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# A Dust Sensor for Planetary Rovers

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## Abstract

The LDEX (Lunar Dust EXperiment) onboard the lunar orbiter LADEE (Lunar Atmosphere and Dust Environment Explorer) identified successfully the dust cloud above the lunar surface along the spacecraft orbit [1]. In contrast, reliable in-situ dust measurements on the surface have not been successful until today. Simple instruments placed on the lunar surface can monitor both ejecta and lofted dust, respectively [2]. Both populations are candidates to maintain the lunar dust cloud. A dust detector onboard a lunar rover has serval advantages. In this paper we describe the design of a compact dust sensor for electrically charged micron-sized dust particles with low velocities. This sensor will monitor the interaction of the rover with the lunar dust environment, but its concept is suitable for sensing the dust environment of small atmosphereless bodies like asteroids or comets as well.

## 1 Laboratory Model Concept

The laboratory model of the sensor is based on charge induction with heritage of the LDX sensor for a lunar lander mission. A laboratory model was manufactured using a 3D printer and it contains two shielding grids and only one active plane containing three grid electrodes (Figure 1). All electrodes are formed by etched grid segments, and these segments have a size of approximately 5 cm × 5 cm. The distance between the nearby segments on each plane is 3 mm in order to allow for a mounting structure and a low capacitance between the electrodes.

The signals were simulated using the Coulomb software package in addition to laboratory tests (Figure 2). The signals show the relative amplitudes of 'Nearby Segments' for different insertion points in Z direction (Za(1) = 0 m- m, Za(2)= 10 mm, Za(3)= 20 mm and Za(2)= 23 mm, where Za(1) = 0 mm is in the middle of the center grid). The incident angles $\alpha$ are 0 degree and 32.4 degrees. Equation 1 gives the entrance position information as:

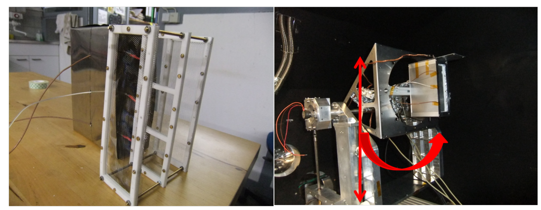

Figure 1: The set up of the laboratory model at the dust accelerator in Heidelberg. The instrument was mounted on an articulated platform.

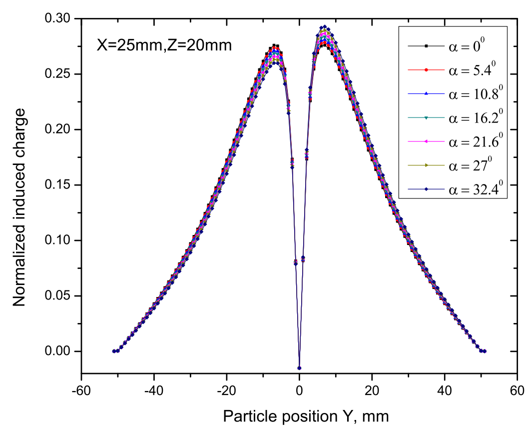


Figure 2: The induced charge signals of 3-girds electrodes detector.

$$Z = 34.85 - 8.8 \times lg(Q_{alpha} - 0.1041) \quad (1)$$

As the 3-grid electrodes just have a single plane to obtain the position information, the method reported [2] cannot be used here for the particle trajectory determination. Fortunately, the ratio k between two grid amplitudes Q changes with particle trajectories (k = Q1/Q2). The ratio k varies with the intersection point at the grid electrode as shown in Figure 3. Considered with Equation 1 and Figure 3, we can get the particle trajectory $\alpha$ by:

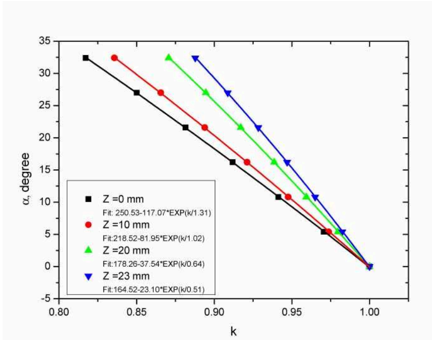


Figure 3: The ratio k for different crossing locations as a function of the particle trajectory with angle $\alpha$.

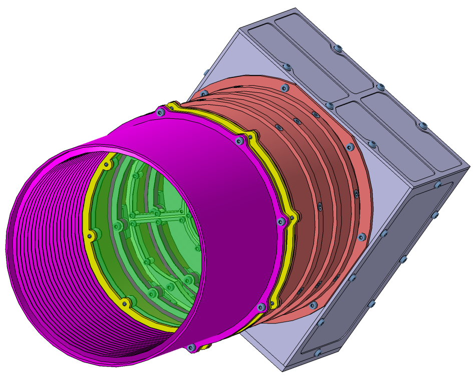

Figure 4: Mechanical structure of LDX-c with a cylindrical housing and a baffle for solar UV protection.

$$\alpha = f_1(Z) - f_2(Z) \times e^{\frac{k}{f_3(Z)}} \quad (2)$$

where:

$$f_1(Z) = 378.39 - 127.84 \times e^{\frac{Z}{44.67}} \quad (3)$$

$$f_2(Z) = 265.76 - 148.63 \times e^{\frac{Z}{46.82}} \quad (4)$$

$$f_3(Z) = 2.36 - 1.05 \times e^{\frac{Z}{40.43}} \quad (5)$$

Even a primitive grid design with one active electrode plane is capable to derive trajectory information. This ensures a low instrument complexity, a low power consumption, a low data rate and a low instrument mass. Furthermore, an alternative cylindrical design (LDX-c) (Figure 4) with the parameters given in in Table 1.

Table 1: Parameters study of LDX-c, as shown in Figure 4.

| | | | |
|---|---|---|---|
| LDX-c | Open area | | 80 cm2 |
| | Mass | House structure | 265 g |
| | | fastener | 10 g |
| | | E-box | 330 g |
| | | Sunshade | 100 g |
| | | SUM | 705 g |
| | Voltage | CSAs | 12V |
| | Power | CSAs (7) | 0.42 W |

# References

[1] M. Horanyi, S. Gagnard, et al,: Lunar Dust Experiment (LDEX): First Results, EGU General Assembly, 2014.

[2] Y. W. Li, R. Srama, H. Henkel et al.: Instrument study of the Lunar Dust eXplorer (LDX) for a lunar lander mission, Adv. Space. Res., In Press, 2014.