AS-ITP-92-06

ASITP

INSTITUTE OF THEORETICAL PHYSICS ACADEMIA SINICA

AS-ITP-92-06

SPIN DETERMINATION AND STRUCTURE CHANGE OF THE EXCITED SUPERDEFORMED BAND IN ^{146}Gd

J.Y.ZENG

C.S.WU

J.MENG

P.O.Box 2735, Beijing 100080, The People's Republic of China

Telefax : (086)-1-2562587 Telephone : 2568348

Telex : 22040 BAOAS CN Cable : 6158

Spin determination and structure change of the excited superdeformed band in ^{146}Gd

J. Y. Zeng*, C. S. Wu* and J. Meng

China Center of Advanced Science and Technology (World Laboratory),
Center of Theoretical Physics, P. O. Box 8730, Beijing 100080, China,
Department of Physics, Peking University, Beijing 100871, China
and
Institute of Theoretical Physics, Chinese Academy of Science, Beijing 100080, China

Abstract: Using the *ab* fitting approach, the spin of the lowest level observed in the excited superdeformed (SD) band ^{146}Gd* (fed by 856 keV transition) is determined to be $I_0 = 33$. The analyses of the dynamic moment of inertia $\mathcal{J}^{(2)}$ and the ratio $\sqrt{[\mathcal{J}^{(1)}]^3/\mathcal{J}^{(2)}}$ shows indication of a structure change near $I \approx 52$ ($\hbar\omega \approx 0.67$ MeV), though not so significant as that observed in the yrast SD band ^{146}Gd.

PACS number(s): 21.10.Dr, 21.10.Re, 23.20.Lv, 27.60.+j

*Mailing address: Department of Physics, Peking University, Beijing 100871, China

Recently an excited superdeformed (SD) band in ^{146}Gd (hereafter called ^{146}Gd*) was found [1]. The spin of the lowest level observed (fed by 856 keV γ-ray) is assigned to be $I_0 > 29$. It was pointed out that ^{146}Gd* and the previously identified yrast SD band ^{146}Gd [2] are probably not signature partners, and for ^{146}Gd* the dynamic moment of inertia changes smoothly with frequency which shows no evident indication of band crossing as observed in the yrast SD band at $\hbar\omega \approx 0.65$ MeV [2,3].

In [4, 5] an effective method was proposed to determine the spins of the SD bands directly from the transition energies. In this approach (hereafter called *ab* fitting) the observed transition energies are least squares fit to

$$E_\gamma(I) \equiv E_\gamma(I \to I-2) = a\left[\sqrt{1+bI(I+1)} - \sqrt{1+b(I-2)(I-1)}\right] \qquad (1)$$

deduced from the closed two-parameter $I(I+1)$ expression

$$E(I) = a\left[\sqrt{1+bI(I+1)} - 1\right], \qquad (2)$$

which may be derived from the Bohr Hamiltonian for a well-deformed nucleus with small axial asymmetry [6]. It is found that, once a correct spin value of the lowest SD level, I_0, is assigned, the calculated $E_\gamma(I)$'s coincide with the observed results very well. However, if I_0 is shifted from the correct one, the root-mean-square deviation will increase drastically. Therefore, the I_0 value, hence all the spin values of the SD band levels, can be determined reasonably. Using this method the spin of the lowest level observed in the SD band ^{146}Gd* is determined to be $I_0 = 33$ (see Fig. 1). In Table 1 the comparison of the calculated and observed E_γ's are given. It is found that if the lower nine transitions are involved in the fitting the observed E_γ's can be reproduced incredibly well ($|E_\gamma^{cal} - E_\gamma^{exp}| \leq 0.3$keV). However, the calculated four higher transitions (which are less closely related to the bottom of the band [7]), $E_\gamma(I)$'s for $I = 53, 55, 57$, and 59 are systematically a little larger than the corresponding observed results, i.e. the observed four highest levels are slightly depressed in compared with the prediction of eq. (2), which seems to indicate some changes of the intrinsic structure.

In Fig. 2 are given the dynamic moments of inertia $\mathcal{J}^{(2)}$ extracted by $\mathcal{J}^{(2)}(I) \approx 4\hbar^2/[E_\gamma(I+2) - E_\gamma(I)]$ from the observed transition energies (solid circles) and calculated

by the expression [4]

$$\mathcal{J}^{(2)} = \frac{\hbar^2}{ab}\left[1 - \frac{(\hbar\omega)^2}{a^2 b}\right]^{-3/2} \tag{3}$$

for $I_0 = 31$, 33, and 35 (lines in the figure). It can be seen that while for the lower nine transitions ($\hbar\omega \leq 0.65$MeV) the calculated $\mathcal{J}^{(2)}$'s for $I_0 = 33$ coincide with the observed results very well, but a significant deviation is found for the several highest γ-transitions ($\hbar\omega > 0.70$ MeV). This gives an additional support for the spin assignment of $I_0 = 33$ and shows that there exists structure change in ^{146}Gd* at $I \sim 53$ ($\hbar\omega \sim 0.67$ MeV), though not so significant as that in the yrast SD band ^{146}Gd [3]. Calculation shows that for $I_0 = 33$ both the calculated $\mathcal{J}^{(2)}$ and $\mathcal{J}^{(1)}$ ($> \mathcal{J}^{(2)}$) decrese smoothly with ω and in the range of $\hbar\omega \sim 0.43 - 0.65$ MeV, $\mathcal{J}^{(2)}$ decreases by about 10% in accordance with the observation.

From eq. (2), one may derive an analytic expression for $\mathcal{J}^{(1)}$ [4]. It can be proved that the ratio $R \equiv \sqrt{[\mathcal{J}^{(1)}]^3/\mathcal{J}^{(2)}}$ is ω- (or I-) independent within a rotational band, which has been verified by the extensive data of rotational bands for normally deformed as well as SD nuclei [8]. The $R-\omega$ plot for ^{146}Gd* is displayed in Fig. 3, which also indicates a structure change at $I \sim 53$.

The above analyses seem to support the scenario I in ref. [3] (see Fig. 7(a) there) for the neutron configuration of the SD bands ^{146}Gd ($7^1 \otimes [642]^{\alpha=-1/2}_{5/2}$) and ^{146}Gd* ($7^1 \otimes [642]^{\alpha=1/2}_{5/2}$). In this case both SD bands ^{146}Gd and ^{146}Gd* should experience a crossing where the $[642]^{\alpha}_{5/2}$ interacts $[651]^{\alpha}_{1/2}$ ($\alpha = -1/2$ and $1/2$, respectively). However, the latter crossing is predicted to occur at higher frequency but with less interaction strength.

This work was supported by the Doctoral Programm Foundation of the Institution of Higher Education of China, the National Natural Science Foundation of China, and the Science Foundation of Peking University.

References

[1] T. Rzaca-Urban et al., Z. Phys. **A339** (1991) 421.

[2] G. Hebbinghaus et al., Phys. Lett. **B240** (1990) 311.

[3] V. G. Janzen et al., Proc. Int. Conf. on High Spin Phys. and Gamma-Soft Nuclei (Pittsburgh, 1990, ed. J. X. Soladin, R. A. Sorensa and C. M. Vincent, World Scientific, Singapore) p.225.

[4] J. Y. Zeng, J. Meng, C. S. Wu, E. G. Zhao, Z. Xing, and X. Q. Chen, Phys. Rev. **C 44** (1991) R1745.

[5] C. S. Wu, J. Y. Zeng, Z. Xing, X. Q. Chen, and J. Meng, Phys. Rev. **C 45** (in press).

[6] For example, C. S. Wu and J. Y. Zeng, Commun. Theor. Phys. (Beijing) **8** 51 (1987).

[7] F. S. Stephens et al., Phys. Rev. Lett. **66** (1991) 1378.

[8] C. S. Wu, L. Cheng, C. Z. Lin and J. Y. Zeng, Preprint AS-ITP-91-68.

TABLE I. Transition energies in the SD band of ^{146}Gd*. The calculated values are obtained from the least squares fitting (with parameters $a = -8.4491 \times 10^5$keV, $b = -1.5900 \times 10^{-5}$). Only the nine lowest transitions are involved in the fitting. Data are taken from ref. [1].

E_γ^{exp}	E_γ^{cal}	$E_\gamma^{cal} - E_\gamma^{exp}$	Spin assignments
1532	(1548.4)	16.4	59 → 57
1473	(1485.0)	12.0	57 → 55
1415	(1422.8)	7.8	55 → 53
1359	(1361.9)	2.9	53 → 51
1302	1302.1	0.1	51 → 49
1243	1243.4	0.4	49 → 47
1186	1185.6	−0.4	47 → 45
1129	1128.8	−0.2	45 → 43
1073	1072.8	−0.2	43 → 41
1018	1017.6	−0.4	41 → 39
963	963.1	0.1	39 → 37
909	909.4	0.4	37 → 35
856	856.2	0.2	35 → 33

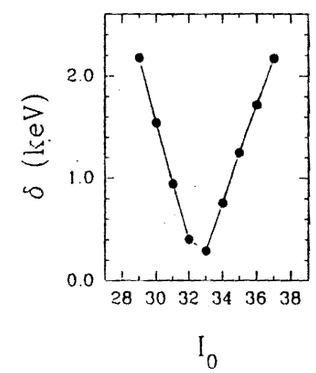

Fig. 1 The root-mean-square deviations $\delta = \left[\frac{1}{n}\sum_{i=1}^{n} \left| E_\gamma^{cal}(I_i) - E_\gamma^{exp}(I_i)\right|^2\right]^{1/2}$ for various spin assignments for the SD band in ^{146}Gd*. I_0 is the spin value prescribed to the lowest level observed [i.e. $E_\gamma(I_0 + 2 - I_0) = 856$keV].

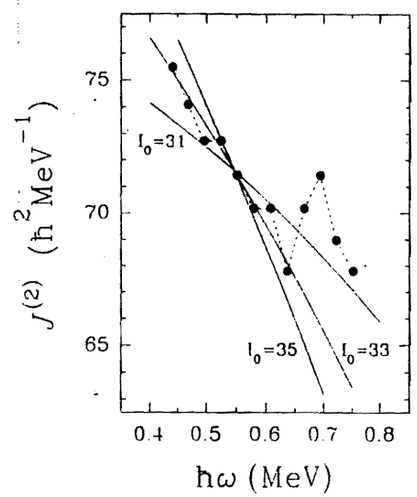

Fig. 2 The dynamic moments of inertia of the SD band ^{116}Gd*. The values extracted from the observed ΔE_γ's are represented by solid circles, while those calculated from eq. (3) are denoted by solid lines. The rotational frequency is given by $\hbar\omega(I) = (1/2)[\hbar\omega(I+1) + \hbar\omega(I-1)] = (1/4)[E_\gamma(I+2 \to I) + E_\gamma(I \to I-2)]$

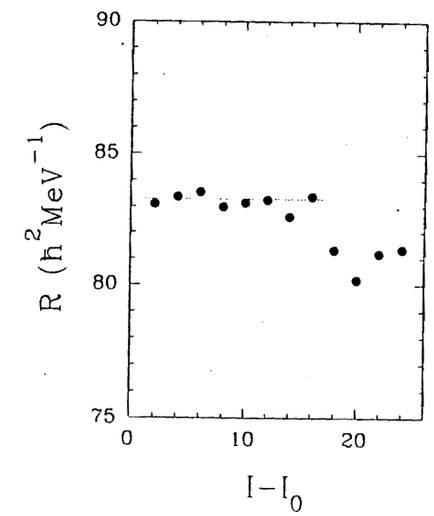

Fig. 3 The ratio $R \equiv \sqrt{[\mathcal{J}^{(1)}]^3/\mathcal{J}^{(2)}}$ values for various spin assignments for the SD band ^{116}Gd*. A slight structure change can be seen at $I \approx 52$.