OPTICAL PROPERTIES OF FERROMAGNETIC SEMICONDUCTORS WITH LASER INDUCED SURFACE GRATINGS

O.Yu. Semchuk[1], L.G. Grechko[1], M. Willander[2] and M. Karlsteen[2]

[1]*Institute of Surface Chemistry, National Academy of Sciences,*
17 General Naumov Street, 030164, Kyiv, UKRAINE, e-mail:user@surfchem.freenet.kiev.ua
[2]*Department of Physics, Chalmers University of Technology and Göteborg University,*
S-41296, Göteborg, SWEDEN, e-mail: mkn@fy.chalmers.se

Abstract

This article introduces the basic physical concepts of laser radiation influences on physical properties of ferromagnetic semiconductors (FMSC). A system of transport equations is derived to describe the electron-magnon system in a FMSC illuminated with several coherent light beams (CLB) along with a static heating electric field. It is shown that interference of CLB in FMSC has the effect that several parameters of nonequilibrium electrons and magnons exhibit superlattice behavior. The depth of modulation of the parameters describing superlattices is estimated. Propagation and diffraction of an additional electromagnetic wave in a FMSC with a gratings induced by CLB is considered. The light reflection coefficient and the refractive index of FMSC with laser induced gratings are calculated.

1. Introduction

Ferromagnetic semiconductors is a new class of materials having both semiconductor and ferromagnetic properties and being the unique materials with new qualitative features of physical properties for the last few years are intensively studied. In connection with the last achievements in synthesis of new "high-temperature" ferromagnetic semiconductors on a basis on $LaMnO_3$ and diluted ferromagnetic semiconductors with the Curie temperature of the order of 300K, these systems are of great interest [1]. The presence of a strong s-d-exchange interaction between electronic and magnetic subsystems FMSC enables one to observe a lot of unique effects in this systems: metal - dielectric phase transition, giant magnetoresistanse, shift of edge of optical absorption, anomaly of electrical properties near the Curie temperature, photoinduced magnetic effects etc [2,3]. On the basis of FMSC and multi-layers (thin-film planar structures) metal /FMSC containing FMSC: EuO, EuS, $CdCr_2Se_4$, $HgCr_2Se_4$, $LaMnO_3$, etc. the solid-state sources of polarized electrons [4], spin transistors [5], ferromagnet-semiconductor devices with tunable tunnel characteristic [6] are already have been developed. On the basis of such FMSC and FMSC multi-layers a new direction in microelectronics – "micromagnetoelectronics" already emerged.

All mentioned above effects represent a result of interaction of equilibrium electronic and magnetic sub-systems. The presence of a strong electromagnetic wave essentially changes character of quasiparticles interaction in semiconductors. It produce in a lot of the various nonlinear and nonequilibrum phenomena in detail described in the literature [7-9]. The presence of a strong electromagnetic wave among other things means that in quasiparticles system of the semiconductors there are new characteristic sizes: amplitude of conduction electrons (where and from now on well for certainty, we will speak about conduction electrons, but it concerns holes as well) oscillations in a field of an electromagnetic wave Λ and frequency of an electromagnetic wave ω [10]. If ω becomes comparable with one of characteristic frequencies of the semiconductor: quasiparticles relaxation times, free run times of quasiparticles etc. it is possible to expect occurrence on new effects. For example, quasiparticles interaction in semiconductors essentially depends on the ratio between quantum energy of an electromagnetic wave $\varepsilon_f = \hbar\omega$ and average electron energy $\bar{\varepsilon}$. If $\hbar\omega < \bar{\varepsilon}$, the electromagnetic wave will be weak and its action will be reduced only to occurrence of the small amendments to the phenomena already existing and without it. If $\hbar\omega > \bar{\varepsilon}$, the electromagnetic wave will be strong and its occurrence by all means will result in both essential updating of existing phenomena and in occurrence of new one in this case it is impossible to use classical Boatsman kinetic equation for the description quasiparticles kinetics. On the other hand, if the amplitude of electromagnetic wave is considered as not small, so the influence of an electromagnetic wave on character of quasiparticles interaction cannot be considered within the framework of the perturbation theory and for the description of the quasiparticles kinetics in these conditions it is necessary to have the new kinetic equations - the quantum kinetic equations. It was obtained by a number of authors for various cases: for the description of electron-phonon interaction without the account [10], and in view of spatial dependence of an electromagnetic wave field [11,12], for electron-magnon interaction without the account [8] and in view of spatial dependence of an electromagnetic wave field [11,12].

On the other hand, the situation when several CLB rather than a single beam induce on a semiconductors is of a special interest. Having a high degree of monochromaticity a CLB under certain conditions can create in medium a interference picture of intensity modulation in space under the periodic law. This major property of CLB, distinguishing them from a usual single electromagnetic wave, is now widely used in science and engineering and has practical use of various nonlinear optical effects [13]. For example, in a field of intensive CLB the optical properties (e.g. refractive index, coefficient of absorption, etc.) of matter become spatially modulated. However the most interesting from the scientific and practical points of view is the ability of CLB to induce in medium, and, in particular, in semiconductors, spatial - periodic structures - gratings of various types and nature. The first type of laser induced gratings are permanent gratings. These gratings are created by CLB registered by usual methods, using silver-halide photographic emulsions, photochromic, thermoplastic and other materials and used for permanent hologram recording (see for example [14). The second type of laser induced gratings are dynamic or transient gratings. These gratings disappear after the inducing light source (CLB) switching off. These gratings have been produced in a large number of solids, liquids and gases, and are detected by diffraction of a probing beam or by self-diffraction of the light waves inducing the grating. The formation of transient gratings is the basis of real-time holography, phase conjugation, and for-wave mixing [14].

The special place among laser induced gratings is occupied by surface gratings on nonequilibrium free electrons and another quasiparticles. This gratings for the first time was considered for the usual (non-ferromagnetic) semiconductors in Ref. [11,12], and for the ferromagnetic semiconductors in Ref. [15,16], for the case when the frequency of CLB satisfying the inequality $\bar{\varepsilon} << \hbar\omega << \varepsilon_g$ (ε_g is the band gap). It follows that the CLB which do not exchange the total number of electrons in semiconductor can lead to a redistribution of their density. Interference effects, producing by CLB, lead to new features of the interaction of a high-frequency field with free carriers , phonons and magnons. Formally, the situations with a single electromagnetic wave and several CLB's differ from each that since the probability of scattering of a corer from phonons, magnons and impurities in a sample illuminated with single an electromagnetic wave and in a sample illuminated with several CLB, by spatially modulation of several CLB the probability of quasiparticles interaction and also because the transport equation for electrons contains a spatially modulated force of the high-frequency pressure of the field of CLB's acting on free carriers. Spatial modulation of the collision integrals and the force due to the high-frequency pressure on electrons caused by interference effects can generate new type of nonlinearly

- static and dynamic gratings in the system of nonequilibrium free electrons in normal (non-ferromagnetic) semiconductors and free electrons and magnons in ferromagnetic semiconductors. In the differ from the non-magnetic semiconductors in FMSC devote for the weakly coupling with magnons and phonons and intensity electron-magnon interaction can be heating not only electrons but magnons too [15,16]. Thus, in FMSC we may observe the new type of gratings - the grating on nonequilibrium magnons and coupling with it, as the magnon temperature coupling according to the Bloch law magnetization, the grating of nonequilibrium magnetization.

The given article is devoted to research of influence CLB on optical properties of FMSC. The consideration begins with study of influence CLB on character of conduction electron movement in the FMSC. We were the first who calculated the wave function and quasi-energy of conduction electrons in the field of CLB. It is shown, that on the conduction electrons in the fields of CLB acts the force which corresponds to a pressure exerted by CLB on the electron gas.

FMSC with laser induced gratings are of great interest in physics of dynamical holograms as the new registration media, and may have many interesting applications at the various branches of semiconductor technology, nonlinear optic, radiophysics, electrotechniques, etc. They also tool for studying the properties of nonequilibrium electrons, magnons and phonons in solids by highly sensitive optical methods, etc. In this connection the study of electrical, optical and magnetic properties of FMSC with laser induced grating seems rather interesting.

2. Wave function and quasi-energy of conduction electrons in FMSC in the field of CLB

Let us consider the motion of electrons in FMSC in an infinite conduction-band in the field of CLB. The CLB vector potential is given as

$$\vec{A}(\vec{r},t)=\sum_j \vec{A}_j\cos\left(\omega t-\vec{k}_j\vec{r}-\varphi_j\right) \tag{1}$$

Here the frequency ω satisfies the condition $\omega\tau>>1$ (τ is the electron mean free time) in the approximation of isotropic effective mass. FMSC are a special type of semiconductors which properties depend on the interaction of electrons with the quanta of magnetic subsystem - magnons. Usually a model describing the interaction of the conduction electrons with the localized spins the so-called s-d exchange model is used [3]. This model, evidently, can describe the real physical situation for wide-band semiconductors in a sufficiently adequate way. The effect of the s-d exchange interaction of the conduction electrons eliminates the degeneration of spin and the conduction band splits into two sub-bands having different spin orientations [3]. So, the spectrum of electrons is given by

$$\varepsilon_{\vec{p}\uparrow,\downarrow}=\varepsilon_{\vec{p}}\mp\frac{\Delta}{2} \tag{2}$$

where $\Delta=IS$ is the subbands shift, I is the s-d exchange energy, S is the mean value of the localized spin. In the isotropic effective mass approximation, the single-electron operator is written as

$$\hat{H}_e=\frac{1}{2m}\left[\hat{\vec{p}}-\frac{e}{c}\vec{A}(\vec{r},t)\right]^2-\frac{\Delta}{2}\hat{\sigma}\ , \tag{3}$$

where $\sigma=\uparrow,\downarrow$ is the spin index.

The motion of a conduction electron in FMSC in a high-frequency field of CLB is described the Schrödinger equation

$$i\hbar\frac{\partial\Psi(\vec{r},t)}{\partial t}=\left\{\frac{1}{2m}\left[\hat{\vec{p}}-\frac{e}{c}\vec{A}(\vec{r},t)\right]^2-\frac{\Delta}{2}\sigma\right\}\Psi(\vec{r},t),, \tag{4}$$

where e and m are charge and effective mass of electron, c is the velocity of light, and $\hat{\vec{p}} = -i\hbar\nabla$ is the canonical momentum operator of the electron. The solution of E.g. (4) is

$$\Psi_{\vec{p}\uparrow,\downarrow}(\vec{r},t) = \hat{\chi}_{\uparrow,\downarrow} \exp\left\{ i\frac{\vec{p}\vec{r}}{\hbar} - \frac{i}{\hbar}\int_{t_0}^{t}\left\{ \frac{1}{2m}\left[\vec{p} - \frac{e}{c}\vec{A}(\vec{r},t')\right]^2 \mp \frac{\Delta}{2}\right\}dt'\right\}, \tag{5}$$

where $\hat{\chi}_\uparrow = \begin{pmatrix}1\\0\end{pmatrix}$, $\hat{\chi}_\downarrow = \begin{pmatrix}0\\1\end{pmatrix}$ are the eigenfunctions of the spin operator $\hat{\sigma}_z$

By assuming that the field of CLB is adiabatically included at $t_0 = -\infty$, we obtain from (4)

$$\Psi_{\vec{p}\uparrow,\downarrow}(\vec{r},t) = \hat{\chi}_{\uparrow,\downarrow} \exp\left\{\frac{i}{\hbar}[\vec{p}\vec{r}]\right\}\sum_{n,l=-\infty}^{+\infty} J_{2n-l}\left(\frac{e\gamma_{\vec{p}\vec{A}_j}}{mc\hbar\omega}\right)J_l\left(\frac{e^2\gamma_{\vec{A}_j\vec{A}_{j'}}}{8mc^2\hbar\omega}\right)e^{i\left\{\left(2X_{\vec{A}_j\vec{A}_{j'}} + X_{\vec{p}\vec{A}_j}\right)l - nX_{\vec{p}\vec{A}_j}\right\}}$$

$$\exp\left\{-\frac{i}{\hbar}\left(\frac{p^2}{2m} \pm \frac{\Delta}{2} + \frac{e^2}{4mc^2}\sum_{jj'}\vec{A}_j\vec{A}_{j'}Cos\left[\left(\vec{k}_j - \vec{k}_{j'}\right)\vec{r} + \varphi_j - \varphi_{j'}\right] + n\hbar\omega\right)t\right\}. \tag{6}$$

where $J(x)$ is the Bessel function,

$$\gamma^2_{\vec{p}\vec{A}_j} = \sum_{jj'}\left(\vec{p}\vec{A}_j\right)\left(\vec{p}\vec{A}_{j'}\right)Cos\left[\left(\vec{k}_j - \vec{k}_{j'}\right)\vec{r} + \varphi_j - \varphi_{j'}\right] \quad X_{\vec{p}\vec{A}_j} = arctg\left(\frac{\sum_j \vec{p}\vec{A}_j Sin\left(\vec{k}_j\vec{r} + \varphi_j\right)}{\sum_j \vec{p}\vec{A}_j Cos\left(\vec{k}_j\vec{r} + \varphi_j\right)}\right),$$

$$\gamma^2_{\vec{A}_j\vec{A}_{j'}} = \sum_{jj'j''j'''}\vec{A}_j\vec{A}_{j'}\vec{A}_{j''}\vec{A}_{j'''}Cos\left[\left(\vec{k}_j + \vec{k}_{j'} - \vec{k}_{j''} - \vec{k}_{j'''}\right)\vec{r} + \varphi_j + \varphi_{j'} - \varphi_{j''} - \varphi_{j'''}\right]$$

$$X_{\vec{A}_j\vec{A}_{j'}} = arctg\left(\frac{\sum_{jj'}\vec{A}_j\vec{A}_{j'}Sin\left[\left(\vec{k}_j + \vec{k}_{j'}\right) + \varphi_{j'} + \varphi_j\right]}{\sum_{jj'}\vec{A}_j\vec{A}_{j'}Cos\left[\left(\vec{k}_j + \vec{k}_{j'}\right) + \varphi_{j'} + \varphi_{j'}\right]}\right)$$

From (6) it follows that the time dependence of electron wave function in the field of electromagnetic wave has not of the type $\exp\left(-i\varepsilon_{\vec{p}\uparrow,\downarrow}t\right)$. Therefore, we have no stationary state with the energy $\varepsilon_{\vec{p}\uparrow,\downarrow}$. A new quantum number, the quasi-energy $E_{\vec{p}\uparrow,\downarrow}$, describing the conduction electrons in the field of an electromagnetic wave [17] determined from the relation:

$$\Psi_{\vec{p}\uparrow,\downarrow}(\vec{r},t+T_0) = \exp\left(-\frac{i}{\hbar}E_{\vec{p}\uparrow,\downarrow}T_0\right)\Psi_{\vec{p}\uparrow,\downarrow}(\vec{r},t). \tag{7}$$

($T_0 = \frac{2\pi}{\omega}$ is a period of the CLB field). By comparing (7) and (6), we obtain an expression for quasi-energy of conduction electrons in FMSC under the field of CLB :

$$E_{\vec{p}\uparrow,\downarrow\vec{A}_j,n} = \frac{p^2}{2m} \pm \frac{\Delta}{2} + \frac{e^2}{4mc^2}\sum_{jj'}\vec{A}_j\vec{A}_{j'}Cos\left[\left(\vec{k}_j - \vec{k}_{j'}\right)\vec{r} + \varphi_j - \varphi_{j'}\right] + n\hbar\omega \tag{8}$$

From (8), one can see that the quasi-energy is defined within size $n\hbar\omega$ ($n = 0 \pm 1, \pm 2, \ldots$). The value

$$E_{\vec{p}\uparrow,\downarrow A_j} = \frac{p^2}{2m} \pm \frac{\Delta}{2} + \frac{e^2}{4mc^2}\sum_{jj'}\vec{A}_j\vec{A}_{j'}Cos\left[\left(\vec{k}_j - \vec{k}_{j'}\right)\vec{r} + \varphi_j - \varphi_{j'}\right] \tag{9}$$

can be considered as the mean value of quasi-energy, and the values, which are produced by the additional $n\hbar\omega$ can be regarded as satellites or "photon repeating".

In the case of the standard parabolic energy law of electrons and when the amplitude of electrical field of electromagnetic wave $\vec{E}$ does not depend of coordinate $\vec{r}$ ($\vec{E}(t)=\vec{E}_0 Sin\omega t$) we find from (8) and (9)

$$E_{\vec{p}\uparrow,\downarrow\vec{A}_j,n} \equiv E_{\vec{p}} = \frac{p^2}{2m} \pm \frac{\Delta}{2} + \frac{e^2E_0^2}{4m\omega^2} + n\hbar\omega . \tag{10}$$

Thus, in this case quasi-energy is connected only with the electromagnetic wave which produces a shift of $\Delta E = e^2E_0^2/(4m\omega^2)$. The value ΔE is small and can be neglected in (12). But in the field of CLB, whit the space dependence of vector-potential CLB, we cannot neglect this term. In this case the value

$$\Delta E = \Delta E_{\vec{A}_j\vec{A}_{j'}} = \frac{e^2}{4mc^2}\sum_{jj'}\vec{A}_j\vec{A}_{j'}Cos\left[\left(\vec{k}_j-\vec{k}_{j'}\right)\vec{r}+\varphi_j-\varphi_{j'}\right. \tag{11}$$

and, obviously, the quasi-energy, will become a functions of coordinate $\vec{r}$. The value $\Delta E_{\vec{A}_j\vec{A}_{j'}}$ has a simple physical meaning. Let's consider movement of a conduction electron in the FMSC in a field of CLB. For simplicity shall be restricted consideration of electron movement in sub-zone with $\sigma=\uparrow$. In the non-relativistic approximation, the equation of motion of conduction electrons is

$$m\frac{d^2\vec{r}}{dt^2} = e\vec{E}(\vec{r},t)+\frac{e}{c}\frac{d\vec{r}}{dt}\times\vec{H}(\vec{r},t), \tag{12}$$

where $\vec{E}(\vec{r},t)$ and $\vec{H}(\vec{r},t)$ are electric and magnetic fields of CLB, respectively.

If the frequency of the CLB is sufficiently high, the solution of equation (13) can be written as a sum of slowly varying (in terms of the oscillation period of the CLB) function $\vec{r}_0(t)$ and an oscillation function $\vec{r}_1(t)$ (frequency ω). Assuming that $\vec{r}_1(t)$ is much smaller than the distance L over which the amplitude of the CLB changes notably, $|\vec{r}_1| << L$ and neglecting terms of the order of $|\vec{r}_1/L|$ and $|\vec{r}_0/L|$, by averaging equation (12) over the period of CLB, we obtain an equation for $\vec{r}_0(t)$:

$$m\frac{d^2\vec{r}_0(t)}{dt^2} = -\frac{e^2}{4mc^2}\nabla\sum_{jj'}\vec{A}_j\vec{A}_{j'}Cos\left[\left(\vec{k}_j-\vec{k}_{j'}\right)\vec{r}_0-\varphi_j-\varphi_{j'}\right]. \tag{13}$$

This is mean that on the conduction electron in the field of CLB the following force acts

$$\vec{F} = -grad\Delta E_{\vec{A}_j\vec{A}_{j'}} = -\frac{e^2\nabla}{4mc^2}\sum_{jj'}\vec{A}_j\vec{A}_{j'}Cos\left[\left(\vec{k}_j-\vec{k}_{j'}\right)\vec{r}_0+\varphi_j-\varphi_{j'}\right], \tag{14}$$

which is corresponding to the pressure exerted by CLB on the electron gas [15,16]. The expression for this force has been obtained earlier [15,16]. Then by using the standard methods of quantum transport equations and quantum-mechanic operators for the construction of quantum kinetic equations for electrons and magnons in the field of CLB. This method does not require usage of wave function. In the present report the wave function for such system is obtained for the first time.

It is possible to specify some such cases when the calculation of a value ΔE is necessary:

1. The system contains some types of carriers with different charges or effective masses. In this case for each type of carriers there will be a shift ΔE, that results a change of distance between appropriate branches of a spectrum.
2. If the initial energy spectrum non-parabolic, i.e. electron effective mass have different values in different parts of a conductivity band.

The wave function for conduction electrons in FMSC in the field of CLB may be has some applications. For example, with the help of the obtained wave function (9) one can study the probabilities of electron transitions from the state described by the canonical momentum $\bar{p}\sigma$ to the state $\bar{p}'\sigma'$ exposed to a weak potential V at the time t

$$W_{\bar{p}\sigma\to\bar{p}'\sigma'}=\frac{d}{dt}\left|\int_0^t d\tau<\Psi^{*}_{\bar{p}'\sigma'}(\tau)|V|\Psi_{\bar{p}\sigma}(\tau)>\right| \tag{15}$$

in the field of CLB. This fact offers a possibility for another way of constructing quantum kinetic equations for interaction of quasi-particles in the field of CLB. In comparison with the standard method a quantum transport equation for the quantum-mechanic operators [19-20], it allows one oneself the effect of external CLB fields that acts on the elementary processes of quasi-particles interactions to be analyzed. There are already similar methods suggested, for example, in [8].

3. The conduction electrons mechanical trajectory in the field of CLB

Consider the instance where the outer surface $z=0$ of FMSC is exposed to two symmetrically oriented CLB that converge in the bulk of the semiconductor at a small angle 2ϑ and whose vector-potential is given by the following expression (Fig..1)

$$\vec{A}(\vec{r},t)=\vec{A}_1Cos(\omega t-k_xx-k_zz-\varphi_1)+\vec{A}_2Cos(\omega t-k_xx+k_zz-\varphi_1),\quad \vec{A}\|OY. \tag{16}$$

Received as a result of an interference these two CLB the interference picture with good precision can be approximated by a standing laser wave with the spacing period $L=\lambda_0/2Sin\vartheta$ (λ_0 is the CLB wavelength in the semiconductor bulk) [18]. Thus, in the bulk of semiconductor, CLB may be approximated by the laser standing wave

$$\vec{E}=\vec{E}_0Sin(k_zz)Sin(\omega t), \tag{17}$$

where $\vec{E}_0=\frac{\omega}{c}\vec{A}_1\approx\frac{\omega}{c}\vec{A}_2$ average electric field intensity of a standing laser wave (CLB). Now we shall analyze the character of electron motion in the bulk of FMSC in a field of CLB more details. With this aim, we shall re-write (13) as

$$\frac{d^2\vec{r}_0(t)}{dt^2}=-\nabla W$$

High frequency potential W corresponding to the interference picture in the bulk of FMSC is equal to

$$W\approx\left(\frac{eE_0}{2m\omega}\right)^2Sin^2k_zz. \tag{18}$$

In a Fig. 2 the structure of dimensionless high-frequency potential $W/W_0\left(W_0=\left(\frac{eE_0}{2m\omega}\right)^2\right)$ is shown.

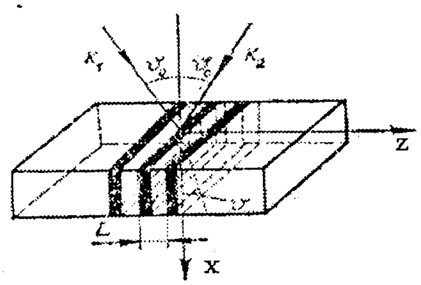


Fig.1. Interference picture from two CLB when they illuminated the front surface $z=0$ of FMSC Sample ($L=\lambda_0/2\sin\vartheta$ is the period of interference picture)

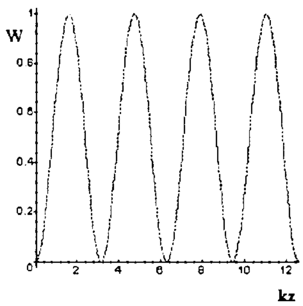


Fig. 2. The structure of dimensionless high-frequency potential W/W_0 as a function of dimensionless coordinate *kz*.

Therefore, the high-frequency potential W may be considering as a periodic potential well for the conductivity electrons moving along the OZ axis in the inside of semiconductor bulk.

That a conduction electron, which moving with velocity v_0 ($v_0 = \sqrt{2eV_0 / m}$ is the initial velocity of conduction electron in the point $z=0$), along an OZ axis could be located in inside of a potential well, created by CLB, the fulfillment of a condition is necessary

$$eV_0 / m < W \tag{19}$$

which together with a condition $|\vec{r}_1| << L$ imposes the following restriction on amplitude of an electric field of CLB, creating a potential well

$$2\omega\sqrt{mV_0 / e} < E_0 << m\omega^2 L / e \tag{20}$$

Thus, if at centers of a potential well $E_0 = 0$, the conduction electrons with energy equal eV_0, is located inside a potential well, on which the boundary conditions (20) are executed.

Now we shall consider a movement of a conduction electron inside of the potential well in more details. Substituting (17) and (18) into (12) and (13) we obtain the following equations for determining z and x

$$\ddot{z} + \omega_z^2 z = 0, \qquad x = -\left(\sqrt{2}z / \omega\omega_z\right)\sin \omega t, \tag{21}$$

where $\omega_z = eE_0 / \sqrt{2}mc$ is the electron oscillation frequency inside of a one-dimensional potential well, produced by CLB. The first of the equations under number (21) is the free electron harmonic oscillation equation. Its solution

$$z = C_1 Cos\omega_z t + C_2 Sin\omega_z t, \tag{22}$$

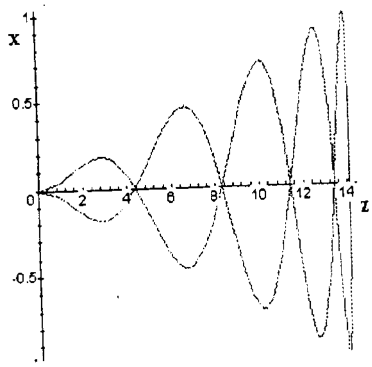
which satisfies the initial conditions $C_1 = 0$, $C_2 = v_0 / \omega_z$ has the form

$$z = (v_0 / \omega_z) Sin\omega_z t. \tag{23}$$

Making use of (21), write down now the equations, which describe the conduction electron mechanical trajectory as:

$$z = (v_0 / \omega) Sin\omega_z t, \qquad x = -(v_0 / \omega)\sqrt{2} Sin(\omega_z t) Sin(\omega t). \tag{24}$$

In a Fig.3 the conduction electron mechanical trajectories in a field of CLB is shown.



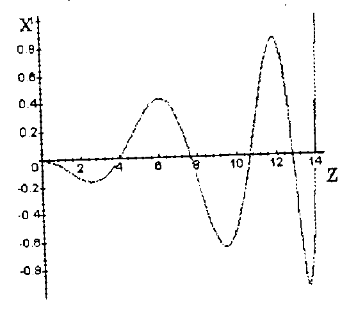


Fig.3. The conduction electrons mechanical trajectories in a field of CLB for the following meanings of parameters: a - $\omega / \omega_z = 10, \omega_z z_{\max} / c = 1, z > 0$; b - $\omega / \omega_z = 11, \omega_z z_{\max} / c = 1, z > 0$.

Depending on a ratio between frequency of a CLB field ω and a frequency of oscillation of conduction electrons inside a potential well ω_z the conduction electrons mechanical trajectories will be various. From the Fig. 3a, for example, when $\frac{\omega}{\omega_z} = 10$ follows, that the conduction electron mechanical trajectory inside of a potential well will be made. It means that the electron alternately being reflected from walls of a potential well will make inside of oscillations with frequency ω_z. In a case when $\frac{\omega}{\omega_z} = 11$, from a Fig. 3b follows, that the conduction electron mechanical trajectory will be open. It means, that having made some oscillations in inside of a potential well the electron can be abandon and further move only under the activity of a field of CLB.

Thus, the electron in the field of CLB takes part simultaneously in two motions. Namely, it oscillates with the frequency ω and amplitude $\vec{a} = \frac{e\vec{E}_0}{m\omega^2}$ in the field of CLB and performs forced oscillation at the frequency $\omega_z << \omega$ of inside on one-dimensional well, produced along OZ axis by CLB.

4. System of kinetic equations for electrons and magnons

Let us consider a wide-gap donor type FMSC with mean carrier density n_0 in the spin-wave temperature range placed in an external constant electric field $\vec{F}_0 \| OZ$. Its from surface is subjected to several CLBs, whose frequencies satisfy the inequality $\bar{\varepsilon} << \hbar\omega << \varepsilon_g$ (ε_g is the energy-gap width) Electrons are considered to be non-generate, and their energy in the CLB field $\varepsilon_{\vec{P}} << JS$ ($\vec{P} = \vec{p} + e\vec{A}(\vec{r},t)/c$ is the electron electromagnetic momentum). This inequality makes it possible to confine our consideration to a subzone with $\sigma = \uparrow$, so that the spin index σ may be omitted. In the secondary quantization representation, the Hamiltonian of the system of electrons and magnons, which are subjected to action of the external electric field $\vec{F}_0$ and in the high-frequency CLB field are interact with phonons, has the following form:

$$\hat{H} = \sum_{\vec{p},\vec{\chi}} \left[-\frac{e}{mc}\vec{p}\vec{A}_{\vec{\chi}} + \frac{e^2}{2mc^2} A^{(2)}_{\vec{\chi}} - ie\vec{F}_0 \left(\frac{\partial}{\partial \vec{\chi}} \delta_{\vec{\chi},0} \right) \right] a^+_{\vec{p}+\hbar\vec{\chi}} a_{\vec{p}} + \sum_{\vec{p}\vec{q}\vec{r}} C_{\vec{p}\vec{q}\vec{r}} a^+_{\vec{p}} a_{\vec{p}-\vec{r}} b^+_{\vec{q}} b_{\vec{q}+\vec{r}} + \hat{H}_e + \hat{H}_m + \hat{H}_{mm} + \hat{H}_{mp}, \quad (25)$$

where $\vec{A}_{\vec{\chi}}$ and $A^{(2)}_{\vec{\chi}}$ are Furier components of the CLB vector potential $\vec{A}(\vec{r},t)$ and $A^2(\vec{r},t)$, respectively, $C_{\vec{p}\vec{q}\vec{r}}$ is the electron-magnon interaction matrix element taking into account both two-magnon processes in the first-order approximation of perturbation theory and one-magnon processes in the second approximation [2], $a^+_{\vec{p}}(a_{\vec{p}})$ and $b^+_{\vec{q}}(b_{\vec{q}})$ are creation and annihilation operators for electrons and magnons with quasi-momentum of $\vec{p}$ and $\vec{q}$, respectively, $\hat{H}_e$ and $\hat{H}_m$ are the Hamiltonians for free electrons and magnons, respectively, $\hat{H}_{mm}$ describes processes of interaction between magnons [18], and $\hat{H}_{mp}$ is the Hamiltonian of the magnon-phonon interaction [19].

In the general case, the kinetic equations for electrons and magnons are quantum equations, and we shall derive them on the basis of quantum analogues of the microscopic distribution function for electrons $\hat{f}$ and magnons $\hat{N}$ in Wigner representation. Them, from the equations of motion for $\hat{f}$ and $\hat{N}$ operators with the Hamiltonian (25), a set of equations for ordinary distribution functions of electrons $f(\vec{r},\vec{P},t)$ and magnons $N(\vec{r},\vec{q},t)$ is obtained in the usual way [15,16].

First, let us consider a set of kinetic equations for the amplitudes subjected to frequency averaging $(2\pi/\omega)$, $f^{(0)}(\vec{r},\vec{P})$ and $N^{(0)}(\vec{r},\vec{q})$. This set has the following form [15,16]:

$$\frac{\vec{P}}{m}\frac{\partial f^{(0)}}{\partial \vec{r}}+\left\{e\vec{F}_0-\frac{e^2}{4mc^2}\frac{\partial}{\partial \vec{r}}\left[\sum_{jj'}\vec{A}_j\vec{A}_{j'}\cos\left[\left(\vec{k}_j-\vec{k}_{j'}\right)\vec{r}+\varphi_j-\varphi_{j'}\right]\right]\right\}\frac{\partial f^{(0)}}{\partial \vec{r}}=I_{em}\left\{f^{(0)},N^{(0)}\right\},$$
$$\frac{\partial \omega_{\vec{q}}}{\partial \vec{q}}\frac{\partial N^{(0)}}{\partial \vec{r}}=I_{me}\left\{f^{(0)},N^{(0)}\right\}+I_{mp}\left\{n^{(0)},N^{(0)}\right\}+I_{mm}\left\{N^{(0)}\right\} \tag{26}$$

When deriving (26), it is supposed that both energy and momentum of the electrons relax on magnons, and the dispersion law for electrons and magnons are isotropic and parabolic.
The integral of electron-magnon collisions I_{em} may be written in the following form [15,16]:

$$I_{em}=\frac{2\pi}{\hbar}\sum_{\vec{P}\vec{q}\vec{q}'n}J_n^2\left(\frac{e\gamma_{\vec{P}\vec{A}_j}}{mc\hbar\omega}\right)\left|C_{\vec{P}'\vec{q}\vec{q}'}\right|^2\left\{\begin{matrix}f^{(0)}(\vec{r},\vec{P})N^{(0)}(\vec{r},\vec{q}')\left(1+N^{(0)}(\vec{r},\vec{q})\right)-\\ f^{(0)}(\vec{r},\vec{P})N^{(0)}(\vec{r},\vec{q}')\left(1+N^{(0)}(\vec{r},\vec{q})\right)\end{matrix}\right\}\times$$
$$\delta\left(\vec{P}+\vec{q}-\vec{P}'-\vec{q}'\right)\delta\left(\varepsilon_{\vec{P}}-\varepsilon_{\vec{P}'}+\omega_{\vec{q}}-\omega_{\vec{q}'}+n\hbar\omega\right) \tag{27}$$

Integrals of magnon-electron I_{me}, magnon-phonon I_{mp}, and magnon-magnon I_{mm} collisions in explicit form can be found , for example, in [15,16].
As follows from the analysis of the set equations (26), the high-frequency field of CLB acts on the FMSC electron-magnon system in two ways. Firstly, the electrons experience an additional pressure caused by the CLB. Secondly, I_{em} and I_{me} become periodic functions of $\vec{r}$. It is this periodic variation of the CLB pressure, alongside with the periodic dependence of I_{em} and I_{me} on $\vec{r}$, that caused the formation of superlattices - laser induced gratings in FMSC. For the first time , they were discussed in [15,16], where it was shown that the system on non-equilibrium electrons and magnons of a FMSC sample in a CLB field formed gratings of carrier density n_0, electric field intensity F, electron T_e and magnon T_m temperatures, etc. In the case of incidence on the FMSC surface of only two waves symmetrically oriented beams (16) this gratings could be represented as

$$n=n_0\left(1+\xi_1\cos 2k_{1z}z+\xi_2 c\sin 2k_{1z}z\right),\qquad F=F_0\left(1+\varsigma_1\cos 2k_{1z}z+\varsigma_2 c\sin 2k_{1z}z\right),$$
$$T_e=T_e^{(0)}\left(1+\eta_0+\eta_1\cos 2k_{1z}z+\eta_2 c\sin 2k_{1z}z\right),$$
$$T_m=T_m^{(0)}\left(1+\mu_0+\mu_1\cos 2k_{1z}z+\mu_2 c\sin 2k_{1z}z\right) \tag{28}$$

Here, $T_e^{(0)}$ and $T_m^{(0)}$ are electron and magnon temperatures in the absence of the CLB field. The expressions for amplitudes $\xi_i,\varsigma_i,\eta_i,\mu_i$ in the general case have very awkward forms and are given in [15]. The common characteristic property of $\xi_i,\varsigma_i,\eta_i,\mu_i$ amplitudes is that all of them tend to zero, when the external electric field strength increases.

5. Electromagnetic waves diffraction on the laser induced grating of electron concentration in FMSC

Now let us consider the peculiarity of the propagation of electromagnetic waves in FMSC with the electron concentration grating, produced by CLB. Let a weak electromagnetic wave, with the polarization that differs from CLB, which production a grating, propagate in semiconductor along the OX-axis, We suppose for simplicity that the amplitude of the weak electromagnetic wave depends on the coordinate z and is given by the expression

$$\vec{E} = \vec{E}(x)\exp\{i(s_x x + s_z z - \Omega t)\}. \tag{29}$$

We considering resonance case when $s_z = k_{1z}$ and the frequency of weak wave Ω is considerably higher than the frequency of electron collisions.

When electromagnetic wave propagate in the electron gas in semiconductors it produced the perturbation of electron velocity $\Delta\vec{v}_e$ (and, therefore, produce the additional electric current) which may be determined from the linearization the motion equation for the incident wave (29)

$$\frac{\partial \Delta\vec{v}_e}{\partial t} = \frac{e}{m}\vec{E} \tag{30}$$

and can be written as

$$\Delta\vec{v}_e = \frac{ie}{\Omega m}\vec{E}. \tag{31}$$

Thus, current density $\vec{I}$, induced by wave (29), now can be presented as:

$$\vec{I} = en\Delta\vec{v}_e = i\frac{e^2 n(z)}{\Omega m}\vec{E} = i\frac{e^2 n_0}{\Omega m}\left[1 + \frac{n_1(z)}{n_0}\right]\vec{E}. \tag{32}$$

Substitution (32) into Maxwell equations for the wave (29), we obtained

$$\nabla^2\vec{E} + \frac{\varepsilon_0}{c^2}\frac{\partial^2\vec{E}}{\partial t^2} = -\frac{4\pi}{c^2}\frac{\partial\vec{I}}{\partial t} \tag{33}$$

and supposing that the grating of electron concentration, producing by CLB already existing $n(z) = n_o(1 + \xi_1 Cos2k_{1z}z + \xi_2 Sin2k_{1z}z)$ and weakly electromagnetic wave (29) only producing small perturbation of this grating, we obtain

$$\nabla^2\vec{E} + \frac{\varepsilon_0}{c^2}(\Omega^2 - \omega_p^2)\vec{E} = \alpha_1\left(\xi^*\exp(2ik_{1z}z) + \xi\exp(-2ik_{1z}z)\right)\vec{E}, \tag{34}$$

where $\omega_p^2 = \dfrac{4\pi n_0 e^2}{\varepsilon_0 m}$, $\alpha_1 = \dfrac{\varepsilon_0\omega_p^2}{2c^2}$, $\xi^* = \xi_1 + i\xi_2$. Further, using well-known procedure the solution of equation (34) we may be look in the form

$$\vec{E} = \sum_l \vec{E}_l(x)\exp\{i(s_x x + k_{1z}z) + 2lk_{1z}z\}, \tag{35}$$

with the boundary conditions

$$\vec{E}(0) = \vec{E}_0, \qquad \vec{E}^{(0)}_{l\neq 0} = 0. \tag{36}$$

Thus, using the equation (34), we may be received the next coupling between functions $\vec{E}_l(x)$ and $\vec{E}_{l-1}(x)$

$$\frac{d^2\vec{E}_l}{dx^2} + 2is_x\frac{d\vec{E}_l}{dx} - 4l(l+1)k_{1z}^2\vec{E}_l = \alpha_1\left(\xi^*\vec{E}_l + \xi\vec{E}_{l+1}\right) \tag{37}$$

Since in our case $|\xi << 1|$, the most significant terms in the above expansion of $\vec{E}_l(x)$ are those with l=0 and l=-1. Moreover, the small value of the parameter $|\xi|$ leads to the following set of equations:

$$\frac{d\vec{E}_0}{dx} = -i\frac{\alpha_1\xi^*}{2s_x}\vec{E}_{l-1}, \qquad \frac{d\vec{E}_{-1}}{dx} = -i\frac{\alpha_1\xi}{2s_x}\vec{E}_0, \tag{38}$$

which have a simple solution satisfying the boundary conditions (33):

$$E_0 = E^{(0)}Cos\left(\frac{\alpha_1^2|\xi|}{2k_x}x\right), \qquad E_{-1} = -i\frac{|\xi|}{\xi^*}E^{(0)}Sin\left(\frac{\alpha_1^2|\xi|}{2k_x}x\right). \tag{39}$$

The solutions (39) defines two waves , which arise as e result of diffraction of an incident wave (29) on grating of electron density, production by coherent light beams, which turns out to be a periodic function of x-coordinate. The relative intensity of this waves

$$\frac{I_{-1}}{I_0} = \frac{|E_1|^2}{|E_0|^2} = \frac{Sin^2\left(\frac{\alpha_1^2|\xi|}{2k_x}x\right)}{Cos^2\left(\frac{\alpha_1^2|\xi|}{2k_x}x\right)}. \tag{40}$$

Thus, we can se that take place the periodical energy transfer from one waves to another, dependence with coordinate x. As the period of this waves proportional $|\xi|^{-1}$ and dependence with $\vec{F}_0$, that constant electric field may be produce the variation character of diffraction, and, at the fixed thickness of the semiconductor samples d $(x \le d)$, may be crossing from the Bragg-diffraction to another types of diffraction.

6. Electromagnetic wave scattering in FMSC with laser induced gratings

Now let consider a weak electromagnetic wave with the polarization that differs from the CLB failing from on the semiconductor surface z=0. Its electric field can be writing as

$$\vec{E} = \vec{E}(x,z)\exp(-i\Omega t). \tag{41}$$

Using the designation

$$\vec{E}(x,z) = \vec{\Psi}(z)\exp(is_x x) \tag{42}$$

we now can be written for the amplitude $\vec{\Psi}$ the wave equation in the form, analogy equations (34):

$$\frac{d^2\vec{\Psi}}{dz^2} + s_z^2\vec{\Psi} = \alpha_1\left(\xi^* e^{2ik_{1z}z} + \xi e^{-2k_{1z}z}\right)\vec{\Psi}(z). \tag{43}$$

If $|\xi| << 1$ for the solution of the equation (43) we may be using perturbation theory. But nearly the Bragg resonance region when $s_z = k_{1z} + \Delta k$ $(\Delta k \to 0$ the parameters which describe the deviation from the Bragg resonance) this theory is noncorrect and we may be using the dynamically theory of electromagnetic wave diffraction on periodic structures [20]. Given the function $\vec{\Psi}$ as the sum

$$\vec{\Psi}(z) = \sum_{l=0}^{\infty}\left\{\vec{B}_l \exp\{[i(2l+1)k_{1z} + \delta]z\} + \vec{C}_l \exp\{-i[(2l+1)k_{1z} - \delta]z\}\right\} \tag{44}$$

where $\delta \to 0$ the small parameter which will be determine. Just as take place the inequality $(\alpha_1 / k_{1z}^2) << 1$ in the sum (44) give up only the terms with l=0, i.e. using two wave approximation:

$$\vec{\Psi}(z) = \vec{B}_0 \exp\{i(k_{1z} + \delta)z\} + \vec{C}_0 \exp\{-i(k_{1z} - \delta)z\}. \tag{45}$$

Substituting (45) into (43), we determine the parameter δ and the amplitudes relativity R_s falling B_0 and reflection C_0 waves :

$$\delta = \pm\sqrt{(\Delta k)^2 - \frac{\alpha_1^2}{4k_{1z}^2}|\xi|^2}, \qquad R_s = \frac{C_0}{B_0} = \frac{\alpha_1\xi}{2k_{1z}(\Delta k + \delta)} = \frac{2k_{1z}(\Delta k - \delta)}{\alpha_1\xi^*}. \tag{46}$$

Note that the sign δ in the equation (46) determine the finite of the solution (45) at $z \to \infty$ and the direction of energy transfer from wave (45) to the side of positive z.

Now let us consider calculation of reflection coefficient of an electromagnetic wave on the surface z=0 in semiconductors with a periodical grating of electron concentration, produced by

CLB, We determine the electric field of the weakly incident wave in vacuum (according with the reflection wave fields) as :

$$\vec{E}_s(\vec{r},t)=\vec{E}^{(0)}\{\exp[i(u_x x+u_z z)]+R_0\exp[i(u_x x-u_z z)]\}\exp\{-i\Omega t\}, \qquad (47)$$

where $\quad \Omega^2=c^2\left(k_x^2+u_z^2\right),\quad u_z^2=\left(\frac{\omega_p}{c}\right)^2+\frac{k_x^2-(\varepsilon_0-1)s_z^2}{\varepsilon_0},\quad s_z=k_{1z}+\Delta_k,\quad \Delta k\to 0.$

Continuity of the functions (43) and (47) and their derivatives at the point z=0 together with the expression (46) enables us to determine the constants A_0 and B_0 and reflection coefficient $|R_0|^2$. For example, the obtained reflection coefficient to be equal too

$$|R_0|^2=\frac{(k_{1z}-u_z)^2+(k_{1z}+u_z)^2|R_s|^2-\left(k_z^2-u_z^2\right)\left(R_x+R_s^*\right)}{(k_{1z}+u_z)^2+(k_{1z}-u_z)^2|R_s|^2-\left(k_z^2-u_z^2\right)\left(R_x+R_s^*\right)}. \qquad (48)$$

From (48) follow the Bragg resonance region when $|R_s|^2=1$ the weakly wave reflection coefficient $|R_0|^2=1$ and take place the full reflection. Somewhat involved calculation gives the following expression for the reflection coefficient nearly the Bragg resonance region:

$$|R_0|^2=\frac{2k_{1z}\left(u_z^2+k_{1z}^2\right)\Delta k-4u_z k_{1z}^2\delta-\alpha_1\left(k_{1z}^2-u_z^2\right)\xi_1}{2k_{1z}\left(u_z^2+k_{1z}^2\right)\Delta k+4u_z k_{1z}^2\delta-\alpha_1\left(k_{1z}^2-u_z^2\right)\xi_1}. \qquad (49)$$

From (49) whence it follows that at such Δk with increasing field $\vec{F}_0$ the reflection coefficient will continuously pass from some initial value (if initial value smaller $|R_0|^2_{\lim}$) to its limiting value, $|R_0|^2_{\lim}$ corresponding to the reflection coefficient of the homogeneous (non illuminated by CLB) semiconductor material:

$$|R_0|^2_{\lim}=\left(\frac{k_{1z}-u_z}{k_{1z}+u_z}\right)^2. \qquad (50)$$

Note, that the dependencies ξ_1,ξ_2 and δ of F_0 allow, changing F_0 at the fixed Δk, change $|R_0|^2$ from 1 to its limiting value $|R_0|^2_{\lim}$. Interesting, that the dependence its from F_0 determine not only the value of Δk and its sign too. If the sign of Δk and ξ_1 is equal then $|R_0|^2$ have minimum at

$$\Delta k=\frac{\alpha_1}{2}\frac{k_{1z}^2+u_z^2}{k_{1z}^2-u_z^2}\frac{\xi_1^2-\xi_2^2}{\xi_1}. \qquad (51)$$

This fact confirm the numerical calculations , presented on Fig 4 and Fig.5 , where one can see the results of the numerical calculations the dependencies of the reflection coefficient on the parameters Δk and F_0.

From the analysis of fig.4 one can see that in the EuO at $n_0=10^{19}\,cm^{-1}$, $\omega=5\cdot10^{15}\,s^{-1}$, $T=0.5\cdot10^{-21}\,J$, $F_0=2\cdot10^3\,V/cm$ the reflection coefficient decrease up to the minimum equal to $2.547\cdot10^{-4}$ at $\Delta k=-0.2$ [21].

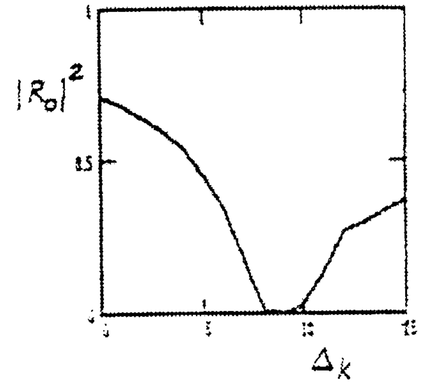


Fig.4. The dependence of the $|R_0|^2$ of the parameters Δk. For the value Δk introduce the marks: 0 – 0.2, 5- (-0.50), 10 – (-0.22), 15 – (-0.238).

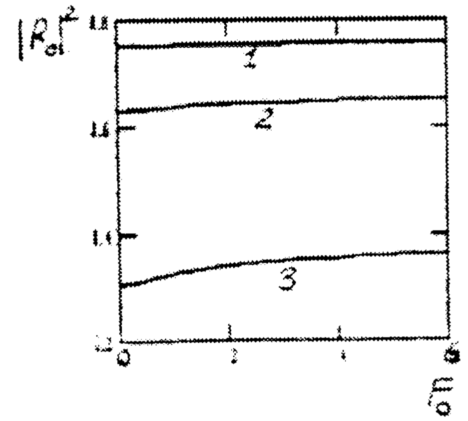


Fig. 5. The dependence $|R_0|^2$ of the F_0 (KV/cm). Curves 1 - $\Delta k = 0.3$, 2 - $\Delta k = 0.1$, 3- $\Delta k = -0.1$.

On Fig. 5 one can see the results of the numerical calculations electric field dependence on $|R_0|^2$ in ferromagnetic semiconductor EuO for the different values of the $\Delta k = 0.3, \quad 0.1, \quad -0.1$.

From the analysis of Fig.5 one can see (curve 3) as the $\Delta k = -0.1$, $|R_0|^2$ really slowly increasing with increasing of F_0 from $|R_0|^2 \approx 0{,}3$ and set to $|R_0|^2_{\lim} \approx 0.4026$. As the $\Delta k > 0$, when the initial value of the reflection coefficient $|R_0|^2_{int} > |R_0|^2_{lim}$ one can see only slowly increasing $|R_0|^2$ (curves 1 and 2).

Thus, we have carried out a study of the optical phenomena in the FMSC with a periodical structures – gratings on nonequilibrium quasiparticles producing by coherent light beams. Results of this study allow the following conclusions:

1. As a result of the electromagnetic waves diffraction on the periodical grating of electron density in semiconductors, appears two waves propagate along OX-axis and take place the periodic energy transfer from one wave to another, dependence on coordinate.
2. The reflection coefficient $|R_0|^2$ under conditions of Bragg resonance depends indirectly on the strength of heating field, on the angle of impinge waves and on the parameters of semiconductors. Varying those and the value of F_0, one can decrease the reflection coefficient $|R_0|^2$, i.e. make semiconductor "antireflective", as well as to increase it up to the value leading to almost total reflection of the electromagnetic wave from outer surface of semiconductors.
3. The light reflection coefficient $|R_0|^2$ at the Bragg resonance area dependence at the constant heating electric field F_0. When this field increasing up, the reflection coefficient is slowly increasing too, as the $\Delta k = -0.1$ reflection coefficient in FMSC EuO really increasing with

increasing F_0 from $|R_0|^2 \approx 0.3$ and set to $|R_0|^2_{\lim} \approx 0.4026$. as the $\Delta k > 0$, when the initial value of reflection coefficient $|R_0|^2_{\mathrm{int}} > |R_0|^2_{\lim}$, one can see only slowly increasing $|R_0|^2$.

7. Conclusion and outlook

In this report some new results obtained recently in the theory of kinetic and optical phenomena in FMSC on strong external constant electric field and high-frequency field of coherent light beams (CLB) have been surveyed. The approach based on the accurate account of the system of quantum kinetic equations for interaction quasiparticles in the strong external fields, which, as been demonstrated, may be successful using for the description various phenomena's in FMSC under high-frequency field of CLB. There is every ground to believe that the development of the theory of nonlinear and nonequilibrium phenomena in FMSC under intense CLB fields is interesting not only from the point of view of considering the possible new mechanisms of the creating the nonequilibrium states and nonlinear phenomena but also to the practical application of these phenomena's for the now rapidly developing trend of creating new materials and devices for high-frequency electronics, semiconductor technology, etc.

FMSC acquires new properties in a high-frequency CLB field. In particular, the effect of high-frequency CLB field on the collisions between quasiparticles in FMSC become important at the quanta energy of CLB field $\hbar\omega$ more of the average carrier energy $\bar{\varepsilon}$. In this conditions may be take place the effect of immediate participation in quasiparticles collisions quanta of CLB fields and as the interference effects appear the spatial modulation of the collision integrals and high-frequency pressure on electrons. Thus, it follows from the foregoing that the CLB produce in FMSC a static and dynamic periodical structures – gratings (superlattices).

Presence of this gratings essentially changing the physical properties of FMSC. Grating of electron concentration essentially exchange the optical properties of semiconductors. On this grating may be take place the diffraction of the weakly electromagnetic wave, which propagate at the enter of the semiconductor. As the result of this diffraction appear two waves, and take place the periodic energy transfer from one wave to another. As the period of this waves dependence of constant electric fields it may be produce the variation of the diffraction character, and at the next fixed thickness of the semiconductor sample, may be crossing from the Bragg diffraction to another types of diffraction. The coefficient of electromagnetic wave reflection for the outer surface of the semiconductors under the conditions of Bragg resonance depends indirectly on the strength of heating field, high-frequency field of CLB, on the angle of impinge and on the parameters of semiconductors. Varying those and the value of electric field strength , one can decrease the reflection coefficient, i.e. make semiconductor "antireflective", as well as to increase it up to the value leading to almost total reflection of the weakly electromagnetic wave from the outer surface of semiconductors.

Circumscribed in this paper, the methods of theoretical investigation of electrical and optical properties of FMSC with spatially - periodic nanostructures - laser induced gratings on nonequilibrium electrons and magnons carry rather general character and are not rendered concrete. Therefore they can be applied for study of a wide class of the various phenomena in FMSC, caused by influence strong electrical, magnetic and intensive high-frequency CLB fields. The further development of examinations in this direction now leaves on a new level. Some more years ago investigations in the field of physics of FMSC carried, in main, only scientific interest. For Curie temperature of the majority from them did not exceed 100K and the problem on their wide introduction in practice did not stand. Now the situation was cardinal changed. With occurrence some years ago of new "high-temperature" ferromagnetic semiconductors on a basis on $LaMnO_3$ and diluted magnetic semiconductors (Ga, Mn)N and (Zn, Mn)O, and etc., which have Curie temperature above at room temperature (T_c> 300K) [1] interest too magnetic and, in particular, to FMSC hardly has increased. Now we stand on the verge of a "magnetoelectronics" revolution, in which these new phenomena will be exploited in devices combining magnetism with traditional electronic elements. The exploration of spin polarization of carriers represents not only departure for the field of magnetism and magnetic materials but also a new direction for the field of electronics - spin-dependence electronics. Now already proposed a number of new solid-state devices, using electron spin, for example: spin-polarization light-emitting diode, spin transistor, magnetoresistive random-access memory chips, magnetic field sensors, etc.

All above-stated allows to approve, that the further development of investigation of influence of laser radiation on physical properties of ferromagnetic semiconductors now becomes very actual, both with only scientific, and with practical of points of view.

References

1. Thousandfold Change in Resistively in Magnetoresistive La-Ca-Mn-O Films /Jin S., Tiefel T.H., McCormack M., Fastnachi R.A., Remesh R., and Chen L.H. // Science. - 1994. - V. 264.- P. 413-415.
2. Nagaev E.L. Physics of Magnetic Semiconductors. - M.: Mir, 1983. - 400 p.
3. Nagaev E.L. and. Kovalenko V.F. Photoinduced magnetism // Uspekhi Fiz. Nauk - 1986. - V.148, No.4. - P. 561-602.
4. Spin injection into semiconductors / Oestreich M., Hubner J., Hagele D., Klar P.J., Heimbrodtt, Ruhle W.W., Ashenford D.E, and Lunn B. // Appl. Phys. Lett. -1999. - V.74, No.9. - P.1251-1253.
5. Spin-valve effects in a semiconductor field-effect transistor: A spintronic device/ Gardelis S., Smith C.G., Barnes H.W., Linfield E.H., and Ritchie D.A. // Phys.Rev. B. - 1999. - V.60, No.11. - P.7764-7766.
6. Heide C. Ferromagnet-semiconductor device with tunable tunnel characteristics // J. Appl. Phys. - 2000. - V.87, No.9. - P.6379-6381.
7. Tzoar N. Nonlinear Exitation of Density Fluctuations in Electron-Phonon System // Phys.Rev. - 1967. - V. 164, No.2. - P. 518-522.
8. Seminozhenko V. P. Kinetics of interaction quasiparticles in strong eternal fields // Phys.Rep. - 1998. -V. 91, No.3.- P. 103-182.
9. Epstein E.M,.Shmelev G.M. and Tsyrkan G.I. Photostimulating processes in semiconductors. - Kishiney: Shtiintsya, 1987. - 170 p.
10. Melnikov V.I. Quantum kinetic equation for electrons in a high-frequency field // Sov. Phys. JETP Letter. - 1969. - V. 9, No.3-5. - P.120-122.
11. Dykman I.M. and Tomchuk. P.M. Influence on coherent light beams on free carriers in semiconductors // Sov.Phys.Solid.State. - 1984, - V. 26, No.9. - P.1653-1655.
12. Dykman I.M., and Tomchuk P.M. Superlattice on heated carriers formed in the semiconductor by coherent light beams // Ukr. J. Phys. - 1985. - V. 30. - P.40-48.
13. Eichler Gunter P, and. Pohl D.W. Laser-Induced Dynamic Gratings. Berlin: Springer-Verlag, 1986. - 350p.
14. Smith. H.M. Topics Applied Physics. Berlin: Springer, 1977. - 200 p.
15. Semchuk A.Yu., Levshin A.E., and Tomchuk P.M. Superlattices formed in ferromagnetic semiconductors by coherent light beams // Sov.Phys.Solid State . - 1986. - V.28, No.2. - P. 229-232.
16. Semchuk O.Yu, Grechko L.G., and Ogenko V.M. Field influent on the parameters of ferromagnetic semiconductor superlattices formed by coherent light beams // Phys.Stat.sol. (b). - 1990. - V.157. - P.451-458.
17. Sambe H. Steady States and Quasienergies of a Quantum-Mechanical System in an Oscillating Field // Phys. Rev. A. - 1973. - V.7, No.6. - P.2203-2213.
18. Akhieser A.I., Baryakhtar V.G., and Peletminski S.V. Spin Waves. Nauka: Moscow, 1967. - 367p.

19. Semchuk O.Yu., Rozhkov S.S. Transient magnetic susceptibility of ferromagnetic semiconductors // Sov. Phys. Solid State. - 1982. - V.24, No.10. - P.1730-1732.
20. Dykman I.M. and Tomchuk P.M. Electromagnetic waves in inhomogeneous semiconductors with non-equilibrium carriers // Phys.Stat.Sol. (b) -1978. - V.86, No.2. - P.773-780.
21. Semchuk O.Yu., and Gozhenko V.V. Influence of superlattice, produced by coherent light beams, on the optical properties of ferromagnetic semiconductors // Semicond. Phys. Quantum Electronics & Optoelectronics. - 1999. - V.2, No.3. - P.10-12.