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Polaritonic Crystal Formed by a Tunnel Connected Array of Microcavities Containing Ensembles of Quantum Dots

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Abstract: Numerical model for a defect-containing lattice of microcavities with embedded ultracold atomic clusters (quantum dots) is developed. It is assumed that certain fractions of quantum dots are absent, which leads to transformation of polariton spectrum of the overall structure. Using the virtual crystal approximation based on the diagonalization of the averaged Hamiltonian of the system, dispersion relations for polariton modes are derived. The group velocity of polariton excitations in the structure under study is calculated depending on the structure defects concentrations and elastic strain. It is shown that, as a result of elastic strain of the system and presence of structural defects under study, it is possible to achieve necessary changes in its energy structure (and, therefore, optical properties) determined by the rearrangement of the polariton spectrum. This results in formation of slow light mode that can be efficiently controlled by the externally applied strain. The obtained results demonstrate the possibility of controlling the group velocity of excitations, which is responsible for signaling rates in optical integrated circuits of optoelectronic devices. Numerical simulations performed on the basis of the constructed model contribute to modeling of the new class of functional porous materials, namely the so-called polaritonic systems (microcavity arrays with embedded quantum dots) where controlling of propagation of electromagnetic excitations is accomplished by an appropriate introduction of structural defects and elastic deformation.

Keywords: One-dimensional Microcavity Lattice, Quantum Dots, Electromagnetic Excitations, Structure Defects, Uniform Elastic Deformation, Group Velocity of Polaritonic Excitation

1. Introduction

The important features of photonic band-gap structures under discussion [1] are connected with ‘slow’ light, which is one of the promising fundamental physical phenomena that can be explored in the design of various quantum optical storage devices. In particular, the effective reduction of the group velocity demonstrated in the associated optical waveguide resonators [2, 3] as well as in the different types of solid-state semiconductor multilayer structures [4]. Key role in reducing the group velocity in these systems is played by so-called light and dark polaritons, which are linear superposition of photon states of the external electromagnetic field and the macroscopic (coherent) perturbations of two-level atomic medium.

In atomic systems, the lifetime of polaritons limited by lifetime of the excited atoms and is usually characterized by nanoscale [5]. The present level of development of nanotechnologies and nanophotonics makes it possible to study the "slow" light and the phase transitions of polaritons by creating an array of coupled microcavities containing two-level atoms [6-8]. Technologically, the data structures can be obtained based on photonic crystals with defects as microcavities doped with two-level atoms [9].

In the context of this class of problems, a spatially periodic atomic structure - polaritonic crystal formed by ensembles of atomic clusters (quantum dots) weakly interacting with the localized electromagnetic field in a tunnel connected array of

microcavities is proposed in the paper. A remarkable feature of this structure is the possibility of localization of polaritons, which is similar to the possibility of localization of light in photonic crystals in nonlinear optics (see, eg, [9]) or the localization of excitons in quasi-periodic structures in solid state physics [10].

Based on the representations of the ideal photonic structures developed previously [11], the non-ideal system of this class - the polaritonic crystal with the atomic subsystem containing the impurity atom clusters is considered in the paper. In this context, a rapidly developing research sub-area is the photonics of imperfect structures. Some of our previous works have been devoted to the design of multi-microcavity structures [12] where the dispersion of photon modes may be altered by introduction of a defect in the photonic supercrystal [13-16]. For applications, the structural defects in supercrystals are less practical than temporary defects introduces by application of external fields or strain. In the present work we consider the effect of a uniform elastic strain on one-dimensional arrays of microcavities with embedded quantum dots. This system combines advantages of an extreme optical non-linearity provide by the coupling of quantum dots to photonic modes and the high sensitivity of the optical eigen-modes to the applied strain. We focus on particular realization of topologically ordered micropores system composed by tunnel-coupled micropores containing and without quantum dots (atomic cluster). Such systems have a high potentiality for applications in optical integrated circuits.

2. Theoretical Background

Basing on the approach developed in Refs. [12-16], let us consider the dispersion of optical eigen modes in the most general case of a microcavity supercrystal composed of s sublattices. Each of tunnel-coupled microcavities is assumed to confine a single optical mode. The assumption of a low density of excited states of structural elements in the resonator and atomic subsystems makes it possible to describe the quadratic part $\hat{H}^{ex}$ of Hamiltonian, which describes elementary excitations in a microcavity chain (containing quantum dots or otherwise) within the Heitler-London approximation [17]. In the one-level model, taking into account the uniform elastic deformation in the system, $\hat{H}^{ex}$ is dependent on the deformation tensor $\hat{\varepsilon}$ that is sensitive to the applied strain. Adapting the Heitler-London approximation and a single-level model, the Hamiltonian $\hat{H}^{ex}\left(\hat{\varepsilon}\right)$ can be written as:

$$\begin{aligned}\hat{H}^{ex}\left(\hat{\varepsilon}\right) &= \sum_{\substack{\mathrm{n},\mathrm{m},\alpha,\beta,\\ \lambda,\sigma}} D^{\lambda\sigma}_{\mathrm{n}\alpha,\mathrm{m}\beta}\left(\hat{\varepsilon}\right)\hat{\Phi}^{+}_{\mathrm{n}\alpha\lambda}\hat{\Phi}_{\mathrm{m}\beta\sigma} = \\ &= \sum_{\substack{\alpha,\beta,\lambda,\sigma\\ \mathrm{k}}} D^{\lambda\sigma}_{\alpha\beta}\left(\mathrm{k},\hat{\varepsilon}\right)\hat{\Phi}^{+}_{\alpha\lambda}\left(\mathrm{k}\right)\hat{\Phi}_{\beta\sigma}\left(\mathrm{k}\right)\end{aligned} \tag{1}$$

where

$$\begin{aligned}&D^{11}_{\mathrm{n}\alpha,\mathrm{m}\beta}\left(\hat{\varepsilon}\right) = \hbar\omega^{at}_{\mathrm{n}\alpha}\delta_{\mathrm{n}\alpha,\mathrm{m}\beta} + V_{\mathrm{n}\alpha,\mathrm{m}\beta}\left(\hat{\varepsilon}\right),\\ &D^{22}_{\mathrm{n}\alpha,\mathrm{m}\beta} = \hbar\omega^{ph}_{\mathrm{n}\alpha}\delta_{\mathrm{n}\alpha,\mathrm{m}\beta} - A_{\mathrm{n}\alpha,\mathrm{m}\beta}\left(\hat{\varepsilon}\right),\\ &D^{12}_{\mathrm{n}\alpha,\mathrm{m}\beta}\left(\hat{\varepsilon}\right) = D^{21}_{\mathrm{n}\alpha,\mathrm{m}\beta}\left(\hat{\varepsilon}\right) = g_{\mathrm{n}\alpha}\left(\hat{\varepsilon}\right)\delta_{\mathrm{n}\alpha,\mathrm{m}\beta},\\ &\hat{\Phi}^{\lambda=2}_{\mathrm{n}\alpha} = \hat{\Psi}_{\mathrm{n}\alpha},\ \hat{\Phi}^{\lambda=1}_{\mathrm{n}\alpha} = \hat{B}_{\mathrm{n}\alpha}\end{aligned} \tag{2}$$

In Eqs. (1, 2) $\omega^{ph}_{\mathrm{n}\alpha}$ is the frequency of the photonic mode localized in the $\mathrm{n}\alpha$-th lattice site (microcavity), $\hat{\Psi}^{+}_{\mathrm{n}\alpha}, \hat{\Psi}_{\mathrm{n}\alpha}$ are bosonic creation and annihilation operators for this mode written in the node representation, $\hbar\omega^{at}_{\mathrm{n}\alpha}$ is excitation energy of the quantum dot in the $\mathrm{n}\alpha$-th lattice site, $\hat{B}_{\mathrm{n}\alpha}, \hat{B}^{+}_{\mathrm{n}\alpha}$ are creation and annihilation operators of quantum dot excitons, $A_{\mathrm{n}\alpha\mathrm{m}\beta}\left(\hat{\varepsilon}\right)$ is the matrix of resonance interaction, which describes an overlap between optical fields of resonators in the $\mathrm{n}\alpha$-th and $\mathrm{m}\beta$-th lattice sites and hence defines the jump probability of the corresponding electromagnetic excitation, $V_{\mathrm{n}\alpha\mathrm{m}\beta}\left(\hat{\varepsilon}\right)$ is the matrix of resonance interaction between quantum dots embedded in the $\mathrm{n}\alpha$-th and $\mathrm{m}\beta$-th lattice sites, $g_{\mathrm{n}\alpha}\left(\hat{\varepsilon}\right)$ is the matrix of resonance interaction between quantum dot in the $\mathrm{n}\alpha$-th lattice site and electromagnetic field localized at the same site. Values 1 and 2 of indices λ, σ indicate, respectively, the presence or absence of quantum dots in corresponding cavities.

In the right-hand side expression of Eq. (1) (summation over k) matrices $D^{\lambda\sigma}_{\alpha\beta}\left(\mathrm{k},\hat{\varepsilon}\right)$ and $\Phi_{\alpha\lambda}\left(\mathrm{k}\right)$ have the forms $D^{\lambda\sigma}_{\alpha\beta}\left(\mathrm{k},\hat{\varepsilon}\right) = \sum_{\mathrm{m}} D^{\lambda\sigma}_{\mathrm{n}\alpha\mathrm{m}\beta}\left(\hat{\varepsilon}\right)\exp\left[i\mathrm{k}\cdot\left(\mathrm{r}_{\mathrm{n}\alpha} - \mathrm{r}_{\mathrm{m}\beta}\right)\right]$ and $\hat{\Phi}_{\alpha\lambda}\left(\mathrm{k}\right) = \frac{1}{\sqrt{N}}\sum_{\mathrm{n}}\hat{\Phi}_{\mathrm{n}\alpha\lambda}\exp\left(-i\mathrm{k}\cdot\mathrm{r}_{\mathrm{n}\alpha}\right)$ (N is the number of elementary cells in the lattice). Such representation of matrices is possible due to preservation of the translation invariance of the system under the uniform strain. Let us note that the wave vector k, which characterizes eigenstates of electromagnetic excitations, ranges within the first supercrystal Brillouin zone, whose boundaries are in their turn functions of strain through the dielectric tensor $\hat{\varepsilon}$.

Eigenvalues of the Hamiltonian (1) are found by its diagonalization through the Bogolyubov-Tyablikov transformation [17]. This yields the following equation for elementary excitation spectrum $\Omega\left(\mathrm{k},\hat{\varepsilon}\right)$:

$$\det\left\| D^{\lambda\sigma}_{\alpha\beta}\left(\mathrm{k},\hat{\varepsilon}\right) - \hbar\Omega\left(\mathrm{k},\hat{\varepsilon}\right)\delta_{\alpha\beta}\delta_{\lambda\sigma}\right\| = 0 \tag{3}$$

On the basis of this equation below we investigate in detail the spectrum of exciton-polariton modes in a non-ideal lattice of tunnel-coupled micropores with embedded quantum dots.

3. Results and Discussion

3.1. Polaritonic Excitations in a One-Dimensional Two-Sublattice Non-ideal Microcavity Lattice

Basing on the general theory developed in Section 2 let us proceed to consider polaritonic excitations in a two-sublattice one-dimensional microcavity lattice – a chain of tunnel-connected micropores-resonators with a variable period (see Figure 1) with same-type quantum dots embedded in one of the sublattice (e.g. in the first one, i.e. $\alpha = \beta = 1$). Let's consider a model one-dimensional two-lattice system – a chain of tunnel-connected micropores-resonators with a variable period (Figure 1). Moreover, the pores of one of the sublattices (e.g. the first one, i.e. $\alpha = \beta = 1$) contain atomic nanoclusters as an atomic subsystem (same-type quantum dots) Concentrations of structural defects associated with random variation of the distances between micropores in the first and second sublattices, respectively, C_1 and C_2.

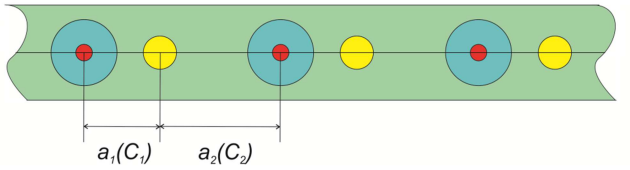

Figure 1. Schematic of the non-ideal two-sublattice one-dimensional microcavity array with quantum dots embedded in the first sublattice.

Within the nearest neighbor approximation) the relations (1)-(3) yield the following equation for the elementary excitation spectrum $\Omega(k)$:

$$\begin{Vmatrix} \hbar\omega_1^{at} - V_{11}(k) - \hbar\Omega(k) & 0 & g_1 & 0 \\ 0 & -\Omega(k) & 0 & 0 \\ g_1 & 0 & \hbar\omega_1^{ph} - \hbar\Omega(k) & -A_{12}(k) \\ 0 & 0 & -A_{21}(k,) & \hbar\omega_2^{ph} - \hbar\Omega(k) \end{Vmatrix} = 0 . \quad (4)$$

Since composition of quantum dots is not being varied the parameter of resonant interaction g_1 between a quantum dot and electromagnetic field localized at a same site is always the same.

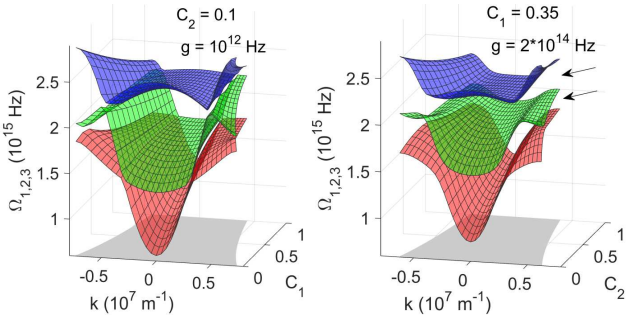

Figure 2. Dependence of polariton dispersion on structural defect concentration plotted for various values of parameter responsible for the resonant interaction between a quantum dot and electromagnetic field localized at a same site (arrows indicate the effect of changing on the width of the so-called "bottle neck".

Calculation of quantities, which define the spectrum shape of polaritonic excitations was performed for the above data and excitation frequency of quantum dots $\omega_2^{at} = 2\pi \cdot 202\ THz$. Also similarly to Ref. [15] we put $V_{11}/2\hbar = 1 \cdot 10^{13}\ Hz$, $g_1/\hbar = 5 \cdot 10^{12}\ Hz$. Figures 3a, b shows surfaces, which describe the dispersion dependence of polaritonic frequencies $\Omega_{1,2,3}(k, C_1, C_2)$ in the two-sublattice microcavity array with quantum dots embedded in one of the sublattice (surfaces are numbered bottom-up). The wave number k ranges as always within the first Brillouin zone $-\frac{\pi}{d(C_1,C_2)} < k < \frac{\pi}{d(C_1,C_2)}$ (shaded region in the plane $(k, C_{1(2)})$ in Figures 2a, b).

Let us note that the presence of local minima at $k \neq 0$ in the dispersion surface $\Omega_3(k, C_1, C_2)$ in Figure 2 indicates the possibility of existence (for certain defect concentrations) of Bose-Einstein polaritonic condensate for non-zero k's (in addition to Bose-Einstein condensation at $k=0$ at the corresponding minima in surfaces $\Omega_{1,2}(k, C_1, C_2)$).

The band gap widths of polaritonic spectrum $\Delta\Omega_{12(23)}(C_1, C_2) \equiv \min_k \left[\Omega_{2(3)}(C_1, C_2) - \Omega_{1(2)}(C_1, C_2)\right]$ are plotted as functions of concentrations of structural defects in Figures 3a, b.

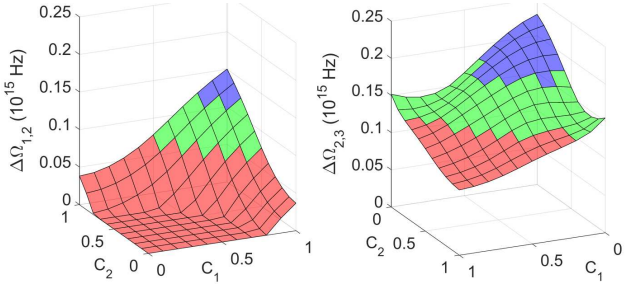

Figure 3. Dependences $\Delta\Omega_{12(23)}(C_1, C_2)$ of the band gap widths on structural defect concentrations: a) $\Delta\Omega_{12}(C_1, C_2)$, b) $\Delta\Omega_{23}(C_1, C_2)$.

3.2. Array of Microcavities Containing Quantum Dots Under a Uniform Elastic Deformation

As next example, let's consider polaritons in a one-sublattice quantum-dot-containing chain of unevenly spaced microcavities under a uniform elastic deformation. We consider the array of identical cavities with randomly embedded quantum dots of two types, whose concentrations are, correspondingly, $C_C^{(1)}$ and $C_C^{(2)}$. It is assumed, in addition, that microcavities are unevenly spaced; namely that $C_T^{(1)}$ neighboring pairs of cavities are separated by distance $a_1(\varepsilon)$ and the remaining $C_T^{(2)}$ pairs are separated by distance $a_2(\varepsilon)$. Here we also adopt the virtual crystal approximation [18, 19] based on the diagonalization of the averaged Hamiltonian (1). The corresponding procedure yields a system of uniform linear equations, whose solvability condition is given by:

$$\left\| \begin{matrix} \hbar\left\langle \omega_n^{at}(\varepsilon)\right\rangle_C + \left\langle V(k,\varepsilon)\right\rangle_{C,T} - \hbar\Omega(k,\varepsilon) & \left\langle g_n(\varepsilon)\right\rangle_C \\ \left\langle g_n(\varepsilon)\right\rangle_C & \hbar\omega^{ph}(\varepsilon) - \left\langle A(k,\varepsilon)\right\rangle_T - \hbar\Omega(k,\varepsilon) \end{matrix} \right\| = 0 \tag{5}$$

where $\left\langle \omega_n^{at}\right\rangle_C = \sum_{\nu=1}^{2} \omega_\nu^{at} C_C^\nu$, $\left\langle g_n\right\rangle_C = g^{(1)}C_C^{(1)} + g^{(2)}C_C^{(2)}$, (it is implied that $C_C^{(1)} + C_C^{(2)} = 1$, and hence $C_C^{(1)} = 1 - C_C^{(2)} \equiv C_C$);

$\left\langle V(k)\right\rangle_{C,T} = \sum_{\nu,\mu=1}^{2} V^{\nu\mu}\left(k,\{C_T\},\varepsilon\right) C_C^\nu C_C^\mu$, $V^{\nu,\mu}\left(k,\{C_T\},\varepsilon\right) = \sum_m \left\langle V_{nm}^{\nu\mu}(\varepsilon)\right\rangle_T \exp\left[ikr_{nm}\left(\{C_T\},\varepsilon\right)\right]$. Similarly,

$A\left(k,\{C_T\},\varepsilon\right) = \sum_m \left\langle A_{nm}(\varepsilon)\right\rangle_T \exp\left[ikr_{nm}\left(\{C_T\},\varepsilon\right)\right]$, where $r_{nm}\left(\{C_T\},\varepsilon\right) = d\left(\{C_T\},\varepsilon\right)(n-m)$, ($C_T^{(1)} + C_T^{(2)} = 1$, $C_T^{(1)} = 1 - C_T^{(2)} \equiv C_T$).

Angular brackets in (5) denote the procedure of configuration averaging of the microcavity array over all possible positions of cavities (index "T") and compositions of quantum dots (index "C"). $d\left(\{C_T\},\varepsilon\right)$ is the period of the "virtual" one-dimensional microcavity lattice obtained by averaging $d\left(\{C_T\},\varepsilon\right) = C_T^{(1)}a_1(\varepsilon) + C_T^{(2)}a_2(\varepsilon)$.

Within the nearest-neighbor approximation, the quantities $V\left(k,\{C_T\},\varepsilon\right)$, $A\left(k,\{C_T\},\varepsilon\right)$ can be found as:

$$\begin{bmatrix} V^{\nu\mu}\left(k,\{C_T\},\varepsilon\right) \\ A^{\nu\mu}\left(k,\{C_T\},\varepsilon\right) \end{bmatrix} = 2\begin{bmatrix} V^{\nu\mu}\left[d\left(\{C_T\},\varepsilon\right),\varepsilon\right] \\ A^{\nu\mu}\left[d\left(\{C_T\},\varepsilon\right),\varepsilon\right] \end{bmatrix} \cos\left\{kd\left[\{C_T\},\varepsilon\right]\right\}. \tag{6}$$

It follows from (5) that the dispersion relation $\Omega\left(k,\{C_C,C_T\},\varepsilon\right)$ of polariton modes is defined by frequency characteristics of the cavities and the dots as well as by the explicit form of expressions $A\left(k,\{C_T\},\varepsilon\right)$ and $V^{\nu,\mu}\left(k,\{C_T\},\varepsilon\right)$. In the framework of our model, the functions $A\left[d\left(\{C_T\},\varepsilon\right),\varepsilon\right]$ and $V^{\nu\mu}\left[d\left(\{C_T\},\varepsilon\right),\varepsilon\right]$ of the strain degree and the defect concentrations are assumed (for $a_2(\varepsilon) > a_1(\varepsilon)$) to be equal to:

$$\begin{bmatrix} V^{\nu\mu}\left[d\left(\{C_T\},\varepsilon\right),\varepsilon\right] \\ A\left[d\left(\{C_T\},\varepsilon\right),\varepsilon\right] \end{bmatrix} = \begin{bmatrix} V^{\nu\mu}\left(a_1|_{\varepsilon=0}\right) \\ A\left(a_1|_{\varepsilon=0}\right) \end{bmatrix} \exp\left[-\frac{\left|d\left(\{C_T\},\varepsilon\right) - a_1(\varepsilon)\right|}{a_1(\varepsilon)} - \varepsilon\right], \tag{7}$$

$a_1|_{\varepsilon=0} \equiv a_1$, $a_2|_{\varepsilon=0} \equiv a_2$. Quantities $A(a_1), V^{\nu\mu}(a_1)$ characterize an overlap of optical fields of neighboring cavities and an interaction between neighboring quantum dots in a one-dimensional lattice with period a_1, respectively. Such a lattice is chosen to be a reference one for the subsequent variation of distances between resonators.

The numerical calculations were carried out for the following modeling values of parameters. The frequency of cavity-localized resonance photonic modes was put equal to $\omega^{ph} = 2\pi \times 203\ THz \approx 1280 \cdot 10^{12}\ Hz$; the two types of quantum dots were assumed to be characterized by the exciton resonance frequencies $\omega_1^{at} = 2\pi \cdot 191\ THz \approx 1200 \cdot 10^{12}\ Hz$ and $\omega_2^{at} = 2\pi \cdot 202\ THz \approx 1269 \cdot 10^{12}\ Hz$, whereas $A/2\hbar = 8 \cdot 10^{13}\ Hz$, $V^{11}/2\hbar = 1 \cdot 10^{13}\ Hz$, $V^{22}/\hbar = 3 \cdot 10^{13}\ Hz$, $V^{12} \approx V^{21} = 6 \cdot 10^{13}\ Hz$, $g^{(1)}/\hbar = 5 \cdot 10^{12}\ Hz$, $g^{(2)}/\hbar = 1.5 \cdot 10^{12}\ Hz$ (within the adopted approximation the magnitude of resonance interaction of a quantum dot with an electromagnetic field localized at the same cavity is independent of deformation ε). The lattice periods were set equal to $a_1 = 3 \cdot 10^{-6} m$ and $a_2 = 7 \cdot 10^{-6} m$.

The two dispersion branches $\Omega_\pm\left(k,C_C,C_T\right)$ of the considered collective excitations in the microcavity array are plotted in Figures 4a, b for several values of C_C and C_T. Let us remind that k ranges between the values of the corresponding values:

$$-\frac{\pi}{a_2(\varepsilon) + C_T\left[a_1(\varepsilon) - a_2(\varepsilon)\right]} \le k \le +\frac{\pi}{a_2(\varepsilon) + C_T\left[a_1(\varepsilon) - a_2(\varepsilon)\right]} \tag{8}$$

where as C_T ranges between 0 to 1.

It should be noted that the shape of the dispersion curve in Figure 4a indicates the existence of Bose-Einstein exciton condensate, where the energy minima occur for a number of states with non-zero k's (in addition to those with $k=0$).

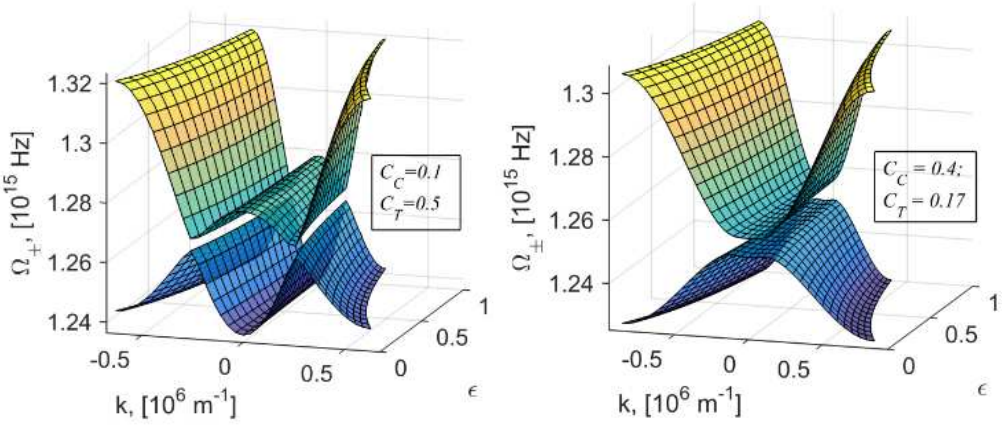

Figure 4. *Dispersions* $\Omega_{\pm}(k,C_C,C_T)$ *of polaritonic excitations in a one-sublattice quantum-dot-containing chain of unevenly spaced microcavities plotted for different values of the dot concentrations* C_C,C_T.

3.3. Group Velocity of Polaritonic Excitation Propagation in the System of Micropores

Let us consider the peculiarities of the dependence of the group velocity $V(\mathrm{k})=\dfrac{\partial\Omega(\mathrm{k})}{\partial\mathrm{k}}$ of propagation of elementary excitations in a given system of micropores on the concentration of structural defects. The features of the group velocity of polariton excitations from the concentration of structural defects follow from relation (4). Figure 5a shows the lines of the minimum level of the function $\Omega_{1,2,3}(k,C_1,C_2)$ obtained from the condition $V_{1,2,3}(k,C_1,C_2)=0$ for the corresponding values of the value g, Of particular interest is the dependence $k(C_1,C_2)$ that follows from the condition $V_3(k,C_1,C_2)=0$ (Figure 5b).

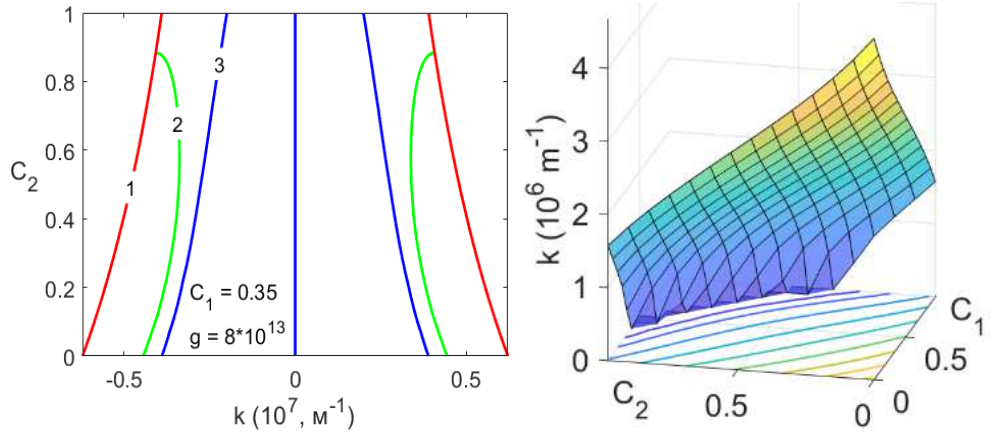

Figure 5. *The lines of the minimum level of the function* $\Omega_{1,2,3}(k,C_1,C_2)$ *obtained from the condition* $V_{1,2,3}(k,C_1,C_2)=0$ *for the corresponding values of the value g; (b) - the dependence* $k(C_1,C_2)$ *that follows from the condition* $V_3(k,C_1,C_2)=0$.

This result is important when searching for the possibility of obtaining a Bose-Einstein polariton condensate for values $k\neq 0$.

The analysis of the graphs $\Omega(k,C_C,C_T,\varepsilon)$ shown in Figures 4a, b shows that in the presence of deformation in the structure under study, the minimum of the function $\Omega_{\pm}(k,C_1,C_2,\varepsilon)$ at which the group velocity $V_{+}(k,C_1,C_2,\varepsilon)=0$ for $k\neq 0$ is not achieved for any concentration values (unlike the system considered above in the absence of deformation).

Figure 6 shows the critical values C_{C0},C_{T0} of the concentrations of structural defects at which the transition from case a) to case b) occurs in Figure 4.

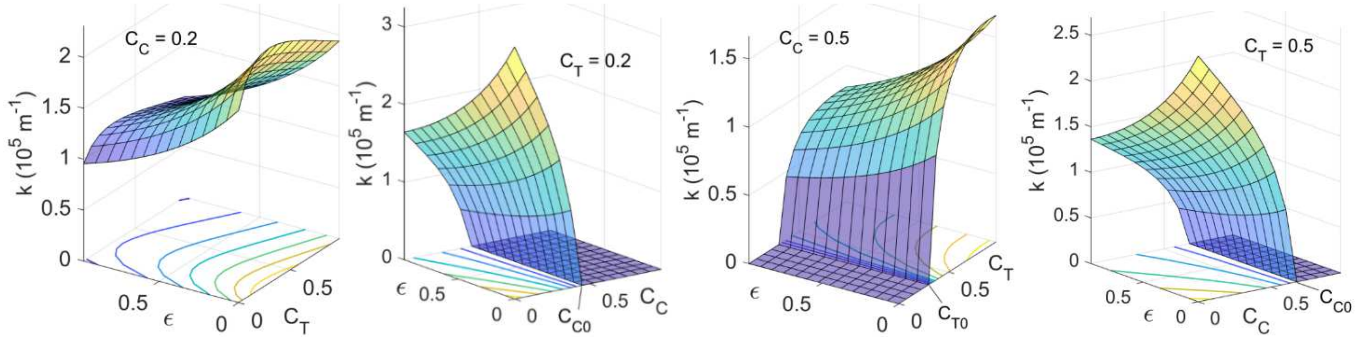

Figure 6. *The dependence* $k(C_1,C_2)$, C_{C0},C_{T0} *is the critical values of the concentrations of structural defects.*

4. Conclusion

The theoretical study of the photonic band structure of non-ideal lattices of tunnel-coupled microcavities shows that subjecting the system to the controllable elastic strain and presence of structural defects are an effective tool for altering its eigen mode structure and optical properties. This applies both for the cases of a microcavity arrays with embedded quantum dots and for quantum-dot-free lattices [13, 15]. The strain and the structural defects lead to the increase of the effective mass of the propagating photon modes in the structure and hence to the decrease of their group velocity. This results in formation of slow light mode that can be efficiently controlled by the externally applied strain. The obtained results demonstrate the possibility of controlling the group velocity of excitations, which is responsible for signaling rates in optical integrated circuits of optoelectronic devices. Numerical simulations performed on the basis of the constructed model contribute to modeling of the new class of functional porous materials, namely the so-called polaritonic systems (microcavity arrays with embedded quantum dots) where controlling of propagation of electromagnetic excitations is accomplished by an appropriate introduction of structural defects and elastic deformation.

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