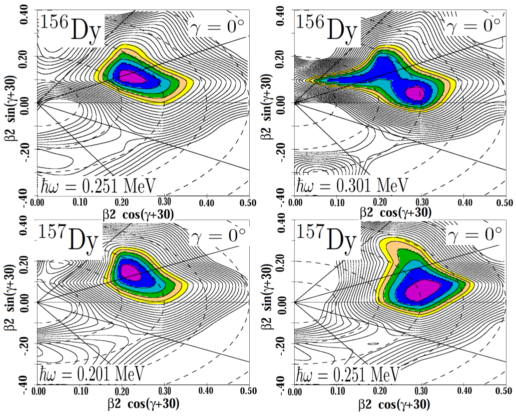

FIG. 1: Results of TRS calculation for ^{156}Dy (upper panel) and ^{157}Dy (lower panel). It shows the onset of triaxiality at $\hbar\omega = 0.301$ MeV and 0.251 MeV for ^{156}Dy and ^{157}Dy, respectively.

Results and Discussion

The representative TRS plots are shown in Fig. 1. It shows the results for ^{156}Dy and ^{157}Dy. For ^{157}Dy, the calculations were performed with odd-neutron in the positive-parity positive-signature as well as positive-parity negative-signature states, corresponding to the $\nu i_{13/2}$ configuration. We have got very similar results for both the signatures.

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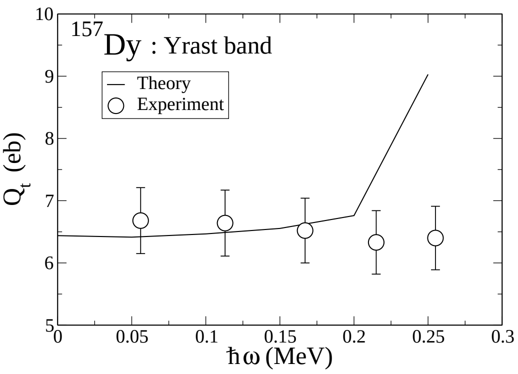

FIG. 2: Plot of experimental and the calculated transition quadrupole moment $Q_t(eb)$ with frequency $\hbar\omega$ in ^{157}Dy.

It can also be seen from Fig. 1 that both the nuclei have prolate deformation at smaller rotational frequencies with $\beta_2, \gamma = 0.25$, 2° and $\beta_2, \gamma = 0.27$, 6°, for ^{156}Dy and ^{157}Dy, respectively. Interestingly, it has been observed that the deformation changes to a triaxial shape at higher frequencies for both the nuclei with $\beta_2, \gamma = 0.29$, -22° for ^{157}Dy at $\hbar\omega = 0.301$ MeV and $\beta_2, \gamma = 0.28$, -23° for ^{156}Dy at $\hbar\omega = 0.251$ MeV. The higher rotational frequencies correspond to the one after the pair alignments. It is also seen that the γ-softness in ^{156}Dy reduces in ^{157}Dy at the higher frequency.

The systematic study of the ground state shape evolution of the even-even Dy isotopes, obtained from this work shows that deformed prolate shape is gradually developed in Dy isotopes and collective rotational band corresponding to deformed shape is expected for ^{154}Dy and the heavier isotopes. Therefore, an onset of deformation in Dy nuclei is expected at neutron number $N = 88$.

We have compared the results obtained for ^{157}Dy with the experimental one. The quantity that can be compared for a deformed nucleus is the quadrupole moment (Q_t) which is obtained through the B(E2) values deduced from the measured lifetimes. The theoretical values of Q_t were obtained from the deformation parameters β_2 and γ using the equation:

$$Q_t = \frac{6}{\sqrt{15\pi}} Zer_0^2 A^{2/3} \beta_2 (1+0.36\beta_2) cos(30+\gamma) \quad (1)$$

The experimental Q_t values, obtained from the measured lifetimes in Ref.[2] are plotted in Fig. 2. The calculated values obtained from this work are also shown in this plot as a solid line. It can be seen that the experimental values are well reproduced by the calculation below $\hbar\omega = 0.25$. The calculated value increases after that because calculated shape has increased β_2 and close to maximum triaxiality with negative γ at high frequency.

In conclusion, onset of deformation at $N = 88$ and triaxial shape at high $\hbar\omega$ (this needs further experimental investigation) is predicted from a systematic theoretical study of shape evolution in Dy isotopes from TRS calculations. The Q_t values from the measured lifetimes in ^{157}Dy is well reproduced in the calculations before the alignment.

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