

INTRODUCTION: Ice in clouds interacts with both incoming solar and upwelling terrestrial radiation. Understanding how ice is formed in the atmosphere is a major outstanding challenge in understanding and predicting weather and climate. Of the known initial ice formation pathways in the atmosphere (homogeneous, deposition, immersion, condensation, and contact), the least understood is contact nucleation [1]. Measurement of the ability of an aerosol particle's effectiveness in the contact mode requires that the particle be brought into contact with a supercooled water drop, and the subsequent nucleation event (if any) detected. Previous research has shown that contact nucleation is effective at temperatures as high as -4°C [2] and may be catalyzed by aerosols as small as 10 nm in diameter [3]. In contrast, the other heterogeneous nucleation pathways are typically not effective at temperatures greater than -10°C and require aerosol particles larger than 100 nm. Contact nucleation may be the cause of ice production that occurs in the atmosphere where no other nucleation mechanisms are effective (due to higher temperatures or small aerosol particles).

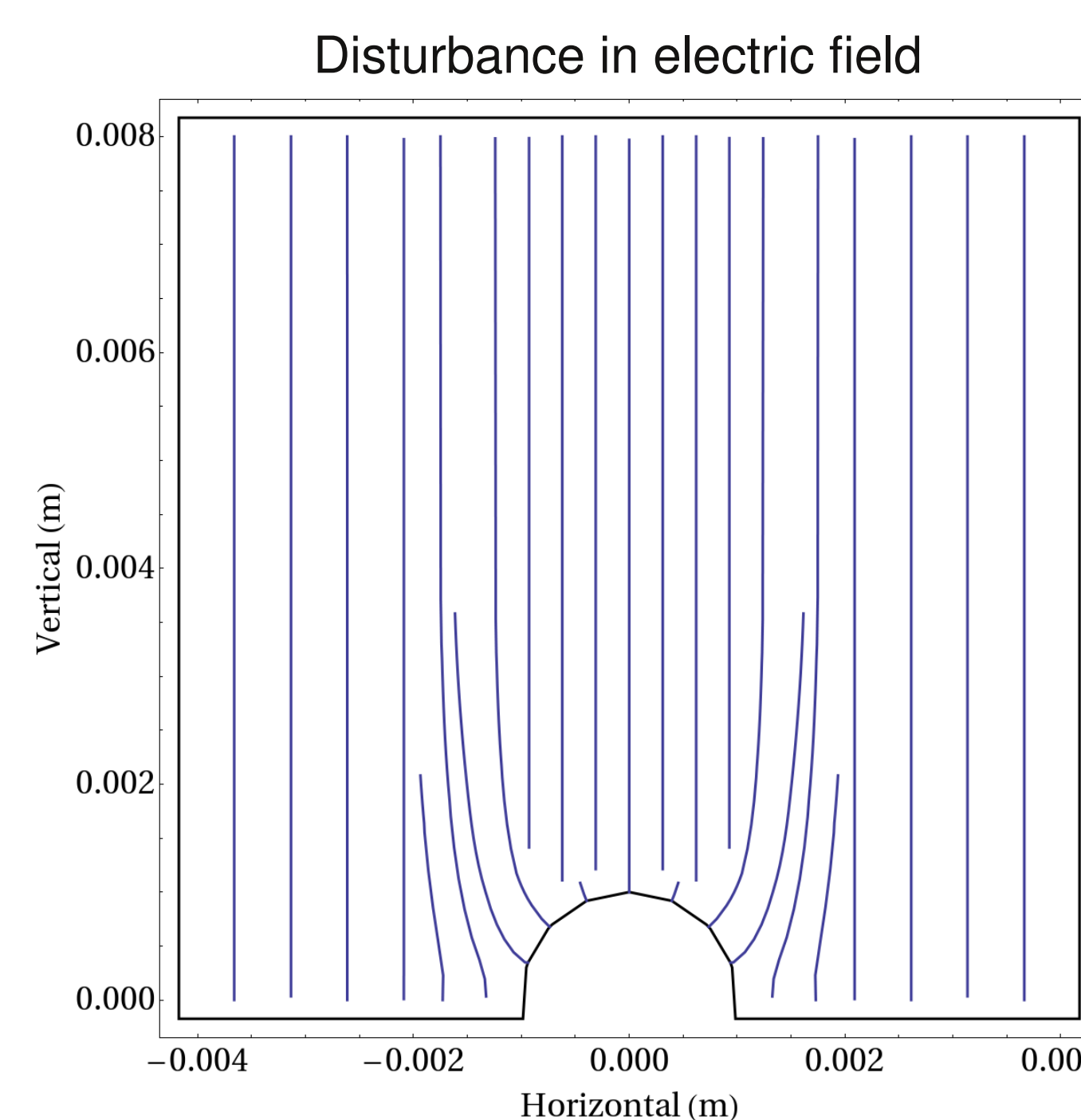
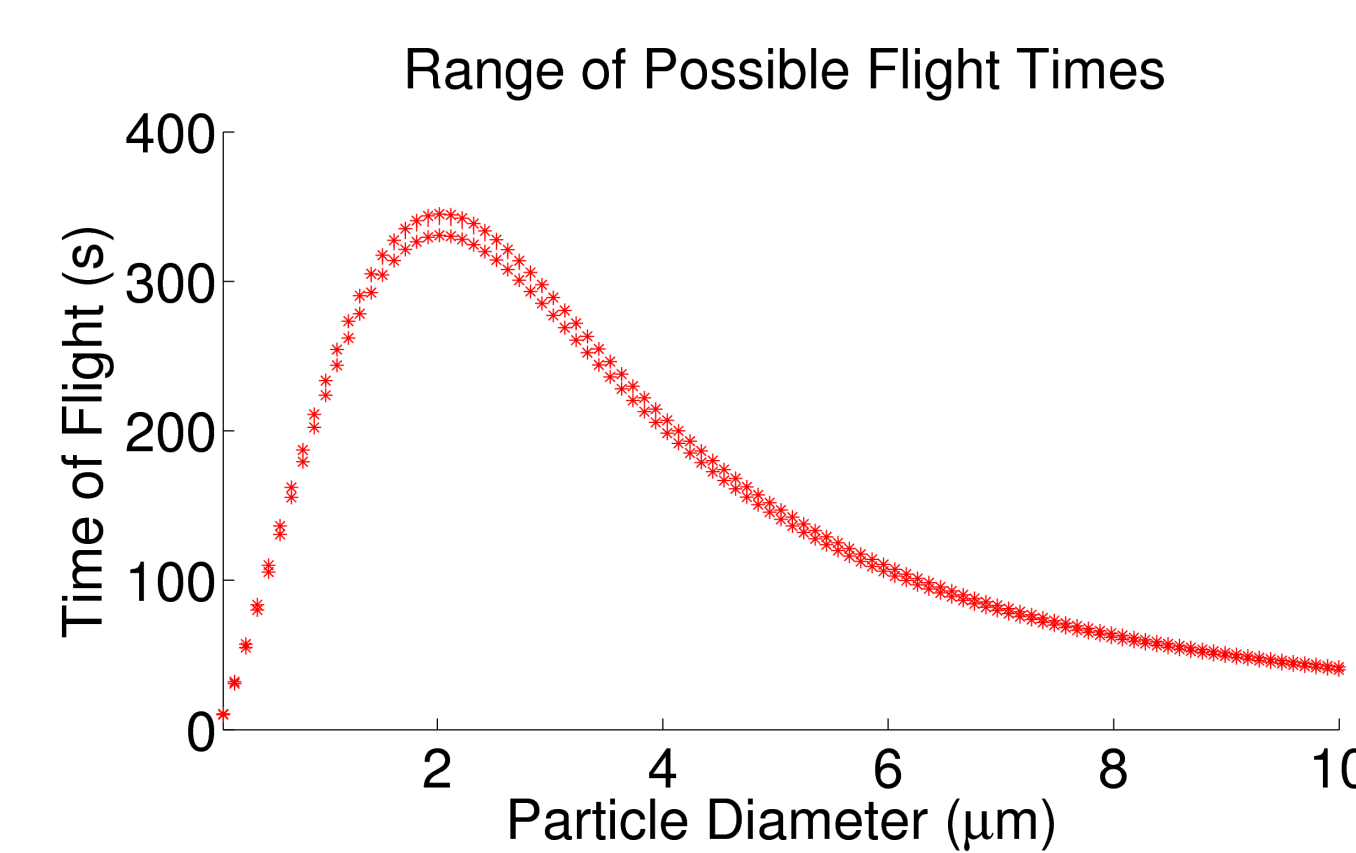
TYPICAL EXPERIMENT:

- Purge the chamber with clean air
- Draw in aerosol (a thin, laminar ribbon at the top of the chamber)
- Close valves to isolate the chamber (no air flow)
- Turn on high voltage power supply to impose electric field
 - the conducting plates are parallel, so the field is uniform
- Monitor thermodynamic phase of drop using a laser and photodiode
- The time elapsed between turning on the power supply and a nucleation event corresponds with the contact nuclei's diameter

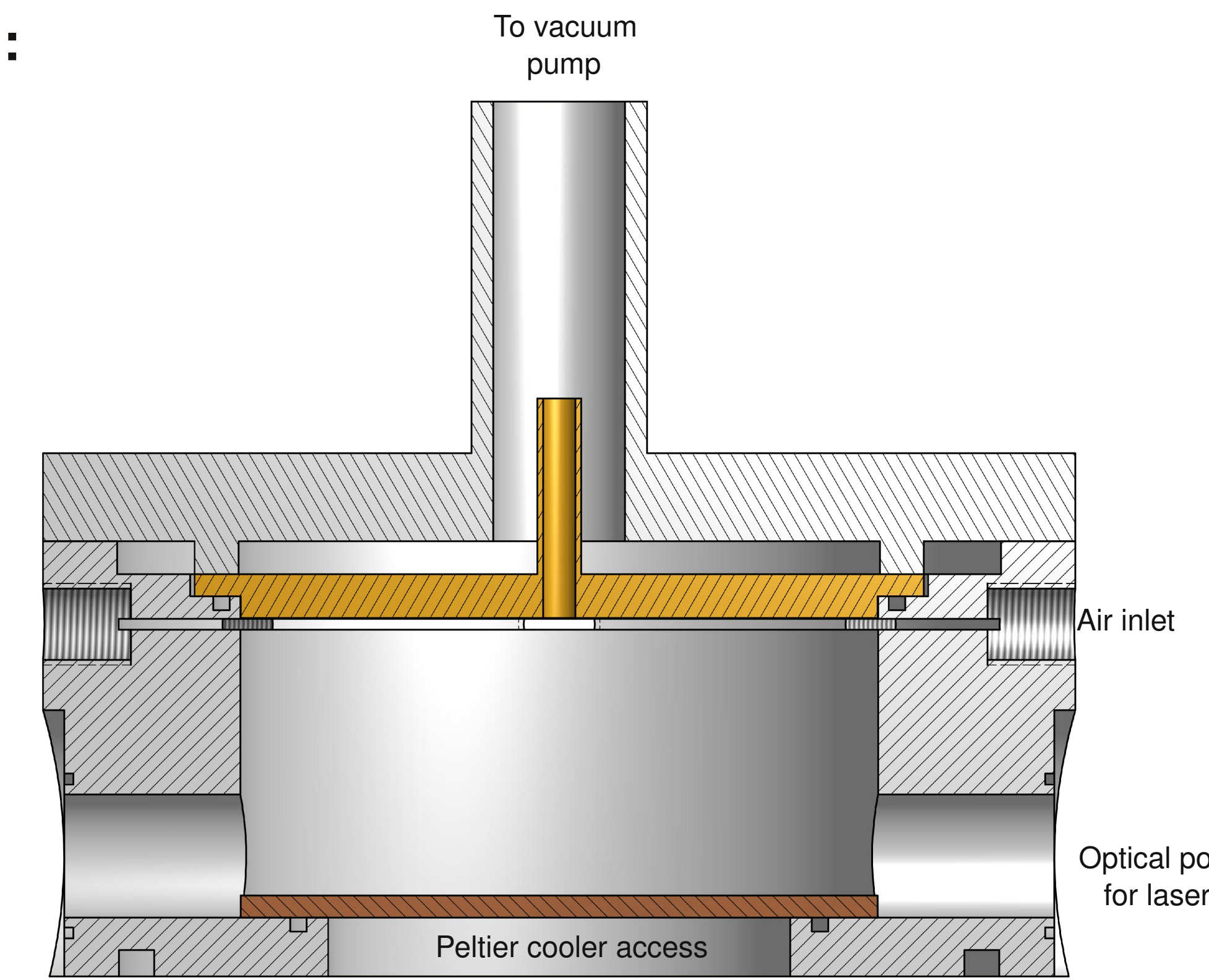
The time required for an aerosol to contact the water drop is related to the aerosol's terminal velocity:

$$v_t = \frac{neEC_c}{3\pi\eta D_p} + \frac{\rho_p D_p^2 C_c}{18\eta}$$

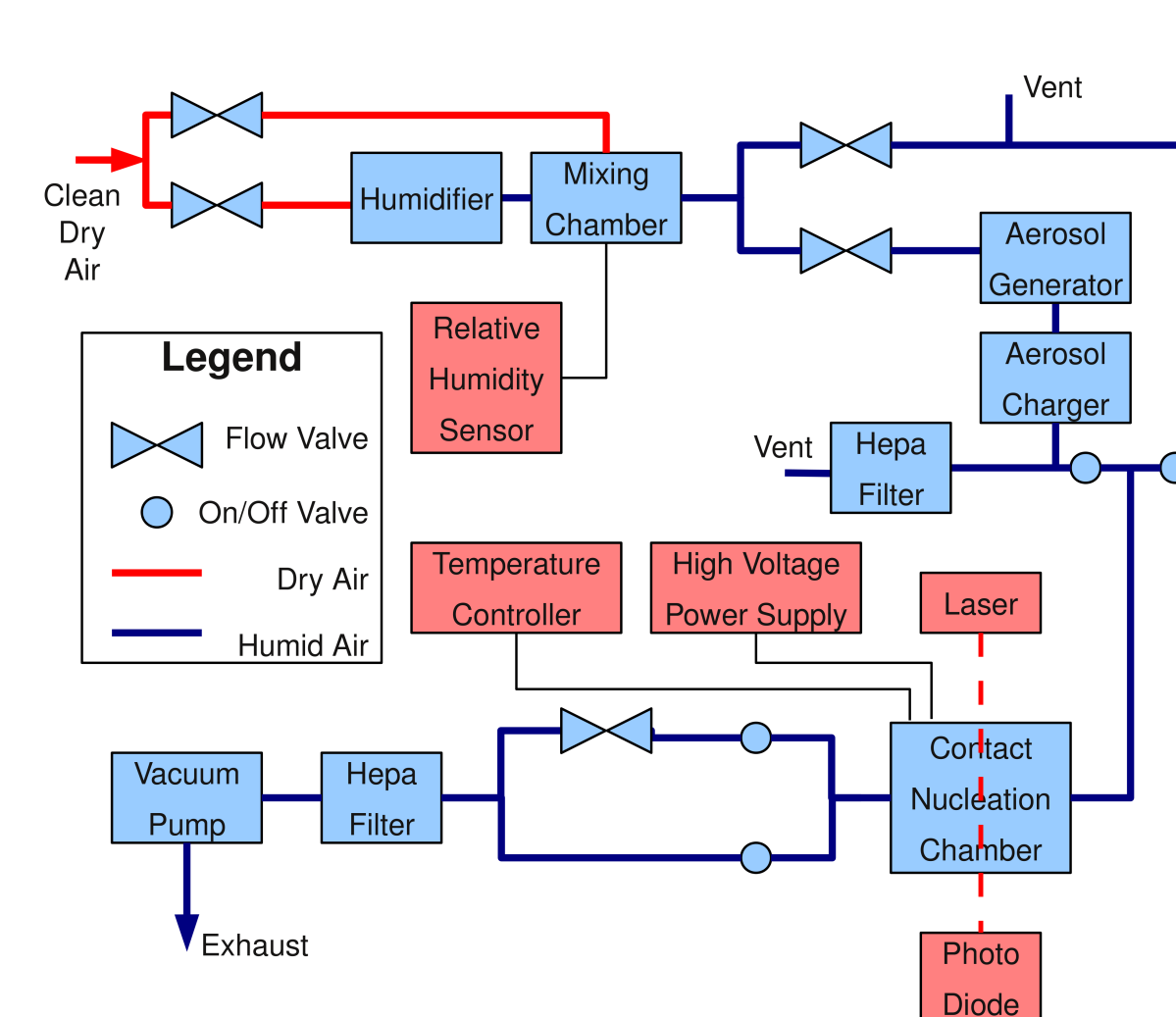
where n is the number of elementary charges, e , on an aerosol of diameter d_p , η is the dynamic viscosity of air, E is the magnitude of the electric field, ρ_p is the aerosol density, and C_c is the Cunningham slip correction factor. The first term on the RHS is due to the electric force, while the last term is due to gravitational settling.



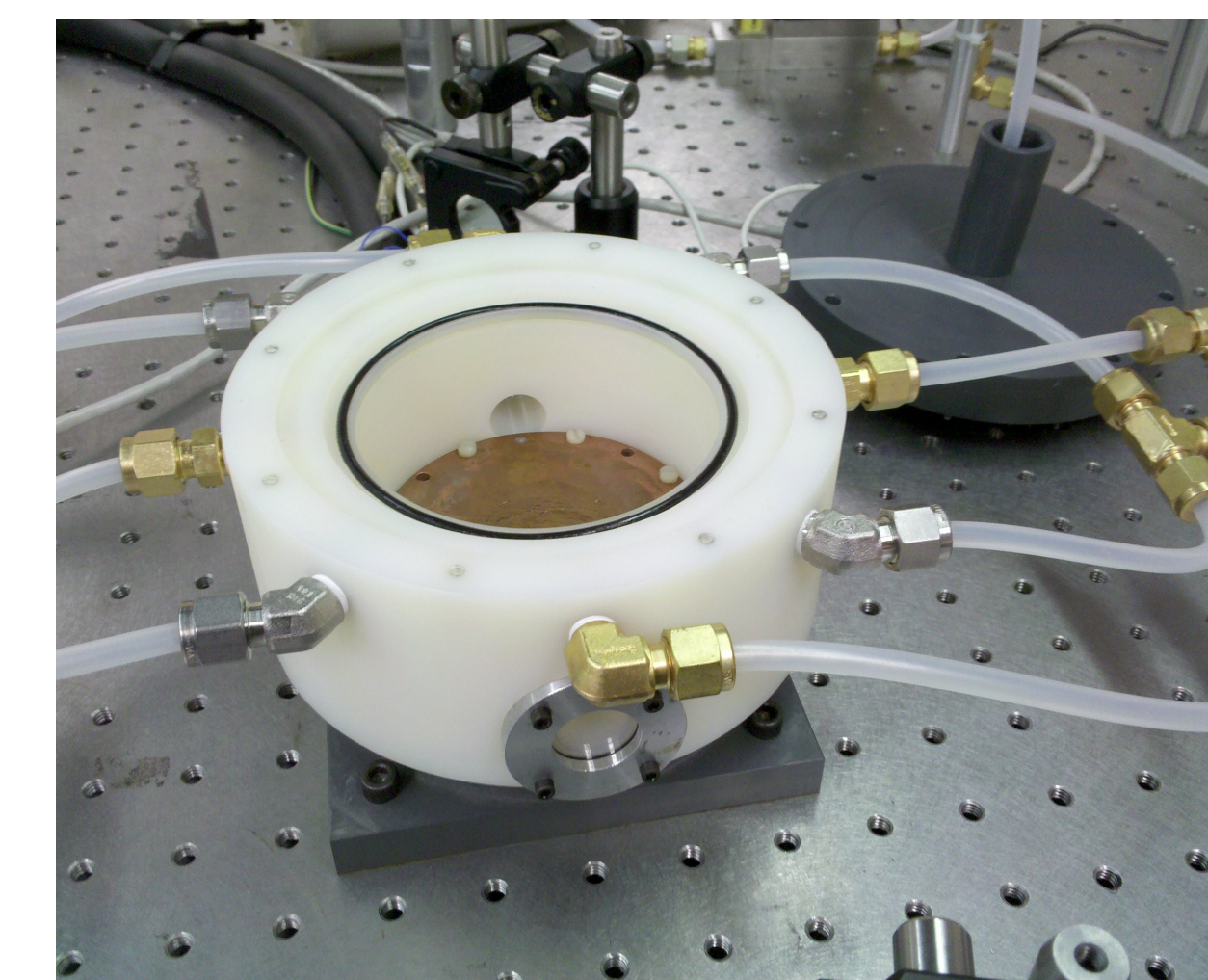
DESIGN:



Section view of chamber



Block Schematic of Setup

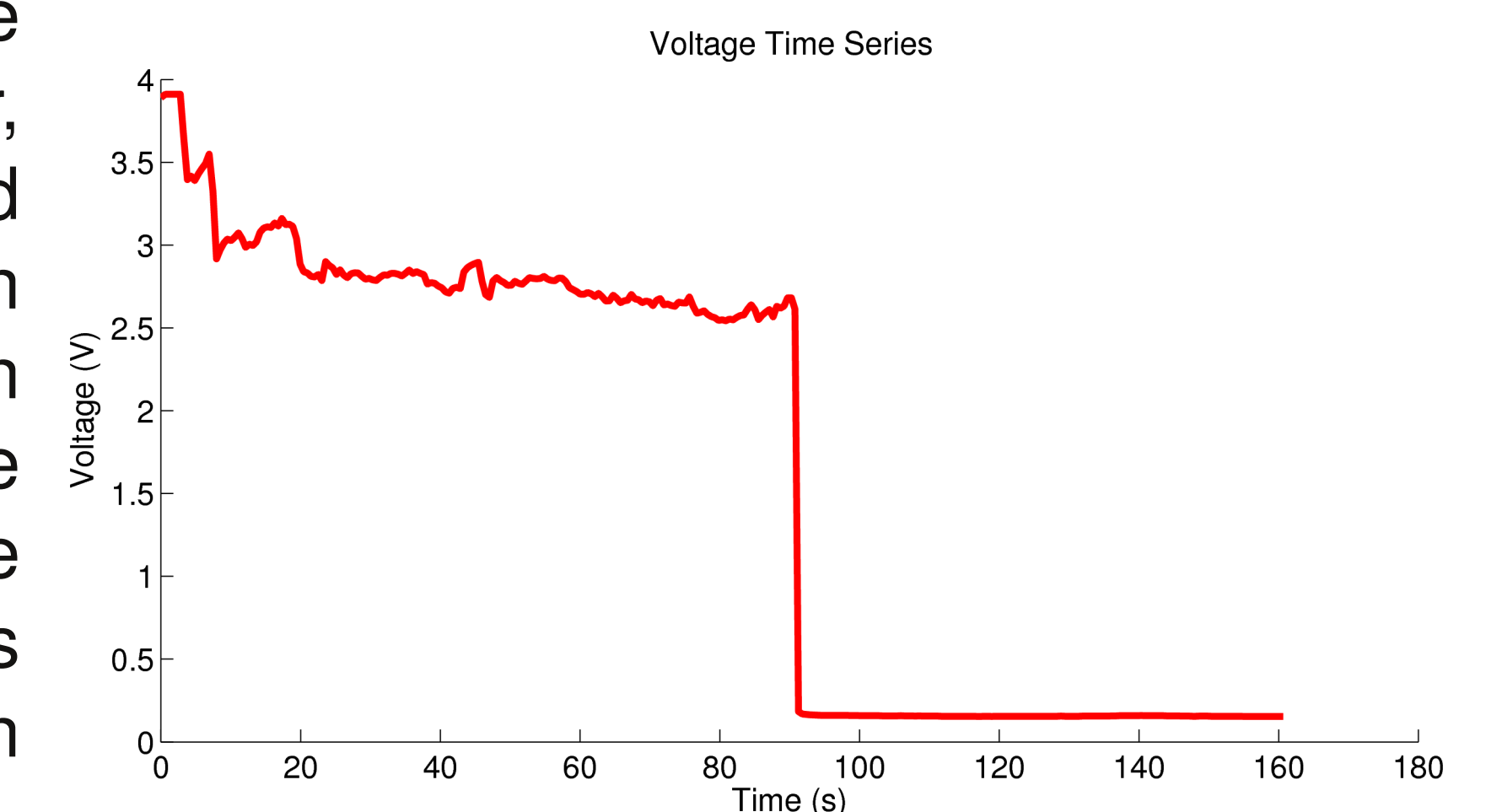


Picture of chamber in the lab with the lid off

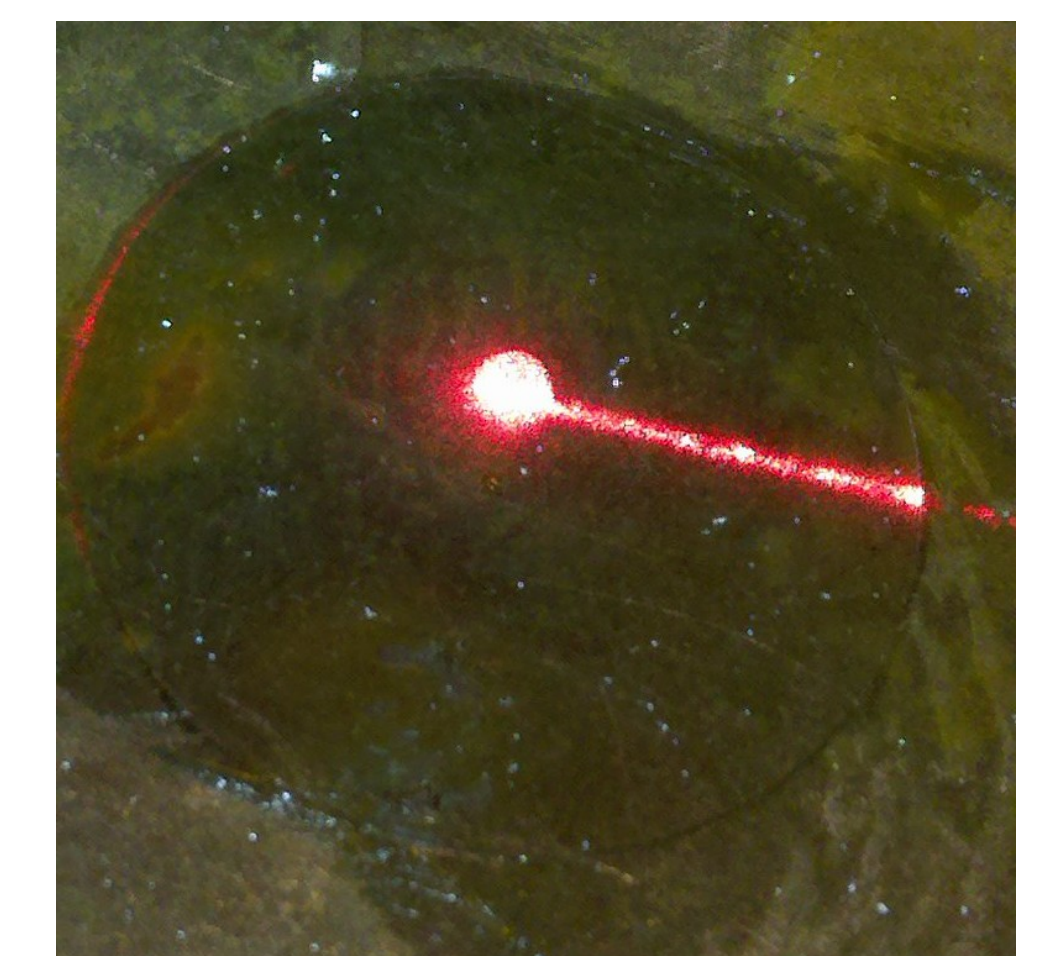
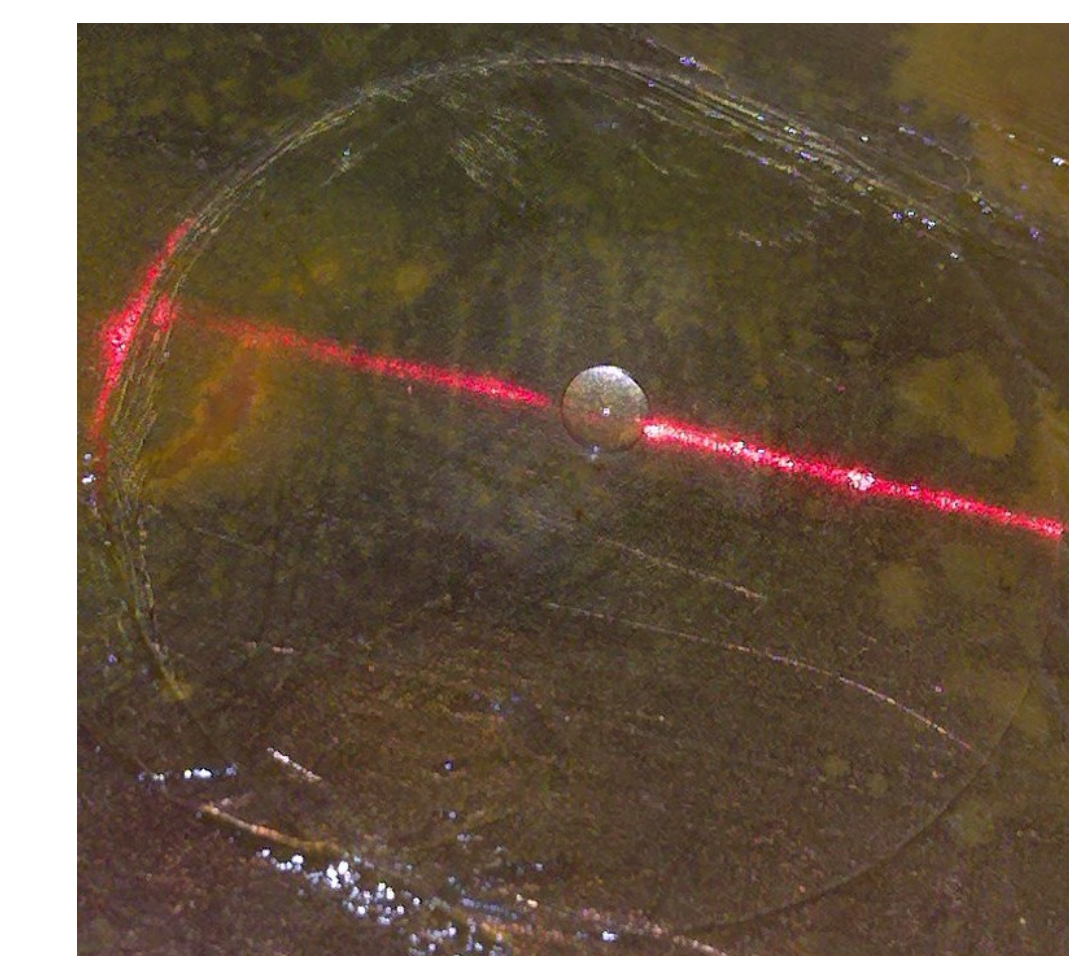
The essence of the apparatus is an electric field, created using parallel conducting plates, a temperature control system using a peltier cooler, and ports for optical access. An experiment starts by placing a water drop (5 to 10 μl) on a silanized glass slide that sits on the bottom plate and aligning a laser through the water drop. The chamber is then sealed, cooled to a specified temperature and purged with filtered humid air (the relative humidity can be controlled). Sample air is then drawn into the chamber just below the top plate in a thin laminar layer (1.6 mm). The sample air has a known number concentration and composition of charged aerosol particles. A high voltage power supply is turned on to place a potential difference (5000 V) between the conducting plates. Contact nucleation occurs at higher temperatures than other forms of heterogeneous nucleation [4], so the probability that the supercooled droplets in the apparatus freeze by any mechanism other than contact nucleation is vanishingly small; thus if a phase change is detected it is from contact nucleation.

INITIAL RESULTS:

Nucleation events are detected using a laser, which is focused through the droplet on to a photodiode. When the droplet freezes, the voltage across the photodiode changes due to the change in transmitted/scattered laser light.



Example of a nucleation event.



The above images are an example of the change in transmitted and scattered light from liquid and solid. The left image is liquid and the right is solid. Note the drops are on a silanized glass slide.

Preliminary results, using the ultrafine fraction of Arizona Test Dust. The diameters marked '?' indicate that the freezing event occurred after all aerosol particles should have been precipitated from the chamber. Those results suggest that there may be a (significant) time lag between contact with the surface and nucleation. (Tests in which filtered air was drawn into the chamber did not result in freezing events.)

Drop Temperature (C)	Time of freeze (S)	Calculated Diameter (μm)
-17.9	981	?
-17.9	91	0.4
-18.2	1094	?
-17.9	570	?
-17.9	551	?
-17.9	625	?
-17.9	821	?
-17.9	399	?
-17.9	1066	?
-17.2	18	0.1
-17.2	31	0.2
-16.9	47	0.9

CONCLUSIONS: We have successfully measured contact nucleation with our chamber. According to the terminal velocities, all aerosols should have reached the bottom of the chamber after about 350 seconds. From our initial data, we have seen freeze times greater than 350 seconds. Thus there could be a significant time delay between aerosol contact and nucleation.

References:

- [1] W. Cantrell and A. Heymsfield 2005 *Bull. Am. Meteorol. Soc.* **86** 795
- [2] R. Pitter and H. Pruppacher 1973 *Quart. J. R. Met. Soc.* **99** 540-550
- [3] R. Sax and P. Goldsmith 1972 *Quart. J. R. Met. Soc.* **98** 60-72
- [4] A. Durant, J. and R. Shaw, A. 2005 *Geophys. Res. Lett.* **32** L20814

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