Investigation of the atmosphereless bodies dust dynamics: experimental set-up

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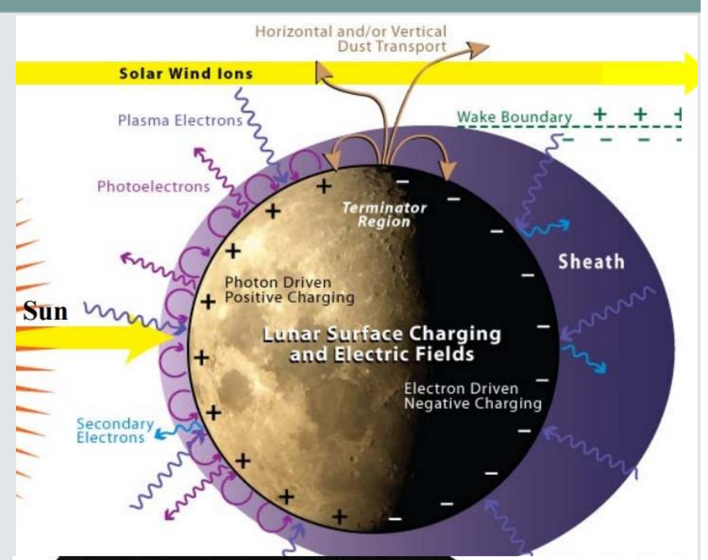
Background

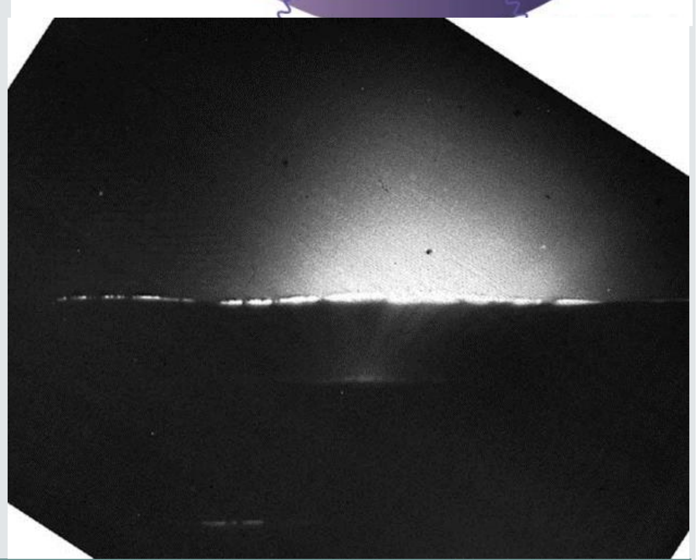
The surface of the Moon, as well as the surface of any space body without an atmosphere, is subjected to the solar wind and ultraviolet radiation influence. As a result, a charge appears on the surface and electric fields near it are induced. Dust particles from the lunar regolith occurring in the near-surface plasma can levitate over the surface, forming dusty plasma clouds. One of the main problems of future missions to the Moon is associated with lunar dust.

In order to gain a better understanding of mass transfer processes occurring on surfaces of the Moon and other atmosphereless celestial bodies it is necessary to conduct physical simulations in a laboratory. Usually, when the UV impact on dust particles is experimentally studied, dust levitation is provided by electric fields of a non-photoemission nature [1], or is not observed at all [2].

Due to rising interest to this problem at the last years a number of magnificent instruments and experiments for this purposes are occurred.

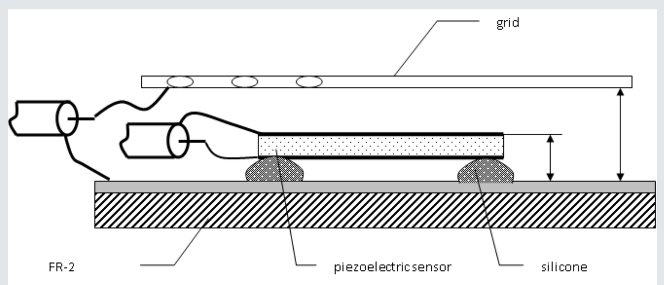
For the Dust Instrument PmL is provided by IKI for the investigation of lunar dusty exosphere began, we started to develop the simulation setup for the ground-base investigation of dusty exosphere as well as for the spaceborn device calibrations.



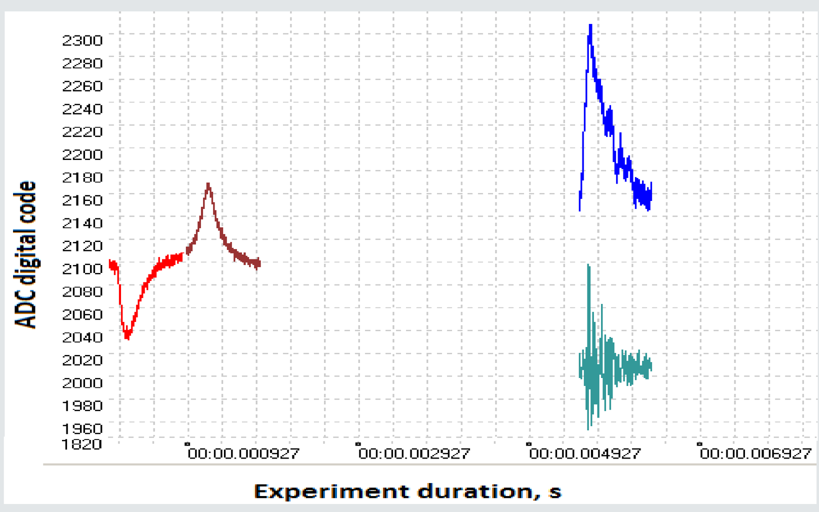


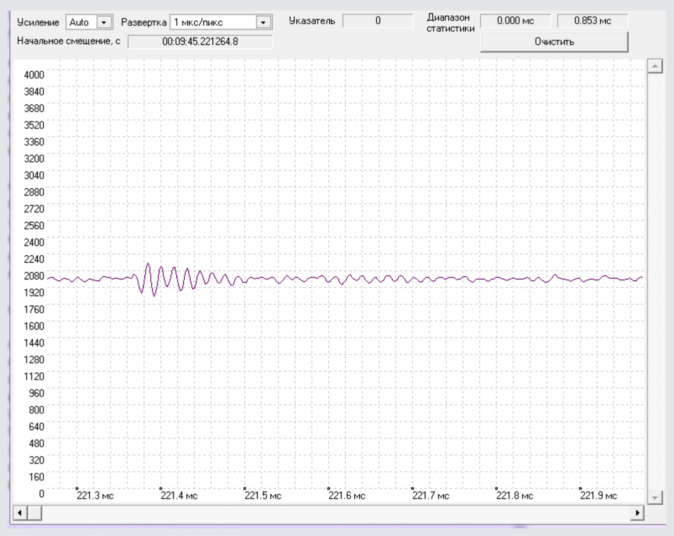
Results

I. Dust instrument validation and calibration



Measurement technique



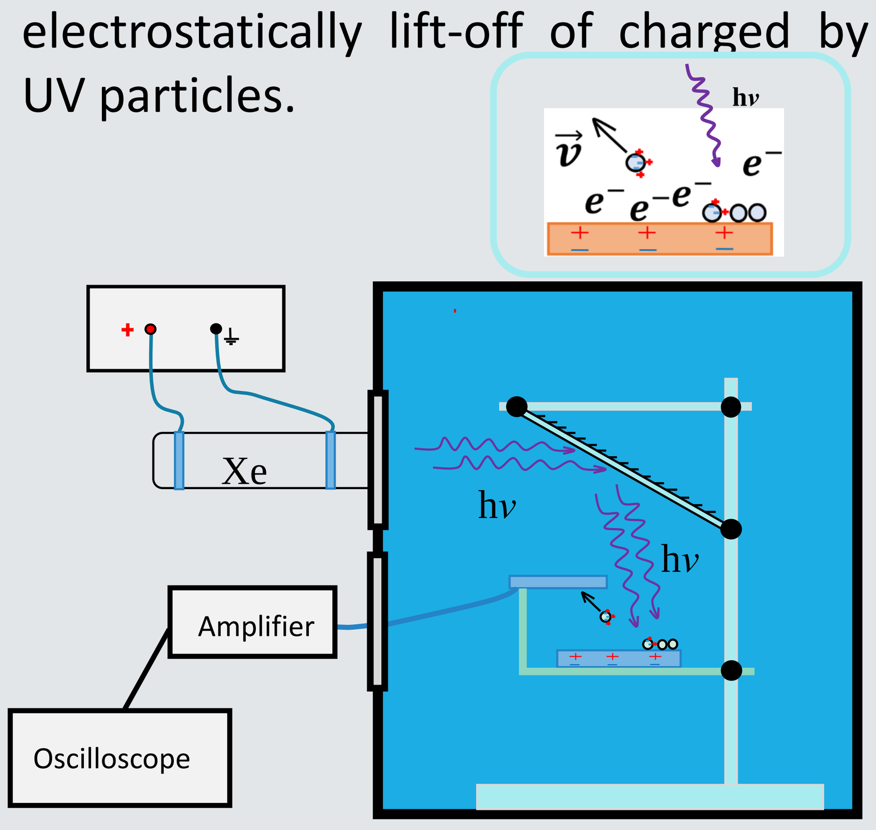


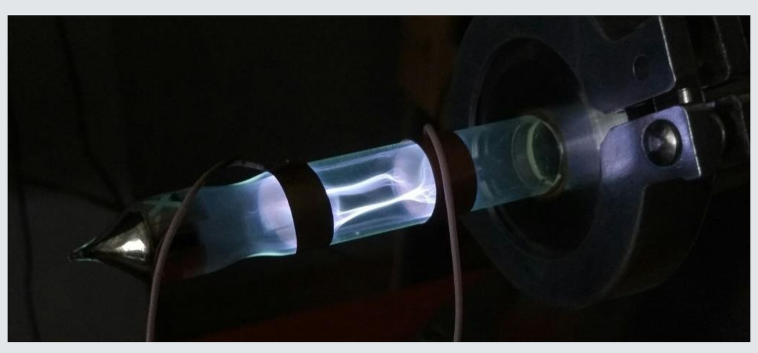
PZT signal from ~25 um particle at speed ~10 m/s.

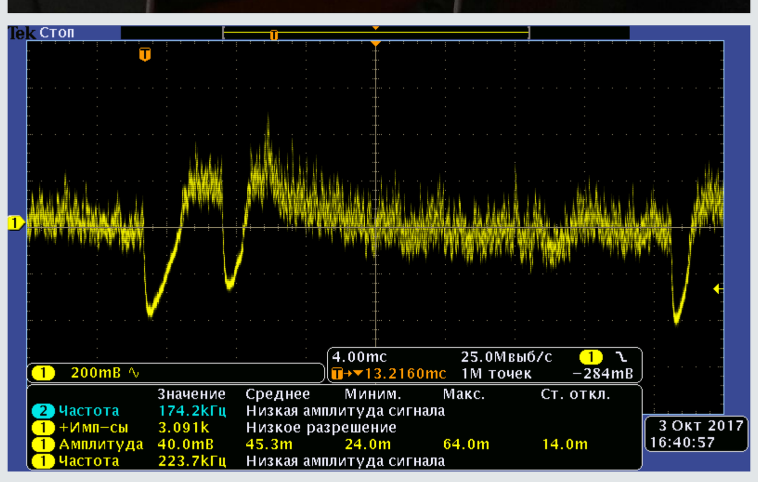
Dust particle, captured inside the calibration set-up.
The red and brown lines represent a particle pass through the internal inductive sensor (IIS) – the part of the set-up.
The blue curve represents an electrical pulse of the charge-sensitive grid. The green curve represents the PZT signal.

II. Investigation of the UV influence on the lunar regolith

The idea was to recreate the solar irradiation conditions for the lunar regolith. UV source here is Xe eximer lamp (172 nm).
The material is 20 um dielectric glass spheres.
As a result we can see a lot of events, which only can be connected with electrostatically lift-off of charged by UV particles.





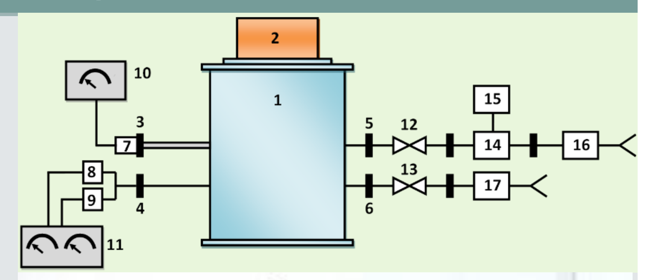


References

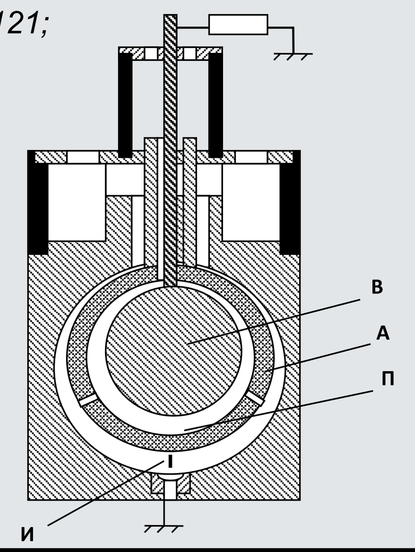
Sickafoose A.A., Colwell J.E., Horányi M., and Robertson S., J. Geoph. Res., 107, 1408 (2002)
Filippov A.V., Babichev V.N., Fortov V.E., Gavrikov A.V., Petrov O.F., Starostin A.N., and Sarkarov N.E., J. Exp. Theor. Phys.,11 2, 884 (2011)
Duncan N. A., Gruen E., Auer S., Xie J., Sternovsky Z., Drake K., Horanyi M., Robertson S. H. The Electrostatic Lunar Dust Analyzer (ELDA) Instrument // American Geophysical Union, Fall Meeting 2009, abstract #P23C-1263.
Drolshagen G., Dikarev V., Landgraf M., Krag H., Kuiper W. Comparison of Meteoroid Flux Models for Near Earth Space // Earth Moon Planet, 2008,Vol. 102, pp. 191–197.

PmL Calibration Setup

Scheme of the vacuum unit:
1 – vacuum chamber MSH D400 H600KR;
2 – injector charged particles;
3 , 4 – fittings NW25;
5, 6 – fittings NW40;
7, 8 – lamp ПМТ-2 (manometric thermocouple transducer);
9 – lamp ПМИ-2 (manometric ionization transducer);
10 – vacuum meter AB 3401;
11 – vacuum meter ВИТ – 2 (ionization-thermocouple vacuum meter);
12 – entrance valve;
13 – inlet valve;
14 – turbo-molecular pump BALZERS THP050;
15 – control of turbo-molecular pump BALZERS TCP121;
16 – forevacuum pump PDV 500 GB;
17 - filter



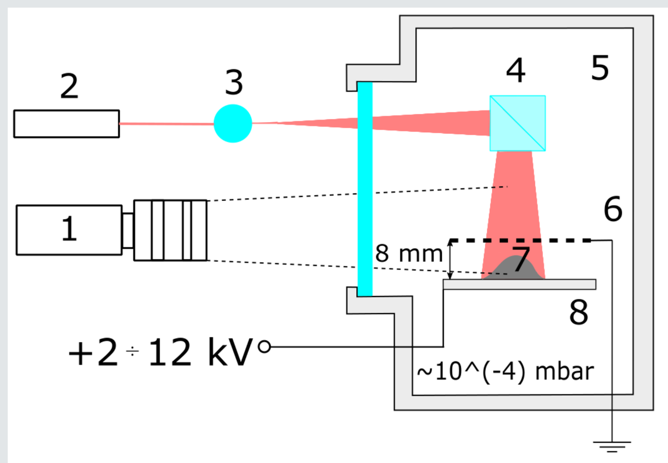
The state near the lunar surface are modeled using a vacuum system (under pressure <1,01325 Pa) and an injector of the charged particles (particle size 1 ÷ 300 μm, velocity 10 ÷ 100 m/s, charge ≥ 1000e–). Solar radiation is simulated by mercury arc lamps of low pressure (wavelength 170 ÷315 nm).



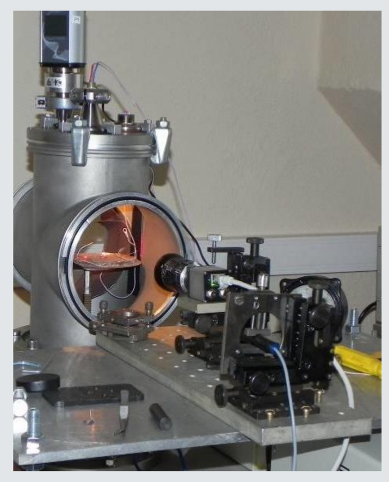
Mass, kg	Size, um	Electrical properties	Velocity, m/s	Momentum, N·s	Plasma state	Charge, e^-
$>10^{-12}$	10 – 400	Conductive	2 – 100	$10^{-12} – 10^{-8}$	In developing	>1000

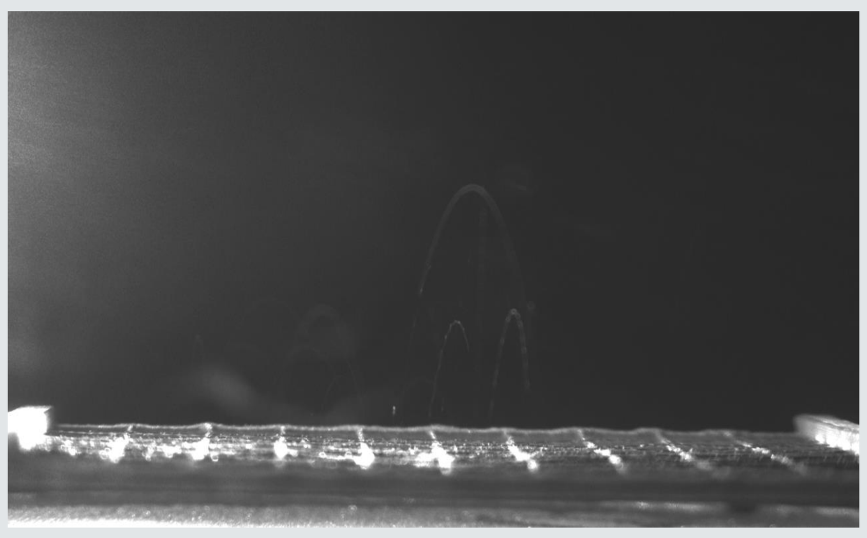
Results

III. Dust particles lift off and levitation

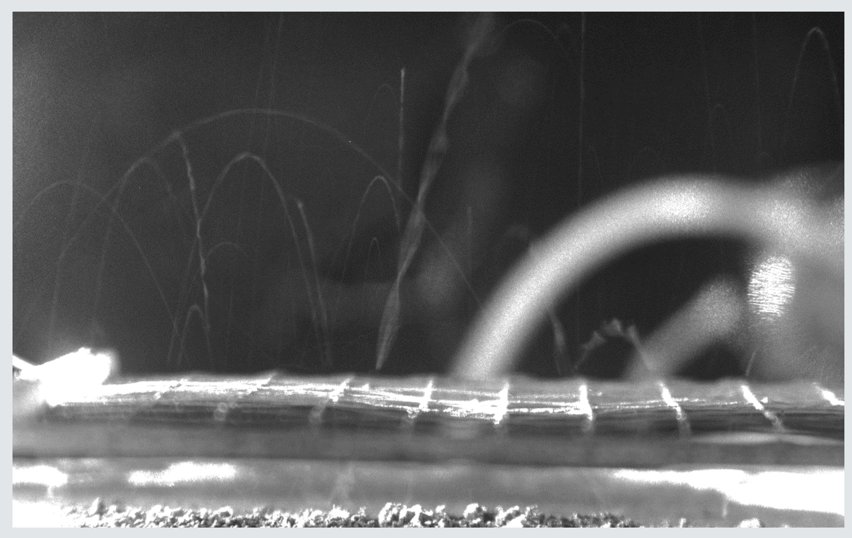


1 – Camera;
2 – Laser source;
3,4 – probing optical system;
5 – vacuum chamber;
6 – grid (GND connected);
7 – dust samples (1 μm, Fe; 40÷100 μm, SiO_2);
8 – conductive Cu plate

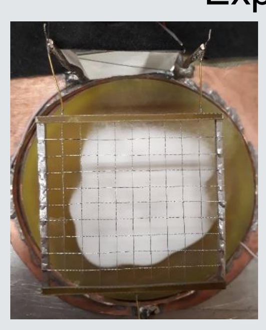




Dust particles lifting off process. 2,5 kV on bottom plate. Grounded grid 3 mm above. SiO2 40…100 um particles. Exposure time 100 μs.

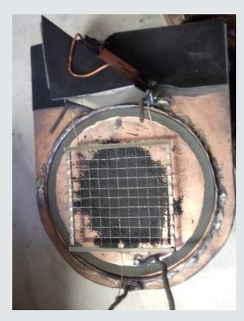


Dust particles lifting off process. 6 kV on bottom plate. Grounded grid 3 mm above. Fe 1 um particles. Exposure time 100 μs.



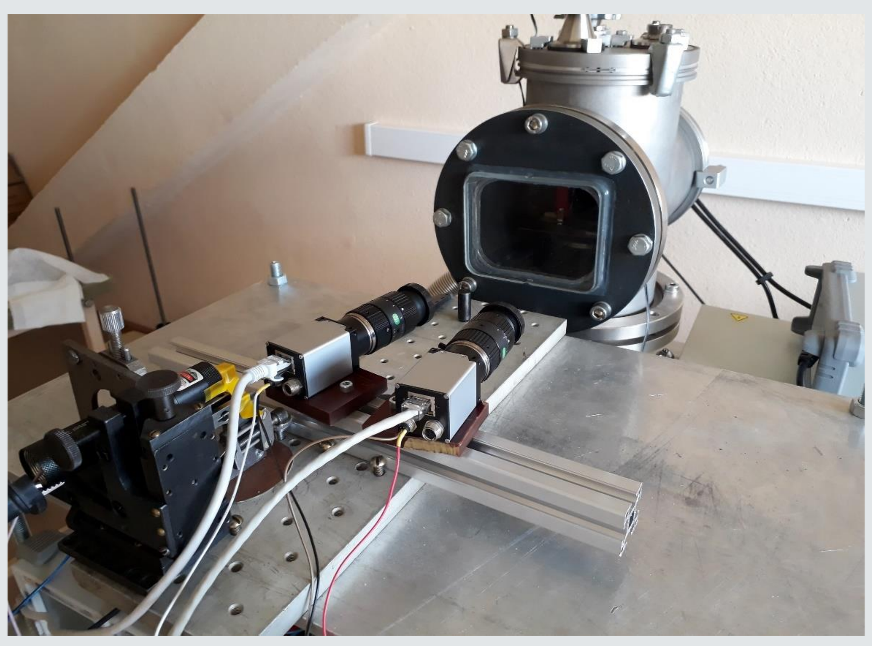
Before

After ~ 1 h experiment

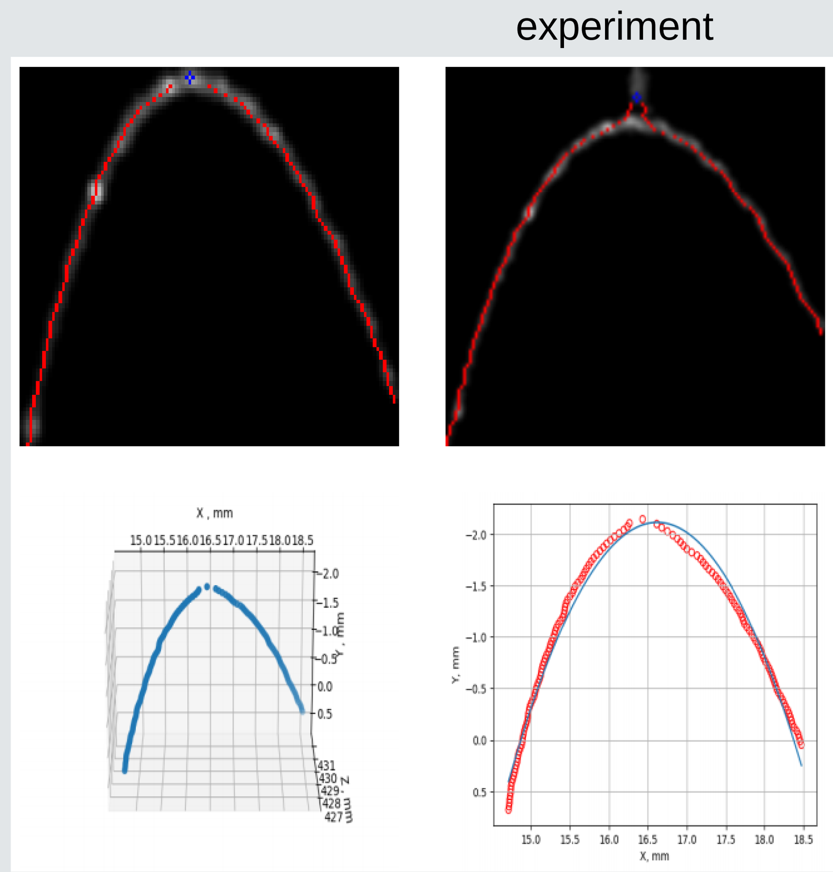


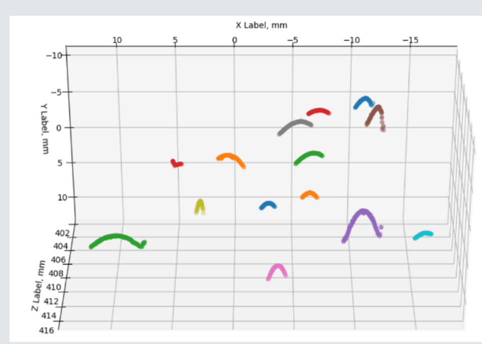
Before

After ~ 1 h experiment



Optical Stereosystem for dust particles trajectory registration





Restored Dust Trajectories

Processing. Parameters:
Correlation max 0.475; Traj. Length 10.3548 mm;
Parabola: a=0.6867 b=-22.8277 c=187.594;
Vy = 0.6123 m/s; Vx = 0.0845 m/s; V = 0.6181 m/s
Lift-off angle = 82.14°; $R_{particle}$ =5E-05 m;
$M_{particle}$=2.8798E-10 kg; $Q_{particle}$=2.7757E-14 C

Acknowledgements

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