Photoacoustic transformation of Bessel light beams in layers of achiral and chiral carbon nanotubes

George S. Mityurich[1,*], **Ekaterina V. Lebedeva**[1], **Anatoly N.Serdyukov**[2], **Valentina V. Sviridova**[2]

[1] *Belarusian Trade and Economics University of Consumer Cooperatives, prospekt Oktyabrya 50, 246029 Gomel, Belarus*
[2] *Gomel State University, ul. Sovetskaya 104, 246019, Gomel, Belarus*
* george_mityurich@mail.ru

Carbon nanotubes (CNTs) are promising materials in various fields of science and technology. One of the main advantages of these structures is the ability to control the properties of the created CNT layers by changing the geometric dimensions and configuration of nanoobjects. The classical theory of electrodynamics can not always be applied to the description of nanotubes, and here it is required to search for new quasi classical theoretical approaches and studies that would allow solving the problems of micro- and macroscopic electrodynamics [1] underlying the theoretical basis of modern photoacoustic spectroscopy.

This work is devoted to the construction of a model of photoacoustic transformation of modes Bessel light beam (BLB) in a layer of chiral CNTs for the case of piezoelectric recording of the signal detection.

The exposure of a BLB on the absorbing layer of chiral nanotubes leads to a periodic change in the temperature field, which can be described by the equation of thermal conductivity

$$\nabla^2 T - \frac{1}{\beta_S}\frac{\partial T}{\partial t} = -\frac{1}{2k_S} Q(1 + \mathrm{e}^{i\Omega t}), \qquad (1)$$

where k_s – coefficient of thermal conductivity. In equation (1) Q is volume density of thermal sources, which is determined by expression

$$Q = \sigma_{cn}|E|^2, \qquad (2)$$

where $|\sigma_{cn}| = 2\pi|\sigma_{zz}|/\lambda$ is conductivity of the CNT layer. Substituting into formula (2) the relation that describes the intensity of the wave $I = 1/2\, n\sqrt{\varepsilon_0/\mu_0}\, |E|^2$, it is easy to obtain the energy dissipation rate:

$$Q = \left[2\sigma_{cn}/c\sqrt{\varepsilon'}\varepsilon_0\right] I_0 \exp\left(-2\alpha_{eff} z\right) \qquad (3)$$

Thus, in cylindrical coordinates, the energy dissipation rate of BLB in the layer of absorbing chiral CNTs can be represented as follows

$$Q^{TE} = \frac{c\varepsilon_0 k_0}{4\pi} Q(n_1^2 + n_2^2)\left[\left(\frac{m}{q\rho}\right)^2 J_m^2(q\rho) + J'^2_m(q\rho)\right].$$

Using the technique described in [2], an expression for the amplitude of a photoacoustic signal is obtained.

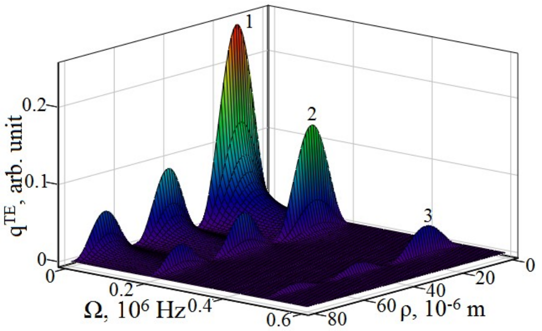

Fig.1. Dependence of the photoacoustic signal on the radial coordinate and modulation frequency of the BLB (α=1°)

The analysis of the expression for the amplitude of the photoacoustic signal (the case of the free boundaries of the "sample-piezoelectric converter" system) showed the presence of resonance peaks in the region of megahertz frequencies (Fig.1).

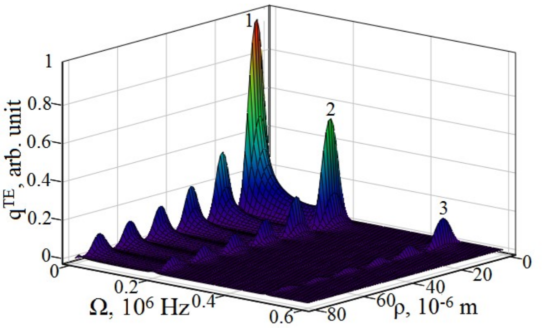

Fig.2. Dependence of the photoacoustic signal on the radial coordinate and modulation frequency of the BLB (α=2°)

The increase in the cone angle of the BLB affects the frequency of the resonance peaks as a function of the radial coordinate ρ, as well as the amplitude of the photoacoustic signal (Fig.2).

[1] S.A. Maksimenko. "Elektrodinamika uglerodnyih nanotrubok". Radiotehnika i radioelektronika. Vol. 47, p. 261 (2002).
[2] G.S. Mityurich, E.V. Chernenok, V.V. Sviridova et al. "Photoacoustic transformation of Bessel light beams in magnetoactive superlattices". Crystallography Reports, p. 273 (2015).