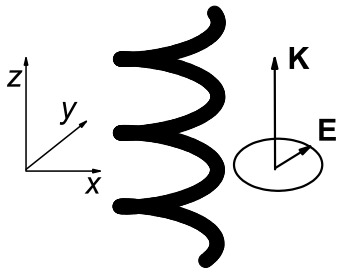
Spiral quantum wire affected by light: optical and electric response.

M.V. Entin, L.I. Magarill

Institute of Semiconductor Physics, SD of RAS, Novosibirsk, 630090, Russia

We study the electrical and optical properties conditioned by the spiral geometry of quantum wire (see Figure).



The light absorption by a spiral quantum wire is strongly subjected by the transformation of almost uniform electric field of electromagnetic wave (EMW) to spiral coordinates. In this system the circular-polarized EMW transforms to the running wave with the wavelength determined by the spiral period; the direction of propagation depends on the light polarization and the direction of the spiral. The artificial reduction of wavelength allows the collisionless absorption of light by free electrons.

Another considered effect is the appearance of the stationary current caused by the circular polarized light (photogalvanic effect, PGE). Speaking formally, this symmetry allows the existence of the third rank antisymmetric tensor, responsible for circular PGE. Figuratively speaking, the spiral transforms the rotation (circular polarized light) to the translation (current). In other words, the running wave drags electrons. In the case of intraband absorption and constant relaxation time τ the stationary current along the spiral is

$$J_0 = -\zeta\xi\tau\frac{e\pi}{2m\omega d}\ \mathrm{Re}\left[\sigma(\omega,\frac{2\pi}{d})\right](1-\eta^2)E_0^2.$$

Here $\sigma(\omega,q)$ is the one-dimensional dynamic conductivity, ω is the light frequency, q is the wave vector, η is the ratio of the pitch of the helix to the length of its turn d, E_0 is the amplitude of the electric field of EMW; the sign of $\xi=\pm1$ defines the helix direction (plus correspond to the left spiral), $\zeta=\pm1$ is the polarization of circularly EMW.

The geometry induced gyrotropy of a 3D medium constructed from identical parallel helical quantum wires is studied also. This system possesses an antisymmetric third-rank tensor $\gamma_{ijk}=-\gamma_{jik}$, arising from the expansion of space-dispersing dielectric permeability in the first-order on the wave vector $\mathbf{K}$. The gyrotropy tensor has two independent non-vanishing components of γ_{xyz} and $\gamma_{yzx}=-\gamma_{xzy}$. We have found them in the framework of free-electron model.