CHARACTERIZATION OF BACKBENDING IN EVEN-EVEN $^{120-130}Te$ ISOTOPES

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In this paper, the nuclear structure of yrast bands of even-even $^{120-130}Te$ isotopes has been described as a result of the backbending phenomena of moment of inertia. The square of rotational frequency, moment of inertia and fermi energy of those nuclei has been calculated from available experimental values. We have studied systematic moment of inertia, fermi energy as a function of even neutron number of $^{120-130}Te$ isotopes. Moment of inertia as a function of the square of the rotational angular velocity for even neutron numbers from $N = 68$ to 78 in Te isotopes indicates the nature of backbending properties. The investigation of the backbending phenomena in ordinary space for even-even Te isotopes with even neutron number $N = 68$ to 78 are carried out and compared with gause space. Keywords: Moment of inertia; Te isotopes; Backbending; even-even nuclei; ground state band.

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1. INTRODUCTION

The even-even tellurium isotopes Te ($Z = 52$) have been extensively investigated both theoretically and experimentally in recent years with special emphasis on interpreting experimental data via collective models. It is known that low-lying collective quadrupole $E2$ excitations occur in even-even nuclei $Z = 52$, which have been studied both theoretically and experimentally [1-4]. The electric quadrupole moments of even $^{120-128}Te$ isotopes have been studied within the framework of the semi-microscopic model [5], two-proton core coupling model [6], dynamic deformation model [7] and the interacting boson model-2 [8-10].

Discovery of backbending phenomenon at high spins in the ground state rotational bands of even-even rare earth nuclei, it has been studied extensively in many nuclei [1, 12]. The sudden decrease of the rotational frequency along with anomalous increase in the moment of inertia have been found to occur in many deformed nuclei. The word backbending refers to the phenomenon where a plot of twice the moment of inertia versus the square of rotational frequency for various spin states has an S-shaped form [13]. The variable moment of inertia (VMI) model has a term of two parameters added to the rotational energy equation by Mariscottoi for the fitting of energies with the measured energies [14]. Recently calculation of the backbending were made using the models, angular momentum projected Tomm-Dancoff approximation [15], neutron-proton interaction in the framework of the Bardeen-Cooper-Schrieffer (BCS) model [16], projected shell model [17], and projected configuration interaction (PCI) method in which the deformed intrinsic states are directly associated with shell model wave function [18]. We have earlier studied evolution properties and backbending properties of yrast states for even-even $^{100-110}Pd$ and $^{104-122}Cd$ isotopes [19,20]. Electromagnetic reduced transition probabilities of even-even $^{104-112}Cd$ [21], $^{102-106}Pd$ [22], and $^{108-112}Pd$ [23], isotopes have been studied by interacting boson model ($IBM-1$). So far backbending properties of yrast states for even-even $^{120-130}Te$ isotopes are not found in the literature. For this purpose, we did an extensive analysis of the backbending properties of even $^{120-130}Te$ isotopes by phenomenological model. The nobility of this work is to demonstrate the study of extensive analysis of the backbending properties of even $^{120-130}Te$ isotopes.

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2. THEORETICAL CALCULATION

2.1. Moment of inertia θ and gamma energy E_γ

The relation between the moment of inertia (ϑ) and gamma energy E_γ is given by [19]:

$$\frac{2\vartheta}{\hbar^2} = \frac{4I-2}{E(I)-E(I-2)} = \frac{4I-2}{E_\gamma}\,. \quad (1)$$

And the relation between E_γ and $\hbar\omega$ is given by [24]:

$$\hbar\omega = \frac{E(I)-E(I-2)}{\sqrt{I(I+1)}-\sqrt{(I-2)(I-1)}} = \frac{E_\gamma}{\sqrt{I(I+1)}-\sqrt{(I-2)(I-1)}}\,. \quad (2)$$

2.2. Fermi energy (Gauge space)

The Fermi energies are calculated by using the following relation [25]:

$$\lambda(N,I) = \frac{1}{2}[E_x(N+1,I)-E_x(N-1,I)-S_{2n}^{N+1}]\,, \quad (3)$$

where N is the neutron number between the two even neighboring isotopes which are compared and S_{2n}^{N+1} is the separation energy

$$S_{2n}^{N+1} = E_B(Z,N) - E_B(Z,N-2)\,. \qquad (4)$$

3. RESULTS AND DISCUSSIONS

Table 1 presents transition level, gamma ray energy, moment of inertia, square of rotational energy for the ground state band of even-even $^{120-130}Te$ isotopes [26-31].

Table 1. *Excitation energies, moment of inertia and square of rotational energy for even-even $^{120-126}Te$ isotopes [26-31]*

Nucl.	I	$I(I+1)$	$E_{exp}(I)$, keV	Transition Level	E_γ, keV	$2\vartheta/\hbar^2$, MeV^{-1}	$(\hbar\omega)^2$, $(MeV)^2$
^{120}Te	2	6	560.4	$2^+ \to 0^+$	560.4	10.714	0.0784
	4	20	1161.1	$4^+ \to 2^+$	601.1	23.294	0.0903
	6	42	1775.7	$6^+ \to 4^+$	614.6	35.772	0.0946
	8	72	2652.4	$8^+ \to 6^+$	876.7	34.246	0.1918
	10	110	3543.4	$10^+ \to 8^+$	891.0	42.648	0.1984
	12	156	4459.4	$12^+ \to 10^+$	916.0	50.218	0.2097
^{122}Te	2	6	560.4	$2^+ \to 0^+$	560.4	10.639	0.0795
	4	20	1161.5	$4^+ \to 2^+$	601.1	22.690	0.0952
	6	42	1776.1	$6^+ \to 4^+$	614.6	38.596	0.0812
	8	72	2652.8	$8^+ \to 6^+$	876.7	41.394	0.2100
	10	110	3273.8	$10^+ \to 8^+$	621.0	61.191	0.0964
	12	156	3978.8	$12^+ \to 10^+$	705.0	65.248	0.1243
	14	210	4888.8	$14^+ \to 12^+$	910	59.34	0.2070
^{124}Te	2	6	602.7	$2^+ \to 0^+$	602.7	9.967	0.0906
	4	20	1248.6	$4^+ \to 2^+$	645.9	21.705	0.1040
	6	42	1747.0	$6^+ \to 4^+$	498.4	36.756	0.2139
	8	72	2664.4	$8^+ \to 6^+$	917.4	44.117	0.1156
	10	110	3267.1	$10^+ \to 8^+$	602.7	86.363	0.0484
^{126}Te	2	6	666.3	$2^+ \to 0^+$	666.3	9.009	0.1109
	4	20	1361.3	$4^+ \to 2^+$	695.0	20.437	0.1173
	6	42	1776.2	$6^+ \to 4^+$	414.7	53.14	0.0428
	8	72	2765.6	$8^+ \to 6^+$	989.6	30.333	0.2445
	10	110	2973.6	$10^+ \to 8^+$	208.0	182.692	0.0108
^{128}Te	2	6	743.2	$2^+ \to 0^+$	743.2	8.0753	0.1380
	4	20	1497.0	$4^+ \to 2^+$	754.8	18.5676	0.1421
	6	42	1811.2	$6^+ \to 4^+$	314.2	70.0637	0.0246
	8	72	2655.4	$8^+ \to 6^+$	844.2	35.5450	0.1781
	10	110	2756.7	$10^+ \to 8^+$	101.3	376.2576	0.0026
	12	156	3473.1	$12^+ \to 10^+$	717.4	64.1562	0.1285
	14	210	4306.8	$14^+ \to 12^+$	833.7	64.8259	0.1738
^{130}Te	2	6	839.5	$2^+ \to 0^+$	839.5	7.1513	0.1759
	4	20	1632.9	$4^+ \to 2^+$	793.5	17.6544	0.1572
	6	42	1814.3	$6^+ \to 4^+$	182.3	120.879	0.0083
	8	72	2648.6	$8^+ \to 6^+$	833.4	20.367	0.5424

Table 2 presents Fermi energy of even-even $^{120-130}Te$ isotopes [26-31].

Table 2. *Fermi energy $\lambda(N, I)\, MeV$ of even-even $^{120-130}Te$ isotopes [26-31]*

I	^{120}Te	^{122}Te	^{124}Te	^{126}Te	^{128}Te	^{130}Te
0	-9.420	-9.040	-8.176	-7.847	-7.567	-7.249
2	-9.063	-8.960	-8.157	-7.815	-7.495	-7.201
4	-9.0897	-8.982	-8.162	-7.827	-7.499	-7.229
6	-9.0899	-9.012	-7.999	-8.103	-7.583	-7.315
8	-9.0282	-8.969	-8.293	-7.693	-7.606	-7.598
10	-9.0377	-9.124	-8.267	-7.963		

3.1. Moment of inertia

The positive parity yrast levels are connected by a sequence of stretched $E2$ transition with energies which increase smoothly except around the backbends. The transition energy $\Delta E_{I,I-2}$ should increase linearly with I for the constant rotor as $\Delta E_{I,I-2} = I/(4I-2)$ does not increase, but decrease for certain I values. The moment of inertia $2\vartheta/\hbar^2$ and rotational frequency $\hbar\omega$ have been calculated from Eq.(1) and (2) respectively. The ground state bands up to 14 units of angular momentum are investigated for moment of inertia in even $^{120-130}Te$ nuclei. The moments of inertia are plotted versus even neutron number in Fig.1.

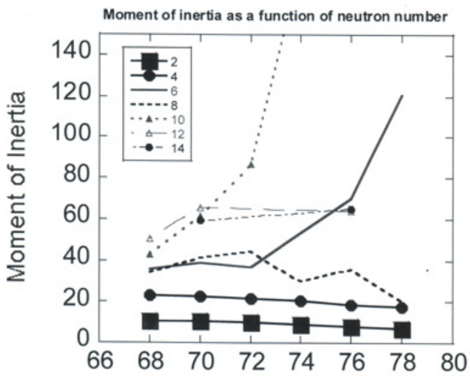

Fig.1. *Moments of inertia versus even neutron number $N = 68 - 78$ of $^{120-130}Te$*

It is shown that $2\vartheta/\hbar^2$ as a function of neutrons do not changes upto spin 4^+. $2\vartheta/\hbar^2$ as a function of square of rotational energy in even $^{120-130}Te$ nuclei are plotted in Fig.2. In the lowest order according to variable moment of inertia (VMI) model this should give a straight line in the plot of inertia $2\vartheta/\hbar^2$ as a function of ω^2. It is seen that the backbending behaviour changes from one isotope to another in this mass region, the $^{122-128}Te$ show backbending at $I = 6^+$ and $I = 8^+$ while ^{120}Te and ^{130}Te do not at all. Moment of inertia are rapidly increases at 8^+ states for $N = 72$ and 6^+ states for $N = 76$. Results are presented on collective $\Delta I = 2$ ground band level sequence for the variation of shapes for Te isotopes with even neutron from $N = 68 - 78$. The back-bending phenomena appear clearly in the diagram $2\vartheta/\hbar^2$ vs $(\hbar\omega)^2$.

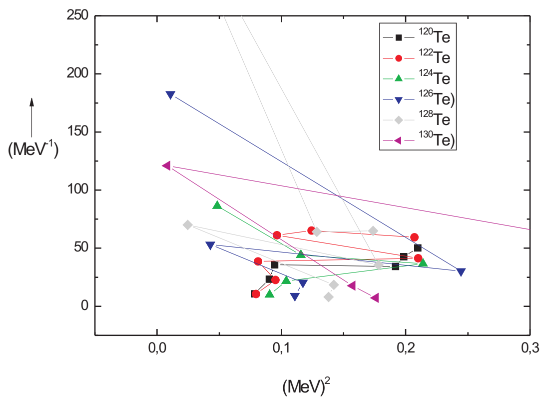

Fig.2. *$2\vartheta/\hbar^2$ as a function of square of rotational energy in even $^{120-130}Te$ isotopes*

3.2. Fermi energies

It is more elucidating to confirm our results in gauge space plot which show a backbending behaviour when a change in deformation occurs. The Fermi energies $\lambda(N, I)$ of even $^{120-130}Te$ are calculated from equation (3). The comparisons of Fermi energies of Te isotopes with even neutron $N = 68 - 78$ in gauge space for different states are presented in Fig.3.

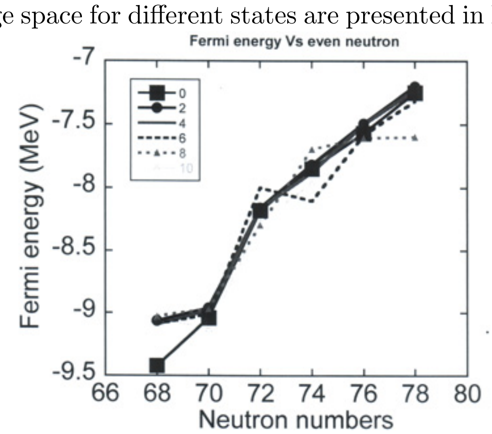

Fig.3. *Fermi energies as a function of even neutron $N = 68 - 78$ of Te isotopes*

The Fermi-energy of those nuclei at different levels $(2^+, 4^+, 6^+, ...14^+)$ are given in Table 2. The change of deformation can be explored though the so-called "gauge-plots" of Fermi energy versus even neutron number. Fig.3 shows the backbending between the spherical nuclei with $N < 72$ and deformed nuclei with higher neutron number, the $\lambda(N, I)$ curve reflects the level density at the Fermi surface. At present Gauge-plots show a sudden increase in level density tends to change the deformation.

4. CONCLUSIONS

Even-even $^{120-130}Te$ isotopes have drawn the attention to the analogy between the rotational frequency in ordinary space and Fermi energy in gauge space. The investigation of the backbending phenomena in ordinary space for even-even $^{120-130}Te$ isotopes are observed and compared with gauge space for the Fermi energies up to levels 14^+. Results are extremely useful for compiling nuclear data table.

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ХАРАКТЕРИЗАЦИЯ ЯВЛЕНИЯ BACKBENDING В ЧЕТНО-ЧЕТНЫХ ИЗОТОПАХ $^{120-130}Te$

М. Хуссейн, И. Хоссайн, С.А. Мансоур

Описана ядерная структура yrast полос (зон) четно-четных изотопов $^{120-130}Te$ как результат явления backbending момента инерции. Квадрат вращательной частоты, момент инерции и энергия Ферми этих ядер были вычислены из доступных экспериментальных данных. Мы изучили системный момент инерции и энергии Ферми, как функции четного нейтронного числа $^{120-130}Te$ изотопов. Момент инерции, как функция квадрата угловой скорости вращения для четных чисел нейтронов от $N = 68$ до 78 в Te изотопах, обнаруживает backbending свойства. Исследования backbending явления в обычном пространстве были выполнены для четно-четных изотопов Te с четными числами нейтронов от $N = 68$ до 78, и проведены сравнения с результатами для Гауссова пространства.

ХАРАКТЕРИЗАЦІЯ ЯВИЩА BACKBENDING В ПАРНО-ПАРНИХ ІЗОТОПАХ $^{120-130}Te$

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Описана ядерна структура yrast смуг (зон) парно-парних ізотопів $^{120-130}Te$ як наслідок явища backbending момента інерції. Квадрат обиртової частоти, момент інерції і енергія Фермі цих ядер були обраховані із наявних експериментальних даних. Ми вивчили системний момент інерції і енергію Фермі, як функції парного нейтронного числа $^{120-130}Te$ ізотопів. Момент інерції, як функція квадрата кутової швидкості обертання для парних чисел нейтронів від $N = 68$ до 78 в Te ізотопах, проявляє backbending властивості. Були вивчені backbending явища для парно-парних ізотопів Te в звичайному просторі для парних чисел нейтронів від $N = 68$ до 78, і проведені порівняння з даними для Гауссового простору.