1. INTRODUCTION

The description of the propagation of electromagnetic radiation at the microscopic level in a solid implies taking into account the interaction between electromagnetic field quanta and elementary excitations existing in the crystal. This leads to the formation of excitations of a new type that combine the properties of the initial excitations and the electromagnetic field. An example of such excitations is provided by exciton polaritons that are formed as a result of the interaction of light with excitons. Currently, exciton polaritons have been studied in a lot of works, which is associated with the role played by these excitations in the process of light propagation [1, 2], as well as with the prospect for their use in various devices [3, 4]. Exciton polaritons at the macro level manifest themselves in the form of a property of the medium such as the spatial dispersion [5]. Since the violation of the locality of interactions can take place only when the dissipative damping factor is sufficiently small, the effect of spatial dispersion for the majority of media appears to be suppressed and, usually, is ignored. In this case, if it is assumed that the imaginary part of the complex permittivity, which is responsible for the absorption of light, is small in comparison with the real part, the absorption line shape is described by the Lorentzian function. Therefore, the absorption coefficient integrated over the entire frequency range does not depend on the dissipative damping factor. With an increase in the dissipation, the integrated absorption is saturated, which can be interpreted as the loss of spatial dispersion. Inelastic processes associated with exciton polaritons have been investigated in a large number of works (see, for example, [7, 8]), including a detailed analysis of the relation between events of inelastic interactions at the microscopic level and a macroscopic phenomenon such as the light absorption. In this paper, we have considered a similar relation, but the objects of our investigation are elastic collisions that occur in the scattering of excitons, for example, by impurity centers in the case of low temperatures. Similar processes were considered in [9–15]. In [9, 10], the effect of polariton scattering by impurities is reduced to the delay of the propagation of polaritons toward the surface of the sample, which makes it more sensitive to elastic processes and, thus, affects the photoluminescence and reflection spectra. The interference of mixed modes due to the elastic scattering of polaritons in the presence of spatial dispersion was discussed in [11]. The spectra of light absorption by GaAs samples of high crystalline perfection were considered in [15], where it was established that the absorption can depend on the scattering by impurities. However, in all these studies, the authors gave only a phenomenological description of the relation between the observed optical transitions and the exciton scattering by impurities. Further, we constructed a microscopic theory of elastic scattering of exciton polaritons by impurity centers.
2. EFFECT OF ELASTIC INTERACTIONS ON THE ENERGY ABSORPTION

Let us consider a damped harmonic oscillator under the action of a driving force. It can be shown that a variation in the dissipative damping factor $\gamma$ leads to a change in the external power absorbed at a given frequency in such a way that the absorption integrated over all frequencies does not depend on $\gamma$. For clarity, we consider a system of mechanical oscillators (for example, elastic rods that can make vibrations in any plane containing the axis of the rod) coupled by a “stiffness” that characterizes the spatial dispersion of the medium (Fig. 1).

In the absence of friction, the excitation of one of the oscillators leads to the coherent excitation of neighboring oscillators and, after a certain time, to the excitation of all oscillators of the systems, including those not subjected to direct external influences. In this case, the energy expended on the excitation of the first oscillator is distributed among all the oscillators of the system. Actual physical media are always dissipative. Consequently, the oscillators will be damped with time, and the system will return to the ground state. Therefore, we are dealing here with a complete absorption of the energy expended on the excitation of the medium. An increase of the dissipative damping $\gamma$ in each oscillator leads, as mentioned above, to a redistribution of the absorbed power over the frequencies of external loading events. However, since the neighboring oscillators are coupled directly to each other, this redistribution ceases to retain the value of the integrated absorption. The calculation performed in [6] showed that, in this case, the integrated absorption increases with an increase in the dissipative damping factor $\gamma$. But if the dissipation becomes so large that the entire energy expended on the excitation of one oscillator is absorbed more rapidly than the excitation reaches the nearest neighbor oscillator, a further increase in the dissipative damping factor $\gamma$ will not lead to an increase in the integrated absorption (because, in this case, there is no distribution of the excitation energy between the oscillators of the system and, hence, the power as a whole is dissipated in one oscillator). The system of oscillators will satisfy the condition $\gamma \tau > 1$, where $\tau$ is the time required for the energy transfer between the neighboring oscillators (the time $\tau$ is inversely proportional to the effective stiffness of the coupling between these oscillators). The dependence of the integrated absorption on the dissipative damping factor is saturated at a specific value $\gamma_c = 1/\tau$, which is referred to as the critical dissipative damping factor. This is the mechanical interpretation of the results obtained analytically in the investigation of the absorption of light by excitons in [6].

Now, we consider a similar system of oscillators, each subjected to elastic loading, i.e., loading not accompanied by the oscillator energy transfer or oscillator energy loss. If the frequency $\omega$ of events of elastic action on each oscillator is so large that the coherent mode has no time to be established between the neighboring oscillators, i.e., if $\omega > 2\pi/\tau$, we are faced with the loss of the spatial dispersion and, consequently, with the saturation of the dependence of the integrated absorption on the dissipative damping factor. The corresponding frequency $\omega_c = 2\pi/\tau$ can also be referred to as the critical frequency. In the case of the propagation of exciton polaritons in a crystal, the elastic scattering of excitons by impurities can be interpreted in a similar way.

In our previous work [15], we experimentally investigated the absorption of light by exciton polaritons in thin GaAs samples at liquid-helium temperatures and found that, in the region of exciton resonance, the absorption coefficient integrated over the frequency depends on the amount of ionized impurities involved in the scattering (the amount of scatterers could change depending on the magnetic field strength due to the magnetic freezing of impurities). However, this dependence was described phenomenologically. In the present work, we have performed a microscopic analysis of elastic scattering of polaritons by charged and neutral impurities.

3. EXCITON POLARITONS

In crystals, only excitons are scattered by charged and neutral impurities. Therefore, in the further analysis, we will need to know the weight of the exciton component in the total wave function of the polariton. In the case where excitons and photons are described by the corresponding Bose operators $B(k), B^\dagger(k)$ and...