Acousto-Electric Containerless Levitation of 2D and 3D Arrays

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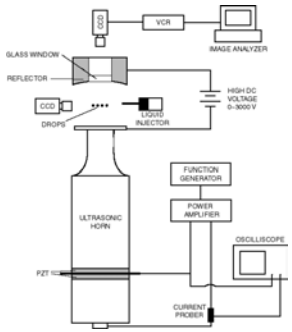
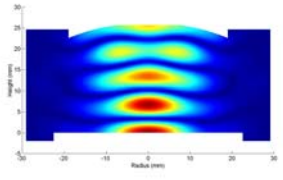
An Acousto-Electric Levitator

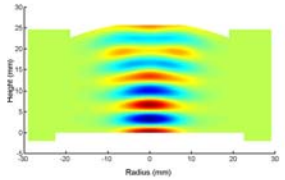


The generation, control, and applications of drop and particle arrays cover a vast subject of fundamental and practical interest in material sciences, fluid dynamics, combustion and environmental research. The acousto-electric levitator is a novel and compact device for studying the behavior of drop and particle arrays without any physical contact by using acoustic and electric fields simultaneously to levitate charged drops and particles.

Numerical Modeling with FEM



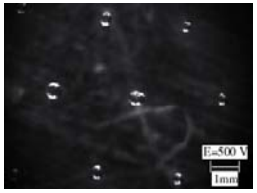
Acoustic pressure amplitude

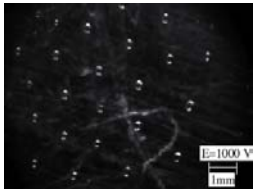


Acoustic radiation potential

In an acousto-electric levitator, there are not only vertical levitation forces, but also lateral acoustic forces that hold arrays to the center. The finite element method with the perfectly-matched-layer absorbing boundary condition has been successfully employed to calculate the 3D acoustic field and acoustic radiation forces in such an open-sided levitator. This method can estimate the resonance frequencies and quality factors of the levitator. It enables us to understand the stability of the levitation, to improve the design of the device, and to better control the drop spacing and array size.

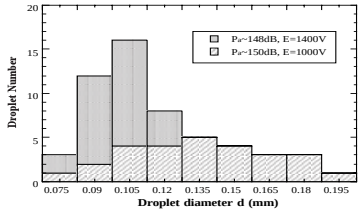
2D Drop Arrays





Charged 2D ethanol drop arrays generated by different electric fields while the acoustic field is kept constant

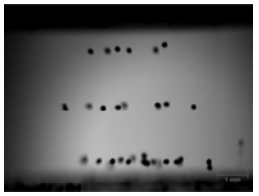
- **Seed droplet formation:** If a few drops of ethanol are placed on the bottom plate of the levitator, the liquid atomizes into fine seed droplets (25-40 μm at 28.4 KHz) due to the strong vibration of the transducer.
- **Cluster formation:** Seed droplets are charged and aggregate together to form a 2D cluster. The size of these clusters is determined by the balance of acoustic attraction and electric repulsion.
- **Cluster coalescence:** The seed droplets in the cluster will coalesce into a larger array drop when acoustic attraction increases.
- **Array formation:** As each array drop forms, it finds its new position in an array with a minimum total energy of the system. The drop spacing and size seem reasonably uniform and controllable with acoustic and electric field adjustment.



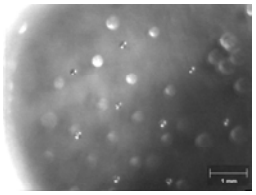
Drop size distributions for two different field conditions

Research Supported By NASA Grant NAG3-2147
and NSF CTS-987005

3D Magnesium Particle Array



Side view



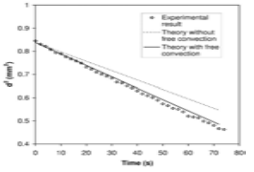
Top view of the middle layer

In a high frequency acousto-electric levitator at 96 KHz, we are able to levitate several layers of 2D charged magnesium particles to generate a 3D array, in which the distance between layers and the drop spacing in each layer are similar.

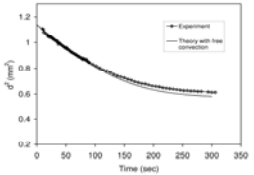
Application in Drop Evaporation

Acousto-electric levitation has been used in the study of single and multiple component drop evaporation. With the compensation of the electric levitation force, the acoustic field can be reduced to the minimum value so that the acoustic streaming effect is greatly decreased. Acousto-electric levitation can keep the drop shape close to a sphere without any physical support. It is very successful in the experiments of evaporation of drops of millimeter size.

Acousto-electric levitation has promising applications in the microgravity environment.



Evaporation of an octane drop



Evaporation of a drop of
a mixture of octane and dodecane