CALCULATION OF CHARACTERISTICS OF A BROWNIAN PHOTOMOTOR WITH A THREE-LEVEL ELECTRONIC SUBSYSTEM

Yuliya A. Kamysh, Irina V. Shapochkina

Department of Physics, Belarusian State University, Belarus
juliak1995@mail.ru

We present the results which are further development of the research of functioning mechanisms and operating modes of Brownian photomotors (ratchets) with a three-level electronic subsystem [1, 2]. Brownian photomotors move directionally due to changes in electronic density of a nanoparticle, in an asymmetric environment, under the action of cyclically acting laser pulses. We simulated the behavior (time changes) of populations of energy levels, including the dynamics of establishment of a stationary mode in the system.

Within the three-level model with a long duration of intervals with the laser turned off, it has been shown that the maximal motor effect is achieved with intensities and lifetimes of the states reducing the system to a two-level one. We investigated the kinetics of the three-level model of the electronic subsystem with arbitrary transition rate constants as well as the mechanism of optimization of functioning of a photomotor due to the contribution of an impurity non-resonant level, at time intervals with the laser turned off. The possibility of controlling the moment of occurrence of the motor effect is demonstrated, and it is concluded that with a certain choice of the system parameters, the main motor effect may occur when the laser is turned off.

The calculation of Brownian photomotor average velocity itself required specification of the potential energy of interaction of a nanoparticle with a substrate along which it moves. In the dipole approximation and under the assumption of one-dimensionality of the motion, this energy can be written as:

$$U(x,t) = -\sum_{j=1}^{3} n_j(t)\mu_j E(x)\,,$$

where μ_j is the dipole moment of the j th level, $n_j(t)$ is the probability of finding an electron in the j th state, and $E(x)$ is the strength the electric field of the substrate. For $\mu_1 = \mu_2 = 0$, $\mu_3 = \mu$, the function $U(x,t)$ is a special case of the additive-multiplicative representation $U(x,t) = u(x) + \sigma(t)w(x)$ with $\sigma(t) = n_3(t) - 1$ and $u(x) = w(x) = \mu E(x)$. This fact made it possible to use the high-temperature results of work [3] (Eq. (10)), specified for a periodic deterministic process (Eq. (15)), to calculate the average velocity of a Brownian photomotor and to study its dependence on frequency and geometric parameters of the system.

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