Self-organized aggregation of a triple of resonant nanoparticles into stable structures with various shapes controlled by a laser field

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Abstract. The method of formation of nanostructures consisting of three particles in the field of quasiresonant laser radiation is considered. To obtain structures, two approaches were used: a third particle is added to a pre-formed particlespair at a certain angle; the necessary structure is formed from three initially isolated particles. Numerically shown that it is possibleto assemble structures of line and pyramid using both previously mentioned approaches.

1. Introduction

Inrecent decades, nanostructures with unique properties other than properties of a bulk sample and dependent on both composition and shape have been studying actively. Therefore, the problem of developing a universal method of nanostructures formation is a subject of interest of many scientists. The least expensive method of obtaining colloidal crystals, which doesn't require a local physical impact on the system, is based on the ability of nanoparticles to self-organize in the process of random Brownian collisions in real disperse systems [1]. However, in such case it is impossible to control the processes of formation of nanostructures with predetermined shapes. Therefore, one of the possible solutions of this problem is the physical impact on the ensembles of nanoparticles that allows the formation of complex nanostructures without additional surface modifications [2]. However, it isn't always possible to achieve the selectivity of the self-assembly process.

Earlier in [4-5], it was shown that the interaction of resonant nanoparticles in the field of laser radiation makes possible the formation of predetermined structures, since the energy of the induced dipole-dipole interaction is sufficient to overcome the barrier that prevents spontaneous aggregation (which makes possible the formation a stable structure), and their geometry depends on the wavelength and the polarization of the external field. In this case, the formation of structures, which scale is much smaller than the wavelength of the laser radiation caused this polarization, becomes possible.The presence of optical resonances in the particle leads to an increase of the interparticle interaction and is the basis for the selective formation of different structures with a predetermined position of the particles in the aggregate.It becomes possible because the energy of the interparticle interaction in the laser radiation field depends on its frequency, the resonance frequencies of the particles, and on the orientation of their group relatively to the plane of polarization.

The experiments [3-5] on the formation of pairs of colloidal quantum dots in the field of laser radiation have shown the possibility of realizing this method. The further formation of more complex structures (three or more particles) can be realized in the way of a step-by-step process, when a third particle is added to an already formed pair of particles, via selecting the wavelength of the external field.

2. Results

In this study, a dynamic self-assembly model for a triple of particles in a laser field using Brownian dynamics is proposed.The possibility of forming a three-particle structure with a predetermined geometry in two variants is studied: from a preformed pair of particles not fixed in a space (Fig. 1) and from triple of isolated particles (Fig. 2).

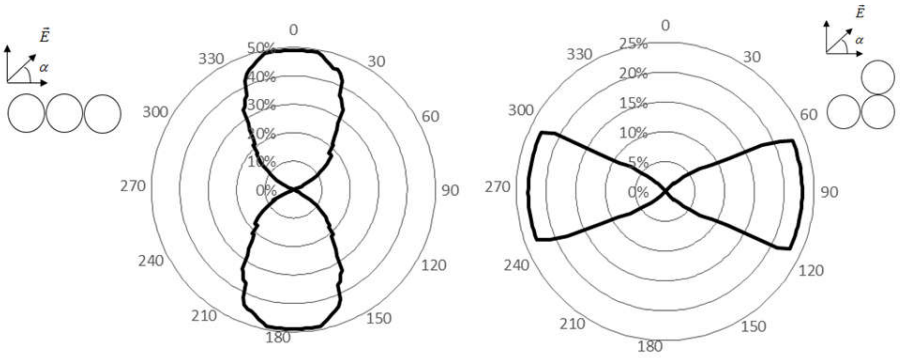

Figure 1. Probability of triple nanoparticles (from preformed pair of particles) aggregation as function of angel α at wavelength of external field λ_r=690 nm.

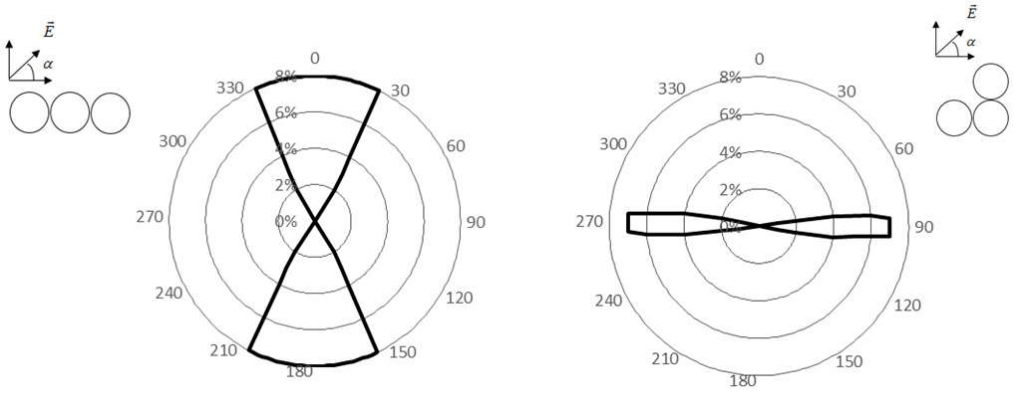

Figure 2. Probability of triple nanoparticles (from isolated particles) aggregation as function of angel α at wavelength of external field λ_r=675 nm.

The obtained results allows to make significant progress in the study of the method of structures self-assembly in the field of laser radiation, which can be use as universal method to form structures with specified properties that will find application as sensors, photodiode elements and solar cells.

3. References

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Acknowledgments
The reported study was funded by Russian Foundation for Basic Research, Government of Krasnoyarsk Territory, and Krasnoyarsk Regional Fund of Science to the research project: «Optical binding as a mechanism for self-assembly of stable complex nanostructures from resonant nanoparticles» (project № 18-42-243008). V.V.S. is grateful for the support from Ministry of Education and Science of the Russian Federation (Grant № 3.6341.2017/6.7).