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Mitigation of Lunar Dust on Solar Panels and Optical Elements for Lunar Exploration Utilizing Electrostatic Traveling-Wave

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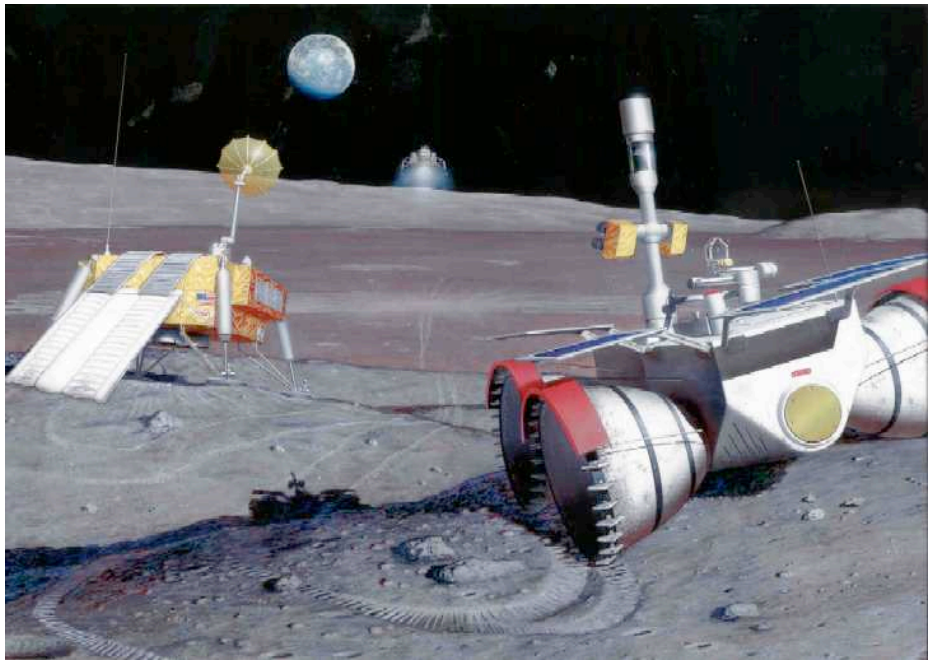
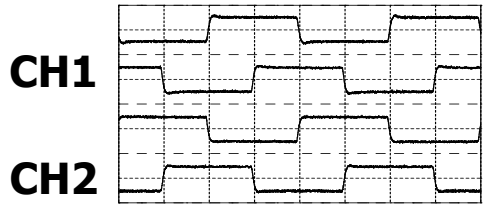
Outline

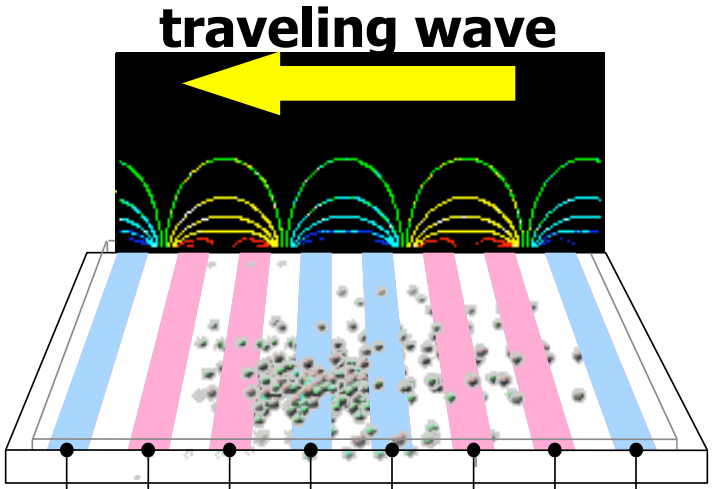
We have developed a self-cleaning device of lunar dust on a solar panel and optical lens utilizing electrostatic force.

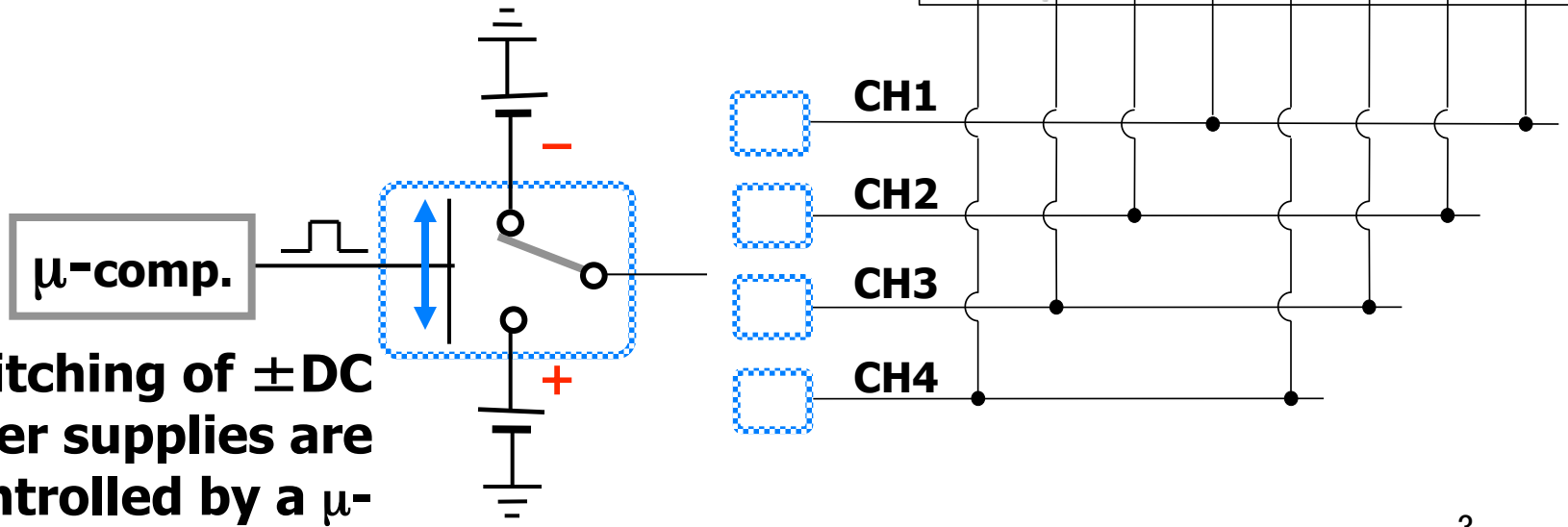


Electrostatic Cleaner of Lunar Dust

traveling wave transport of particles

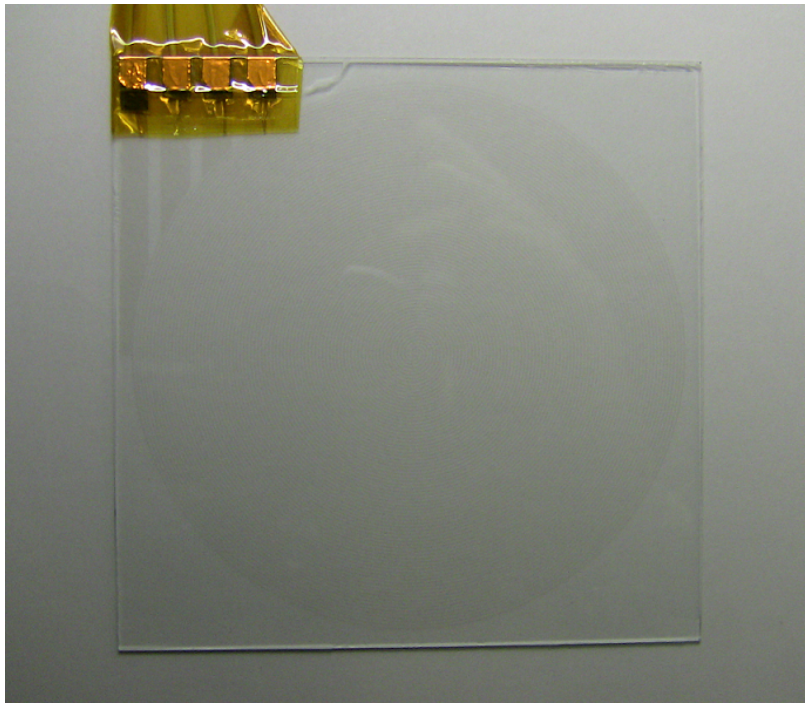


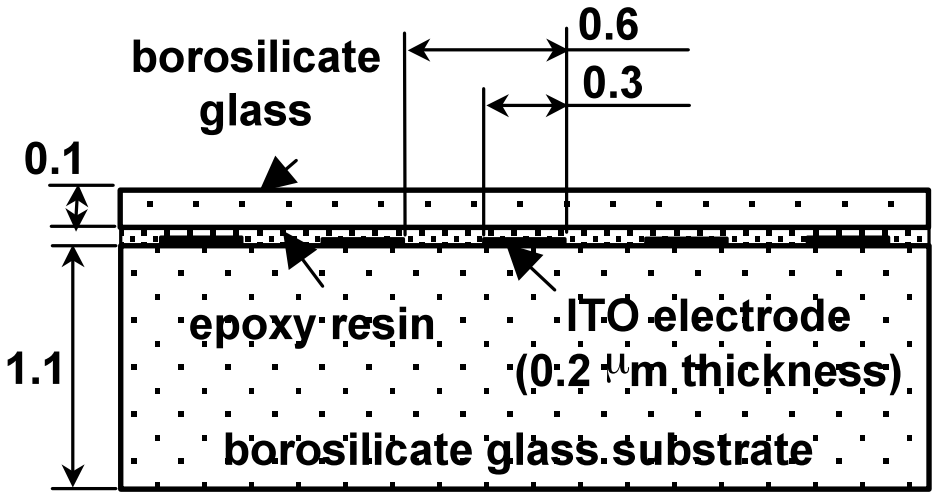


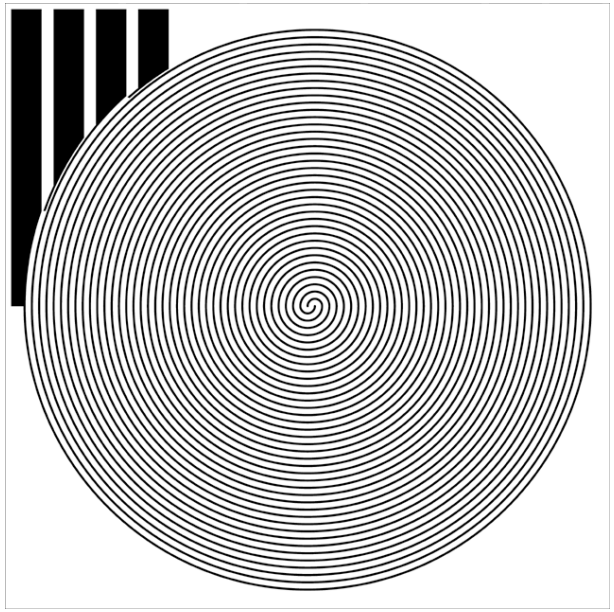


Switching of ±DC power supplies are controlled by a μ-comp.

Cleaner with Transparent ITO Electrodes

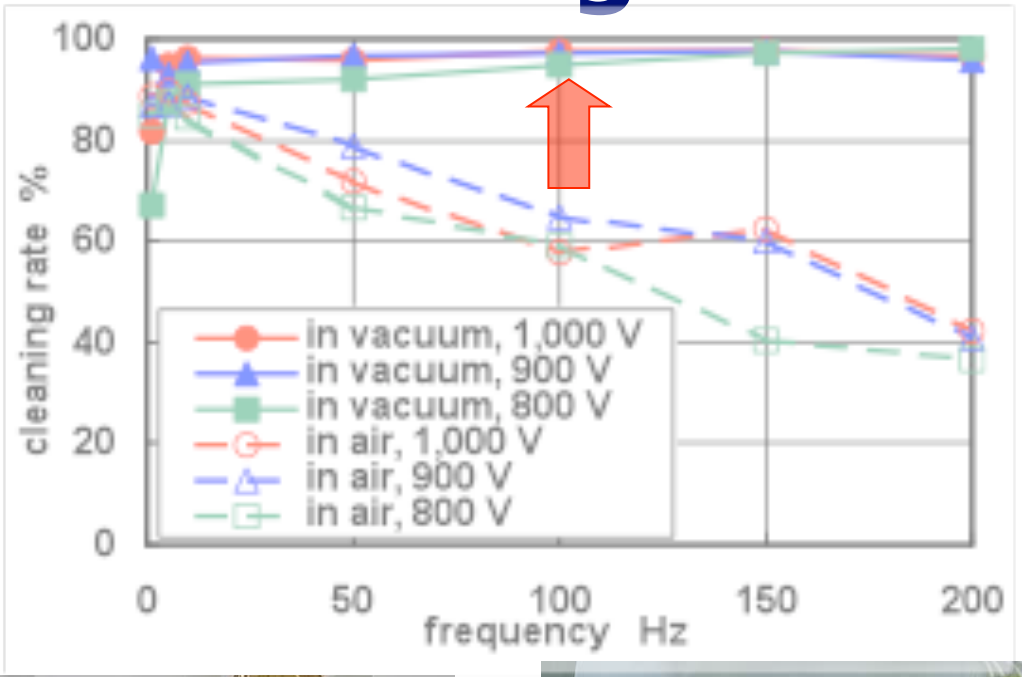


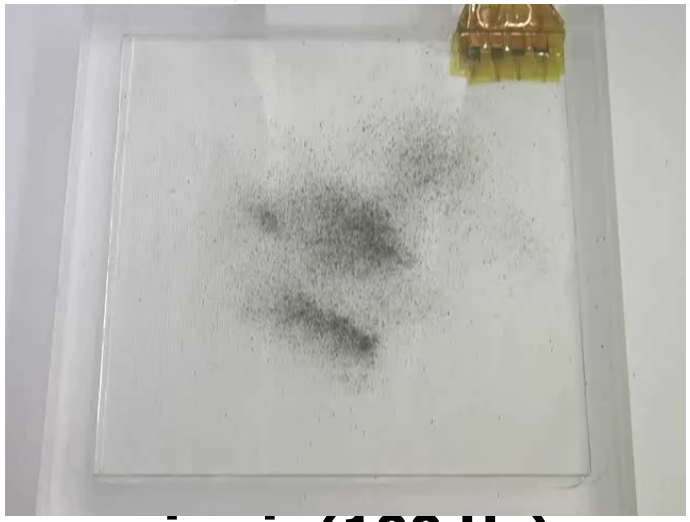




100 ×100 mm

Cleaning Rate





in air (100 Hz)

in vacuum (100 Hz)

Numerical Simulation
-calculated by 3D Discrete Element Method-

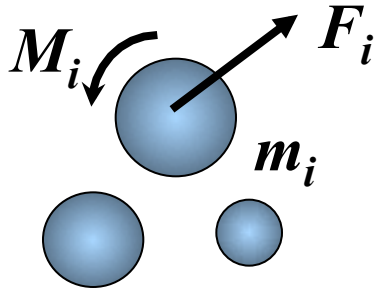
$$m_i\ddot{\boldsymbol{x}}_i + 6\pi\eta R\dot{\boldsymbol{x}}_i = \boldsymbol{F}_{coulomb_i} + \boldsymbol{F}_{dipole_i} + \boldsymbol{F}_{mechanical_i} + \boldsymbol{F}_{adhesion} + m_i\boldsymbol{g}$$

(Air Drag) (Coulomb) (polarization) (collision) (adhesion) (gravity)

↓ 0, **in vacuum**

↓ 1/6 **G, on the Moon**

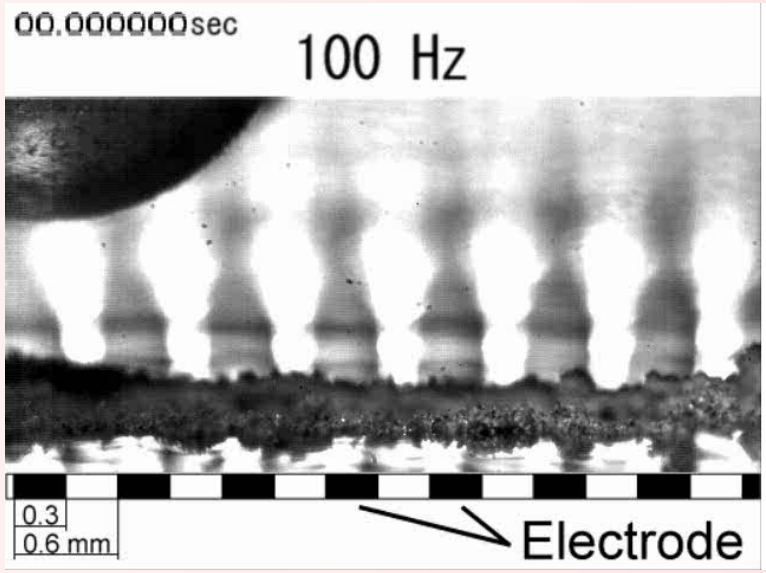
$$I_i\ddot{\boldsymbol{\theta}}_i = \boldsymbol{M}_{mechanical_i} + M_{friction_i}$$

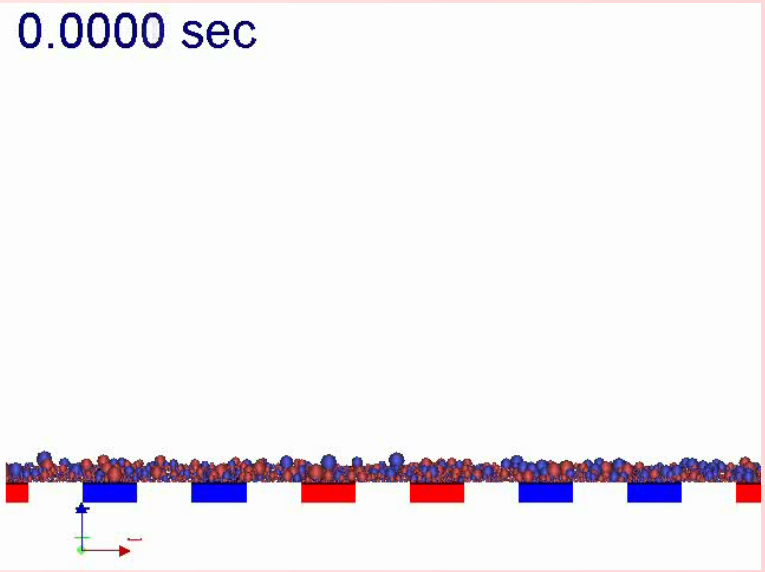


$(i = 1, \cdots, N \quad N : \text{number of particles})$

Transport of Particles in Air and Vacuum

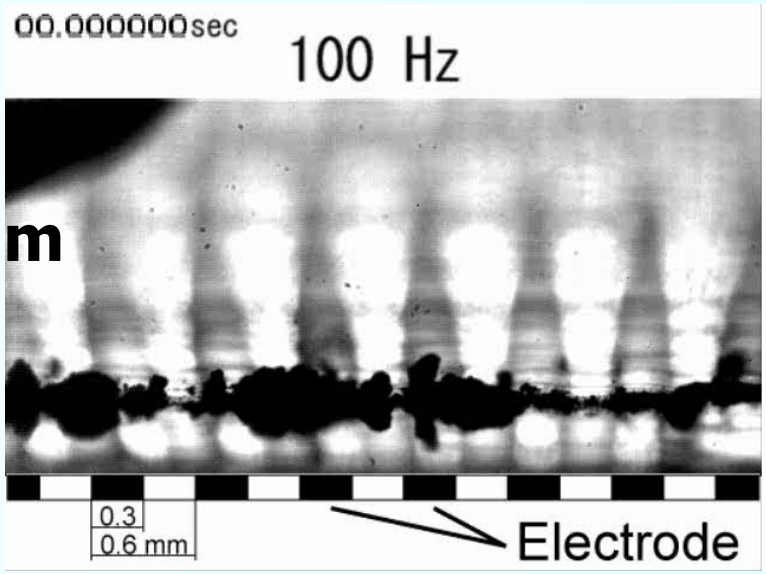
air

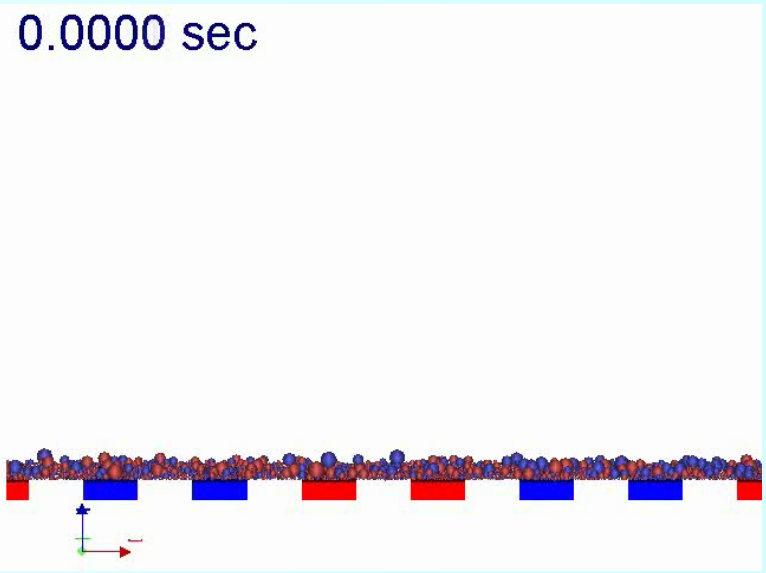




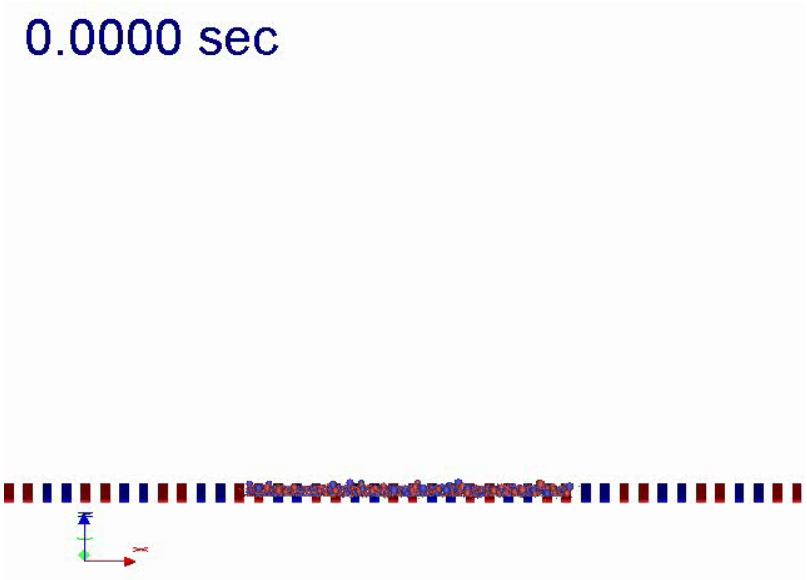
vacuum

10 Pa





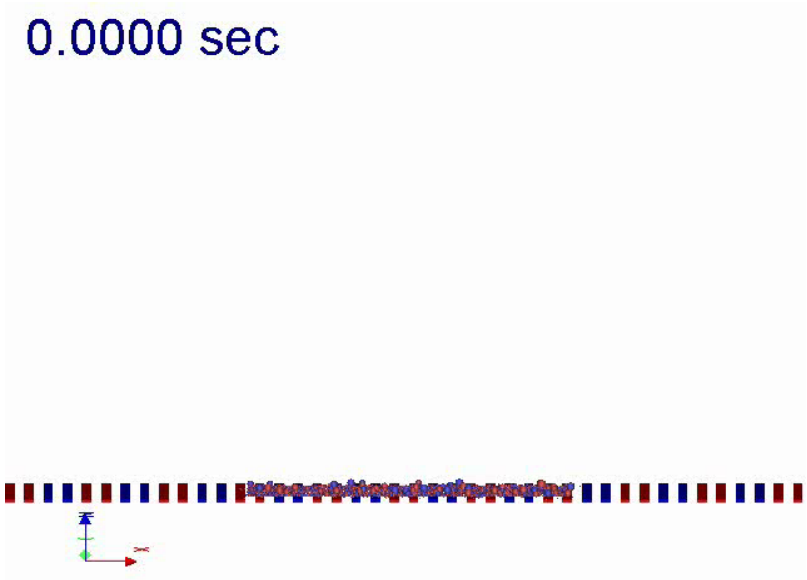
Cleaning Performance on the Moon



on the earth

700 **V 10 Hz**

- **1 G**
- **in air**

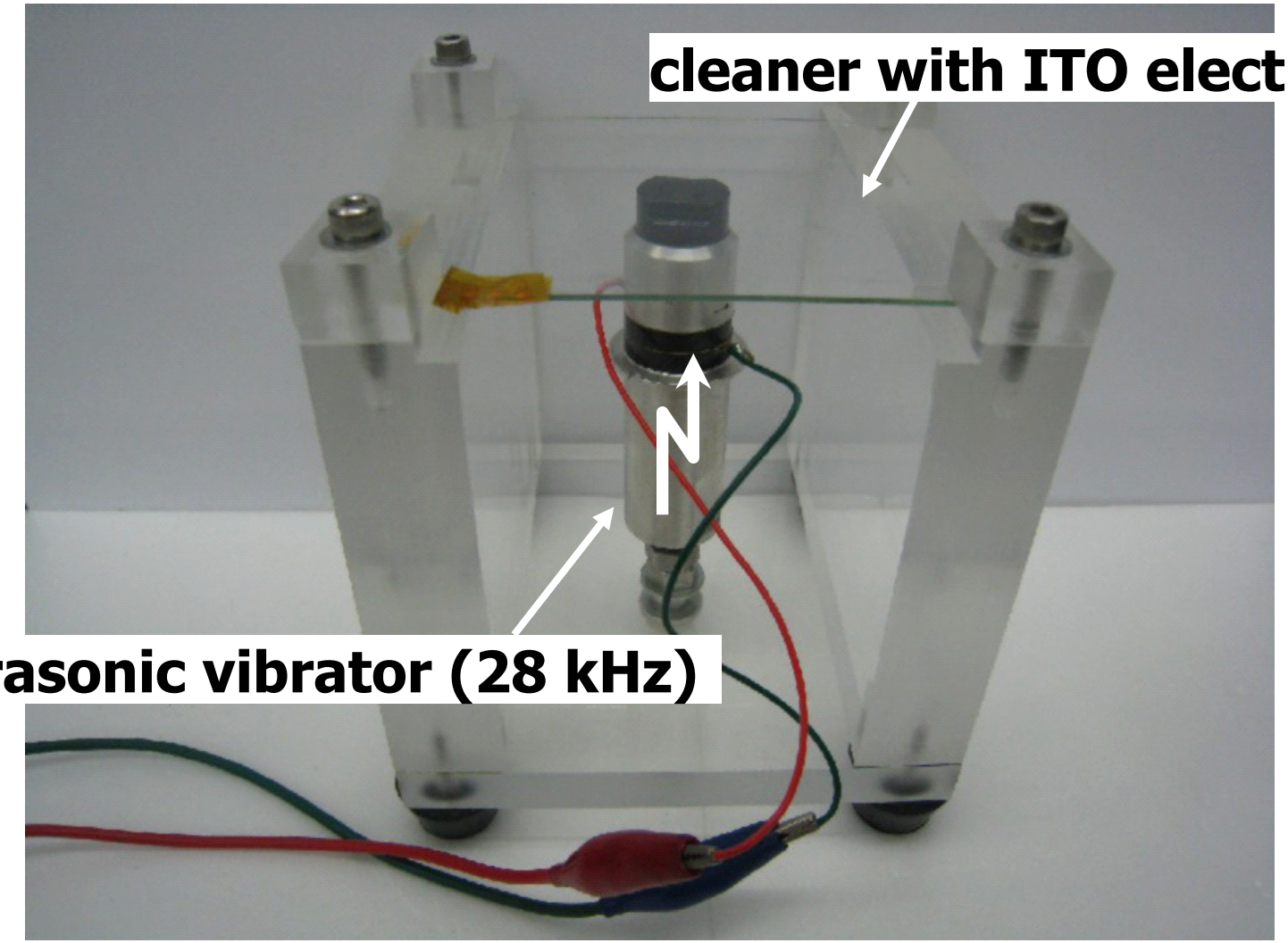


on the moon

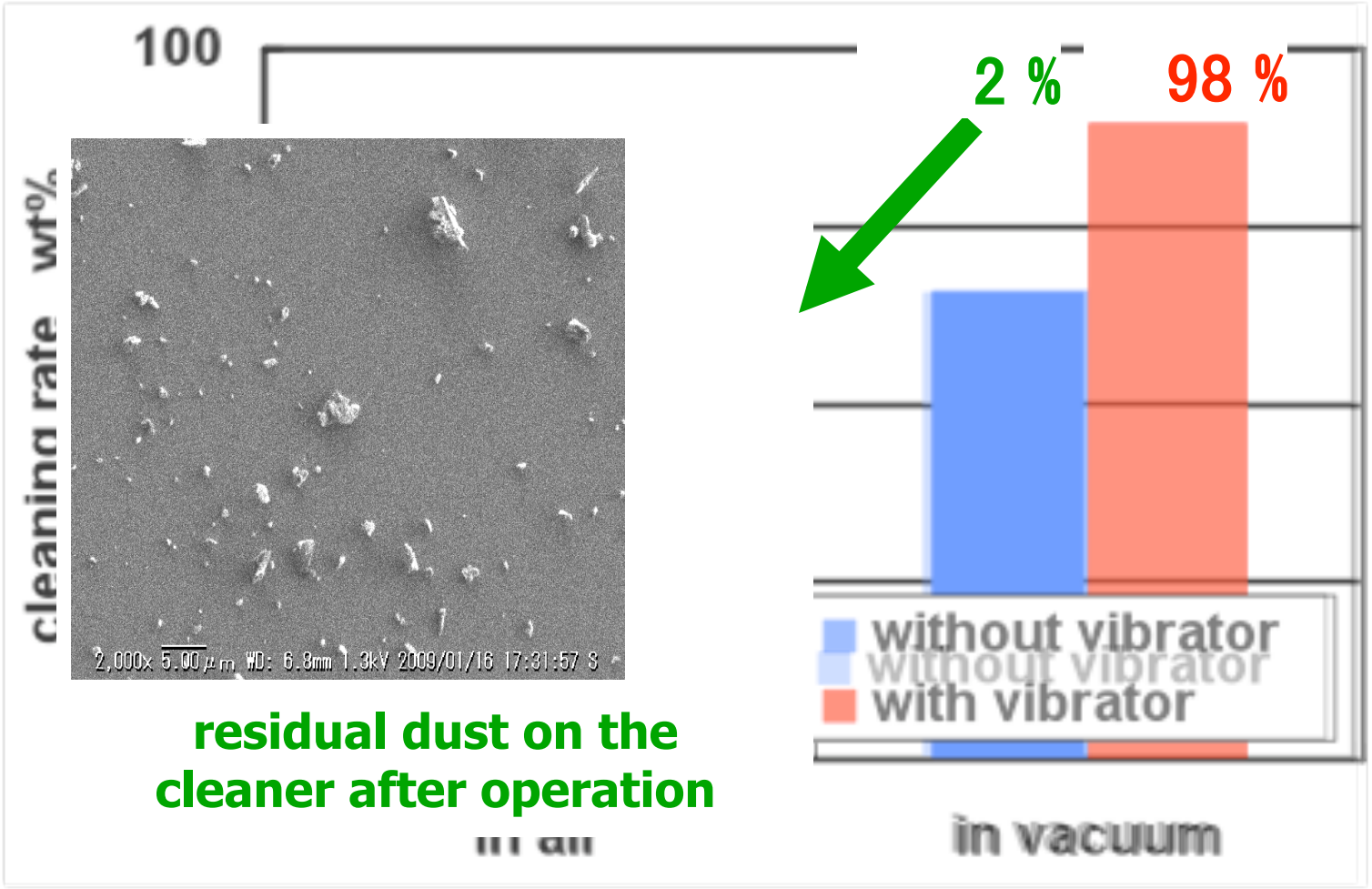
700 **V 10 Hz**

- **1/6 G**
- **in vacuum**

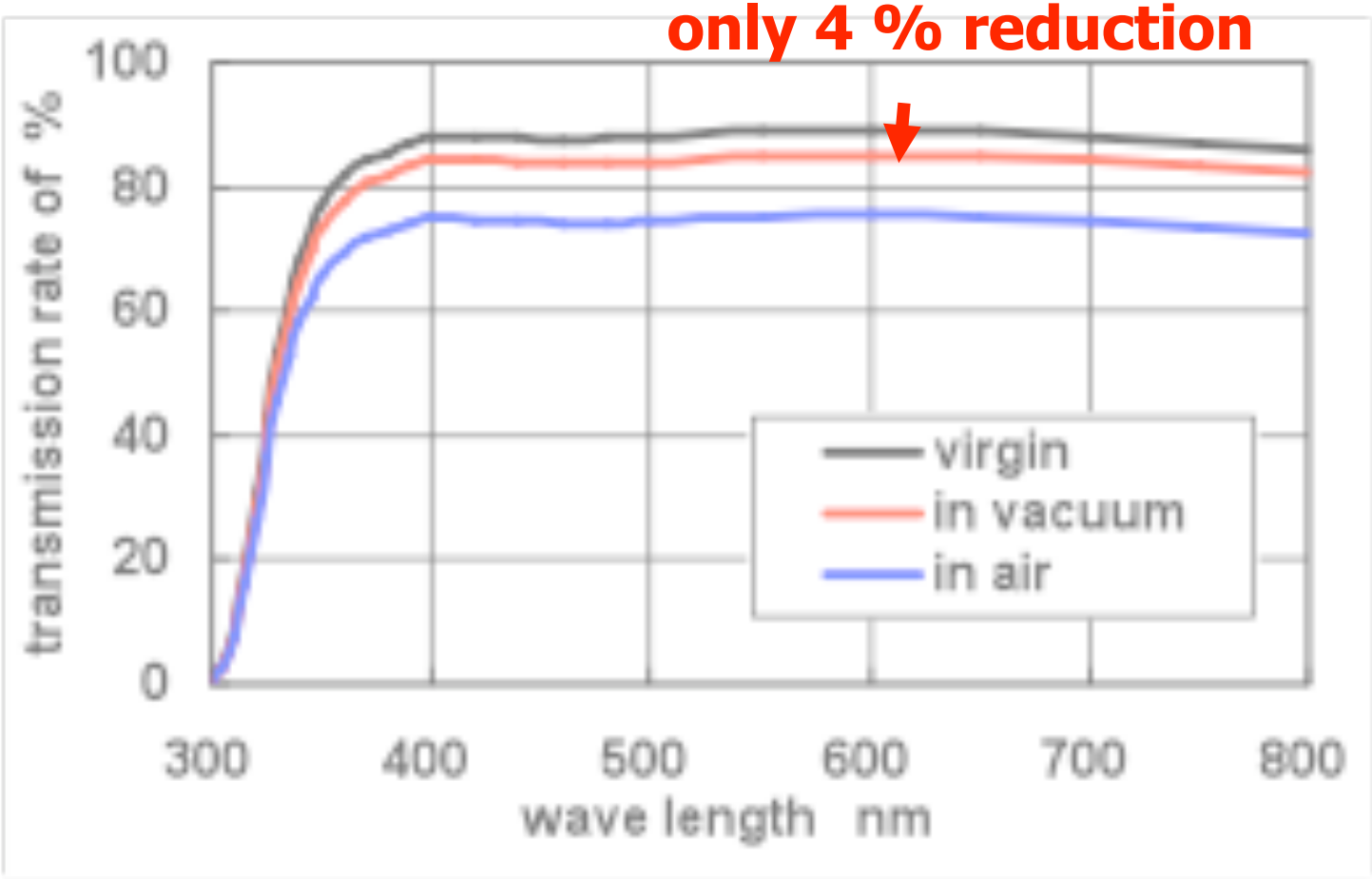
Improved Cleaning System Assisted by Ultrasonic Vibrator



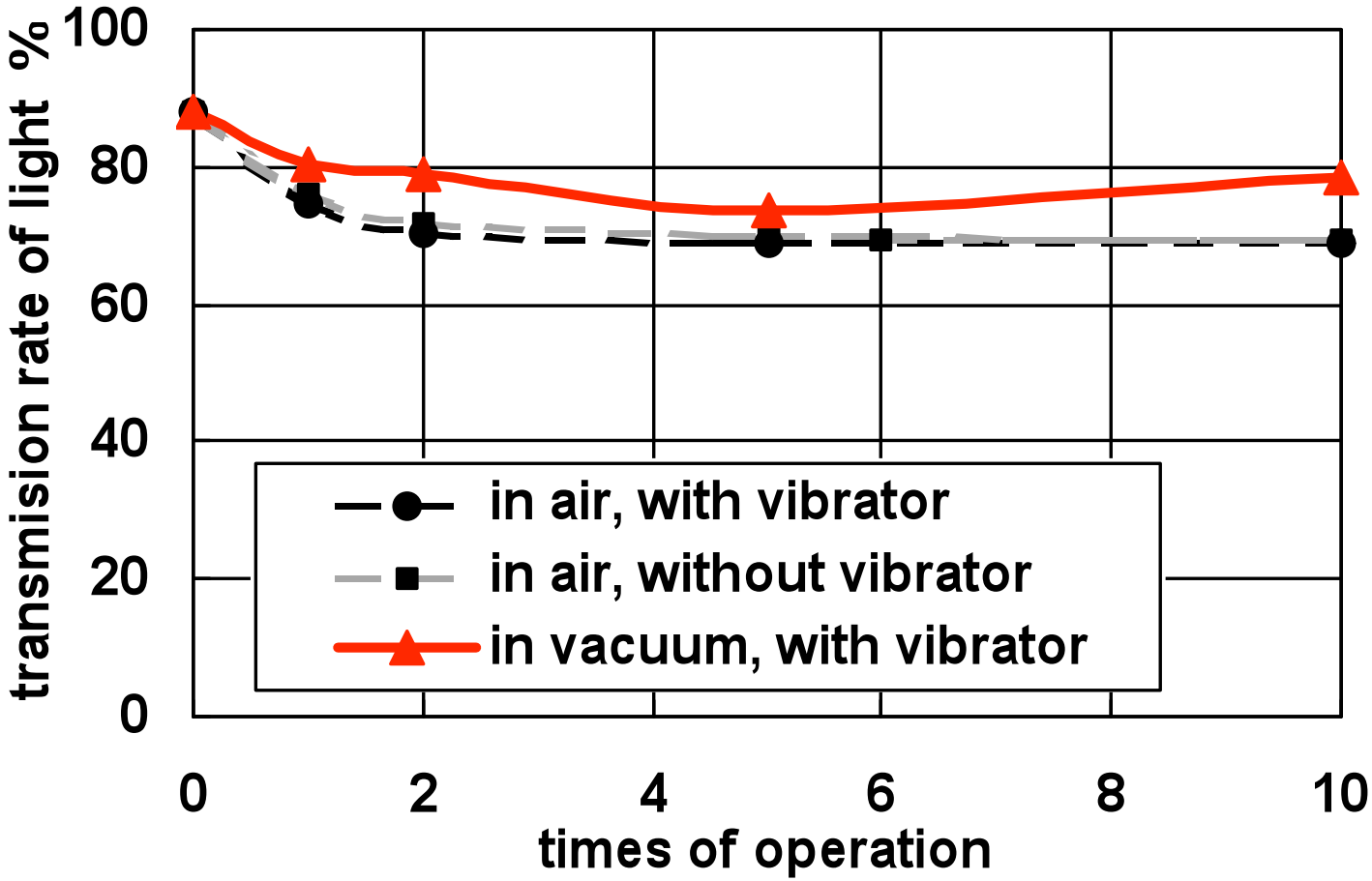
Improved Cleaning Performance with Ultrasonic Vibrator



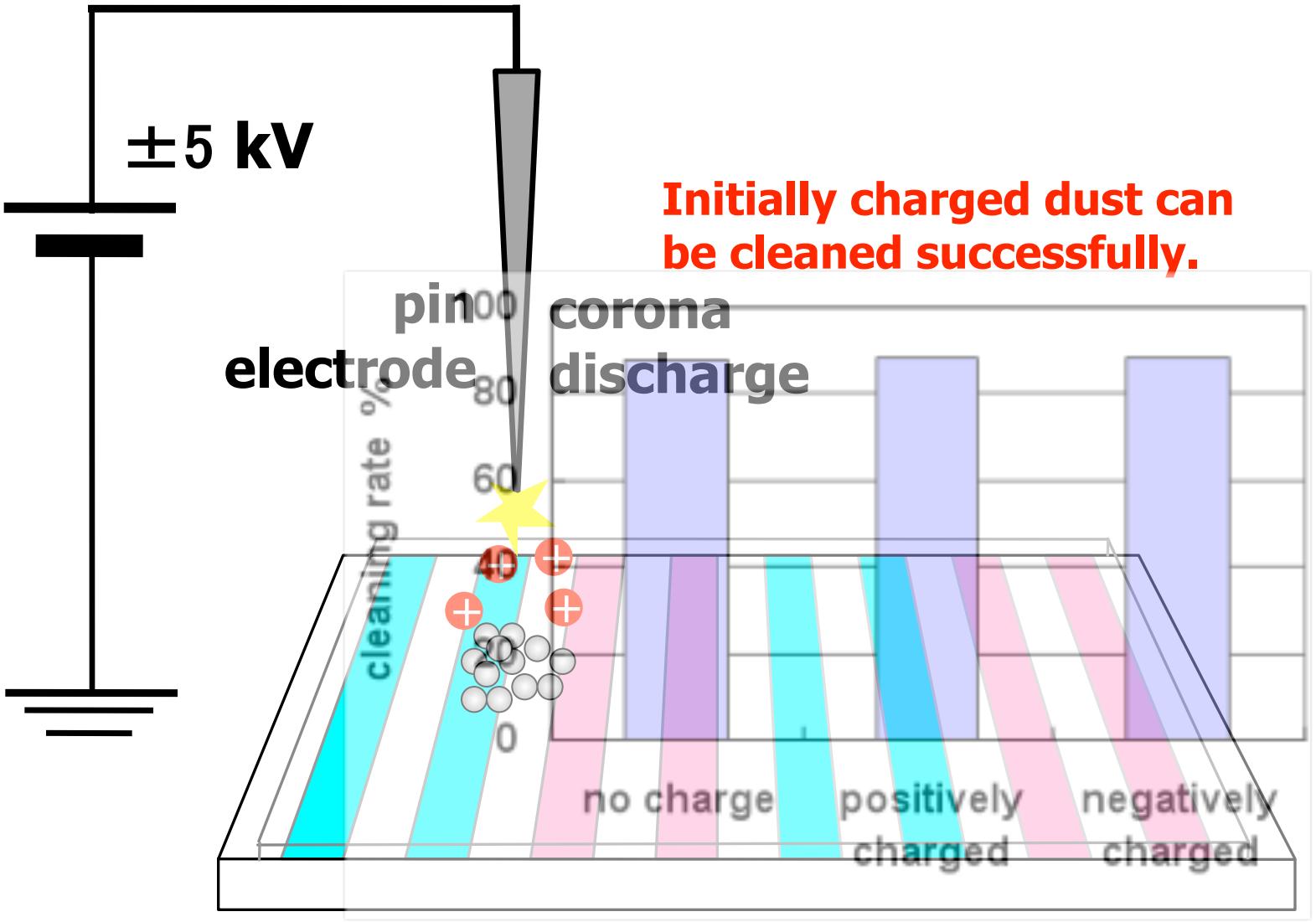
Transmission Rate of Light before/after Operation



Degradation of Cleaning Performance by Repeated Operation

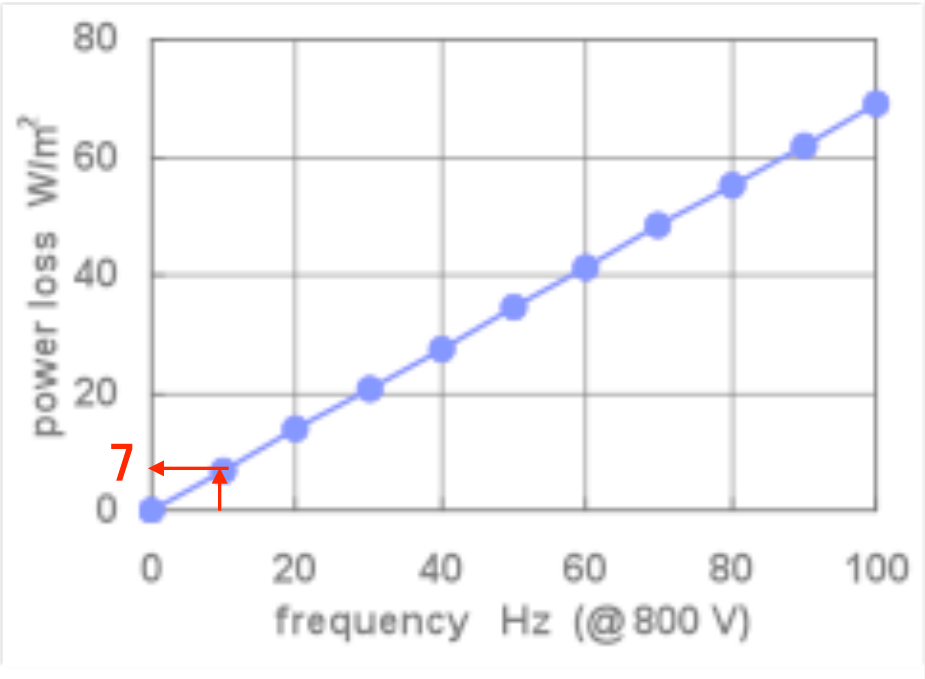


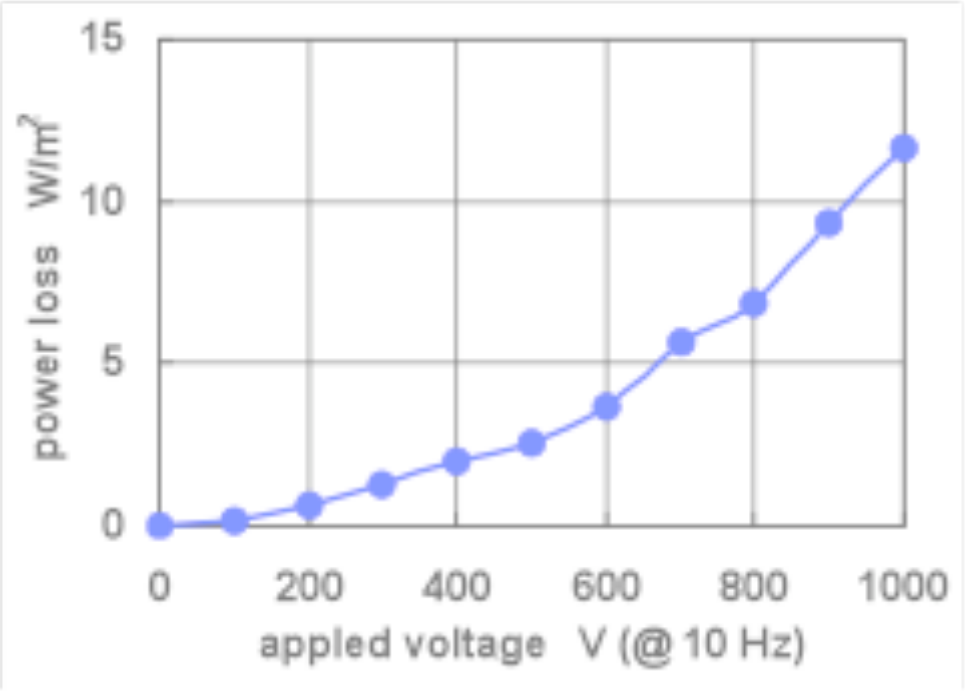
Cleaning Performance of Initially Charged Dust



Power Consumption

@ 1 m^2 cleaner





estimated power consumption:
7 W ×30 sec. = 0.06 Wh for 1 m^2 cleaner

Demonstration of Cleaning Operation Using Real Lunar Dust

Demonstration of Cleaning Operation

Residual Dust on Conveyer after Cleaning Operation

(10084,853 Apollo 11 landing site)

Concluding Remarks

A technology has been developed for lunar dust mitigation for solar panels and optical elements during long-term operations based on electrostatic traveling-waves.

- **High cleaning performance was observed in vacuum with the application of ultrasonic vibrations. A few particles adhered to the surface such that optical performance was reduced by a few percent but further reductions were not observed after repeated operations.**
- **Both positively and negatively charged dust particles could be cleaned without changing the configuration of the system.**
- **Actual lunar dust was successfully removed using the cleaning system.**
- **The power consumption was as low as 0.06 Wh for cleaning an area of 1 m^2.**
- **The cleaning performance of the system is expected to further improve in the low-gravity environment on the Moon.**