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Moon Dust and Other Curious Phenomena

Dr. Steve Rapp
Linwood Holton Governor's School
P.O. Box 1987
Abingdon, VA 24210
srapp@hgs.k12.va.us

***Abstract*—Moon Dust seemed to be a really exciting topic and some research was completed. I presented a lesson on Moon Dust at the National Education Association in Washington, D.C. on July 13. There are connections between Moon Dust and the dust in a plasma as this paper will describe. In any case, data analysis plays an important role in all science fields and is especially important in CASPER's Dusty Plasma Lab. It was discovered that the free program Image J can be very useful in analyzing images of dust particles and that MatLab can be used to further analyze the data. Some examples of that analysis will be presented in this paper and applications to the high school science curriculum will be illustrated. It was also found that some unknown force caused gold coated dust particles and melamine formaldehyde (MF) to separate at 200 W. Very curious indeed.**

Introduction—Moon Dust

Initially it was thought that the researcher was going to be working with the Light Gas Gun firing ampoules of Moon Dust simulant. The plan was to find out what effect the simulant impact would have on a plate of the same kind of material used in spacecraft. However, it was soon realized that this was not going to happen for various reasons. Much was learned about Moon Dust during the research process and so it was decided that this would be a good topic to work with in the high school science curriculum. The researcher thought this would be both motivational and interesting and therefore engage students in the learning process. The main goals for the lesson are as follows:

- Be aware of the significance that lunar dust may play in our return to the Moon.
- Recognize that the Moon is in a plasma environment.
- Realize that research is in full swing to characterize the behavior of Moon dust.

The measurable objectives for the lesson are:

- Know the characteristics of Moon dust.
- Understand how Moon dust is formed.
- Appreciate problems that Moon dust caused for the Apollo astronauts.
- Recognize potential Moon dust problems for “Back to the Moon” exploration.
- Realize the possible solutions for problems caused by Moon dust.

The Moon is an extremely hostile environment. It has no atmosphere hence radiation from the Sun encounters no resistance in reaching the Moon’s surface. The temperatures on the Moon vary from -157^{o}C in the dark to 121^{o}C in the light [1]. The Apollo astronauts knew about these extreme conditions but they encountered something they had not counted on, Moon dust! It caused more problems than anyone could imagine beginning with the first manned landing in 1969. First, Moon Dust will be characterized and then some of those problems will be discussed in the first section of this paper.

Section I: Moon Dust Properties

Moon Dust has the following characteristics:

• Similar to Ash	• SiO_2 (44.72%)

• Electrically Charged	• Mean size= 19 µm
• Jagged Shape	• High Porosity
• Al_2O_3 ((14.86%)	• Variable size, shape

Images 1 and 2 illustrate the varied size and shape of Moon Dust.

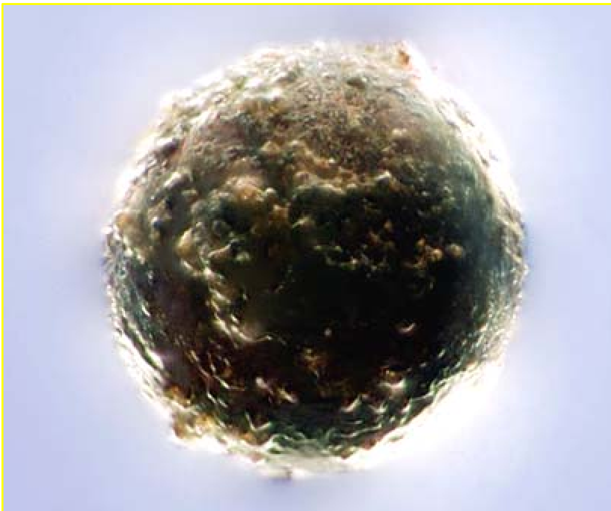


Image 1

Image 2

Problems Caused by Moon Dust

There are several problems associated with Moon Dust: Health issues, dust adhesion, dust abrasion, dust transport and surface charging. Alan Bean on Apollo 12 reported that: “After lunar liftoff…a great quantity of dust floated free within the cabin. This made breathing without a helmet difficult, and enough particles were present in the cabin atmosphere to affect our vision.” [2] It is possible that chronic respiratory problems may develop if the astronauts are exposed to the Lunar Dust for long periods of time. One look at the astronaut in the lunar module cabin shows the adhering gray Moon Dust (Image 3).

Image 4 shows a good illustration of Moon Dust transport and adhesion properties. The lunar rovers in all Apollo missions kicked up dust as they moved across the surface. It was soon found that the Moon Dust settled in the moving parts such as motors and gears creating so much friction that the lifetime of the vehicle was shortened. The scientists and engineers at the National Space and Aeronautics Administration (NASA) will have to redesign the equipment and space suits to counteract the effects on Moon Dust for the return to the Moon by 2020.

Image 3: Astronaut Covered in Moon Dust in the Lunar Module

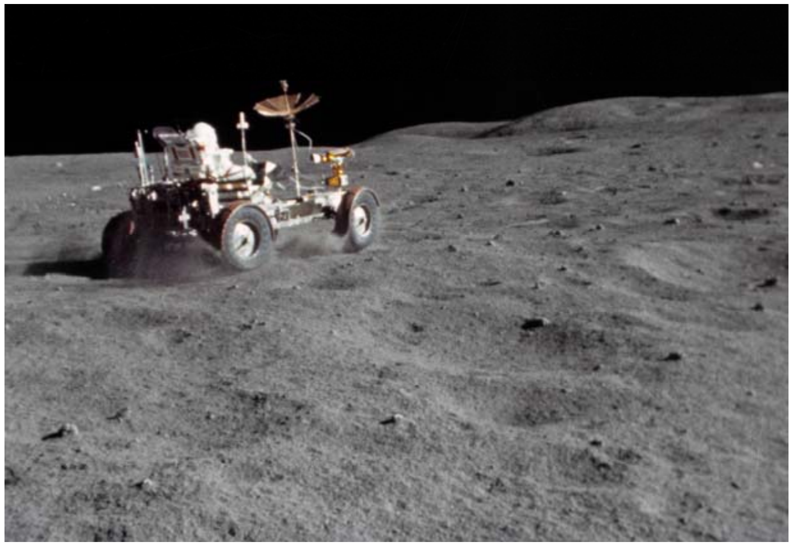


Image 4: Apollo 16 Lunar Rover Kicking Up Moon Dust

Dust abrasion was also a big problem for the Apollo astronauts. Not only was abrasion apparent with the Lunar Rover operation it was also very noticeable in maneuverability of the spacesuits themselves. The dust adhered both mechanically and electrostatically; mechanically because of the sharp projections of the dust grains (see Image 2). Alan bean noted that "… dust tends to rub deeper into the garment than to brush off" [2]. Electrostatic adhesion was caused by photoionization, the solar wind plasma, and triboelectric charging. It was shown in the Apollo missions that the abrasive Moon Dust could wear through the fabric of a spacesuit thus putting the astronauts' life in jeopardy.

Moon Dust has been observed at 100 km above the surface of the Moon. How is this possible? Dust found at high altitudes is electrostatically "lofted" by the "dynamic dust fountain effect." Charged dust grains are accelerated upward through a narrow sheath region by the surface electric field [3]. This of course may affect the optical quality of the lunar environment. The Lunar Ejecta and Meteorites

(LEAM) experiment was placed on the Moon by the Apollo 17 astronauts to detect hypervelocity impacts from meteorites. NASA was surprised to learn that the measurements were dominated by high velocity impacts from electrostatically charged dust particles [2]. Image 5 illustrates how dust transport occurs on the Moon. Triboelectric charging is caused by both differences in contact potential and frictional transfer of charge between grains in contact. Photoionization results in the ionization of an atom or molecule by the absorption of a high-energy photon. Lunar surface dayside charges positive since photoelectron currents caused by solar ultraviolet rays dominate. At night the lunar surface charges negative because plasma electron currents dominate. This lesson is found online at http://www.hgs.k12.va.us/Special_Projects.htm.

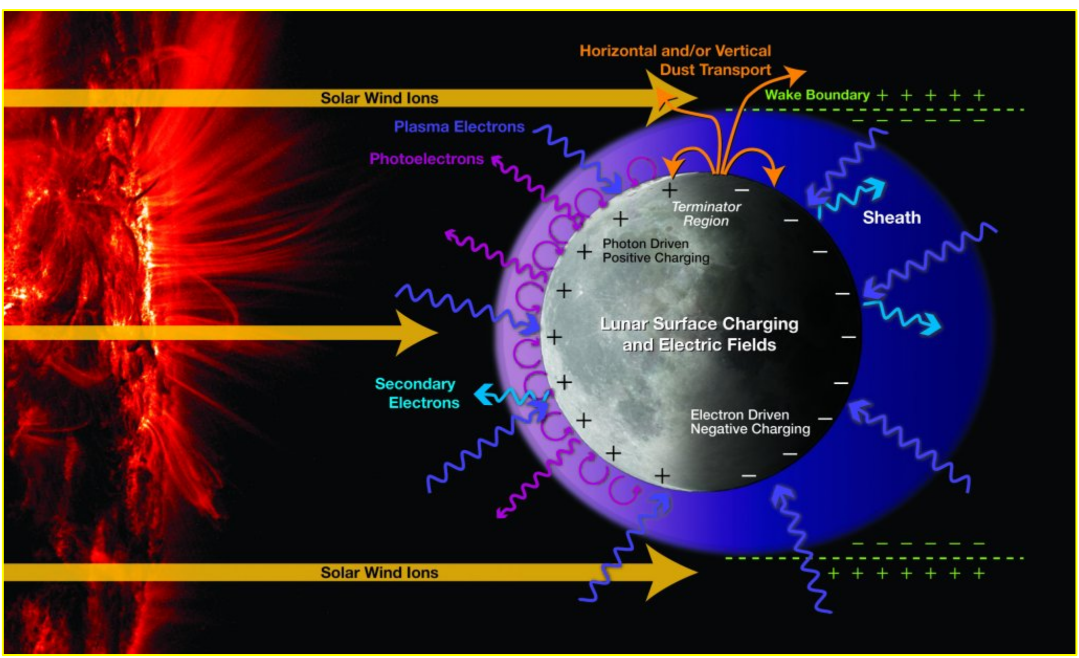


Image 5: Lunar Dust Transport Phenomenon

Section II: Dusty Plasma Lab Phenomena

It is interesting that there is a connection to what happens to dust on the Moon and dust in the Gaseous Electronics Conference (GEC) Radio Frequency Cell (see Image 6) at the CASPER Dusty Plasma Lab. Both Moon Dust and the dust studied in the GEC cell are in a plasma environment. The researcher studied and analyzed many kinds of interactions between dust particles; some particles were observed to form chains (see Images 7 and 8) under specific conditions while others seemed to respond to some mysterious force that propelled them across the GEC cell (see Images 9 and 10).

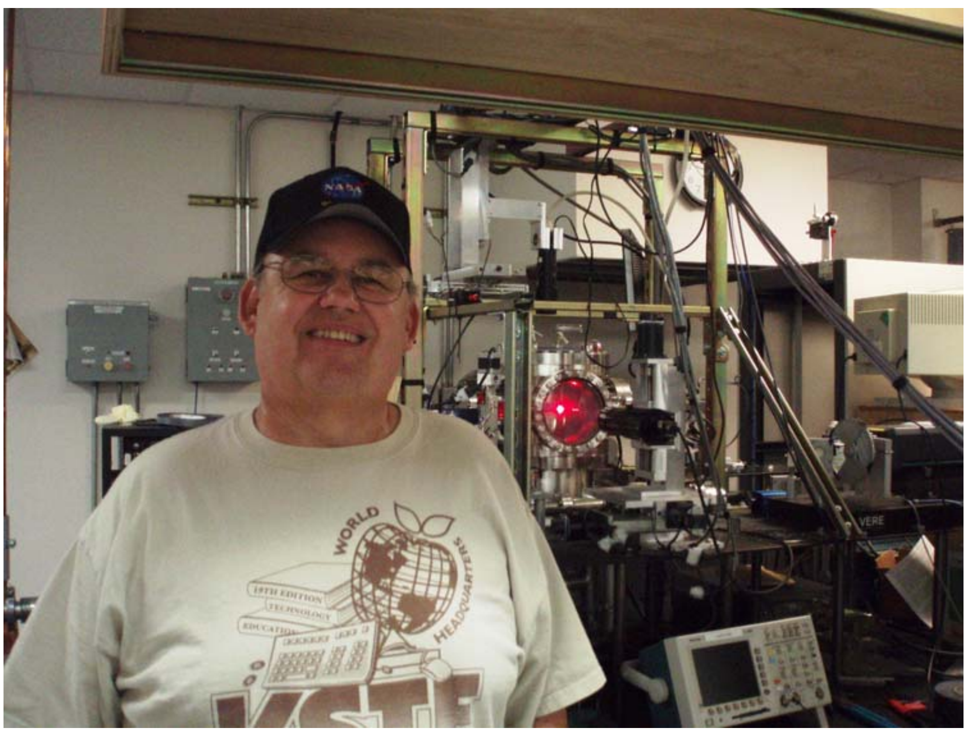
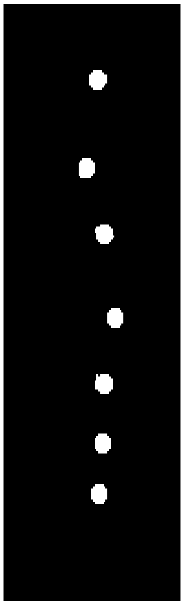


Image 6: Dr. Rapp and the CASPER GEC cell



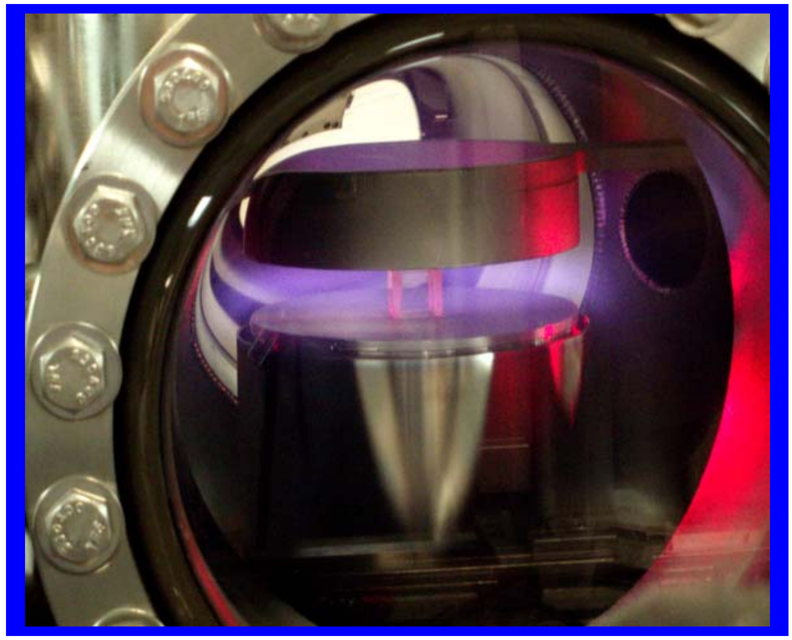


Image 7: Analysis **Image 8: Chains of Particles in Glass Box**

Image 7 is a result of an analysis of seven dust particles in a chain that was done using Image J software which can be downloaded free from the Internet (http://rsbweb.nih.gov/ij/download.html). The researcher plans on using data from the lab and Image J to allow students to analyze data and get the feel of being a researcher. A set of instructions was modified that should allow the students to successfully analyze the data. They are presented here:

Image J Operation Guide (for weak signal)

1. **Import new images**: 'File-Import-Import sequence', select folder and image files, import them.
2. **Crop image:** Use the rectangular selections, drag the cursor to desired image area, select 'Image-Crop' to crop image sequence.
3. **Adjust:** 'Image-Adjust-Brightness/Contrast', adjust to get what you believe the best result; click Apply, save the file 'File-Save as-AVI' in the same folder and give a file name or use the default file name.
4. **Close:** Close all of the windows**;** Open the AVI file saved in last step, 'File-Open'.
5. **Adjust:** 'Image-Adjust-Threshold'. First select B&W, then move the top bar all the way left to minimum (0 reading), adjust second bar to ≤ 66 and, right click 'paintbrush tool', type in 6. Use this paint brush to increase the size of the particle image pixel.

6. **Apply:** After all the images are adjusted, push the 'Apply' button, apply to all the images, check 'calculate Threshold for each image', click OK.
7. **Analyze:** 'Analyze particles', set pixel size 10 – 200, OK. Check for the correct number.
8. **Particle Position:** When the particle positions appear in a new window, check the last number to see if it matches the total number of particles in an image multiplied by the number of images. If the number matches, save these positions by 'File-save as', pick a folder to save it. Save this file at .txt.

Image 8 shows the one inch square box containing the seven-particle vertical chain of melamine formaldehyde dust particles in the GEC cell. By changing the power input to the cell the number of particles can be changed. A change in the frequency results in a change in the oscillation rate. The purpose is to determine the ion drag on the dust particle. MatLab was used to further analyze the data and two graphs show the results of that effort (Images 11 and 12).

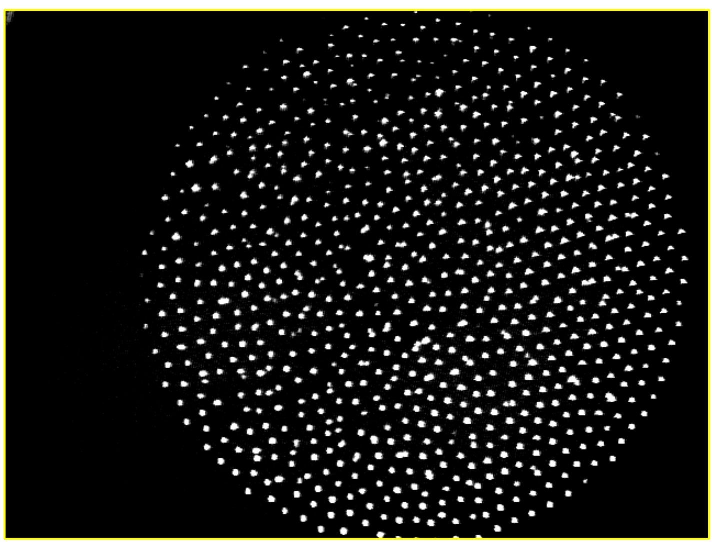


Image 9: Initial Drop 50/50 MF/Au Mix at 2 Watts

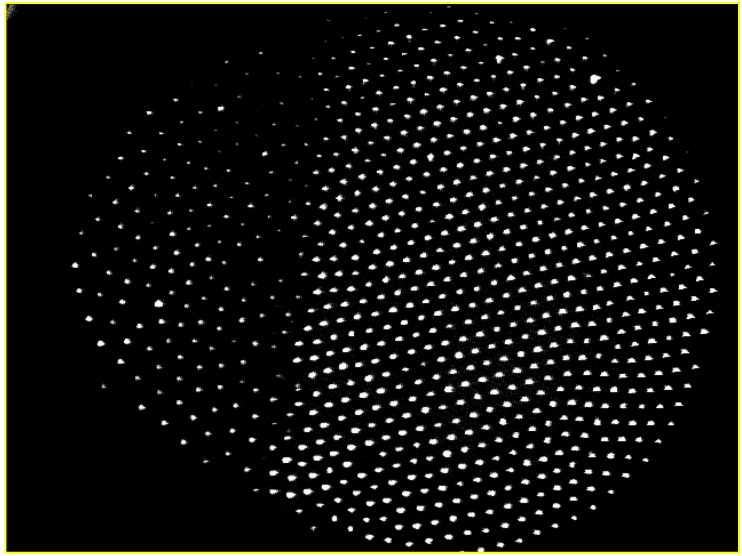


Image 10: Particle Configuration 30 Minutes Later

It is thought that the force at work here is caused by the laser fan that is used to illuminate the dust particles as shown in Image 13. Further research is needed to confirm this idea. Notice in Image 11 that this graph shows that although the amplitude changes the frequency of the particles remain at about 10 Hz. Each line on the graph represents one particles. Image 12 shows that the theoretical model is an almost a perfect with the experimental data. Please note that this data is for a four-particle chain not a seven-particle chain.

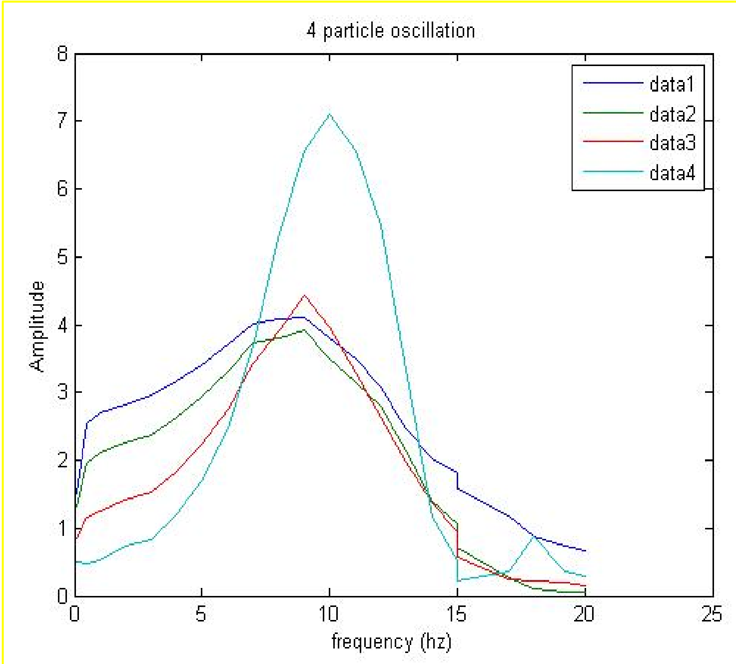


Image 11: Frequency Vs. Amplitude

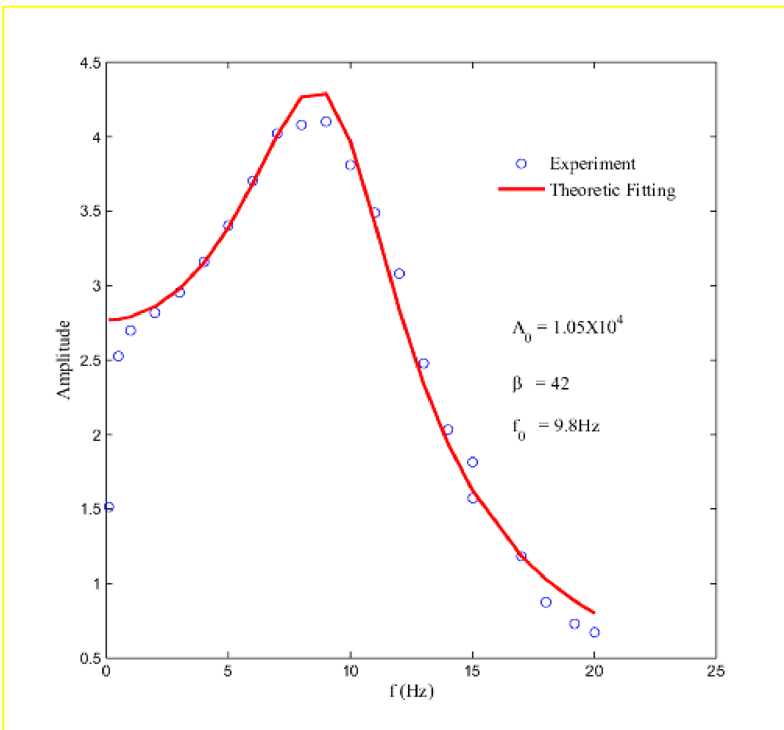


Image 12: Theoretical Model Matches Observed Data

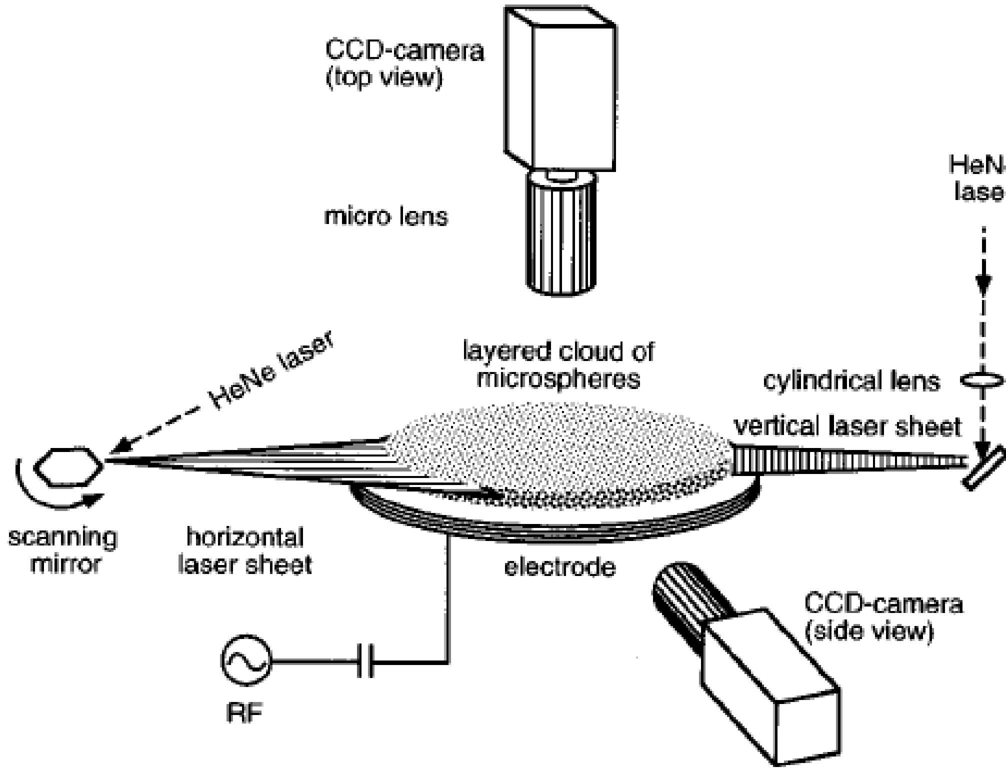


Image 13: Laser Fan Illuminates Dust Particles in the GEC Reference Cell

Conclusion

Even though this researcher did not get to work on Moon Dust research in the Hypervelocity Impact Lab, the research that was completed in the Dusty Plasma Lab was successful and eye-opening. An educational lesson was developed from both the preliminary research done on Moon Dust and from the work done on analyzing dust particle chains. I think both lessons will be engaging and motivational to students and will help them develop some research skills and peak their interest in science. A serendipitous discovery was made in that the laser fan used to illuminate dust particles in the GEC Reference Cell caused gold dust particles of about 8 microns in diameter to transit the cell. More research needs to be conducted to confirm this phenomenon.

References

[1] Benson, Tom (July 2008). The Moon. National Aeronautics and Space Administration, Available: http://www.grc.nasa.gov/WWW/K-12/rocket/moon.html

[2] Stubbs, T. J., Vodrak, R. R. and Farrell, W. M. (January 2007). Impact of Dust on Lunar Explorations, NASA Goddard Spaceflight Center, Available: http://hefd.jsc.nasa.gov/files/StubbsImpactOnExploration.4075.pdf

[3] Sickafoose, A. A. and Colwell, J. E. (2002). Experimental Levitation of Dust Grains in a Plasma Sheath, Journal of Geophysical Research, vol. 107. Available: http://occult.mit.edu/_assets/documents/publications/Sickafoose2002JGR107.ID1408.pdf