



DISC - Dust impact sensor and counter on-board Comet Interceptor mission: experimental set-up for calibration and preliminary results

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Introduction

The purpose of the ESA space mission Comet Interceptor, to be launched in 2029, is to study a Dynamically New Comet (DNC), building upon the significant scientific results of Rosetta, and extend the knowledge of cometary exploration. Exploring DNCs is a challenging task, because the target of the mission must be discovered in advance, according to the standard mission planning timeline. To reach this goal, the spacecraft, after the launch, will reach the L2 Lagrange point, waiting for the target selection. Comet Interceptor includes a main spacecraft (A) and two sub-spacecraft (B1 and B2). DISC, in particular, is part of the Dust, Field and Plasma suite, which will be boarded on the spacecraft A and B2. During the DNC fly-by, DISC will count the dust particles and measure their momentum. The fly-by speed will be in the range between 10-70 km/s.

DISC consists of an aluminium box case, size 121x115,5x46 mm³, equipped with two electronic boards, a sensing plate, a dust shield and three piezoelectric transducers (PZTs). DISC continuously acquires signal from the PZTs, but it starts registering data only when the digital signal reaches a set value. When the event is triggered, the signal is acquired from the PZTS for for 200 microseconds at 1 MHz sampling rate. From the analysis of the three signals acquired it is possible to retrieve the impact position and the particle momentum.

Expected performance

To evaluate the performance of DISC, it is necessary to operate different strategies, in order to take into account the range of dust particles momentum that DISC will hit. Comet Interceptor flyby speed is estimated to be in the range of 10 – 70 km/s. As it is not feasible to perform hyper velocity impact test on a laboratory facility, it was decided to evaluate the performance of DISC simulating the impact with high power pulse laser, in addition to the test performed with real projectiles, useful to cover the range of lower speed. This method is based on the correlation proposed by [Pirri, 1977], which allows to calculate the impact pressure of the laser pulse on a surface, knowing the main operating parameters of the laser: beam radius, pulse time and intensity. In this way, it is possible to reproduce the impact of particles with different size, velocity and contact time. In this study, two different Nd:YAG laser were used, PL2250 and NL300. Both have a wavelength of 1064 nm. Laser PL2250 has a pulse of 80 ps, energy up to 0.1 mJ; Laser NL300 has a pulse of 6 ns, energy up to 1.2 J. Once these parameters are set, it is possible to estimate the range of particles momentum that can be simulated for different values of particle density.

The impact pressure is a function of the impact speed and the particle density, therefore it is possible to correlate the range of interest for DISC calibration. Figure 1 reports the range of impact pressure that DISC must be able to measure, considering a range of particle density of 100 – 2500 kg/m³.

Figure 1: Impact pressure at different speed

Varying the optical energy, it is possible to identify the size and the speed of the particles which we are able to simulate with the lasers. As an example, Figure 2 reports the range of particle diameter and speed achievable with PL2250.

Figure 2: Range of diameter/speed at $\rho = 900 \text{ kg/m}^3$, PL2250

The use of two lasers with different pulse durations allows to evaluate measurement sensitivity to impact time variation, while maintaining the same transmitted energy.

MGSE development

To perform the simulation of hyper velocity dust impact with pulsed laser, the development of a specific laboratory set-up was required. These test aim at verify DISC expected performance and further verify the consistency between laboratory test and numerical simulations. In addition to the two Nd:YAG laser previously described, the experimental setup, includes a vacuum chamber, a beam expander, a converging lens and a 3D automated movement system. DISC is mounted on the automated movement system and positioned inside the chamber, operating at the pressure of 10^{-6} bar.

The lasers are positioned on an optical bench and the pulses are directed through two different optical paths, into a beam expander which increases the pulse width by a factor of 2.5. The pulse, through a window on the vacuum chamber, is directed into a converging lens that focuses it onto the sensitive surface of DISC. The lens has a focal length of 75 mm. By modulating the distance between DISC and the lens on a micrometric scale it is also possible to regulate the spot size and assess the effect of the particle size at a given momentum.

Figure 3: Optical paths to beam expander

The functionality of the Electrical Breadboard of DISC was assessed by mean of impact qualitative test carried out at Leonardo facilities. Metallic spheres of different size, from 0.8 to 2 mm were used as a sample to measure DISC response to the impact from a defined height. The spheres were dropped from the funnel structure represented in Figure 4, to the sensing plate of the EBB. The height was set by mean of a 1-dimension micrometric movement system. Knowing the distance between the drop point and the plate, and the mass of the spheres, it is possible to calculate the momentum of the impact and therefore compare it to the signal response of the PZTs.

All the results obtained from preliminary test, aimed at assessing the functionality of DISC and define sensitivity map of the sensing plate will be shown and discussed in detail.

Figure 4: Set-up for DISC functionality with metal mini-spheres

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