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Dust accelerator tests of the LDEX laboratory model

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Abstract

The LDEX (Lunar Dust EXperiment) sensor onboard lunar orbiter LADEE (Lunar Atmosphere and Dust Environment Explorer) was designed to characterize the size and spatial distributions of micron and sub-micron sized dust grains. Recent results of the data analysis showed strong evidence for the existence of a dust cloud around the moon. LDEX performs in situ measurements of dust impacts along the LADEE orbit. The impact speed of the observed dust grains is close to 1.7 km/s (the speed of the spacecraft), since the dust grains are considered on bound orbits close to the maximum height of their ballistic motion.

LDEX is an impact ionization dust detector for in situ measurements. The detection of a dust grains is based on measuring the charge generated by high speed impacts ($>$ 1km/s) on a rhodium coated target. The impact charge Q is a function of both the speed v and the mass m of the impacting dust particle. The characteristic values are dependent on the instrument geometry, the impact surface properties (material), the impact geometry (impact angle) and the particle properties (material, density, speed, mass, shape). In our tests we used PPy-coated olivine and PPy-coated ortho-pyroxene with impact speeds around 1.7 km/s.

A LDEX laboratory model was designed and manufactured by the University of Stuttgart. The model is used to support calibration activities of the Univ. of Colorado and to perform special tests (impact angle and impact location variations) at the dust accelerator facility at MPI-K (Heidelberg) which is operated by the IRS of the University of Stuttgart.

1 Instrument Description

The laboratory model of LDEX is a to-scale model of the LDEX flight model. It uses the same target material and dimensions. The instrument consists of a hemispherical rhodium target with a size of approx. 10 cm in diameter, an ion grid and a MCP detector in the center. A dust grain impacts at the hemispherical target and generates an impact plasma. An electric field between the ion focusing grid with negative bias potential and the grounded target separates the electrons and negative ions from positive ions. The electrons and negative ions are collected at the target and they are measured by a charge sensitive amplifier (CSA). The positive ions in the center create an induced charge on the ion focusing grid and are measured by a second CSA. Depending on the grid transmission, an ion current is measured as well. After flying through the ion focusing grid, the positive ions are detected by a microchannel plate (MCP) behind the focusing grid. The MCP output is directly connected to a transient recorder to measure the ion signal of individual impacts.

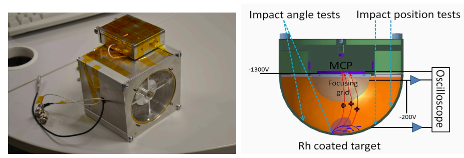

Figure 1: The LDEX laboratory model in the laboratory(left) and the cross section of LDEX with experimental parameters (right). The electrodes are shielded by an aluminum housing and entrance grids. An electronics box is seen at the top.

2 Experiment set up

The LDEX laboratory model was tested and calibrated at the Dust Accelerator Facility at Max Plank Institute for Nuclear Physics, which is operated by Institute of Space Systems at University of Stuttgart, Germany. We used polypyrrole (PPy) costed olivine (ρ = 3.32 g/cm^3) and ortho-pyroxene to (ρ = 3.4 g/cm^3) simulate the mineral dust grains in the lunar environment.

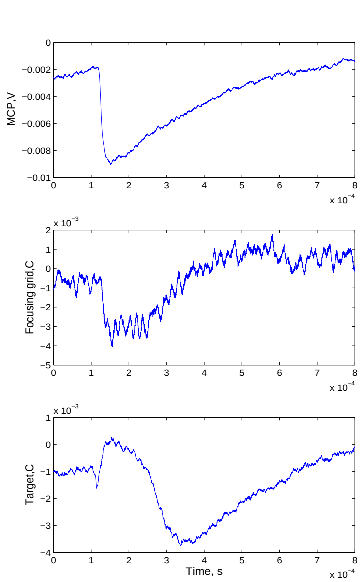

Figure 2: Typical LDEX signals created by a PPy-coated latex dust grain with a mass of 1.5 $\times 10^{-12}$ g, a projectile speed of 1.72 km/s and a primary charge of 1.44 fC. The signals are from the MCP (top), the grid (middle) and the target (bottom)

As comparisons, iron and PPy-coated Latex particle were also used for the calibration. The instrument was bombarded by micron and submicron sized dust grains with the speeds of between 0.5 km/s and 60 km/s. Figure 2 shows an example of typical MCP, focusing grid and target waveforms recorded at the dust accelerator facility.

3 Initial Calibration

We do analyse the impact signals with respect to their amplitde in order to determine the exponents of the relation between particle speed v, particle mass m and impact charge Q of $Q = \alpha m v^{\beta}$. We analysed both, the negative target signal Q_{target} and the positive ion yield Q_{MCP}. We found the following equations

$$m \approx (7.56 \cdot 10^{-5}) \cdot Q_{MCP}^{1.0542 \pm 0.029} \cdot v^{-3.544 \pm 0.11} \quad (1)$$

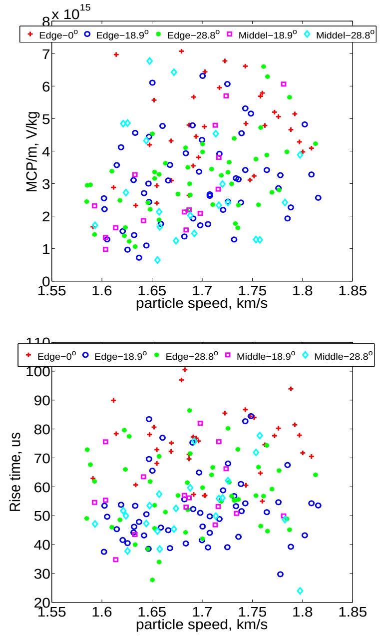

Figure 3: The impact calibration data using PPy-coated Olivine dust grains with different distances from the axis of the symmetry of LDEX. The speeds of impactor are in the range of 1.55 -1.85 km/s.

$$m \approx 0.046 \cdot Q_{target}^{1.115 \pm 0.047} \cdot v^{-2.903 \pm 0.13} \quad (2)$$

where m is the mass of the impactor with a unit of kg; and Q_{MCP} and Q_{target} are the detected charges by the MCP and the target with a unit of C, respecitvely; v is the speed of the impactor with a unit of km/s.
Figure 3 indicates that the charge amplitude and the rise time are independent on the location and on the impact angle.

References

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[2] Sternovsky, Z., Horanyi, M., Gruen, E., et al.: The calibration of the Lunar Dust Experiment (LDEX) instrument, AGU, Fall Meeting 2011, abstract P43A-1666