Vortex motion in a mixture of active and passive Brownian particles

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Introduction

Active colloidal systems are a continuous medium (plasma, gas or liquid) containing distributed absorbing microparticles. A specific aspect of such systems is the ability to convert external energy into directional motion [1]. Systems with solid-phase particles (such as dusty plasma and active suspensions) are characterized by the existence of charge distributed at the surface of active particles and influencing their kinetic properties. Active suspensions are able to form a stable dimensional structures, changing according to the external influence [2].

The results of an experimental study of a motion in a colloidal system, which is a extended structure of particles with coating and without it, under the laser radiation are presented. Dynamic characteristics such as MSD and coefficient of diffusion on time for this active colloidal system are also presented.

Experiment and results

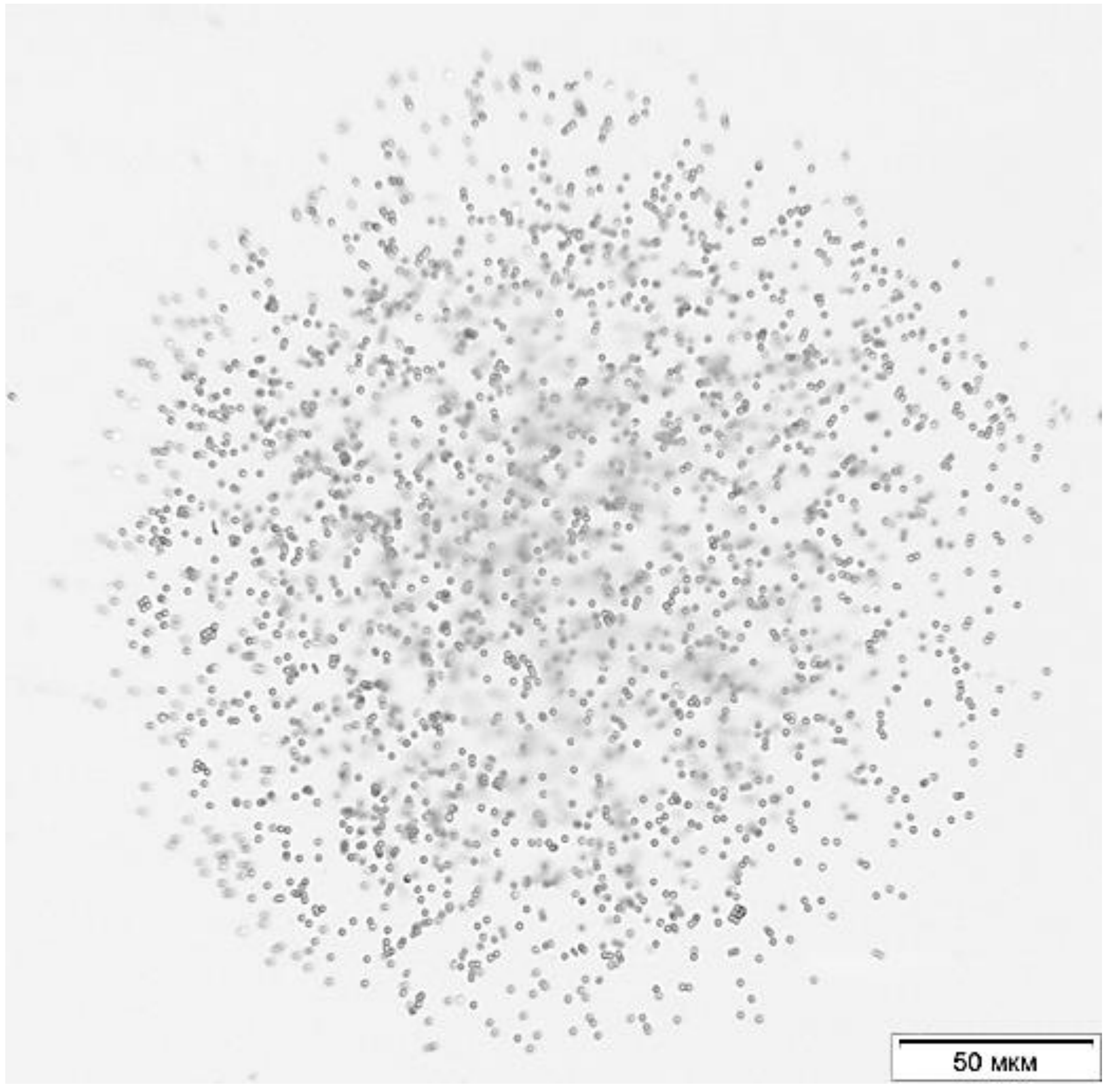

Figure 1. Colloidal system before laser exposure

Experimentally studied the dynamic properties of the system of a mixture of active Brownian particles of melamine-formaldehyde with partial copper coating and passive uncoated particles in a viscous liquid medium (mineral oil) under the laser radiation exposure (see **Figure 1**). The structure contained about 3.000 particles. Laser radiation of fixed power was driving the coated particles. The metal surface of the particles was heated and a local temperature gradient occurred, causing the motion of the particles (see **Figure 2**). Initially, the particles formed a one-directional closed flow of spherical shape. The active particles were carried away the passive particles. The particles obtained different velocities: the highest for active particles absorbing laser radiation and the lowest for passive particles scattering it. During the long exposure in the laser beam, the homogeneous flow was divided into two differently directed vortices, also occurred the separation of particles - slow passive particles moved out to the periphery.

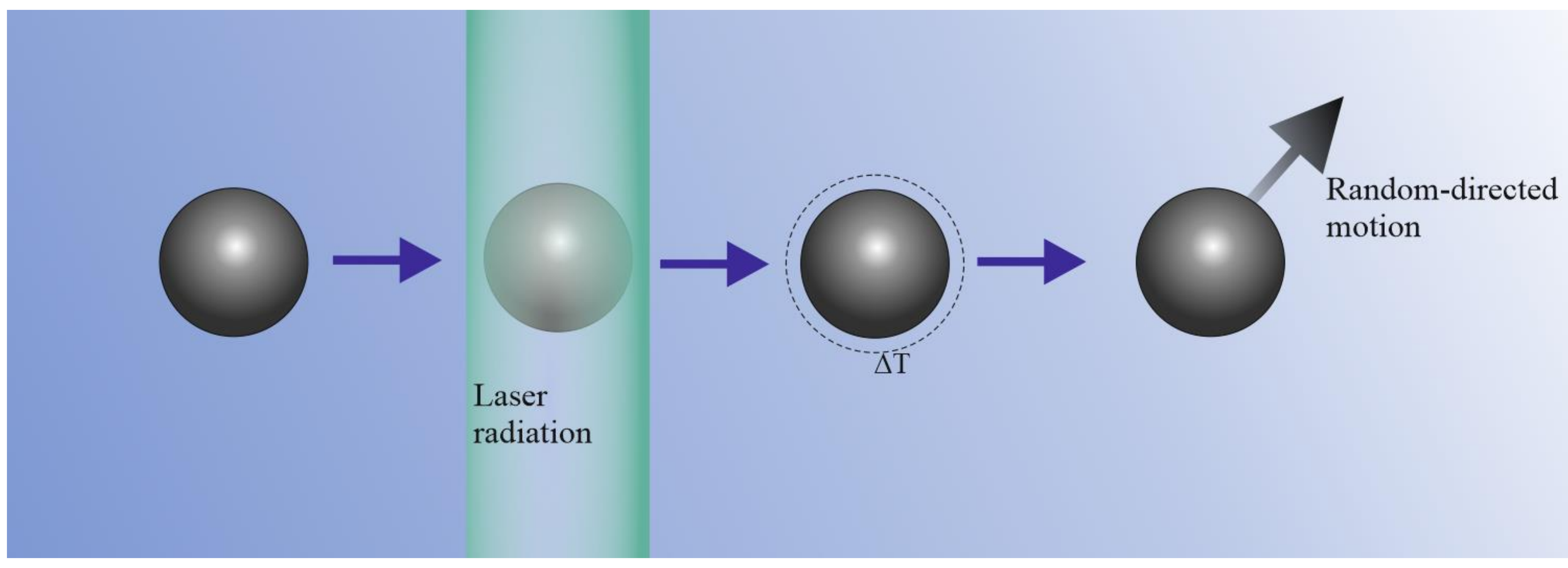

Figure 2. Mechanism of thermophoretic motion of a single particle

The surface charge at each coated particle in its diffused layer was calculated. It is 76.2572 eV for a 3.72 nm thick layer, which corresponds to a layer of hydrocarbon oil ions (see **Figure 3**).

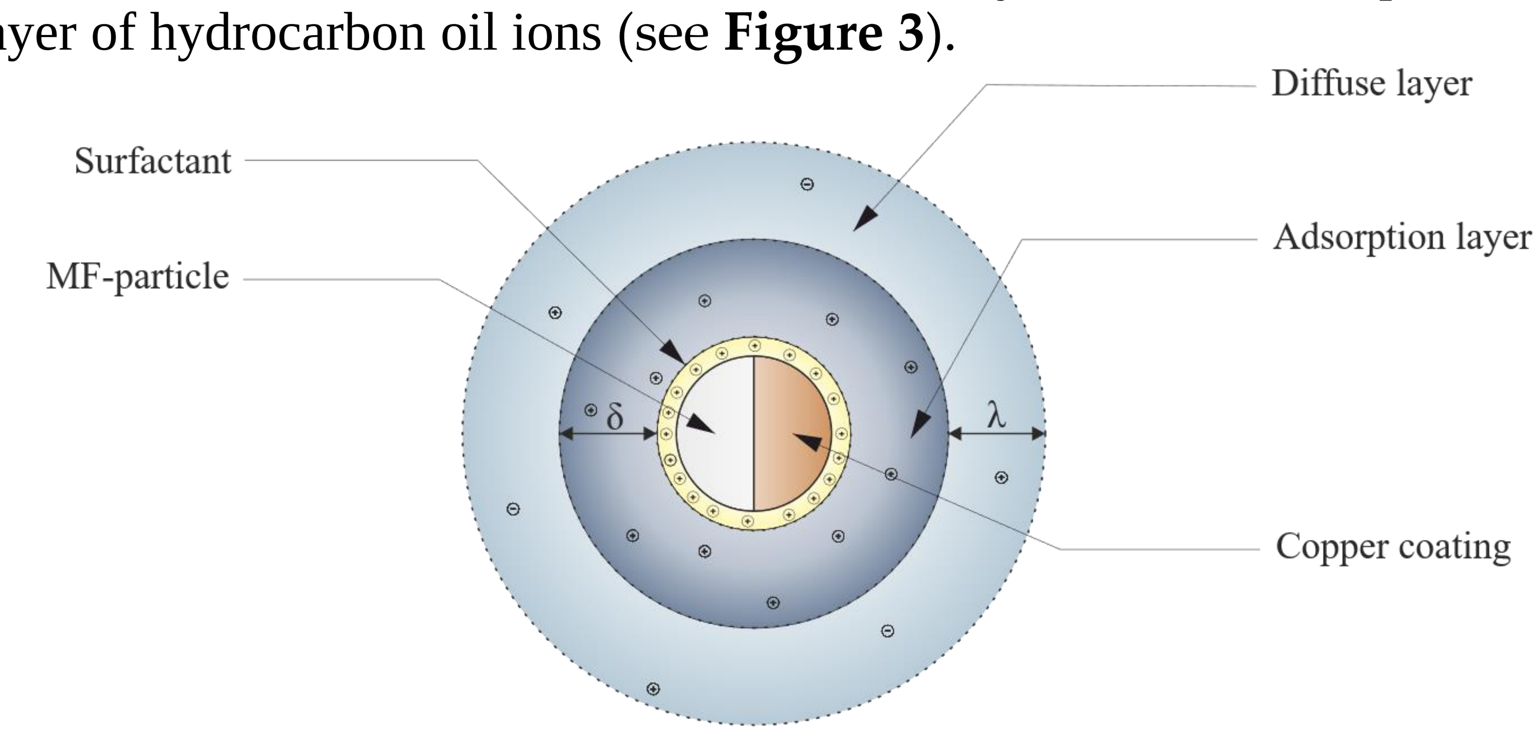

Figure 3. Scheme of a double electric layer at the particles surface

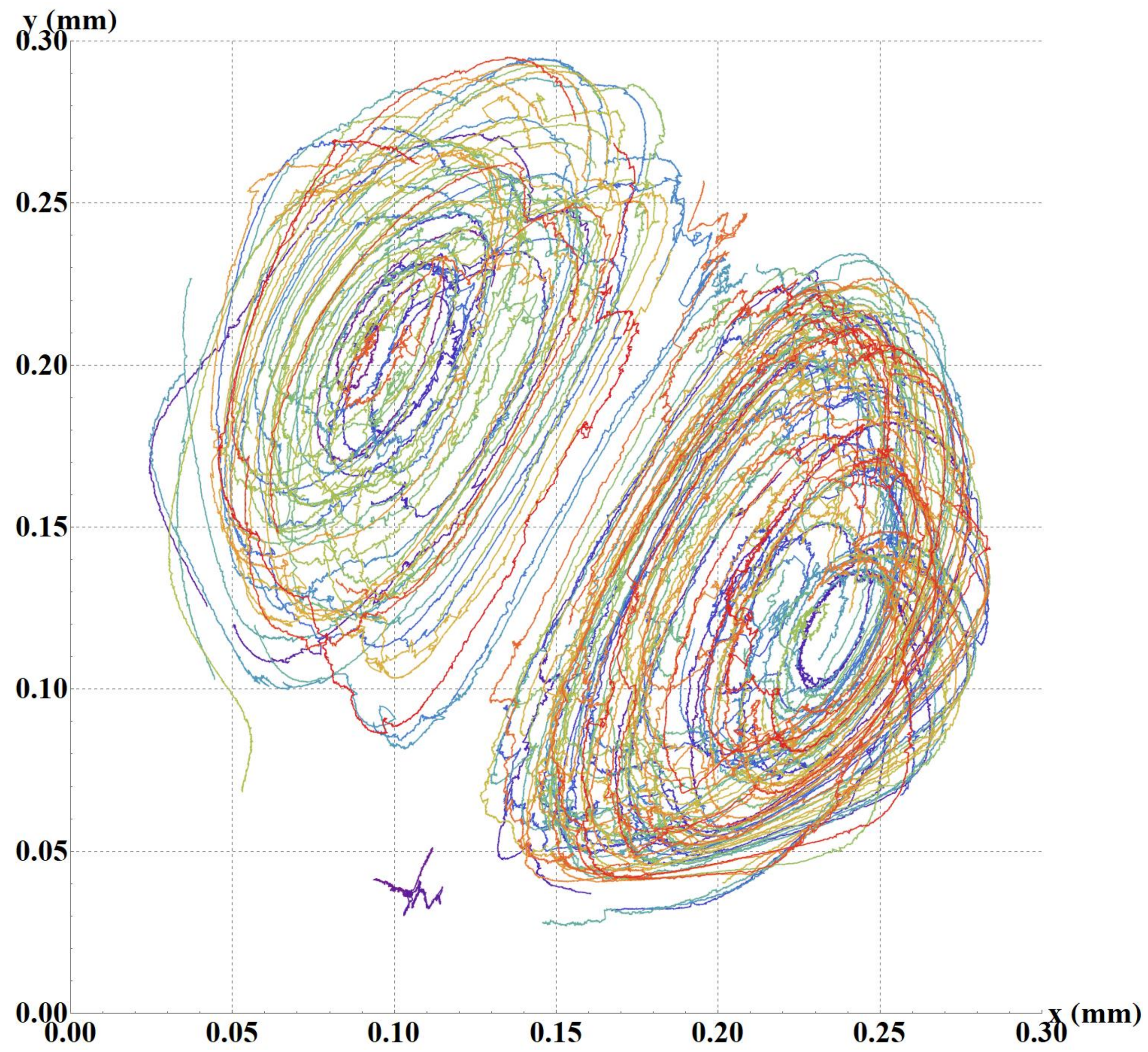

Figure 4. Characteristic particle trajectories

The coordinates of 385 characteristic particles for each moment of time were determined, and their trajectories were constructed and analyzed (see **Figure 4**). Mean velocities, mean square displacement (see **Figure 5**), diffusion coefficients of their motion were measured and analyzed. For active particles D_T is $5.22 \cdot 10^{-8}$ cm²/s and E_k is $1.17 \cdot 10^{-25}$ J. Distribution of particles velocities were constructed (see **Figure 6**).

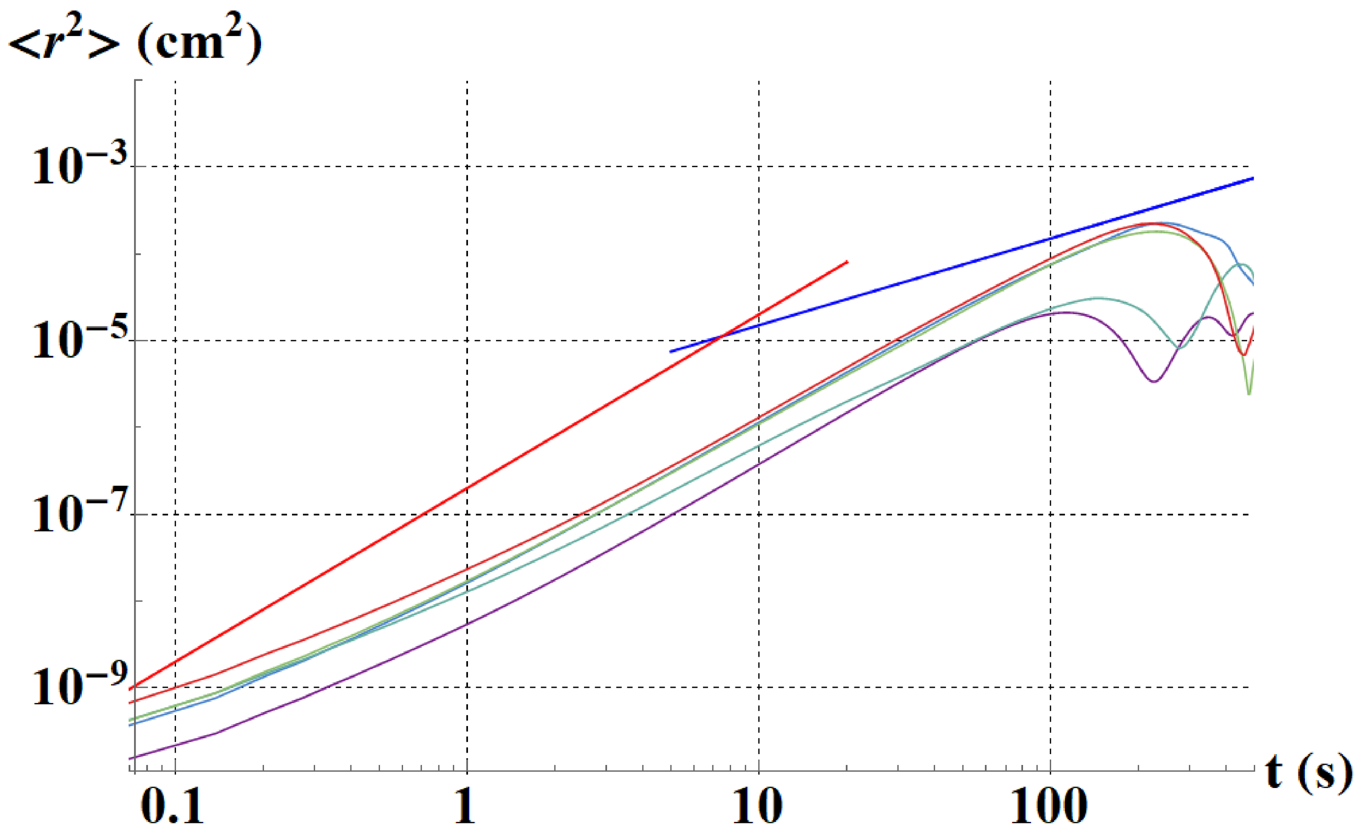

Figure 5. Characteristic particle mean square displacements (MSD)

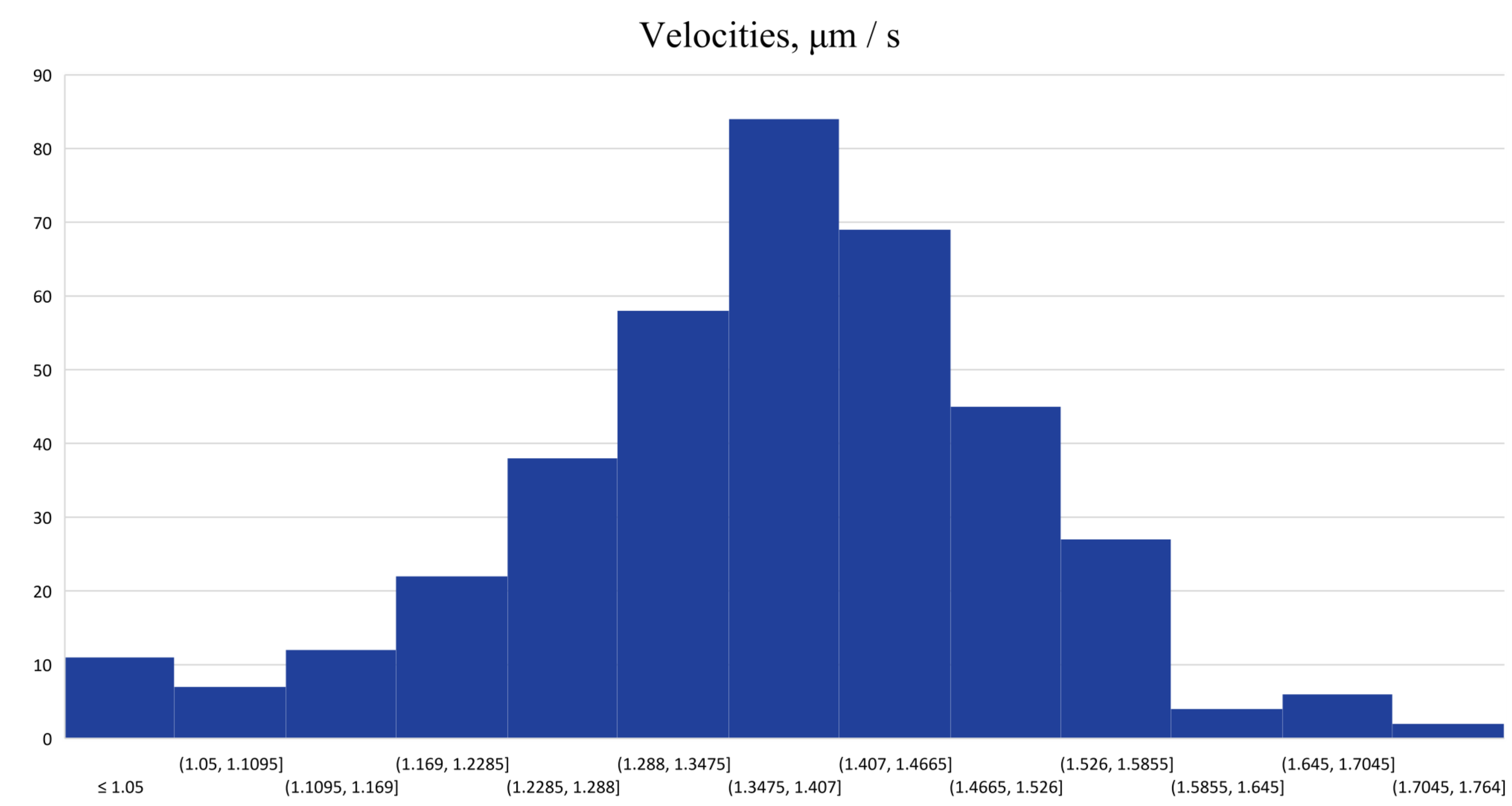

Figure 6. Distribution of particles velocities

References:

1. **Ebbens, S. J.** Active colloids: Progress and challenges towards realising autonomous applications. Current Opinion in Colloid & Interface Science vol. 21 14–23 (2016).
2. **Madden, I. P. et al.** Hydrodynamically Controlled Self-Organization in Mixtures of Active and Passive Colloids. Small vol. 18 (2022).

Conclusion

The vortex motion was experimentally observed in the structure under laser radiation. The separation of active and passive particles in the structure occurred due to their different absorption properties. Similar motion also can be observed in other active colloidal systems such dusty plasma

The study of such active structures in colloidal systems allows us to understand similar processes in natural colloidal systems.