Dynamics of a complex plasma measured with a 3D light field camera

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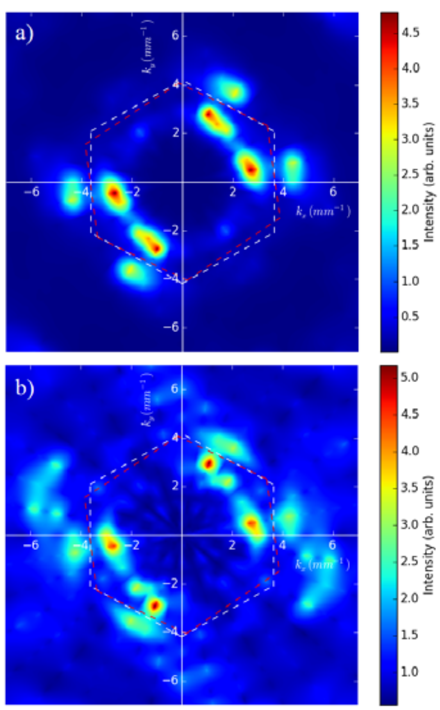
The dynamics of a single-layer complex plasma crystal was measured by performing its three-dimensional (3D) imaging with a light field camera. To enrich the crystal's dynamics, the mode-coupling instability (MCI) was triggered in it by lowering the discharge power below a threshold. 3D coordinates of all particles in the crystal were extracted from the recorded video. All three fundamental wave modes of the plasma crystal were calculated from the particle velocity. In the out-of-plane spectrum, only the MCI-induced hot spots (corresponding to the unstable hybrid mode) were resolved. Both longitudinal in-plane and out-of-plane wave modes show profound anisotropy. The results are in agreement with theory and simulations and show that light field cameras can be used to measure 3D dynamics of complex plasmas.

A complex (dusty) plasma is a suspension of micron-size solid particles in a weakly ionized gas. Particles acquire high electric charges, interact with each other and their environment, and often form strongly coupled subsystems. The particles can be individually imaged in real time, which makes complex plasmas excellent model systems to study various generic phenomena in liquids and solids.

A long-standing challenge in the field of complex plasmas is accurate measurement of individual particles' 3D coordinates. 3D imaging methods used so far include stereoscopy, color gradient method, laser tomography, digital in-line holography. A recent development is using light field cameras for single-camera, single-shot imaging of 3D particle suspensions. In a light field camera, an additional array of microlenses is placed just in front of the image sensor; this allows to measure not only the intensity, but also the direction of the light oncoming on a microlens. Dedicated software uses triangulation to calculate all three coordinates of the imaged particles. In [1], a commercial Raytrix R5 light field camera was used to perform 3D imaging of a single-layer complex plasma crystal suspended in a rf discharge in argon. To enhance the out-of-plane oscillations of particles, the mode-coupling instability was triggered by lowering the discharge power below a threshold.



Fluctuation spectra of the particle velocity for a) longitudinal in-plane mode, b) out-of-plane mode. The white (red) dashed lines indicate the border of the ideal (real) first Brillouin zone. Both wave modes show profound anisotropy.

In this contribution, we present further analysis of the plasma crystal's wave modes calculated from the particles' 3D coordinates. The Fourier transform in space and time domains of the particle velocity was integrated over the hybrid mode frequency (in the range of 8.4-10.8 Hz), the result is plotted on the wave number (k_x, k_y) plane in the Figure. As is clearly seen, both wave modes show profound anisotropy. This result is consistent with a previous experiment, theory [2], and molecular dynamics simulations [3] and is explained by a shear deformation of the plasma crystal.

[1] M. Jambor, V. Nosenko, S. K. Zhdanov, H. M. Thomas, Rev. Sci. Instrum. **87** (2016) 033505.

[2] A. V. Ivlev, T. B. Röcker, L. Couëdel, V. Nosenko, C.-R. Du, Phys. Rev. E **91** (2015) 063108.

[3] I. Laut, C. Räth, S. Zhdanov, V. Nosenko, L. Couëdel, H. M. Thomas, EPL **110** (2015) 65001.