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SPECTRUM OF COLLECTIVE EXCITATIONS IN LIQUID ^{4}He

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Experiments on inelastic coherent scattering of cold neutrons by simple classical liquids reveal the presence of definite elementary excitations of the density-fluctuation type in the frequency region $\omega \sim 10^{12}$ sec^{-1} and in the wave-number region $Q \sim 1 - 3$ Å^{-1} in simple liquids [1, 2]. Theoretical calculations of the spectrum of elementary excitations for liquid argon were carried out in [3, 4]. On the other hand, it was established in [5] that the spectrum of elementary excitations in superfluid liquid helium retains a form similar to the spectrum of elementary excitations in simple classical liquids on going through the λ point, and only the damping of the elementary excitations increases somewhat.

It seems possible therefore to calculate the spectrum of collective excitations in liquid ^{4}He in the region of high frequencies and large wave numbers, where the hydrodynamic description is not applicable [6], and an important role is played by the quasicrystalline properties of the liquid; this was the purpose of the present investigation.

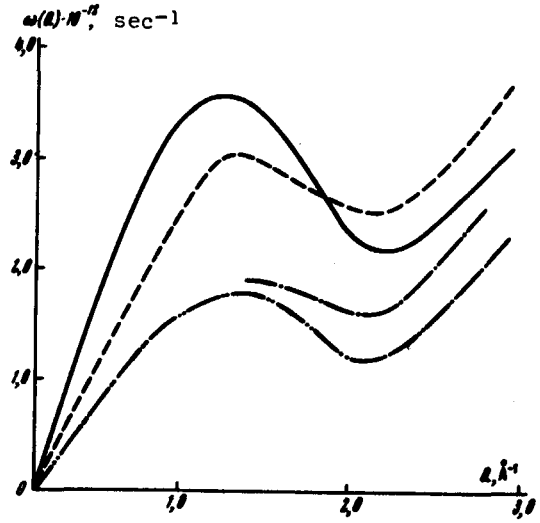
Using the method of equations of motion for two-time Green's function of the "displacement-displacement" type, we obtained the spectrum of the collective excitations in liquid He within the framework of the quasicrystalline model of the liquid [7]. The collective motions in the liquid are regarded as oscillations of the atoms in equilibrium positions, the distribution of which in space is described by the function g(R). To take into account the strong anharmonicity due to the large zero-point oscillations, we used methods of self-consistent theory of anharmonic crystals, which make it possible to take into account all the even orders of anharmonicity [8]. The correlations of importance for solid and liquid helium, of the hard-core type, were taken into account on the basis of the approximate solution of the equation for the T-matrix described in [9]. As a result we obtained the following expressions for the longitudinal oscillation frequency:

$$\omega^2(Q) = \frac{2\pi\rho}{m} \int_0^\infty dR R^2 \int_{-1}^{1} dt \Phi(R) t^2 (1 - \cos QRt), \tag{1}$$

where m is the mass of the helium atom, $\rho = N/V$ the particle density, and $\Phi(R)$ the longitudinal component of the pseudoharmonic force constant:

$$\Phi(R) = g(R)\left(\frac{\partial^2}{\partial R^2} + \frac{1}{R}\frac{\partial}{\partial R}\right)\int \frac{d^3 r}{(2\pi/\alpha^2)^{3/2}} f(r) \exp\left[-\frac{1}{2}\alpha^2 (r - R)^2\right]\phi(r), \tag{2}$$

where g(R) is the distribution function of the equilibrium positions, and is assumed approximately to equal the radial distribution function obtained in



[10]. $\phi(r)$ is the (6 - 12) Lennard-Jones potential with parameters $\varepsilon = 10.22°K$ and $\sigma = 2.556$ Å, $1/\alpha^2 = \langle(\vec{u}(0) - \vec{u}(\vec{R}))^2\rangle$ is the rms relative displacement of the atoms from the equilibrium position, and is determined in a self-consistent manner from the frequency spectrum, and $f(r)$ is the solution of the Bethe-Goldstone equation [9], which makes it possible to take correlations of the hard-core type into account.

In calculating the elementary-excitation spectrum, α for $T = 0°K$ is determined from the condition of minimum energy of the ground state $E(\alpha)$. The calculations were made with a computer. The dispersion dependence for $T = 0°K$ is given in the figure (solid line), which shows for comparison the experimental curve of [5] (dotted) and the results of the calculations of [11] (dashed) and [12] (dash-dot). We see that the results are in satisfactory agreement with experiment, thereby evidencing the applicability of the quasicrystalline model of the liquid to the description of the elementary-excitation spectrum not only in classical liquids, [3, 4], but also in the quantum liquid ^{4}He when account is taken of appropriate corrections required by large-zero-point oscillations.

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TEMPERATURE DEPENDENCE OF THE PROBABILITY OF THE MOSSBAUER EFFECT IN YTTRIUM-IRON GARNETS

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The exchange interaction between octahedral (a) and tetrahedral (d) iron ions in ferrimagnets should exert an influence on the vibrational spectrum of the crystals [1]. We have investigated the temperature dependence of the Mossbauer-effect probability f' on Fe^{57} nuclei at temperatures 78 - 750°K in the iron garnet $Y_3Fe_5O_{12}$ and the substituted iron garnet $Y_3Fe_4Al_1O_{12}$, the physical