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Dust Next Generation Sensor : Innovative instrument and sensors for measuring dynamical parameters of dust in extraterrestrial environment.

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The study of the characteristics of refractory and icy particles in the space environment has become crucial to the understanding of many phenomena in which dust plays a fundamental role..

The project Dust Next Generation Sensor aims to develop next-gen sensors based on optical detection and piezoelectric transducers to retrieve size, mass, velocity, trajectory, and spatial distribution of particles. The sensors will be capable of measuring particles ejected within plumes driven by gas or ejected by different processes (e.g. electrostatic charging), moving in atmospheres and levitating on airless bodies. The proposed project aims to develop an optical detector coupled with an impact sensor, reproducing a multi-sensor instrument able to determine the dynamical parameters of the particles that cross its sensitive area

This type of detector is applicable in different environments such as Planets, satellites or minor bodies orbit and or surface.

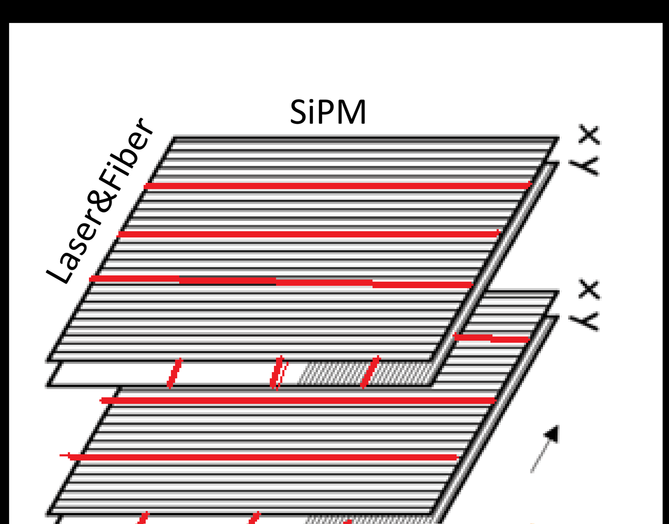
Possible Target : Moon – **Interplanetary Dust Particles (IDPs) and Surface Dust Ejecta (SDE).**

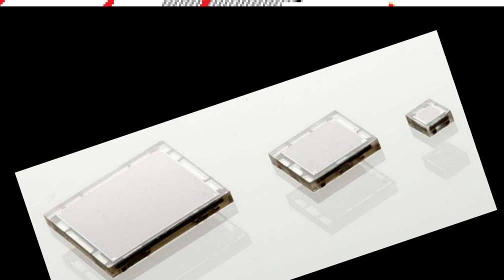
We propose an instrument consisting of three subsystems :

- DISC (Impact Sensor and Counter) which working principle is similar to GIADA-Impact sensor, for measuring the momentum of dust particles hitting its sensing surface.
- Optical Stage formed coupling fiber-coupled lasers and highly sensitive sensors Silicon PhotoMultipliers (SiPMs) to measure the speed, trajectory and optical cross section.
- QCMs to measure accumulation over time of the dust.

Optical Stage

The Optical Stage is the development of the Grain Detection System (GDS) on board GIADA. It will measure the light scattered by dust grain when crosses in a illuminated area. The primary objective of Optical Stage is to measure the scattered light by dust with size in a range 1-100 micrometers. It foreseen 2 optical plane (X,Y) each equipped with 10 laser coupling to fiber and 2 arrey of next-generationoptical sensors SiliconPhotoMultipliers (SiPMs). SiPMs are advanced devices that utilize solid-state technology to detect single photons. They consist of an array of Single Photon Avalanche Diodes (SPADs), named microcells or micro-pixels, that operate independently in parallel. Depending on their dimensions, the number of microcells in the SiPM may vary, while the number of pixels and their shaping at the focal plane is selected by the application.





SiPM

Table 1. PERFORMANCE PARAMETERS

Sensor Size	Microcell Size	Parameter (Note 1)	Overvoltage	Min.	Typ.	Max.	Units
1 mm	10µ	Dark Count Rate	Vbr + 2.5 V		30	96	kHz
	20µ				30	96	kHz
	35µ				30	96	kHz
3 mm	20µ				300	860	kHz
	35µ				300	860	kHz
	50µ				300	860	kHz
6 mm	35µ				1200	3400	kHz
1 mm	10µ, 20µ, 35µ	Rise Time – Fast Output (Note 7)			0.3		ns
3 mm	20µ, 35µ, 50µ				0.6		ns
6 mm	35µ				1.0		ns
1 mm	10µ, 20µ, 35µ	Signal Pulse Width – Fast Output (FWHM)			0.6		ns
3 mm	20µ, 35µ, 50µ				1.5		ns
6 mm	35µ				3.2		ns
1 mm	10µ	Microcell recharge time constant (Note 8)			5		ns
	20µ				23		ns
	35µ				82		ns
3 mm	20µ				23		ns
	35µ				82		ns
	50µ				159		ns
6 mm	35µ				95		ns
1 mm	10µ	Capacitance (Note 9) (anode–cathode)	Vbr + 2.5 V		50		pF
	20µ				90		pF
	35µ				100		pF

SiPM Characteristics

DISC

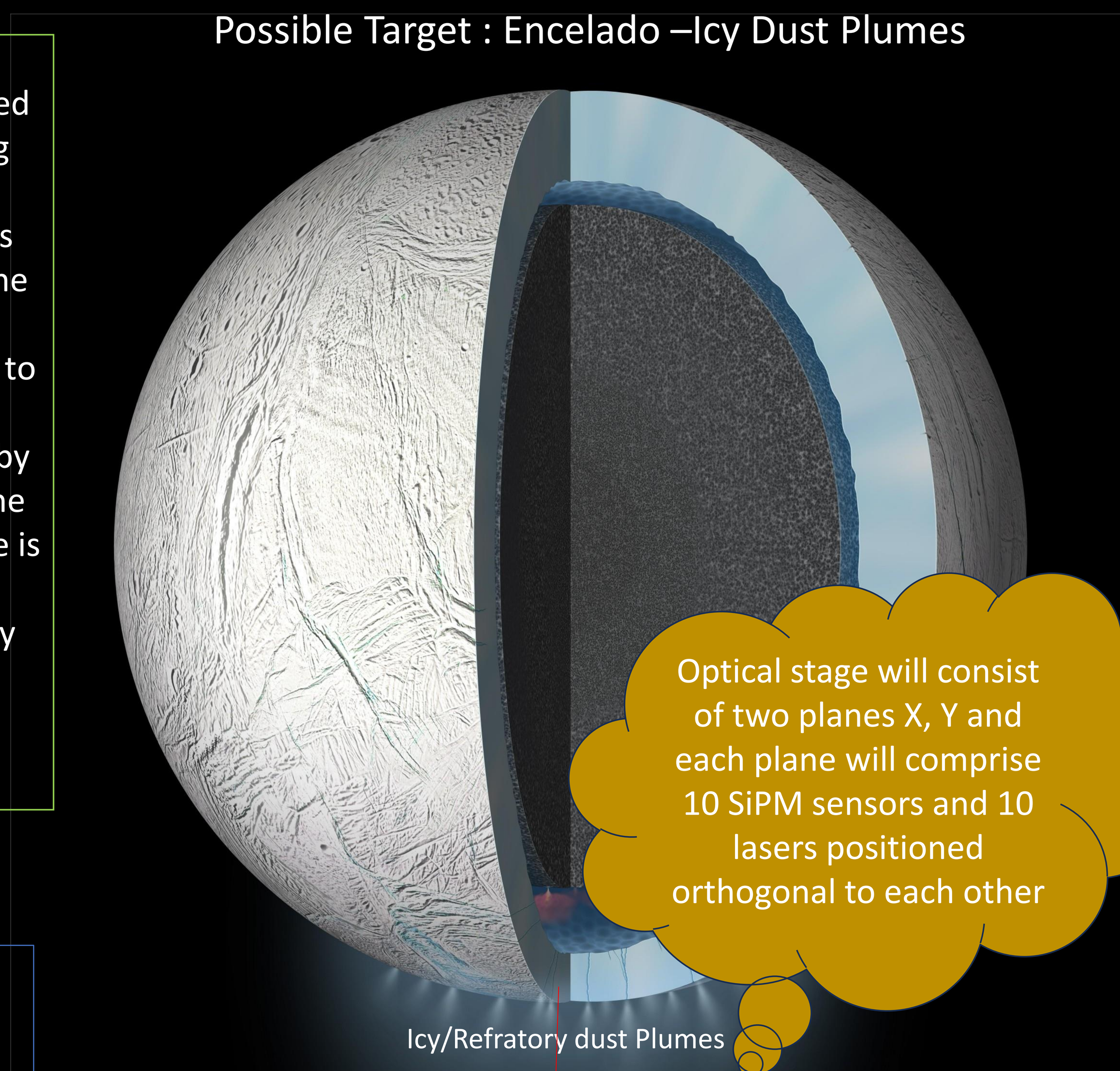
The Impact Sensor and Counter is a further improvement of DISC selected for Comet Interceptor and is able to measure momentum of impinging particles on its sensing surface.
A similar sensor was used on Rosetta ESA mission to measures particles with low speed (<300 m/s) and the same configuration demonstrated the capability to measures particles impacting in hypervelocity regime.
The sensing element is formed by piezoelectric sensors (PZT) connected to a mechanical element: the sensing plate.
The PZTs detect the acoustic bending Lamb waves (Lamb, 1, generated by the dust impact, propagating across the aluminium plate and convert the elastic deformation of the plate into an electrical signal whose amplitude is linked to the momentum of the impacting particle.
These elastic waves are generated both by low speed and hypervelocity impacts and the same sensor configuration shall be applicable.

OS+DISC

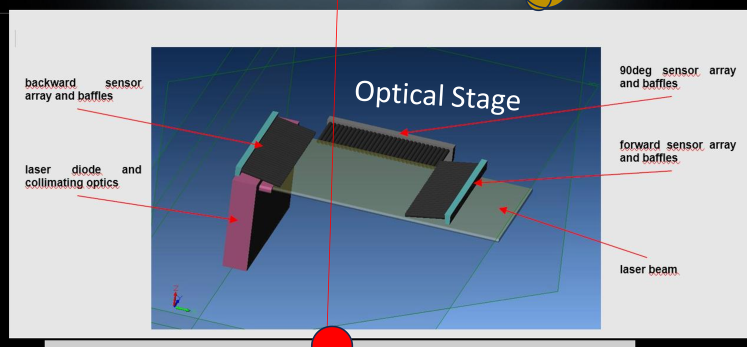
The OS can be coupled with the DISC in a cascade configuration and the measurements from the 2 subsystems can be cobined to retrieve additional
Information on particles crossing their sensing areas:

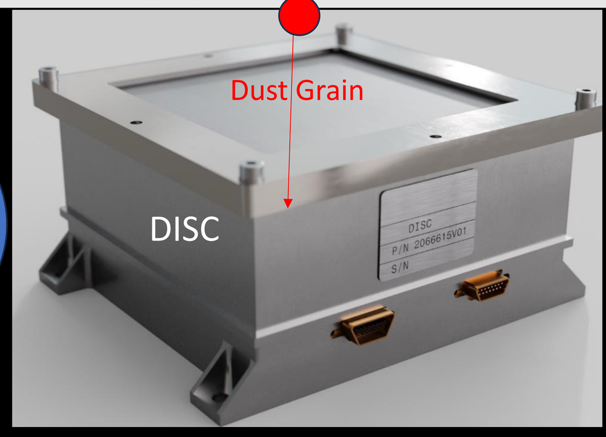
- Optical Cross Section
- Velocity
- Direction
- Partcle mass
- Paricle density

Possible Target : Encelado –Icy Dust Plumes



Optical stage will consist of two planes X, Y and each plane will comprise 10 SiPM sensors and 10 lasers positioned orthogonal to each other

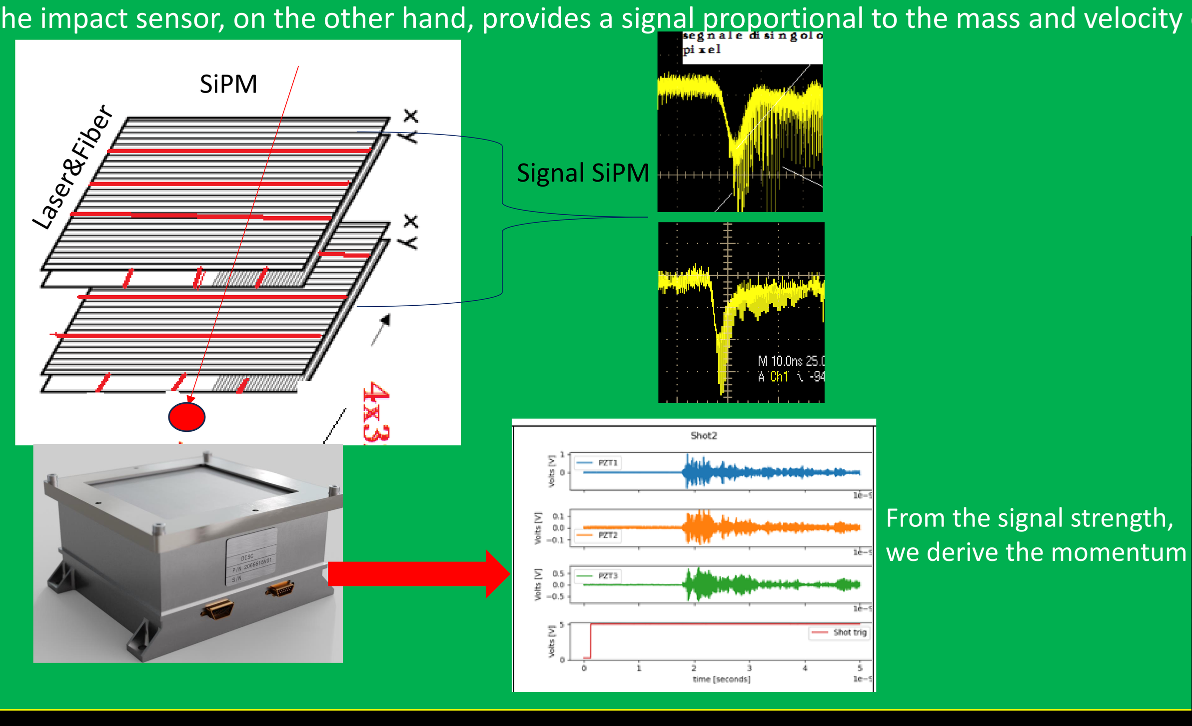




Dust Next Generation Sensor

DISC is provided of 4 piezoelectric sensors (PZT) to able detect the acoustic bending Lamb waves, generated by dust impact on the sensing plate

The Ice and refractory Dust passing trough the light planes generated by the fiber-coupled lasers by scattering light that strikes the arrey of SiPM which return a quantized signal proportional to the grain size. Each SiPM corresponds to a point on a plane so by making the intersection between the planes the trajectory of the grain is obtained. The impact sensor, on the other hand, provides a signal proportional to the mass and velocity of the grain.



QCMs

The third measurement subsystem, the MBS, was formed by a net of Quartz Crystal Microbalances (QCMs) that measure the amount of dust that accumulates its sensitive element. Advanced QCMs have been developed that have the ability to change their temperature, allowing for the desorption of volatile materials. The VISTA-Hera will collect dust in the Didymos asteroid environment, while the DIANA-Tianwen2 will measure low-volatility materials in the dust ejected by the 311P comet. The QCMs currently in development can collect dust at a low relative speed (i.e., a few m/s).

Possible Target : IO – Vulcanic Dust Plumes