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Demonstration of Ion Trap Principles

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Background

Particle trapping is powerful tool for working with micro- and nano-components. Much interest now revolves around length scales where *quantum mechanical* effects become pronounced. Quantum mechanics forms our *only* framework for understanding many problems in solid-state physics (*e.g.*, magnetism), and is playing an ever more important role in applied chemistry, biochemistry and many other areas. Trapping technologies provide a *test bed* for systematic exploration of fundamental paradigms, offering enhancements to our understanding of key mechanisms and, perhaps, opportunities for quantum information technology.

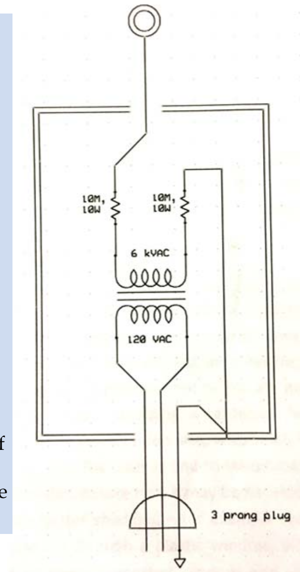
Initial Trapping Sub-System Design

The shape of the *potential energy landscape* produced through application of electric fields is dominated by the *geometry* of any electrodes in close proximity. For our initial work, we have utilized a simple *circular* electrode, suspended vertically.

We *oscillate* the applied voltage at a frequency sufficient to stabilize a trapped particle, which is an issue we hope to more systematically investigate as we move to smaller and smaller particles in environments with less and less damping (to be achieved by evacuating air from the sample space)

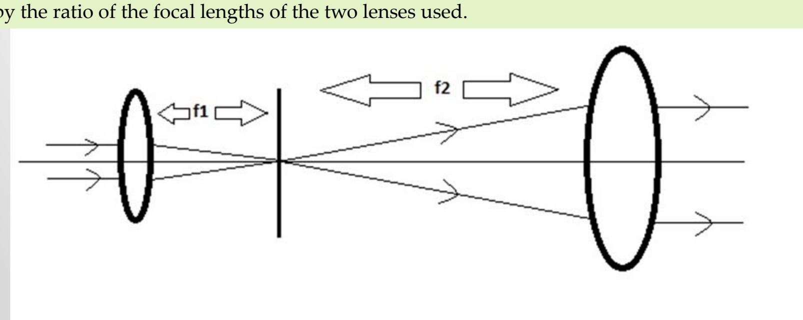
Currently, given 6000 Volt excitation of the circular electrode, 60Hz frequency of oscillation is sufficient for trapping relatively large (~ 25-micron) particles, in air at one atmosphere.

Shown at right is the circular electrode (at top), along with two 10M-ohms resistors, which limit the amount of current required of our source, which is a simple transformer. The resistors and transformer are in a grounded enclosure, minimizing the influence of stray fields.



Initial Detection Sub-System Design

In our initial design, scattering of laser light is utilized for confirmation of particle trapping. Because green light is detectable at very low levels by the human eye, we use a green laser to illuminate the central hole of our circular electrode. So that a large region might be illuminated, we constructed a "beam expander," consisting of two positive lenses separated by the sum of their focal lengths (as shown below): when the collimated input beam passes through the first lens, it becomes a converging beam, until reaching the common focal point of the two lenses, after which it diverges from this point until reaching the second lens. The rays reaching that second lens are emanating from its focal point, and so are transmitted parallel to the optic axis. The result is a collimated output beam, with a diameter enhanced by the ratio of the focal lengths of the two lenses used.

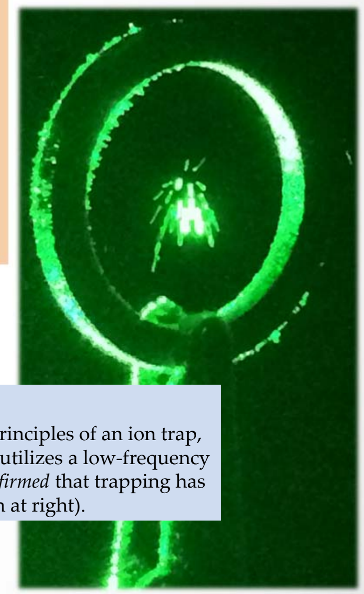


Initial Samples

Our initial samples have been Lycopodium powder (sold commercially as "Dragon's Breath" for use for special effects in the theatre). These non-toxic natural spores, with a diameter of 20-30 micrometers, can be charged up through contact with a Teflon rod that has been rubbed with cloth, to build up a static charge.

When blown into the interior of our circular electrode, the various electrical and gravitational forces acting on the particles balance out, leaving them "trapped" in the region illuminated by our expanded laser beam.

The "streaks" shown at right consist of large numbers of aggregated particles, though trapping is also attainable under these conditions with single spores.



Initial Results

We have assembled a Newtonian Lab demonstration trap, demonstrating key principles of an ion trap, as a first step toward more advanced particle-trapping technology. This system utilizes a low-frequency alternating voltage to trap charged relatively large micro-particles. We have *confirmed* that trapping has occurred, by scattering visible laser beams off of the trapped particles (as shown at right).

Future Work

Our next step is to explore designs for a hybrid combination of high-frequency optical tweezers with the sort of low-frequency electrostatic trap we have demonstrated, with the goal of stabilizing particles trapped in low-pressure atmospheres, where it may be possible to achieve cooling towards the quantum mechanical ground state of at least one degree of freedom.