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SU(6) LIMIT OF THE QUASIPARTICLE-PHONON NUCLEAR MODEL

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1. Introduction

In recent years the Truncated Quadrupole Phonon Model (TQPM) [1,2] and the Interacting Boson Model (IBM)[3] based on the dynamical SU(6) symmetry play an important role in analysing of the properties of collective low-lying states in atomic nuclei. The Hamiltonians of these models are expressed in terms of SU(6) algebra generators. The collective quadrupole operators of coordinates and conjugated moments and their commutators form a closed algebra which is isomorphic to the Lie-algebra of SU(6)-group. The physical assumptions underlying the microscopical derivation of the TQPM Hamiltonian have been first described in[1]. This Hamiltonian, was widely used for the theoretical description of transitional nuclei[4]. But the TQMP parameters were chosen as phenomenological ones. The IBM was formulated as a phenomenological model and had a great success in spectroscopic calculations for many nuclei[5]. The equivalence of the TQPM and IBM on a phenomenological level was established in[6].

The progress of these model using the phenomenological set of parameters in the theoretical description of collective nuclear properties put an essential question about the microscopic calculation of these parameters. There is a lot of such calculations for the IBM[7]. These calculations are based on the mapping procedure of the truncated fermion space on the IBM boson space. The critical analysis of such a procedure has been done in[8]. More straight and consequent way for a microscopic calculation of parameters has been suggested by the TQPM authors[1,4]. To realize their suggestions practically one needs to use a concrete microscopic model in which the collective degrees of freedom are distinguished. One of such models is the quasiparticle-phonon model (QPM)[9]. The QPM Hamiltonian is expressed in terms of the quasiparticle and phonon operators. The structure of the phonon operators is defined by solving the random phase approximation (RPA) equations[9]. The phonon operators and their commutators do not close the SU(6) algebra. In this work we show that only a part of the QPM Hamiltonian, including the monopole and quadrupole degrees of freedom under some conditions has the same algebraic structure as the TQPM and IBM Hamiltonians.

So we demonstrate that the QPM Hamiltonian has the SU(6) limit and can be used for microscopic calculations of the TQPM and IBM parameters.

2. Analysis of the QPM Hamiltonian

The general expression for the QPM Hamiltonian is given in /9/. We consider a case of even-even spherical nuclei. Taking into account the monopole and quadrupole degrees of freedom and keeping the phonon operators which correspond to the first root of the RPA equation we write the QPM Hamiltonian in the following form:

$$H=\sum_{jm}\varepsilon_j\alpha^+_{jm}\alpha_{jm}-\frac{1}{4}\left(\frac{X(n)}{Y(n)}+\frac{X(p)}{Y(p)}\right)\sum_{\mu}\Big[Q_{2\mu 1}Q^+_{2\mu 1}+Q^+_{2\mu 1}Q_{2\mu 1}+(-)^{\mu}\left(Q^+_{2\mu 1}Q^+_{2-\mu 1}+Q_{2-\mu 1}Q_{2\mu 1}\right)\Big]-$$
$$-\frac{1}{2\sqrt{2}}\sum_{\mu\tau}\Big\{\left((-)^{\mu}Q^+_{2\mu 1}+Q_{2-\mu 1}\right)\sum_{j_1j_2}\frac{f_{j_1j_2}v^{(-)}_{j_1j_2}}{\sqrt{Y(\tau)}}B_{\tau}(j_1j_2;2-\mu)+h.c.\Big\}- \tag{1}$$
$$-\frac{1}{10}\sum_{\substack{j_1j_2j_3j_4\\ \mu\tau}}(-)^{\mu}\Big\{(\varkappa_0+\varkappa_1)f_{j_1j_2}v^{(-)}_{j_1j_2}f_{j_3j_4}v^{(-)}_{j_3j_4}B_{\tau}(j_1j_2;2\mu)B_{\tau}(j_3j_4;2\mu)+$$
$$+(\varkappa_0-\varkappa_1)f_{j_1j_2}v^{(-)}_{j_1j_2}f_{j_3j_4}v^{(-)}_{j_3j_4}B_{\tau}(j_1j_2;2\mu)B_{-\tau}(j_3j_4;2-\mu)\Big\}.$$

Here α^+_{jm} (α_{jm}) and $Q^+_{2\mu 1}$ $(Q_{2\mu 1})$ are the quasiparticle and quadrupole phonon creation (annihilation) operators, ε_j is the single-quasiparticle energy, $f_{j_1j_2}$ are the single-particle elements of the quadrupole operator, $v^{(-)}_{j_1j_2}$ is the combination of the Bogolubov transformation coefficients, τ denotes summation over the neutron (n) and proton(p) states. The change of τ by $-\tau$ means $n\leftrightarrow p$.

Total expressions for $X(\tau)$ and $Y(\tau)$ are given in /9/. $\varkappa_0$ and $\varkappa_1$ are the isoscalar and isovector constants of the quadrupole--quadrupole forces

$$B(j_1j_2;\lambda\mu)=\sum_{m_1m_2}(-)^{j_2+m_2}(j_1m_1j_2m_2|\lambda\mu)\alpha^+_{j_1m_1}\alpha_{j_2-m_2}. \tag{2}$$

The operator of the first RPA quadrupole phonon has a usual form:

$$Q^+_{2\mu 1}=\frac{1}{2}\sum_{j_1j_2}\Big\{\psi_{j_1j_2}[\alpha^+_{j_1}\alpha^+_{j_2}]_{2\mu}-(-)^{\mu}\varphi_{j_1j_2}[\alpha_{j_2}\alpha_{j_1}]_{2-\mu}\Big\}=Q^+_{\mu}. \tag{3}$$

To construct the SU(6) limit of the QPM Hamiltonian we have to be convinced that a multitude of operators Q^+_{μ}, Q_{μ} and $B(j_1j_2;2\mu)$ closes the SU(6) algebra. In this case the Jacobi identities have to be fulfilled for these operators. We calculate commutators and receive

$$[Q_{\mu},Q^+_{\nu}]=\delta_{\mu\nu}-\sum_{j_1j_2j_3}(-)^{j_3+j_2}B(j_1j_2;\ell m)\sqrt{5(2\ell+1)}\times$$
$$(2\mu\ell m|2\nu)\left[(-)^{\ell}\psi_{j_1j_2}\psi_{j_3j_1}-\varphi_{j_1j_2}\varphi_{j_3j_1}\right]\begin{Bmatrix}2&2&\ell\\ j_2&j_3&j_1\end{Bmatrix} \tag{4}$$

$$[B(j_1j_2;\lambda\mu),Q^+_{\nu}]=\sum_{\rho}(2\nu\lambda\mu|2\rho)\sqrt{5(2\lambda+1)}\Big\{Q^+_{\rho}\sum_{j_3}(-)^{j_1+j_3}\begin{Bmatrix}j_1&j_3&2\\ 2&\lambda&j_2\end{Bmatrix}\times$$
$$\left[(-)^{\lambda}\psi_{j_1j_3}\psi_{j_2j_3}+\varphi_{j_1j_3}\varphi_{j_2j_3}\right]+(-)^{\rho}Q_{-\rho}[(-)^{\lambda}+1]\,W(j_1j_2;\lambda), \tag{5}$$

where

$$W(j_1j_2;\lambda)=\sum_{j_3}(-)^{j_1+j_3}\begin{Bmatrix}j_1&j_3&2\\ 2&\lambda&j_2\end{Bmatrix}\varphi_{j_1j_3}\psi_{j_2j_3} \tag{6}$$

$$[Q^+_{\mu},[Q_{\nu},Q^+_{\sigma}]]=2\sum_{\rho}[Q^+_{\rho}C_{\mu\nu\sigma\rho}+Q_{\rho}D_{\mu\nu\sigma\rho}] \tag{7}$$

$$C_{\mu\nu\sigma\rho}\equiv\sum_{k=0}^{4}C_k\sum_{\varkappa=-k}^{k}(2\mu 2\nu|k\varkappa)(2\rho 2\nu|k\varkappa)$$

$$C_K = \frac{25}{2} \sum_{j_1 j_2 j_3 j_4} (-)^{j_3 - j_1} \begin{Bmatrix} j_4 & j_3 & 2 \\ j_2 & j_1 & 2 \\ 2 & 2 & K \end{Bmatrix} \Big(\Psi_{j_1 j_2} \Psi_{j_3 j_1} \Psi_{j_2 j_4} \Psi_{j_3 j_4} - \qquad (8)$$

$$- \varphi_{j_1 j_2} \varphi_{j_3 j_1} \varphi_{j_2 j_4} \varphi_{j_3 j_4}$$

$$\mathcal{D}_{\mu\nu\sigma\rho} \equiv \sum_{K=0}^{4} \mathcal{D}_K \sum_{\varkappa=-K}^{K} \big[(-)^{\mu} (2\nu 2 -\mu | K\varkappa)(2\sigma 2\rho | K\varkappa) +$$

$$+ (-)^{\rho} (2\mu 2\sigma | K\varkappa)(2 -\rho 2\nu | K\varkappa) \big]$$

$$\mathcal{D}_K = \frac{25}{2} \sum_{j_1 j_2 j_3 j_4} (-)^{j_3 - j_1} \begin{Bmatrix} j_4 & j_3 & 2 \\ j_2 & j_1 & 2 \\ 2 & 2 & K \end{Bmatrix} \Big(\Psi_{j_1 j_2} \Psi_{j_3 j_1} \Psi_{j_2 j_4} \varphi_{j_3 j_4} - \qquad (9)$$

$$- \varphi_{j_1 j_2} \varphi_{j_3 j_1} \varphi_{j_2 j_4} \Psi_{j_3 j_4} \Big).$$

Deriving expressions (4)-(9) we keep terms including the contribution from the first quadrupole phonon only, as in ref. /1/. One can see from formulae (4)-(9) that

$$B(j_1 j_2; \lambda\mu) = \sum_{\rho\sigma} X_{\rho\sigma}(j_1 j_2; \lambda\mu) \left(\delta_{\rho\sigma} - [Q_\rho, Q_\sigma^+] \right). \qquad (10)$$

The exact expression for $X_{\rho\sigma}(j_1 j_2; \lambda\mu)$ will be done later.

It is easy to calculate commutators $[Q^+, Q^+]$, $[Q, Q]$, $[Q, [Q, Q]]$, $[Q^+, [Q^+, Q^+]]$, etc., and to be convinced that they close the algebra. To receive the SU(6) algebra we have to demand of a fulfilment of the Jacobi identities for any three operators A,B,C of a multitude under consideration $[A, [B,C]] + [B, [C,A]] + [C, [A,B]] \equiv 0$. After rather a tedious analysis of all possible Jacobi identities, one can show that a demand for a fulfilment of these identities leads to definite conditions for the phonon amplitudes /10/:

$$W(j_1 j_2, \lambda) = 0 \qquad (11)$$

$$\mathcal{D}_K = 0, \quad K = 0, 1, 2, 3, 4 \qquad (12)$$

$$C_1 = C_3 = 0 \qquad (13)$$

$$C_0 = C_2 = C_4 = C \qquad (14)$$

$$[Q_\nu^+, Q_\mu^+] = [Q_\nu, Q_\mu] = 0. \qquad (15)$$

From (15) it is seen immediately that the multitude of operators and their commutators has only 35 terms with zero traces: $\{Q_\mu, Q_\mu^+, [Q_\nu, Q_\mu^+]\}$. This is the case of the SU(6) algebra. When using the Tamm-Dankoff method for determining the structure of collective phonons, the amplitudes $\varphi_{j_1 j_2} = 0$ and conditions (11), (12) are fulfilled automatically (see formulae (6) and (9)).

The conditions (11)-(15) lead to an essential simplification of expressions for the commutators (5),(7):

$$[Q_\mu^+, [Q_\nu, Q_\sigma^+]] = C(\delta_{\mu\nu} Q_\sigma^+ + \delta_{\nu\sigma} Q_\mu^+). \qquad (16)$$

From (16) we find

$$[[Q_\mu, Q_\nu^+], [Q_\rho, Q_\sigma^+]] = C\left(\delta_{\rho\nu} [Q_\mu, Q_\sigma^+] - \delta_{\mu\sigma} [Q_\rho, Q_\nu^+]\right). \qquad (17)$$

The right-hand side of the commutator (5) has no annihilation phonon operators. Using the Beliajev-Zelevinski boson expansion method /11/ one can receive the Holstein-Primakoff representation of the algebra (16), (17). Following /11,12/ we look for Q_μ, Q_μ^+ as a power series in ideal quadrupole boson operators b_μ^+, b_μ. The expansion coefficients are defined from the recurrence relations:

$$[X, Y] = Z$$

$$[X^{(n)}, Y^{(1)}] + [X^{(n-1)}, Y^{(2)}] + \ldots + [X^{(1)}, Y^{(n)}] = Z^{(n-1)},$$

where $X = Q_\mu^+$, $Y = [Q_\nu, Q_\sigma^+]$, $Z = C(\delta_{\mu\nu} Q_\sigma^+ + \delta_{\nu\sigma} Q_\mu^+)$,

$X^{(n)}$, $Y^{(n)}$, $Z^{(n)}$ are the n-th order terms of the boson expansion. As a result we have derived the following representations of Q_μ^+ and Q_μ:

$$Q^+_\mu = b^+_\mu - b^+_\mu \sum_{n=1}^{\infty} \frac{(2n-3)!!}{2^n n!}\left(c\sum_\nu b^+_\nu b_\nu\right)^n = \tag{18}$$

$$= b^+_\mu \sqrt{1 - c\sum_\nu b^+_\nu b_\nu}$$

$$Q_\mu = \sqrt{1 - c\sum_\nu b^+_\nu b_\nu}\; b_\mu \tag{19}$$

with $(-1)!! \equiv 1$.

The derived representations for Q^+_μ, Q_μ coincide formally with expressions[1,4,13] for the Tamm-Dankoff phonon operators. However, for the RPA phonon amplitudes $\psi_{j_1j_2}$ and $\varphi_{j_1j_2}$ there are additional conditions which have a more general form than the ones for the Tamm-Dankoff case. The existence of such conditions is not obvious. These conditions are very essential for the microscopic derivation of the TQPM Hamiltonian. Using the wave function of the method of generator coordinates in the following form:

$$|\alpha\rangle = exp\{\sum_{\mu=-2}^{2} \alpha^*_{2\mu} Q^+_\mu\}|0\rangle \qquad Q_\mu|0\rangle = 0$$

one can receive the Dyson boson representation for the algebra (16), (17) (see ref.[4]). After the well-known orthonormalisation procedure[14] we get again the expressions (18), (19). It is clear from (18), (19) that $1/c$ has a sense of the maximal boson number N. To write the Hamiltonian (1) in terms of ideal bosons we must know the boson representation for $B(j_1j_2;\lambda\mu)$.

Using the formulae (5), (10), (16), (18) and (19) we receive:

$$X_{\rho\sigma}(j_1j_2;\lambda\mu) = N\sqrt{5(2\lambda+1)}(2\rho\lambda\mu|2\sigma)X(j_1j_2\lambda) - \delta_{0\sigma} N \frac{5}{6}\frac{\delta_{j_1j_2}}{\sqrt{2j_1+1}}\sum_{j_3}(\psi^2_{j_1j_3}+\varphi^2_{j_1j_3}). \tag{20}$$

where

$$X(j_1j_2\lambda) = \sum_{j_3}(-)^{j_1+j_3}\begin{Bmatrix}2 & 2 & \lambda\\ j_2 & j_1 & j_3\end{Bmatrix}[(-)^\lambda \psi_{j_1j_3}\psi_{j_2j_3} + \varphi_{j_1j_3}\varphi_{j_2j_3}]. \tag{21}$$

From (10), (18)-(20), one can find

$$B(j_1j_2;00) = \delta_{j_1j_2}\sum_{j_3}(\psi^2_{j_1j_3}+\varphi^2_{j_1j_3})\frac{\hat N}{\sqrt{2j_1+1}} \tag{22}$$

$$B(j_1j_2;2\mu) = 5X(j_1j_2 2)[b^+_2\otimes\tilde b_2]_{(2\mu)}. \tag{23}$$

Here $\hat N = \sum_\nu b^+_\nu b_\nu$ is the operator of the boson number, $\tilde b_\mu = (-)^\mu b_{-\mu}$, $[b^+_2\otimes\tilde b_2]_{(2\mu)}$ is a usual tensor product[15].

Let us consider the Hamiltonian (1)

$$\sum_m \alpha^+_{jm}\alpha_{jm} = \sqrt{2j+1}B(jj;00) = \sum_{j_3}(\psi^2_{jj_3}+\varphi^2_{jj_3})\hat N \tag{24}$$

Taking into account (18), (19), (24) and the QPM relations[9] and making some algebraic transformations for the Hamiltonian (1) we find:

$$\begin{aligned} H = {} & h_0 + h_1\hat N + h_2\sum_\nu(-)^\nu\left(b^+_\nu b^+_{-\nu}\sqrt{(N-\hat N)(N-1-\hat N)} + h.c.\right) + \\ & + h_3\left(\sum_\nu(-)^\nu b^+_\nu[b^+_2\otimes\tilde b_2]_{(2-\nu)}\sqrt{N-\hat N} + h.c.\right) + \\ & + \sum_{\mu,L=0,2,4}\sqrt{2L+1}\,h_{4L}[[b^+_2\otimes b^+_2]_{(L\mu)}\otimes[\tilde b_2\otimes\tilde b_2]_{(L-\mu)}]_{(00)}. \end{aligned} \tag{25}$$

where

$$\begin{aligned} & h_0 = -\frac{5}{4}\left(\frac{X(n)}{Y(n)} + \frac{X(p)}{Y(p)}\right) = -\frac{5}{4}q \\ & h_1 = \omega - \frac{5}{2}[(\varkappa_0+\varkappa_1)(G_n^2+G_p^2) + 2(\varkappa_0-\varkappa_1)G_nG_p] \\ & h_2 = -\frac{1}{4N}q \qquad h_3 = -\frac{5}{\sqrt{2N}}\left(\frac{G_n}{\sqrt{Y(n)}} + \frac{G_p}{\sqrt{Y(p)}}\right) \\ & h_{4L} = -\frac{5}{2}\begin{Bmatrix}2 & 2 & 2\\ 2 & 2 & L\end{Bmatrix}[(\varkappa_0+\varkappa_1)(G_n^2+G_p^2) + 2(\varkappa_0-\varkappa_1)G_nG_p] \end{aligned} \tag{26}$$

$$G_{\tau} = \sum_{j_1 j_2 j_3} f^{\tau}_{j_1 j_2} v^{(-)}_{j_1 j_2} X^{\tau}(j_1 j_2 2).$$

The Hamiltonian (25) is the known TQPM Hamiltonian/1,4/ which is constructed of the SU(6) algebra generators. So we have derived the SU(6) limit of the QPM Hamiltonian and expressed the TQPM Hamiltonian parameters through the microscopic values of the QPM Hamiltonian. Note that ω is the energy of the first solution of the RPA equation. The following relation is valid:

$$\omega = \sum_{j_1 j_2} (\mathcal{E}_{j_1} + \mathcal{E}_{j_2})(\psi_{j_1 j_2} - \varphi_{j_1 j_2})^2.$$

As can be seen from a comparison of (1) with (25) the term with the coefficient h_3 in the TQPM Hamiltonian corresponds to the quasiparticle-phonon interaction of the QPM hamiltonian and the terms with the coefficients h_{4L} correspond to the QPM Hamiltonian terms which are proportional to $B(j_1 j_2 2\mu) B(j_1 j_2 2\mu)$.

3. Results of Calculations

Now we can use the derived expressions for numerical calculations. When doing the IBM calculations/7/ the number of bosons N is always counted as the number of valence particle or hole pairs. Within the TQPM N is calculated microscopically:

$$\mathcal{N} = \frac{1}{C} \tag{27}$$

(see formulae (8) and (14)). This is an essential advantage of the TQPM in a comparison with the IBM. That is why it is interesting to compare the results of the microscopic calculation of N with the phenomenological IBM values. As has been mentioned above constructing the SU(6) limit of the QPM we derived additional conditions for the phonon amplitude ψ, φ (11)-(14). As ψ and φ are the RPA phonon amplitudes within the QPM, we have to check fulfilment of the conditions (11)-(14).

As an example we consider the even-even Zn isotopes. We have used the same set parameters for the Saxon-Woods potential and monopole pairing constants as in ref./16/. The constants of the quadrupole-quadrupole interaction have been chosen so as to fit the calculated reduced probabilities B(E2) with experimental data for 2^+_1 level. We give the results of our calculations for the pure isoscalar forces, because including of isovector forces does not change our results in principle. The calculated and phenomenological values of the boson number N for Zn isotopes are given in table 1. The experimental and theoretical values for the 2^+_1 energies ω and E2-transition probabilities B(E2) are shown in table 1, too. As can be seen from this table the microscopic values for N are in a reasonable agreement with phenomenological ones. Let us note that using formula (27) we have chosen $C = C_2$. The calculated coefficients C_K and $\mathcal{D}_K$ are shown in table 2. We give the values of $C_K, \mathcal{D}_K$ for even K only, because for K =1,3 the calculated coefficients $C_K, \mathcal{D}_K \gtrsim 10^{-14}$ and the conditions (12), (13) are fulfilled with a high accuracy. It is seen from table 2 that the condition (14) is fulfilled rather poorly. Although the coefficients $\mathcal{D}_K$ ($K = 0,2,4$) are always less than C_K they differ from zero noticeably and the condition (12) is not satisfied. We did not check the fulfilment of the condition (11) because it naturally follows from the fulfilment of (12) and vice versa. It is worth mentioning that the condition (14) for the Tamm-Dankoff phonon has been tested in ref./13/. The results of ref./13/ are similar to ours. It was found/13/ that the inclusion of the interaction in the particle-particle channel improved the situation slightly. In our calculations we didn't take into account this interaction. As we know from our calculation the inclusion of the isovector interaction improve slightly the fulfilment of the condition (14). So it is interesting to take into account both effects mentioned above. As an illustration we show in table 3 the results of microscopic calculations for the TQPM Hamiltonian parameters in Zn isotopes. These parameters can be used for spectroscopic calculations, but this is not a goal of this paper.

4. Conclusion

In this work we have shown that the QPM Hamiltonian has the SU(6) limit, which is constructed explicitly. That enabled us to perform microscopic calculations of the maximal number of bosons. When constructing the SU(6) limit of the QPM we derived the definite conditions which had to be satisfied for the quadrupole phonon amplitudes. The calculations performed have shown that the conditions derived were fulfilled rather poorly for the RPA phonon amplitudes. In our opinion the most consistent solution of the problem is solving

Table 1. Maximal numbers of the bosons in Zn isotopes

Mass number	Experiment		RPA		N	
	ω, MeV	B(E2) ^{2}fm^4	ω, MeV	B(E2) ^{2}fm^4	Calc.	Phenom.
64	0,99	1580	0,734	1582	4,26	4
66	1,04	1370	1,04	1112	4,95	5
68	1,08	1360	1,08	1343	4,17	6
70	0,89	1600	1,294	1600	2,69	6

Table 2. Coefficients C_K and $\mathcal{D}_K$ for Zn isotopes

Mass number	C_0	C_2	C_4	$\mathcal{D}_0$	$\mathcal{D}_2$	$\mathcal{D}_4$
64	0,582	0,235	0,493	0,274	0,106	0,224
66	0,401	0,202	0,381	0,177	0,081	0,154
68	0,262	0,240	0,387	0,125	0,093	0,152
70	0,015	0,371	0,530	0,011	0,117	0,173

Table 3. The TQPM hamiltonian parameters in Zn isotopes

Mass number	h_1	h_2	h_3	h_{40}	h_{42}	h_{44}
64	0,703	-1.86	-0.65	-0.057	0.012	-0.016
66	1.038	-1.077	-0.22	-0.002	0.0004	-0.0004
68	1.079	-1.387	0,053	-0.0006	0	-0,0002
70	1.21	-2.099	-0.836	0.083	-0.018	0.024

of the equations of motion with additional conditions rather than finding of phonon amplitudes within the RPA.

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Кырчев Г., Воронов В.В.
SU(6)-предел квазичастично-фононной модели ядра

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Показано, что гамильтониан квазичастично-фононной модели имеет SU(6)-предел, т.е. при определенных ограничениях его можно представить как вращательный инвариант, построенный из генераторов SU(6)-алгебры, замыкаемой коллективными фононными операторами приближения случайных фаз и их коммутаторами. Это позволяет получить микроскопические выражения для параметров модели квадрупольных фононов. Для ряда изотопов цинка проведен микроскопический расчет максимального числа бозонов и проверено выполнение ограничений, приводящих к SU(6)-пределу.

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SU(6) Limit of the Quasiparticle-Phonon Nuclear Model

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It is shown that the Hamiltonian of the quasiparticle-phonon nuclear model has the SU(6) limit. Under some conditions this Hamiltonian can be represented as a rotational invariant which is constructed of the generators of the SU(6) algebra. The collective quadrupole RPA phonon operators and their commutators form a closed algebra. The microscopic expressions for the parameters of the truncated quadrupole phonon model are derived. The calculation of maximal numbers of bosons and the test of the conditions giving the SU(6) limit for some Zn isotopes have been performed.

The investigation has been performed at the Laboratory of Theoretical Physics, JINR.

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