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RESIDUAL INTERACTION EFFECT ON ISOSCALAR DIPOLE MODES IN HEAVY NUCLEI

Isoscalar collective dipole excitations in heavy nuclei have been studied in the framework of the kinetic model for small vibrations in a finite Fermi system with a moving surface. An analytical expression for the second-order isoscalar response function of the dipole moment is obtained taking the residual interaction between nucleons into account in the separable approximation. It is shown that the inclusion of the residual interaction does not violate the translation invariance of the model. The strength function has a two-resonance structure, like in the zeroth-order approximation (i.e. neglecting the residual interaction). The account for the isoscalar dipole residual interaction decreases the compressibility of a system and shifts the resonances toward low frequencies, which improves the agreement with experimental data for both low- and high-energy isoscalar dipole modes in heavy nuclei.

Keywords: Vlasov kinetic equation, isoscalar dipole modes, residual interaction, strength function.

1. Introduction

Isoscalar dipole excitations take a special place among collective excitations in a nucleus. Those excitations are associated with the nuclear compression [1]. In particular, the high-energy isoscalar dipole mode is called the anisotropic compression mode in contrast to the isotropic monopole compression mode. Therefore, their research should provide additional information on the compressibility of atomic nuclei.

New experimental data have been obtained recently, which revealed a low-energy isoscalar dipole resonance [2–5]. Isoscalar dipole excitations of nuclei were studied theoretically in the framework of quantum-mechanical approaches of the random-phase-approximation (RPA) type [6–10], including their relativistic generalization [11, 12]. Semiclassical approaches, which are based on the study of the dynamics in the phase space, were also used [13–16]. The low-energy resonance was found to have an essentially vortex character (the toroidal mode) [13, 17–20]. From the theoretical viewpoint, the consideration of isoscalar dipole excitations in a finite Fermi system becomes complicated owing to the fact that those excitations can be connected with the motion of the center of mass. Therefore, in order to study isoscalar dipole excitations, a model is required, in which the translation invariance is not violated, and the excitations of the center of mass are separated from the internal excitations.

In this work, the isoscalar dipole excitations of heavy nuclei are considered in the framework of the kinetic model describing small vibrations in a finite Fermi system confined by a moving surface [21]. This work is a continuation of work [15], in which the main attention was focused on the study of isoscalar dipole excitations in the zeroth-order approximation, i.e. neglecting residual interactions in the system. Owing to the condition of agreement between the motion of the surface and the motion of nucleons in the system, collective isoscalar dipole excitations arise in this kinetic model already in the zeroth-order approximation. In this work, in order to estimate the effects of a residual interaction between the nucleons at isoscalar dipole vibrations, the separable interaction of the dipole-dipole type is considered. Making allowance for the residual interaction modifies the compressibility of the Fermi system and, hence, can affect isoscalar dipole modes. In this work, we use the exact solution of the equation obtained in the framework of the kinetic model and consider the residual interaction in the separable approximation.

In Section 2, the master equations of the kinetic model are considered for isoscalar dipole excitations in a finite Fermi system, and the isoscalar dipole second-order response function for the dipole moment, which is a solution of the kinetic equation (in the first-order approximation, the isoscalar dipole response of the system is a response of the center of mass), is determined. In Section 3, the solution obtained in the zeroth-order approximation [15] is considered. In Section 4, this solution is used to obtain an analytical expression for the response function with regard for the residual interaction between nucleons. With the help of the obtained response function, the motion of the center of mass of the system is discussed, the relation of the internal response function with the energy-weighed and hydrodynamic sum rules is considered, and the effects of the residual interaction on the compressibility parameter for a finite Fermi system are analyzed. Finally, the strength function is calculated numerically.

2. Kinetic Model of Small Vibrations in a Finite Fermi System

In our model, the Vlasov kinetic equation in the linear approximation is used as the dynamical equation. In so doing, we suppose the system to be saturated in the spin-isospin space, so that there is no necessity in introducing those variables explicitly. The dynamical equations for our model can be written in the following form [21]:

$$\frac{\partial}{\partial t}\delta n(\mathbf{r},\mathbf{p},t) + \frac{\mathbf{p}}{m}\frac{\partial}{\partial \mathbf{r}}\Big[\delta n(\mathbf{r},\mathbf{p},t) - - \frac{dn_0(\epsilon)}{d\epsilon}\left[\delta V(\mathbf{r},t) + V_{\rm ext}(\mathbf{r},t)\right]\Big] = 0, \quad (1)$$

$$R(\theta,\varphi,t) = R + \delta R(\theta,\varphi,t), \quad (2)$$

where

$$\delta R(\theta,\varphi,t) = \sum_M \delta R_{1M}(t) Y_{1M}(\theta,\varphi), \quad (3)$$

$$\delta V(\mathbf{r},t) = \int d\mathbf{r}'\, v(\mathbf{r},\mathbf{r}')\,\delta\varrho(\mathbf{r}',t). \quad (4)$$

The external field $V_{\rm ext}(\mathbf{r},t)$ and the residual interaction $v(\mathbf{r},\mathbf{r}')$ are defined below (see Eqs. (8) and (13)).

Thus, we have the equations of motion for the distribution function variation in the phase space, $\delta n(\mathbf{r},\mathbf{p},t)$, with respect to the equilibrium distribution $n_0(\mathbf{r},\mathbf{p})$ and for the variation $\delta R(\theta,\varphi,t)$ of the equilibrium radius R of the system. We assume that the equations of motion satisfy the following boundary conditions implying the free surface:

$$[\delta n(\mathbf{r},\mathbf{p}_\perp,p_r,t) - \delta n(\mathbf{r},\mathbf{p}_\perp,-p_r,t)]\,\big|_{r=R} = = -2p_r\,\frac{dn_0}{d\epsilon}\,\frac{\partial}{\partial t}\,\delta R(\theta,\varphi,t), \quad (5)$$

$$[\delta\Pi_{rr}(\mathbf{r},t)]\,\big|_{r=R} = 0, \quad (6)$$

where $p_r = mv_r$ is the radial momentum of the particle, and $\mathbf{p}_\perp = (0, p_\theta, p_\varphi)$. The variation of the normal component of the momentum flux tensor, $\delta\Pi_{rr}(\mathbf{r},t)$, is defined by the equation [22]

$$\delta\Pi_{rr}(\mathbf{r},t) = = \int d\mathbf{p}\,p_r v_r[\delta n(\mathbf{r},\mathbf{p},t) - \frac{dn_0(\epsilon(\mathbf{r},\mathbf{p}))}{d\epsilon}\delta V(\mathbf{r},t)]. \quad (7)$$

Let us assume below that the equilibrium distribution functions $n_0(\mathbf{r},\mathbf{p})$ depend only on the one-particle energies $\epsilon(\mathbf{r},\mathbf{p})$ and use the approximation of the Thomas–Fermi type

$$\frac{dn_0(\epsilon(\mathbf{r},\mathbf{p}))}{d\epsilon} = -\frac{4}{h^3}\delta(\epsilon - \epsilon_{\rm F}),$$

where $\epsilon_{\rm F}$ is the Fermi energy.

Isoscalar dipole excitations are an effect of the second order for the dipole moment (in the first order, they correspond to the center-of-mass motion [15]). Therefore, we are interested in the second-order isoscalar response function for the dipole moment and suppose that, at the time moment $t = 0$, our system is excited by a weak external field, which looks like

$$V_{\rm ext}(\mathbf{r},t) = \beta\delta(t)\,Q^{(3)}(r)\,Y_{1M}(\theta,\varphi), \quad (8)$$

where $Q^{(3)}(r) = r^3$ is the radial form factor, $\delta(t)$ is the Dirac delta-function in time, and β is a parameter that describes the external field strength. The considered kinetic model is translation-invariant. Therefore, the force associated with the excitation of the center of mass by the external field (8) becomes concentrated at the zero energy. The isoscalar response function for the system with a moving surface is defined as follows:

$$\tilde{\mathcal{R}}_{33}(\omega) = \frac{1}{\beta} \int d\mathbf{r}\, r^3\, Y^*_{1M}(\theta,\varphi)\, \delta\bar{\varrho}_3(\mathbf{r},\omega). \quad (9)$$

Here, $\delta\bar{\varrho}_3(\mathbf{r},\omega)$ is the temporal Fourier transform of the modified particle density variation. In the kinetic model, the latter is defined as follows [23]:

$$\delta\bar{\varrho}_3(\mathbf{r},\omega) = \delta\varrho_3(\mathbf{r},\omega) + \varrho_0\, \delta(r-R)\, \delta R_{1M}(\theta,\varphi,\omega), \quad (10)$$

where

$$\delta\varrho_3(\mathbf{r},\omega) = \int d\mathbf{p}\ \delta n_3(\mathbf{r},\mathbf{p},\omega). \quad (11)$$

Before the solution of the dynamical equations (2) and (1) with the boundary conditions (3) and (4) for spherical systems, it is convenient to change from the phase variables $(\mathbf{r},\mathbf{p})$ to new variables $(r,\epsilon,l,\alpha,\beta,\gamma)$. Here, ϵ is the energy of the particle; l its angular momentum; and α, β, and γ are the Euler angles, which describe the rotation to the coordinate system with the z-axis directed along the vector $\mathbf{l} = \mathbf{r}\times\mathbf{p}$ and the y-axis directed along the vector $\mathbf{r}$. The variations of the distribution function are written in terms of new variables as the series expansion

$$\delta n_3(\mathbf{r},\mathbf{p},\omega) = = \sum_{MN} \left[\delta n^{1+}_{MN}(\epsilon,l,r,\omega) + \delta n^{1-}_{MN}(\epsilon,l,r,\omega)\right] \times \times \left(\mathcal{D}^1_{MN}(\alpha,\beta,\gamma)\right)^* Y_{1N}(\frac{\pi}{2},\frac{\pi}{2}). \quad (12)$$

In order to estimate the influence of the residual interaction on the isoscalar dipole response, we will use a separable interaction of the dipole-dipole type,

$$v(\mathbf{r}\,,\,\mathbf{r}') = \kappa_1 \sum_M r r' Y_{1M}(\theta,\varphi) Y^*_{1M}(\theta',\varphi'), \quad (13)$$

where κ_1 is the isoscalar dipole interaction strength. This parameter will be chosen, by using the properties of the monopole compression mode (the giant monopole resonance) obtained in the framework of the applied kinetic model.

3. Zeroth-Order Approximation for the Response Function

The solution of the dynamical equations (2) and (1) with the boundary conditions (3) and (4) can be obtained in various approximations. First, let us consider the zeroth-order approximation by neglecting the residual interaction between nucleons in the system [15]. It should be noted that the zeroth-order approximation for a system with a moving surface involves the variations of the particle density induced by an external field and associated with the reflection of particles from the moving surface. That is why a finite Fermi system can have collective excitations already in this approximation. The response function (9) in the zeroth-order approximation, $\tilde{\mathcal{R}}^0_{33}(\omega)$, contains the term $\tilde{\mathcal{R}}^0_{\rm c.m.}(\omega)$ proportional to $1/\omega^2$, which is a displacement of the center of mass induced by the external field (8). This term does not excite the system at $\omega \neq 0$. Besides the center-of-mass response, the function $\tilde{\mathcal{R}}^0_{33}(\omega)$ also includes the internal term $\tilde{\mathcal{R}}^0_{\rm intr}(\omega)$, which describes excitations with a positive frequency. Hereafter, the tilde sign is used to designate the response functions for the system with a moving surface and distinguish them from the response functions for the system with a fixed surface. Therefore, the response function $\tilde{\mathcal{R}}^0_{33}(\omega)$ is convenient to be presented in the form

$$\tilde{\mathcal{R}}^0_{33}(\omega) = \tilde{\mathcal{R}}^0_{\rm c.m.}(\omega) + \tilde{\mathcal{R}}^0_{\rm intr}(\omega), \quad (14)$$

where

$$\tilde{\mathcal{R}}^0_{\rm c.m.}(\omega) = \frac{3}{4\pi}\frac{AR^4}{m\omega^2}, \quad (15)$$

$$\tilde{\mathcal{R}}^0_{\rm intr}(\omega) = \mathcal{R}^0_{33}(\omega) - \frac{[\chi^0_3(\omega)]^2}{\chi_1(\omega)} - \tilde{\mathcal{R}}^0_{\rm c.m.}(\omega), \quad (16)$$

and $\mathcal{R}^0_{33}(\omega)$ is the response function for the system with a fixed surface in the zeroth-order approximation (this function is analogous to the quantum-mechanical one-particle response function). The function $\mathcal{R}^0_{jk}(s)$ can be written in the form [15]

$$\mathcal{R}^0_{jk}(s) = \frac{9A}{16\pi}\frac{1}{\epsilon_{\rm F}} \sum_{N=\pm1}\sum_{n=-\infty}^{\infty} \int\limits_0^1 dx x^2 s_{nN}(x) \times \times \frac{Q^j_{nN}(x) Q^k_{nN}(x)}{s + i\varepsilon - s_{nN}(x)} \quad (j,k = 1,3), \quad (17)$$

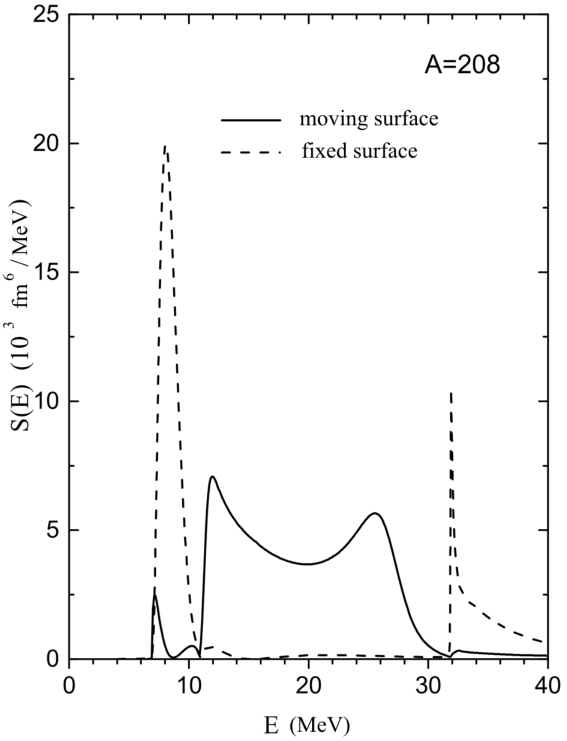

Fig. 1. Dipole strength function (9) in the zeroth-order approximation for systems with moving (solid curve, Eq. (14)) and fixed (dashed curve, Eq. (17) at $j = k = 3$) surfaces. In calculations, the external field (8) with the radial form factor $Q^{(3)}(r) = r^3 - R^2 r$ is used. The system contains $A = 208$ nucleons

where $j = k = 3$. The functions $\chi_3^0(\omega)$ and $\chi_1(\omega)$ describe the dynamical surface effects. They are defined as follows:

$$\chi_k^0(s) = \frac{9A}{8\pi} \sum_{N=\pm1} \sum_{n=-\infty}^{\infty} \int_0^1 dx x^2 s_{nN}(x) \times \times \frac{(-1)^n Q_{nN}^k(x)}{s + i\varepsilon - s_{nN}(x)} \quad (k = 1, 3), \tag{18}$$

$$\chi_1(s) = -\frac{9A}{4\pi} \epsilon_{\rm F}(s + i\varepsilon) \times \times \sum_{N=\pm1} \sum_{n=-\infty}^{\infty} \int_0^1 dx x^2 \frac{1}{s + i\varepsilon - s_{nN}(x)}, \tag{19}$$

where the dimensionless frequencies s and s_{nN} and the dimensionless angular momentum of the particle x,

$$s = \frac{\omega}{v_{\rm F}/R}, \quad s_{nN} = \frac{\omega_{nN}}{v_{\rm F}/R}, \quad x = \sqrt{1 - (l/p_{\rm F}R)^2},$$

$$s_{nN}(x) = \frac{n\pi + N \arcsin(x)}{x},$$

are used, and the quantity $Q_{nN}^k(x)$ is the classical limit of the quantum-mechanical radial matrix elements of the dipole operators r^k $(k = 1, 3)$:

$$Q_{nN}^1(x) = (-1)^n R \frac{1}{s_{nN}^2(x)}, \tag{20}$$

$$Q_{nN}^3(x) = 3R^2 Q_{nN}^1(x) \times \times \left(1 + \frac{4}{3} N \frac{\sqrt{1 - x^2}}{s_{nN}(x)} - \frac{2}{s_{nN}^2(x)}\right). \tag{21}$$

Let us compare the zeroth-order approximations for the dipole strength functions obtained in the examined kinetic model with moving and fixed ($\delta R(\theta, \varphi, t) = 0$ in Eq. (5)) surfaces (see Fig. 1). The strength function is determined by the imaginary part of the response function (16) (see Eq. (34) below).

In calculations, we used the effective external field (8) with the radial form factor $Q^{(3)}(r) = r^3 - R^2 r$. In this field, response function (14) of the system with a moving surface is equal to the internal response function (16), which does not contain excitations associated with the motion of the center of mass. On the other hand, although the response function of the system with a fixed surface, $\mathcal{R}_{33}^0(\omega)$, satisfies the energy-weighed sum rule (see Eq. (27) below), it contains spurious excitations associated with the motion of the center of mass. In numerical calculations, the average static nuclear field was approximated by a spherical well of the radius $R = 1.25 A^{1/3}$ fm, and a system with $A = 208$ nucleons was considered. The Fermi energy was given with the help of the parameter that was chosen above for the radius, $\epsilon_{\rm F} \approx 31$ MeV. We also used the value $\varepsilon = 0.1$ MeV (see Eqs. (17)–(19)).

In Fig. 1, one can see that the isoscalar dipole response of the system with a moving surface has a pronounced two-resonance structure already in the zeroth-order approximation [15]. Therefore, in the model concerned, besides the high-energy compression mode, which also presents in the model of small vibrations of a liquid droplet [15], there is also a low-energy mode. It is known that the new experimental data obtained recently [2–5] revealed a low-energy isoscalar dipole resonance in heavy nuclei.

4. Residual Interaction Effect on Isoscalar Dipole Vibrations

Now, let us consider the isoscalar dipole response function (9) taking the residual interaction between nucleons into account. To study the effects of the residual interaction on dipole excitations, we use a separable interaction of the dipole-dipole type (13). By solving the dynamical equations (2) and (1) with the boundary conditions (3) and (4), we obtain the semiclassical dipole response function (9) in the form similar to that obtained in the zeroth-order approximation (see Eq. (14)),

$$\tilde{\mathcal{R}}_{33}(\omega) = \tilde{\mathcal{R}}_{\text{c.m.}}(\omega) + \tilde{\mathcal{R}}_{\text{intr}}(\omega). \tag{22}$$

Here, the expression for the response of the center of mass, $\tilde{\mathcal{R}}_{\text{c.m.}}(\omega)$, is the same as in the zeroth-order approximation (see Eq. (15)). The internal response function $\tilde{\mathcal{R}}_{\text{intr}}(\omega)$ can be written in the form

$$\tilde{\mathcal{R}}_{\text{intr}}(\omega) = \mathcal{R}_{33}(\omega) + \mathcal{S}_{33}(\omega) - \tilde{\mathcal{R}}_{\text{c.m.}}(\omega), \tag{23}$$

where $\mathcal{R}_{33}(\omega)$ is the collective response function of the system with a fixed surface. The expression for the latter contains not only the response function for the system with a fixed surface in the zeroth-order approximation, $\mathcal{R}^0_{33}(\omega)$, but also the functions $\mathcal{R}^0_{11}(\omega)$ and $\mathcal{R}^0_{13}(\omega)$, determined above (see Eq. (17)), namely,

$$\mathcal{R}_{33}(\omega) = \mathcal{R}^0_{33}(\omega) + \kappa_1 \frac{[\mathcal{R}^0_{13}(\omega)]^2}{1 - \kappa_1 \mathcal{R}^0_{11}(\omega)}. \tag{24}$$

The second term $\mathcal{S}_{33}(\omega)$ in the internal response function (23) is a contribution made by surface vibrations. It can be written in the form

$$\mathcal{S}_{33}(\omega) = -\frac{1}{1 - \kappa_1 \mathcal{R}^0_{11}(\omega)} \times \\ \times \frac{[\chi^0_3(\omega) - \chi^0_3(0)\kappa_1 \mathcal{R}^0_{11}(\omega)]^2}{[-\chi_1(\omega)][1 - \kappa_1 \mathcal{R}^0_{11}(\omega)] + \kappa_1 [\chi^0_1(\omega) - \chi^0_1(0)]^2}. \tag{25}$$

Here, the functions $\chi^0_k(\omega)$ and $\chi_1(\omega)$ are determined by Eqs. (18) and (19). Equation (23) is the main result of this work.

One can found that the poles of the dipole response $\tilde{\mathcal{R}}_{\text{intr}}(\omega)$, which determine the frequencies of collective isoscalar dipole modes, are the solutions of the equation

$$[-\chi_1(\omega)][1 - \kappa_1 \mathcal{R}^0_{11}(\omega)] + \kappa_1 [\chi^0_1(\omega) - \chi^0_1(0)]^2 = 0. \tag{26}$$

By neglecting the residual interaction between the nucleons ($\kappa_1 = 0$ in Eq. (26)), we obtain an equation for the poles of the internal dipole response in the zeroth-order approximation, $\chi_1(\omega) = 0$ (see also Eq. (16)).

The internal response function $\tilde{\mathcal{R}}_{\text{intr}}(\omega)$ satisfies the quantum-mechanical energy-weighed sum rule m_1, which for a system with a sharp surface is given by the formula [6]

$$m_1 = \frac{3\hbar^2}{14\pi} \frac{AR^4}{m}. \tag{27}$$

It can be verified with the help of the theorem about the relation between the high-frequency limit of a response function and the energy-weighed sum rule [24]:

$$\tilde{R}_{\text{intr}}(\omega)|_{\omega \to \infty} = \frac{m_1}{2} \frac{1}{(\hbar\omega)^2} + O\left(\frac{1}{\omega^4}\right). \tag{28}$$

On the other hand, the low-frequency limit of the response function $\tilde{\mathcal{R}}_{\text{intr}}(\omega)$ is related to the hydrodynamic sum rule m_{-1} [24],

$$\lim_{\omega \to 0} \tilde{R}^0_{\text{intr}}(\omega) = -2m_{-1}, \tag{29}$$

which allows us to obtain an expression for the nuclear compressibility in the framework of our kinetic model. Really, the hydrodynamic sum rule is defined as

$$m_{-1} = \int_0^\infty d\omega \frac{1}{\omega} \left[-\frac{1}{\pi} \text{Im} \tilde{\mathcal{R}}^0_{\text{intr}}(\omega)\right]. \tag{30}$$

For a system with a sharp surface and in the presence of the external field (8), it can be written in the form [24]

$$m_{-1} = \frac{3}{35\pi} \frac{AR^6}{K_A}, \tag{31}$$

where the parameter K_A is defined as the compressibility of the system. Calculating the low-frequency limit of the response function $\tilde{\mathcal{R}}_{\text{intr}}(\omega)$, we obtain

$$\lim_{\omega \to 0} \tilde{\mathcal{R}}_{\text{intr}}(\omega) = -\frac{6}{35\pi} \frac{AR^6}{K_A}, \tag{32}$$

where

$$K_A = K_{\text{FG}} \frac{1 - \kappa_1 \mathcal{R}^0_{11}(\omega = 0)}{1 - \frac{5}{14}\kappa_1 \mathcal{R}^0_{11}(\omega = 0)}. \tag{33}$$

Here, $K_{\text{FG}} = 6\varepsilon_{\text{F}}$ is the parameter of Fermi gas compressibility. Since the function $\mathcal{R}^0_{11}(\omega = 0) < 0$ (see

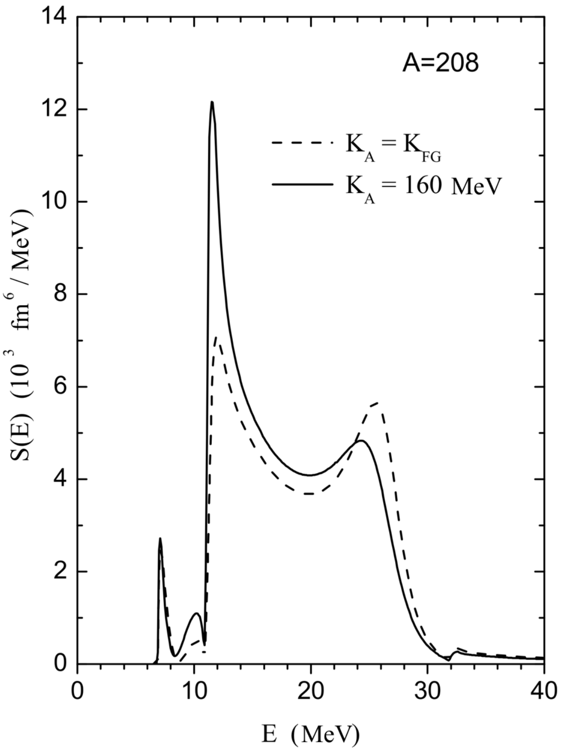

Fig. 2. Internal dipole strength function for a system confined by a moving surface calculated with regard for the residual interaction between nucleons (solid curve, Eq. (23)) and in the zeroth-order approximation (dashed curve, see Eq. (16)). The system contains $A = 208$ nucleons

Eq. 17) at $j = k = 1$ and $\omega = 0$) and the strength parameter $\kappa_1 < 0$ (residual interaction (13) is attractive), the compressibility parameter $K_A < K_{\rm FG}$.

In Fig. 2, the internal dipole strength function $S(E)$, where $E = \hbar\omega$, is exhibited. This function is related to the imaginary part of the response function (23):

$$\mathcal{S}(E) = -\frac{1}{\pi}\mathrm{Im}\tilde{\mathcal{R}}_{\rm intr}(\hbar\omega). \qquad (34)$$

In the calculations, the parameter of the residual interaction (see Eq. (13)) was selected to be $\kappa_1 = -7.5 \times 10^{-3}$ MeV/fm^2 with the aim of reproducing the experimental value for the energy of the giant monopole resonance in Pb^{208} nucleus in the framework of the considered kinetic model. The corresponding compressibility parameter equals $K_A = 160$ MeV (see Eq. (33)). From Fig. 2, one can see that the considered semiclassical model reproduces the experimentally revealed splitting of the isoscalar dipole force into two components (the solid curve). If the residual interaction between nucleons is neglected, the centroids of two resonances are located at higher energies (the dashed curve). The positions of resonance centroids are shifted insignificantly, but the main effect consists in a change of the relative weights of two resonances. The account of the residual interaction improves the agreement with experimental data. The experimental values for the centroid energies of low- and high-energy isoscalar dipole resonances in Pb^{208} nucleus equal 12.7 ± 0.2 MeV and 23.0 ± 0.3 MeV, respectively [4]. Our model reproduces these data satisfactorily (see Fig. 2, the solid curve).

5. Conclusions

To summarize, an analytical expression for the second-order isoscalar response function of the dipole moment, which takes the residual interaction between nucleons into account, is obtained in the framework of the kinetic model of small vibrations in a finite Fermi system confined by a moving surface. It is found that the motion of the center of mass does not bring about internal excitations with a positive frequency. Therefore, the inclusion of a separable residual interaction of the dipole-dipole type does not violate the translation invariance of the model. The inclusion of the residual isoscalar dipole interaction reduces the compressibility and insignificantly affects the isoscalar dipole resonances. The strength function calculated making allowance for the residual interaction has a two-resonance structure, which manifests itself in the zeroth-order approximation as well. The account of the residual interaction gives rise to a shift of the resonances toward low frequencies and improves the agreement with experimental data obtained for low- and high-energy isoscalar dipole modes in heavy nuclei. The considered kinetic model allows the origin of isoscalar dipole modes to be studied in more details, in particular, the character of the velocity field and the properties of the momentum flux tensor at low-frequency isoscalar dipole vibrations. The corresponding result will be published elsewhere.

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ВПЛИВ ЗАЛИШКОВОЇ
ВЗАЄМОДІЇ НА ІЗОСКАЛЯРНІ
ДИПОЛЬНІ МОДИ У ВАЖКИХ ЯДРАХ

Р е з ю м е

Ізоскалярні колективні дипольні збудження у важких ядрах розглянуто в рамках кінетичної моделі малих коливань скінченної фермі-системі, обмеженої рухомою поверхнею. Отримано аналітичний вираз для ізоскалярної функції відгуку дипольного моменту другого порядку з урахуванням залишкової взаємодії між нуклонами у сепарабельному наближенні. Показано, що включення залишкової взаємодії не порушує трансляційної інваріантності моделі. Силова функція, як і в нульовому наближенні (без урахування залишкової взаємодії), має дворезонансну структуру. Врахування ізоскалярної дипольної залишкової взаємодії зменшує стисливість системи і призводить до зміщення резонансів в область більш низьких частот, що покращує узгодженість з експериментальними даними для низькоенергетичної і високоенергетичної ізоскалярних дипольних мод у важких ядрах.