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Investigating the Angular Momentum of Dusty Plasma Multi-Rings

Isaac M. Long
Ohio Northern University

Kiser Z. Colley
Ohio Northern University

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K. Z. Colley, I. M. Long and W. L. Theisen
ONU Physics

Abstract

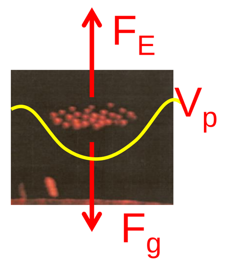
Multi-ring dusty plasma systems were created using a grooved rf electrode. These complex plasma systems had distinct sections consisting of a certain number of rings (1-ring section, 2-ring section, 3-ring section, 4-ring section). These rings had the tendency to rotate azimuthally about the center of the electrode, which allowed for a sectional angular velocity (ω) to be calculated. It was determined that as the number of dust rings (therefore the mass) increased, ω decreased which agrees with conservation of angular momentum. The pressure was also varied and it was found that as pressure increased, the width of the well decreased leading to a reduction of the inter-particle spacing causing ω to decrease.

Plasma

- Glowing gas composed of positively charged ions and electrons.
- Charged particles in the plasma interact with each other exhibiting collective effects.

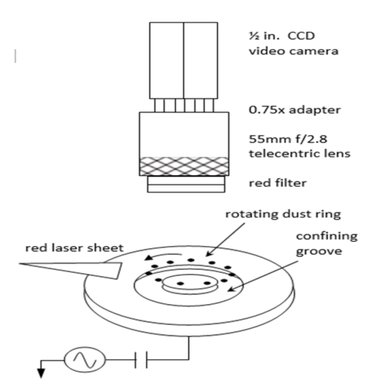
Dusty Plasmas

- Dust particles are found in many types of plasmas.
- The particles carry a negative charge.
- The dust interacts with electric fields, magnetic fields, and gravity.



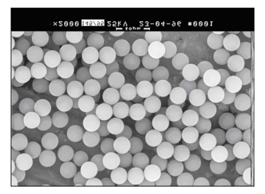
Experiment

- Dust is trapped in the ring shaped plasma sheath formed above the electrode.
- A laser sheet illuminates the dust particles
- Overhead camera records the multi-ring dynamics

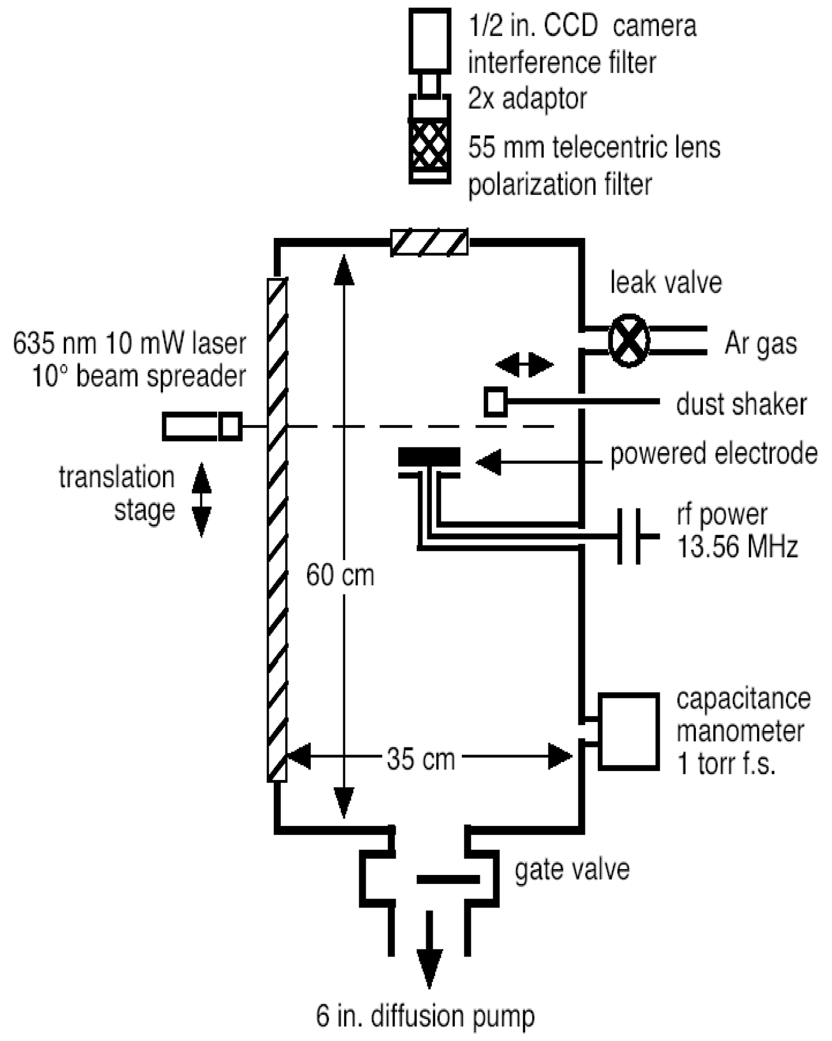


Experimental Parameters

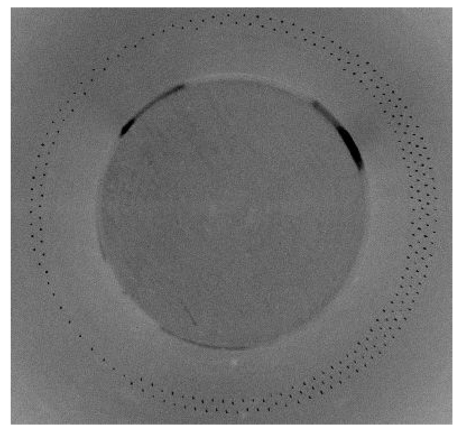
- Neutral Pressure 17.5 mtorr Ar
- rf power ~4.5 W
- rf electrode diameter 89 mm
- Dust particles: microspheres
  diameter = 8.94 ± 0.09 µm
  mass = 5.65 x 10^{-13} kg
- Video: 2048 frames of data at 15 frames/second
  256 x 1024 pixels



Schematic of Dusty Plasma Device



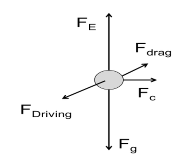
Multi-Ring



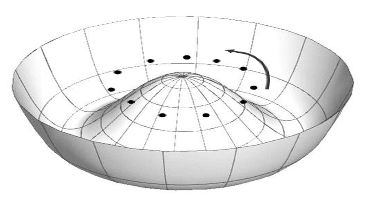
- Multi-ring system is shown
- Sections of the multi-ring rotate at different angular velocities

Force diagram

a) Forces acting on the dust particle

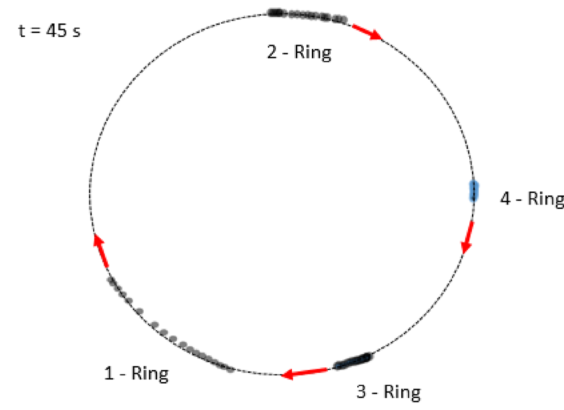


b) Plasma sheath with dust particles



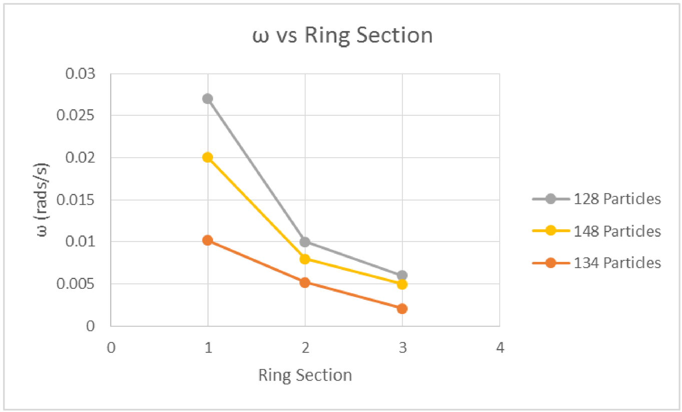
Dust Particle Rotation

- The time-lapse motion of a particle in each section of the ring is shown below for t = 45 s
- The diagram shows that the lower the number of particles in the section, the faster the rotation in a given time
- The rotation rate for each section of the ring is consistent with the conservation of angular momentum
- Arrows have been added to show the direction of rotation



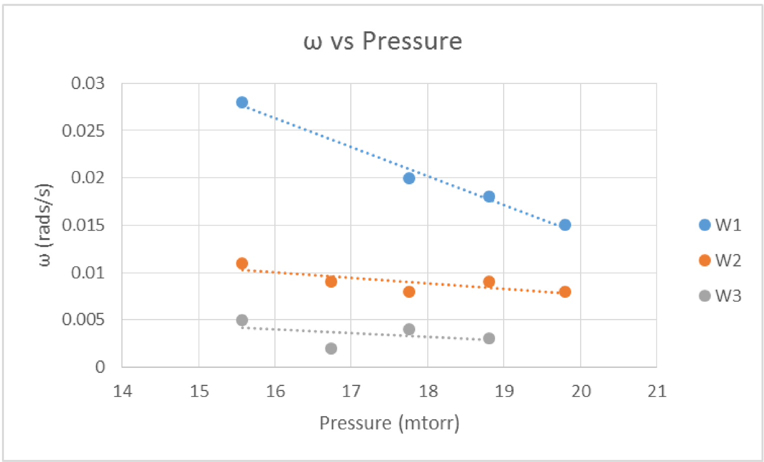
ω vs Ring Section

- Data from three different multi-ring systems is shown
- Data shows that as the number of particles in the ring section increases angular velocity decreases Data is consistent with conservation of angular momentum



ω vs Pressure

- Data is collected from one multi-ring system
- Increasing the pressure narrows the potential well which decreases the inter-particle spacing
- Data shows that as the pressure increases the angular velocity tends to decrease



Further Study

- Further analysis of particle motion in the sheath structure using individual particle motions
- Analysis of the ion drag force that is thought to result from the magnetic field generated by the flow of ions into the anode