Brownian-like motion of a single dust grain in a radio-frequency plasma discharge – comparison of experiments and simulation

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Bronwnian-like motion of a single dust-grain in a radio frequency plasma has been studied by different research groups. The rise of the particles temperature above “room temperature” is attributed to e.g. random fluctuations of the particle charge and fluctuations of the electrical field. Additional disturbance might occur due to gas density variations, temporal variation of the particles mass and particle interaction with the illuminating laser light. In addition, a non-optimal frame rate of the optical diagnostic system and pixel locking can lead to an incorrect estimation of the particle kinetic temperature.

Our experiments are conducted in a weakly ionized radio-frequency gas discharge at a low neutral gas pressure and power. A single micron sized spherical particle is trapped in a harmonic-like potential trap in the sheath of the lower driven electrode [1]. Its two-dimensional planar motion is recorded with a long-distance microscope and a high-resolution camera. From the measured particle positions we derive the probability density function, the velocity autocorrelation function and the mean squared displacement.

We obtain a particle kinetic temperature above 350 K, a neutral gas damping time of about 0.5 sec and a resonance frequency of 1-2 Hz. Anisotropic oscillation of the particle occurs, leading to angle dependent temperatures along the x and y direction in the plane of the recorded images, which can be explained by the presence of an asymmetric horizontal potential trap.

Experimental observations are compared with our simulations using md simulations and the Ornstein-Uhlenbeck stochastic process.

REFERENCES

[1] Rubin-Zuzic, Milenko und Nosenko, Volodymyr und Zhdanov, Sergey und Ivlev, Alexei und Thomas, Hubertus und Khrapak, Sergey und Couedel, Lenaic. Single Particle Dynamics in a Radio-Frequency Produced Plasma Sheath, AIP Conference Proceedings 1925, 020023 (2018), https://doi.org/10.1063/1.5020411