Self-organized aggregation simulation of resonant nanoparticles in a laser field

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***Abstract* — Self-organized aggregation of nanoparticles in external resonant laser field is considered using Brownian dynamics model. Formation probabilities are calculated for the pair of particles in dependence on laser wavelength and mutual orientation of particles. Times required for aggregation are calculated. Possibility of efficient aggregation using pulsed laser is deduced.**

Keywords — interaction of laser radiation with matter, dipole-dipole interaction, nanoparticles, nanostructures

I. INTRODUCTION

A method of nanoparticles self-organization into pre-defined structures under resonant laser field action was proposed in [1, 2]. The method in question allows formation of structures with pre-defined topology in the course of step-by-step self-assembly of several resonant nanoparticles made from different materials. It is evident that dimensions of structures as well as those of constituting particles are much less than the wavelength of laser radiation inducing their aggregation. These attractive results, however, are insufficient for planning the experiment on the formation of the structures in question. Valuable information would be obtained from more detailed studies in order to determine rate of structure formation, preferable operating conditions of laser, frequency and intensity of radiation that are necessary to overcome the barrier preventing spontaneous aggregation of particles. Present work represents the aggregation of nanoparticles under the laser field action in terms of Brownian dynamics considering the dipole-dipole interaction induced by laser field.

II. CALCULATION RESULTS

Following characteristic values were used in the modeling: medium temperature $T = 300$ K, viscosity $\eta = 0.8902$ mPa·s, Intensity of laser radiation was $I = 10^6$ W/cm^2. Results of calculations of aggregation probability for particles at the interaction distance at different positions of them with respect to field polarization are presented in Fig. 1 for external field wavelength 610 nm. Polar angle β denotes the angle between interparticle vector and direction of laser field polarization. Initially particles were considered to be positioned at the distance where pair interaction energy for 610 nm is equal to kT.

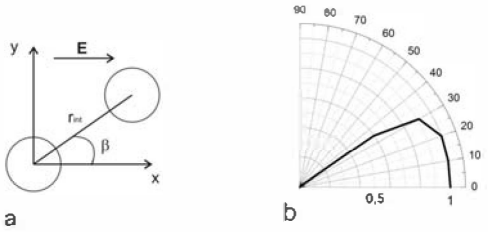

Fig. 1. (a) Configuration of particle pair. (b) Probability of aggregation in dependence on the orientation of the particle pair with respect to field polarization (x axis)

At angles below 20° structure formation probability is close to 100%, and at larger angles it rapidly decreases to approximately zero at 45°. Time required for structure formation in dependence on the mutual orientation of particles for field wavelength $\lambda = 610$ nm is plotted in Fig. 2.

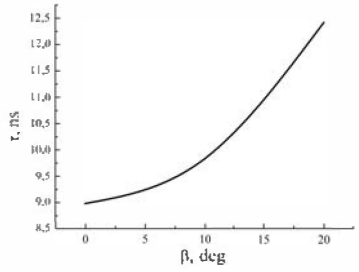

Fig. 2. Dependence of time required for structure formation on the angle β (see Fig. 1a)

At chosen laser intensity structure formation time is of order of 10 ns within the angle range to 20°. At $\beta = 30°$ this time grows to $5.23 \cdot 10^{-7}$ s.

It is shown that the process of nanoparticle dimer formation is possible under medium intensity of laser radiation and the pulse duration order of 10 ns that allows using pulsed laser for aggregation control.

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[2] V.V. Slabko, A.S. Tsipotan, A.S. Aleksandrovsky, "Self-organised aggregation of a pair of particles with different resonant frequencies and electric dipole moments of transitions, controlled by an external quasi-resonant field", Quantum Electron, vol. 43, pp. 458-462, 2013