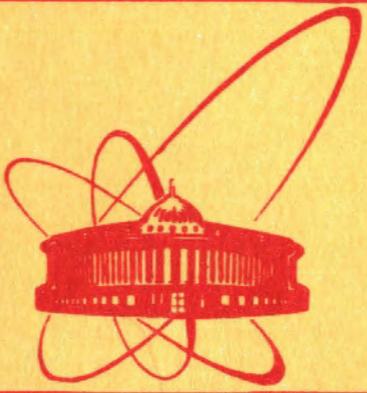

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CORRELATIONS IN THE GROUND STATES OF DEFORMED NUCLEI

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The fragmentation of one-quasiparticle and one-phonon states over many nuclear levels is calculated within the quasiparticle-phonon nuclear model[1]. Those characteristics of nuclei are studied which are determined by one-quasiparticle and one-phonon components of the excited state wave functions. The one-phonon states calculated in the RPA are used as a basis. It has been shown in ref.[2] that for further development of the quasiparticle-phonon nuclear model, one should more exactly take into account the Pauli principle and to study the correlations in the ground states. The influence of the Pauli principle on the two-phonon components of the wave functions in deformed nuclei has been studied in ref.[3].

Several papers have been devoted to the problem of correlations or the average number of quasiparticles in the ground states of doubly even nuclei[4-6]. For the case of spherical and transitional nuclei this problem has been studied in ref.[7]. The average number of quasiparticles in the ground states of deformed nuclei has been calculated in ref.[8] for the quadrupole and octupole phonons without taking into account the isovector forces.

A large number of multipole and spin-multipole phonons is used in the quasiparticle-phonon nuclear model[9-11]. The ground state of a doubly even nucleus is the vacuum for all phonons. The phonons with different values of $\lambda\mu$ give the contribution to the average number of quasiparticles in the ground state. Therefore, one should find the total average number of quasiparticles in the ground state, caused by all phonons.

The present paper is aimed at calculating the average number of quasiparticles in the ground states of doubly even deformed nuclei and elucidating the cases when the phonons calculated within the RPA can be used as a basis for the quasiparticle-phonon nuclear model.

1. BASIC FORMULAE

The phonon creation operator for the deformed nuclei has the form[12]

$$Q^{+}_{\lambda\mu i} = \frac{1}{\sqrt{2}} \sum_{qq'} \{ \psi^{\lambda\mu i}_{qq'} A^{+}(qq') - \phi^{\lambda\mu i}_{qq'} A(qq') \}, \qquad (1)$$

where

$$A^{+}(qq') = \frac{1}{\sqrt{2}} \sum_{\sigma} \sigma a^{+}_{q-\sigma} a^{+}_{q'\sigma} \quad \text{or} \quad \frac{1}{\sqrt{2}} \sum_{\sigma} a^{+}_{q'-\sigma} a^{+}_{q\sigma},$$

$a^{+}_{q\sigma}$ is the quasiparticle creation operator, $(q\sigma)$ are the quantum numbers of a single-particle state, $\sigma = \pm 1$;

$$\psi^{\lambda\mu i}_{qq'} \sim \frac{f^{\lambda\mu}(qq')}{\epsilon(q) + \epsilon(q') - \omega^{\lambda\mu}_{i}}, \quad \phi^{\lambda\mu i}_{qq'} \sim \frac{f^{\lambda\mu}(qq')}{\epsilon(q) + \epsilon(q') + \omega^{\lambda\mu}_{i}}, \tag{2}$$

$f^{\lambda\mu}(qq')$ is the single-particle matrix element of the operator of multipolarity $\lambda\mu$, $\epsilon(q)$ is the one-quasiparticle energy and $\omega^{\lambda\mu}_{i}$ is the phonon energy. For other notation see ref.[12].

The phonon operators satisfy the following commutation relations[13]:

$$[Q_{\lambda\mu i}, Q^{+}_{\lambda'\mu' i'}] = \frac{1}{2} \sum_{qq'} (\psi^{\lambda\mu i}_{qq'} \psi^{\lambda'\mu' i'}_{qq'} - \phi^{\lambda\mu i}_{qq'} \phi^{\lambda'\mu' i'}_{qq'}) -$$

$$- \frac{1}{2} \sum_{q_1 q_2 q_3} (\psi^{\lambda\mu i}_{q_1 q_2} \psi^{\lambda'\mu' i'}_{q_1 q_3} - \phi^{\lambda\mu i}_{q_1 q_3} \phi^{\lambda\mu i}_{q_1 q_2}) B(q_3 q_2), \tag{3}$$

$$[Q_{\lambda\mu i}, Q_{\lambda'\mu' i'}] = [Q^{+}_{\lambda\mu i}, Q^{+}_{\lambda'\mu' i'}] = 0,$$

where

$$B(qq') = \sum_{\sigma} a^{+}_{q\sigma} a_{q'\sigma} \quad \text{or} \quad \sum_{\sigma} \sigma a^{+}_{q-\sigma} a_{q'\sigma}.$$

The condition of orthonormalization should be fulfilled

$$\langle [Q_{\lambda\mu i}, Q^{+}_{\lambda'\mu' i'}] \rangle = \delta_{\lambda\lambda'} \delta_{\mu\mu'} \delta_{ii'} \tag{4}$$

or

$$\frac{1}{2} \sum_{qq'} (\psi^{\lambda\mu i}_{qq'} \psi^{\lambda'\mu' i'}_{qq'} - \phi^{\lambda\mu i}_{qq'} \phi^{\lambda'\mu' i'}_{qq'}) - \frac{1}{2} \sum_{q_1 q_2 q_3} (\psi^{\lambda\mu i}_{q_1 q_2} \psi^{\lambda'\mu' i'}_{q_1 q_3} -$$

$$- \phi^{\lambda\mu i}_{q_1 q_3} \phi^{\lambda'\mu' i'}_{q_1 q_2}) \langle B(q_3 q_2) \rangle = \delta_{\lambda\lambda'} \delta_{\mu\mu'} \delta_{ii'}. \tag{4'}$$

where the averaging is performed over the ground state of a doubly even nucleus. In the calculations within the RPA the number of quasiparticle in the ground state is assumed to be

small, and therefore the following condition is imposed:

$$\langle B(qq') \rangle = 0. \tag{5}$$

Let us find an explicit form for $\langle B(qq') \rangle$. The wave function of the ground state of a doubly even nucleus is determined as a vacuum for phonons, i.e.,

$$Q_{\lambda\mu i} \Psi_0^{(\lambda\mu)} = 0. \tag{6}$$

It has the form[12,13]

$$\Psi_0^{(\lambda\mu)} = \frac{1}{\sqrt{N'}} \exp\{-\frac{1}{4} \sum_{i} \sum_{qq'} \sum_{q_2 q_2'} (\psi^{\lambda\mu i}_{qq'})^{-1} \phi^{\lambda\mu i}_{q_2 q_2'} A^{+}(qq') A^{+}(q_2 q_2')\} \Psi_{00}, \tag{7}$$

where N' is the normalization factor

$$a_{q\sigma} \Psi_{00} = 0.$$

Since eq. (6) should be fulfilled for all multipole and spin-multipole phonons, the wave function of the ground state is

$$\Psi_0 = \prod_{\lambda\mu} \Psi_0^{(\lambda\mu)} \tag{8}$$

and it should be written as

$$\Psi_0 = \frac{1}{\sqrt{N}} \exp\{-\frac{1}{4} \sum_{\lambda\mu i} \sum_{qq'} \sum_{q_2 q_2'} (\psi^{\lambda\mu i}_{qq'})^{-1} \phi^{\lambda\mu i}_{q_2 q_2'} A^{+}(qq') A^{+}(q_2 q_2')\} \Psi_{00}. \tag{8'}$$

Let us derive the expression for $\langle B(qq') \rangle$

$$\langle B(qq') \rangle = (\Psi_0^{*} B(qq') \Psi_0) =$$

$$= \sum_{g} \sum_{q_2 q_2' q''} (\psi^{g}_{q_2 q_2'})^{-1} \phi_{q'' q'} (\Psi_0^{*} A^{+}(q_2 q_2') A^{+}(qq'') \Psi_0) =$$

$$= \sum_{g g_2 g_2'} \sum_{q_2 q_2' q''} (\psi^{g}_{q_2 q_2'})^{-1} \phi^{g}_{q'' q'} \phi^{g_2}_{qq''} \Psi^{g_2'}_{q_2 q_2'} (\Psi_0^{*} Q_{g_2} Q^{+}_{g_2'} \Psi_0) = \tag{9}$$

$$= \sum_{g g'} \sum_{q_2 q_2' q''} (\psi^{g}_{q_2 q_2'})^{-1} \psi^{g'}_{q_2 q_2'} \phi^{g}_{q'' q'} \phi^{g'}_{qq''} = \sum_{g} \sum_{q''} \phi^{g}_{qq''} \phi^{g}_{q'' q'}.$$

Or we can write

$$\langle B(qq') \rangle = \sum_{\lambda\mu} \langle B(qq') \rangle_{\lambda\mu}, \tag{10}$$

$$\langle B(qq') \rangle_{\lambda\mu} = \sum_{iq''} \phi^{\lambda\mu i}_{qq''} \phi^{\lambda\mu i}_{q'' q'}. \tag{10'}$$

These formulae have been obtained strictly with the commutation relations (3).

To calculate the functions $\langle B(qq')\rangle_{\lambda\mu}$ one should take into account all the roots of the secular equation; this is not difficult to perform within the quasiparticle-phonon nuclear model. The functions $\langle B(qq')\rangle_{\lambda\mu}$ for $q\neq q'$ should be small. Indeed, it follows from the conservation of quantum number K that $\langle B(qq')\rangle_{\lambda\mu}=0$ at $K\neq K'$. For $K=K'$, $q\neq q'$ the sum (10') is alternating and $\langle B(qq')\rangle_{\lambda\mu}$ is small. This is confirmed by the numerical calculations, according to which $\langle B(qq')\rangle_{\lambda\mu}\leq 10^{-4}$ at $K=K'$ and $q\neq q'$. Taking into account the small value of $\langle B(qq')\rangle_{\lambda\mu}$ for $q\neq q'$ condition (4') can be rewritten as follows:

$$\frac{1}{2}\sum_{qq'}(\psi^{g}_{qq}\psi^{g'}_{qq'}-\phi^{g}_{qq}\phi^{g'}_{qq'})(1-\frac{1}{2}\langle B(qq)\rangle-\frac{1}{2}\langle B(q'q')\rangle)=\delta_{gg'} \qquad (11)$$

and further, we shall use only the diagonal with respect to q expressions. For the average number of quasiparticles in the ground states, we introduce the following notation:

$$n_q=\frac{1}{2}\langle B(qq)\rangle=\sum_{\lambda\mu} n_q^{\lambda\mu}, \qquad (12)$$

$$n_q^{\lambda\mu}=\frac{1}{2}\sum_{iq'}(\phi^{\lambda\mu i}_{qq'})^2. \qquad (13)$$

2. DETAILS OF CALCULATION AND METHODICAL INVESTIGATIONS

The model Hamiltonian consists of an average field as the Saxon-Woods potential, pairing interaction and residual isoscalar and isovector multipole and spin-multipole forces. The parameters of the Saxon-Woods potential and the pairing constants have been taken from ref.[9,14]. The single-particle neutron and proton levels from the shells with principal quantum number $N=1\div 9$ have been taken into account in the energy interval from -36 to +40 MeV. For instance, in the calculations for ^{166}Er 108 neutron and 132 proton levels have been used, as well as from 1200 to 2100 single-particle matrix elements for each multipolarity $\lambda\mu$.

The multipole one-phonon states with $\lambda\mu=20$, 22, 30, 31, 32 have been taken into account in the calculations. The contributions to n_q of the multipole phonons with $\lambda\mu=21$, 33, $\lambda=1,4,5$ and of the spin-multipole phonons with $\lambda=1,2$ have been neglected, since according to the calculations the total contribution of these phonons to the average number of quasiparticles in the ground state n_q does not exceed 0.001.

Expression for n_q contains the summation over the roots of the secular equation i for each multipolarity $\lambda\mu$. Let us consider the contribution of the first root and of the first ten (fifty roots for $\lambda\mu=20$) roots to $n_q^{\lambda\mu}$. Table 1 shows the corresponding values (in per cent of $n_q^{\lambda\mu}$) for the quadrupole and octupole one-phonon states in ^{152}Sm and ^{166}Er. These results are obtained for the isoscalar interaction ($\kappa_1^{(\lambda)}=0$); the constant $\kappa_0^{(\lambda)}$ has been chosen according to the energy of the lowest vibrational levels with $I^\pi=2^+$, 3^-. Only the states q for which $n_q^{\lambda\mu}>0.05$ have been considered.

Table 1

Contribution of the first one-phonon state and first ten (fifty for $\lambda\mu=20$) one-phonon states to the total values of $n_q^{\lambda\mu}$ for ^{152}Sm and ^{166}Er.

i \ λμ	20	22	30	31	32	33
1	40-70	80-95	75-80	75-85	80-85	75-85
10(50)	85-95	90-95	95-100	85-95	85-95	85-95

It is seen from table 1 that the first root of the secular equation corresponding to the most collective state gives a dominating contribution to $n_q^{\lambda\mu}$, and the first ten (fifty for $\lambda\mu=20$) roots exhaust to a great extent the total value of $n_q^{\lambda\mu}$. Hence, it follows that, first, the contribution to $n_q^{\lambda\mu}$ of the giant resonances (in this case of the isoscalar E2-and E3 -resonances) is negligibly small. Second, the calculation of the values of $n_q^{\lambda\mu}$ can be restricted by the summation of the first ten (fifty for $\lambda\mu=20$) roots of the secular equation only. This is just the case with the calculation of $n_q^{\lambda\mu}$. Table 1 also shows the 0^+ states which are specified by anomalous large values of n_q^{20} and by a large degree of spreading of n_q^{20} over the roots of the secular equation. These specific features of the 0^+ states are due to the collectiveness of the first 0^+ level and to the method of exclusion of a spurious state arising because of the nonconservation of the number of particles.

Since we study the use of the RPA in the quasiparticle-phonon nuclear model, we are first interested in the cases of maximal with respect to q values of $(n_q)_{max}$ and $(n_q^{\lambda\mu})_{max}$. Let us consider the influence on $(n_q)_{max}$ and $(n_q^{\lambda\mu})_{max}$ of the

Table 2

Maximal values of $n_q^{\lambda\mu} \cdot 10^2$ for ^{166}Er with and without isovector residual forces

$\lambda\mu$	$\omega_1^{\lambda\mu}$ [MeV]	$B(E\lambda)_{exp}$ [s.p.u.]	$\kappa_1^{(\lambda)}=0$: $B(E\lambda)_1$ [s.p.u.]	$(n_q^{\lambda\mu})_{max} \cdot 10^2$: N	Z	$\kappa_1^{(\lambda)}=-1.5\kappa_0^{(\lambda)}$: $B(E\lambda)_1$ [s.p.u.]	$(n_q^{\lambda\mu})_{max} \cdot 10^2$: N	Z
$\omega_1^{\lambda\mu}=\omega_{exp}^{\lambda\mu}$								
20	1.460	-	3.3	15	3.9	4.0	27	8.3
22	0.786	5.3	7.5	8.9	4.6	12	14	15
30	1.663	3.0	7.2	2.1	2.4	10	3.6	6.5
31	1.830	-	5.9	1.1	0.7	9.1	1.0	1.0
32	1.458	6.1	5.1	2.0	1.1	9.0	1.6	1.9
$B(E\lambda)_1 \geq B(E\lambda)_{exp}$								
20	1.7		1.3	6.6	1.5	1.7	6.3	2.1
22	1.0		5.3	5.4	2.9	8.6	4.4	4.6
30	2.0		3.2	1.3	1.5	4.9	1.1	2.0

values of the constants of isoscalar and isovector forces $\kappa_0^{(\lambda)}$ and $\kappa_1^{(\lambda)}$ and of the number of single-particle levels used.

The influence of the isovector forces on $(n_q^{\lambda\mu})_{max}$ is shown in table 2. The cases $\kappa_1^{(\lambda)}=0$ and $\kappa_1^{(\lambda)}=-1.5\kappa_0^{(\lambda)}$ are considered [9]. The constant of the isoscalar forces has been fixed in two ways: 1) by the experimental energies of the first vibrational states ($\omega_1^{\lambda\mu}=\omega_{exp}^{\lambda\mu}$), 2) by the experimental values of the reduced probabilities of the $E\lambda$-transitions to the corresponding first nonrotational states ($B(E\lambda)_1 \geq B(E\lambda)_{exp}$) provided that the energies of these states $\omega_{exp}^{\lambda\mu}$ are described approximately. Note, that the first way gives very often considerably overestimated values of $B(E\lambda)_1$. The energies $\omega_{exp}^{\lambda\mu}$ and the quantities $B(E\lambda)_{exp}$ can be correctly described taking into account anharmonic corrections. Since the single-particle basis is sufficiently large, the effective charge has been taken to be equal to zero.

It is seen from table 2 that the consideration of the isovector forces in many cases results in a noticeable increase of $(n_q^{\lambda\mu})_{max}$. This is due to the fact that the isovector interaction increases the collectiveness of the first level. At $\kappa_1^{(\lambda)} \neq 0$ the ratio $(n_q^{\lambda\mu})^N_{max}/(n_q^{\lambda\mu})^Z_{max}$ is seen to decrease.

Table 2 also shows that the increase in the $B(E\lambda)_1$-values of the first vibrational states results in approximately the same increase of $(n_q^{\lambda\mu})^Z_{max}$. The quantity $(n_q^{\lambda\mu})^Z_{max}$ is determined to a great extent by the collectiveness of the first state, corresponding to a given $\lambda\mu$, the measure of which is the $B(E\lambda)_1$-value.

The above investigations have shown that the dependence $(n_q^{\lambda\mu})_{max}$ on the number of single-particle levels is negligibly small. However, upon diminishing greatly the number of single-particle levels, one should introduce the nonzero effective charges $e_{eff}^{(N)}$ and $e_{eff}^{(Z)}$. The introduction of the effective charges may somewhat diminish $(n_q^{\lambda\mu})_{max}$ with a correct description of the energies and the $B(E\lambda)_1$-values for the first state with given $\lambda\mu$.

3. RESULTS AND DISCUSSION

The average number of quasiparticles in the ground state depends on the energy of the single-particle level $E(q)$ with respect to the Fermi level $E(q_F)$ and on quantum numbers $K^\pi[Nn_z\Lambda]$ specifying the single-particle state. Let us show this dependence by the example of ^{166}Er, ^{154}Sm and ^{152}Sm.

Figures 1 and 2 give the values of $n_q^{\lambda\mu}$ and n_q for the neutron and proton single-particle states of an average field in ^{166}Er. The single-particle level energy is given on the axis of abscissae. It is seen from figs. 1,2 that n_q and $n_q^{\lambda\mu}$ have the largest values for the levels lying near the Fermi surface. This is clearly seen for n_q. The quantity n_q being equal to 0.10-0.08 near $E(q_F)$, decreases when going away from $E(q_F)$ and for the levels far from $E(q_F)$ more than by 4÷5 MeV becomes lesser than 0.02. It is seen from figs. 1,2 that we do not observe any asymmetry in the values of n_q and $n_q^{\lambda\mu}$ for the particle and hole states.

The difference in the characteristics of the single-particle levels causes a nonmonotonic nature of the general tendency of n_q and $n_q^{\lambda\mu}$ to decrease when going away from $E(q_F)$. When passing from level to level values of n_q and $n_q^{\lambda\mu}$ strongly fluctuate (see figs. 1,2), and what is more, for the proton states the quantity n_q^{30} is relatively small near $E(q_F)$ and has the maximal values only at the distance 3-4 MeV from $E(q_F)$. This is due to the fact that the single-particle matrix elements of the particle-hole states with $K^\pi=0^-$, including the levels near the Fermi boundary, are much lesser than the matrix element of the state $400\uparrow 551\downarrow$.

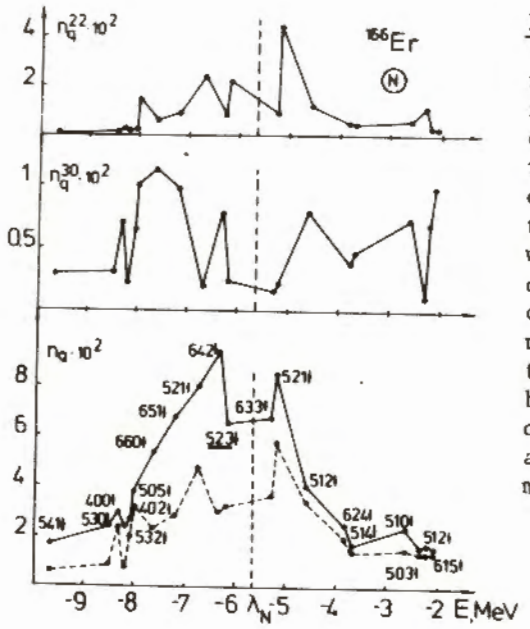

Fig. 1. Values of $n_q^{\lambda\mu}$ and n_q for the neutron states in ^{166}Er. In the lower figure the solid line connects the points corresponding to the values of n_q, and the dashed line to the values of n_q without the contribution of phonons with $\lambda\mu=20$. The chemical potential is denoted by λ_n. The constants $\kappa_0^{(\lambda)}$ and $\kappa_1^{(\lambda)}$ have been chosen from the condition $B(E\lambda)_1 \geq B(E\lambda)_{exp}$ and $\kappa_1^{(\lambda)}=-1.5\kappa_0^{(\lambda)}$. The Fermi level is underlined.

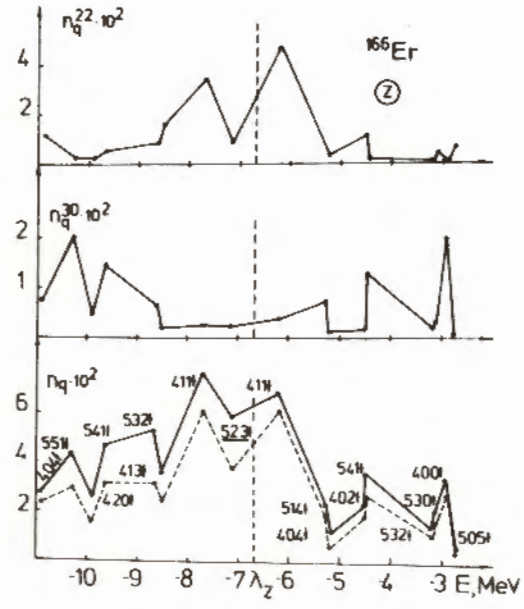

Fig. 2. Values of $n_q^{\lambda\mu}$ and n_q for the proton states in ^{166}Er. Notation is the same as in fig. 1.

Table 3

Values $n_q^{\lambda\mu}\cdot10^2$ and $n_q\cdot10^2$ for a number of single-particle states in ^{152}Sm and ^{154}Sm, calculated at $B(E\lambda)_1 \geq B(E\lambda)_{exp}$. Fermi level is underlined

	q	^{152}Sm					^{154}Sm					
		$n_q^{\lambda\mu}\cdot10^2$				$n_q\cdot10^2$	$n_q^{\lambda\mu}\cdot10^2$				$n_q\cdot10^2$	
		20	22	30	31	32	20	22	30	31	32	
N	402↓	0.50	1.9	1.6	0.63	0.72	5.3	0.35	0.51	1.3	0.41	0.43	3.0
	660↑	13	1.7	3.6	0.98	0.51	20	3.2	0.67	2.6	0.53	0.23	7.2
	505↑	0.28	0.83	2.0	0.45	0.23	3.8	0.35	0.50	1.8	0.32	0.13	3.1
	651↑	17	1.3	4.3	1.0	0.65	24	4.9	0.50	3.2	0.58	0.29	9.5
	521↑	6.0	0.75	1.9	1.4	1.2	11	2.6	0.50	1.5	0.92	0.75	6.3
	642↑	8.3	0.81	1.4	1.2	1.1	13	4.2	0.41	1.4	0.87	0.54	7.4
	523↓	3.5	0.35	0.66	0.73	0.52	5.8	0.28	0.24	0.68	0.46	0.28	2.0
	521↓	2.0	0.68	0.70	0.77	0.62	4.8	1.1	0.55	0.56	0.51	0.37	3.2
Z	420↑	11	0.36	1.6	0.86	1.5	15	3.0	0.19	1.2	0.55	0.82	5.8
	541↑	16	0.89	5.1	1.1	0.55	24	4.6	0.46	4.4	0.69	0.32	10
	532↑	29	0.89	2.3	2.0	1.5	36	6.9	0.46	1.8	1.3	0.85	11
	413↓	7.5	0.90	1.7	0.41	0.70	11	1.2	0.46	1.3	0.25	0.40	3.7
	411↑	5.5	1.4	2.5	1.2	1.7	12	1.1	0.74	1.9	0.75	0.93	5.5
	523↑	4.2	0.62	0.46	1.0	1.1	7.4	1.0	0.32	0.36	0.65	0.62	3.0

Table 4

Experimental and calculated energies $\omega_1^{\lambda\mu}$ and the reduced probabilities $B(E\lambda)_1$ of the first vibrational states in ^{152}Sm, ^{154}Sm, ^{228}Th and ^{238}U.

$\lambda\mu$	^{152}Sm exper. $\omega_1^{\lambda\mu}$ [MeV]	^{152}Sm exper. $B(E\lambda)_1$ [s.p.u.]	^{152}Sm calc. $\omega_1^{\lambda\mu}$ [MeV]	^{152}Sm calc. $B(E\lambda)_1$ [s.p.u.]	^{154}Sm exper. $\omega_1^{\lambda\mu}$ [MeV]	^{154}Sm exper. $B(E\lambda)_1$ [s.p.u.]	^{154}Sm calc. $\omega_1^{\lambda\mu}$ [MeV]	^{154}Sm calc. $B(E\lambda)_1$ [s.p.u.]
20	0.685	1.0	1.0	4.0	1.100	1.0	1.6	2.1
22	1.086	3.4	1.4	6.7	1.400	2.8	1.9	4.1
30	0.963	14.7	1.05	14.8	0.922	8.1	1.2	11.3
31	1.511	8.2	1.511	12.3	1.457	6.0	1.7	7.5
32	1.650	-	1.650	9.9	-	-	2.0	6.3
	^{228}Th				^{238}U			
30	0.328	-	0.328	31	0.680	27	0.68	16

Table 3 shows the values of $n_q^{\lambda\mu}$ and n_q for a number of single-particle levels in ^{152}Sm and ^{154}Sm. The calculations have been performed with the constants $\kappa_0^{(\lambda)}$ and $\kappa_1^{(\lambda)}$ chosen from the conditions $B(E\lambda)_1 \geq B(E\lambda)_{exp}$ and $\kappa_1^{(\lambda)} = -1.5\kappa_0^{(\lambda)}$. The calculated energies $\omega_1^{\lambda\mu}$ and reduced probabilities $B(E\lambda)_1$ of the first states are given in table 4.

It is seen from table 3 that as for ^{166}Er, the quantities $n_q^{\lambda\mu}$ and n_q have the largest values for the levels lying near $E(q_F)$. With increasing distance from the Fermi energy, $n_q^{\lambda\mu}$ and n_q decrease and become less than 0.01 for the states far from $E(q_F)$ by 5 and more MeV. As in ^{166}Er the quantities $n_q^{\lambda\mu}$ and n_q strongly depend on q, what is clearly illustrated by the neutron states 651↑ and 505↑ The small values of $n_q^{\lambda\mu}$ and n_q for 505↑ are obtained sue to the fact that in the vicinity of $E(q_F)$ there are few levels which can form with the level 505↑, having a large projection K(K=11/2), the particle-hole state with $K \leq 2$. This is also due to the small values of the corresponding single-particle matrix elements.

Let us consider the change of $n_q^{\lambda\mu}$ and n_q when passing from a deformed nucleus ^{154}Sm to ^{152}Sm, lying on the boundary of the region of deformed nuclei, in which mostly the first

states with $K^\pi = 0^+$ and 2^+ are lowered. It is seen from table 3 that the value of $n_q^{\lambda\mu}$ (apart from n_q^{20}) increases when passing from ^{154}Sm to ^{152}Sm by 1.5-2 times. At $\lambda\mu=20$ n_q^{20} increases stronger; in some cases up to an order of magnitude. The spurious states 0^+ are included into the ground state of a doubly even nucleus. This fact should be taken into account for a more detailed study of correlations in the ground states (see ref.[15]). Due to a large increase in n_q^{20} the total values of n_q increase by 1.5-3 times when passing rrom ^{154}Sm to ^{152}Sm. The maximal values of n_q in ^{152}Sm achieve 0.24 for the neutron and 0.36 for the proton states. Thus the basic condition of the RPA (5) is not fulfilled in ^{152}Sm. To calculate the 0^+ states in this nucleus, one should use a modified version of the RPA, for instance, in the form given in ref.[4,16].

The values of $(n_q)_{max}$ in some Sm isotopes have been calculated in ref.[7]. It has been shown[7] that $(n_q)_{max}$ increases when passing from ^{144}Sm to ^{150}Sm and in ^{150}Sm becomes larger than 0.5. The comparison of our results with the results of ref.[7] shows that the value of $(n_q)_{max}$ in ^{152}Sm is much lesser than in ^{150}Sm.

The analysis of the values of $n_q^{\lambda\mu}$ for the well deformed nuclei and for those lying on the boundary of the deformation region has been performed also for the actinides. The values of n_q^{30} in ^{228}Th and ^{238}U have been calculated. The calculated energies $\omega_1^{\lambda\mu}$ and reduced probabilities $B(E\lambda)_1$ of the first states are shown in table 4. It is seen from this table that the first nonrotational states with $K^\pi = 0^-$ in ^{228}Th and ^{238}U have small energies and are strongly collectivized. First, the specific properties of these states have been described in ref.[17]. Our calculations show that in ^{228}Th the value of $(n_q^{30})_{max}$ is equal to 0.17 and 0.12 for the neutron and proton states, respectively and in ^{238}U to 0.03 and 0.06. Thus, a strong collectivization of the first states with $K^\pi = 0^-$ causes large values of $(n_q^{30})_{max}$, especially in ^{228}Th. For ^{238}U the condition (5) is fulfilled whereas for ^{228}Th it is violated. Note, that in ref.[18] the corrections to the RPA are calculated, which allow a correct description of the low-lying states in the Ra and Th isotopes.

The correlations in the ground states of rare-earth nuclei have been studied earlier in ref.[8]. Among several versions of the isoscalar residual forces used in ref.[8] the version of surface δ-forces (neglecting the particle-particle and exchange particle-hole interaction) is the most appropriate for our calculations. The results of ref.[8] (e.g., $(n_q^{20})^Z_{max} \approx 0.03$, $(n_q^{22})^Z_{max} \approx 0.05$, $(n_q^{30})^Z_{max} \approx 0.07$ in ^{154}Sm) are sufficiently close to our results for the states with $K^\pi = 0^-$ and somewhat worse for the states with $K^\pi = 2^+$ and 0^+.

4. CONCLUSION

It has been calculated the average number of quasiparticles in the ground states of: a) the well-deformed nuclei ^{154}Sm and ^{166}Er, b) ^{152}Sm lying at the boundary of the range of deformed nuclei, c) ^{228}Th and ^{238}U having low and strongly collective states with $K^{\pi}=0^{-}$. The calculations show that in the well deformed nuclei $(n_q)_{max} = 0.05-0.15$. Therefore, the condition $(5)<B(qq')>=0$ is fulfilled. In such nuclei the vibrational states can be described by the RPA, and the one-phonon states may be a basis for the calculations in the quasiparticle-phonon nuclear model. In the nuclei at the boundary of the region of deformed nuclei and in the transitional nuclei the first vibrational states should be described by using any method that takes into account the correlations in the ground states.

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