Future Electrostatic Accelerometer without Polarization Wire

ONERA — return on innovation

G4.2 Online

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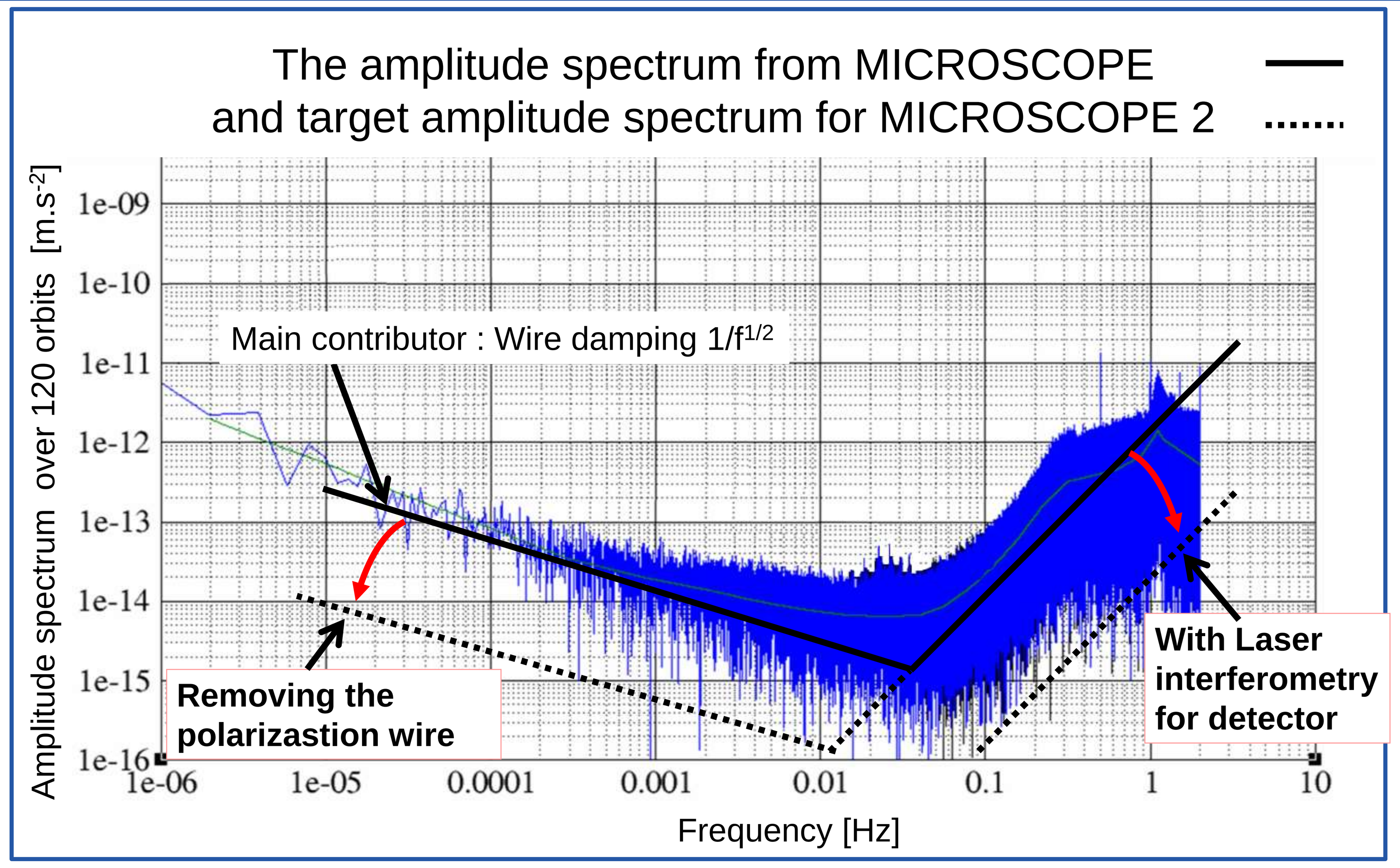
ONERA accelerometers heritage

ONERA (the French Aerospace Lab) is developing, manufacturing and testing ultra-sensitive electrostatic accelerometer for space application. Accelerometers have been successfully developed for the Earth-orbiting gravity missions CHAMP, GRACE, GOCE and GRACE-FO and for Earth-orbiting Fundamental Physics mission MICROSCOPE.

After removing the thermal variations, the wire damping is the main contributor at low frequency.

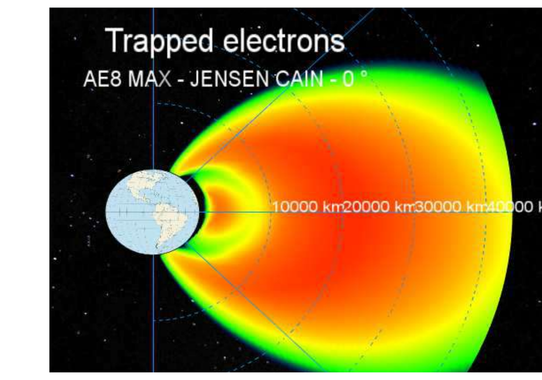


→**Removing the polarization wire will be mandatory to achieve the Microscope 2 mission requirement or the next generation 10^{-14} $m.s^{-2}.Hz^{-(1/2)}$ gradiometer for measuring the Earth gravity field variations.**

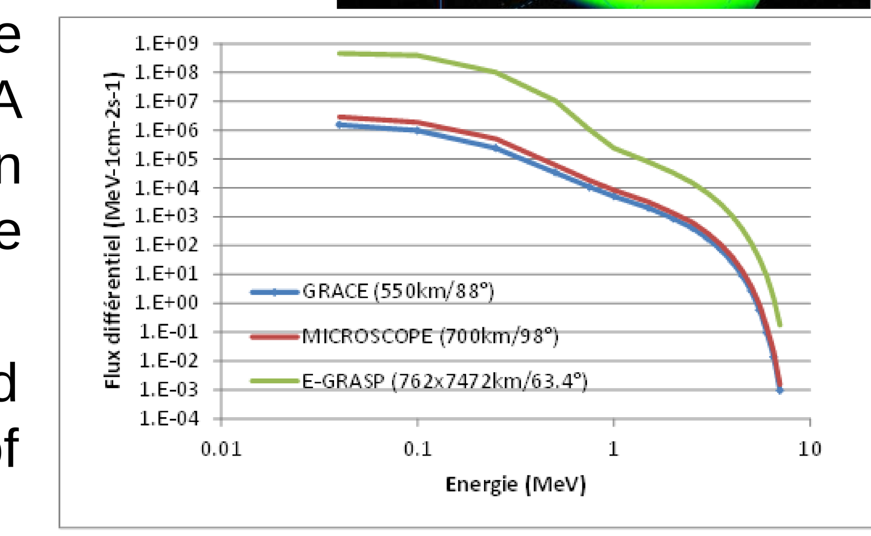
But highly energetic particles of space environment will inevitably penetrate through the spacecraft and charge the isolated proof mass. This phenomenon will affect its controllability and add a noisy charging contribution which need to be addressed.

Space Radiation and Charging Simulation

The study has been focused on 3 target missions : GRACE, MICROSCOPE and E-GRASP-like orbit. Below is presented the mean electron spectrum extracted from the AE8 Nasa environment model.



The electron spectrum and proton spectrum allow us to simulate an internal charging implantation into the proof mass material with Geant4 / GRAS software. A simplified spacecraft has been considered with an equivalent shielding of 20mm Al around the accelerometer sensor.



Moreover 3 different materials have been considered for the proof mass to modulate the performance of the sensor : Silica, Titanium and Platinum.

The following table has been computed for the GRACE environment.

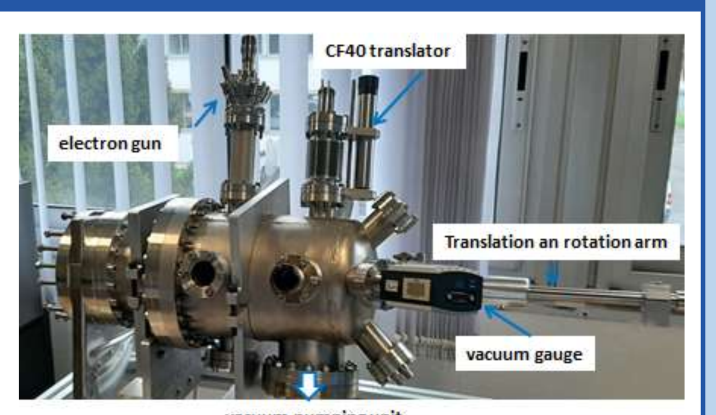
	EA8/AP8	
	e- (ecu/s)	p- (ecu/s)
Platinium	$< 10^{-3}$	18.7
Titanium	$< 10^{-3}$	10.8
Silica	$< 10^{-3}$	3.35

The proof mass is positively charged by the space environment. And the denser the proof mass material is, the more charged it is.

$$\rho_{Silica}<\rho_{Titanium}<\rho_{Platinum} \rightarrow Q_{Silica}<Q_{Titanium}<Q_{Platinum}$$

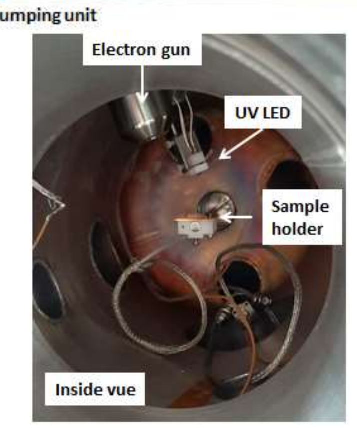
Electron Gun and UV Testing

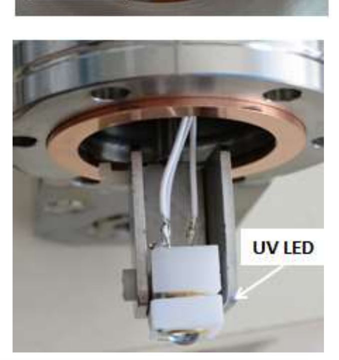
In order to remove this unwanted charge on the proof mass, preliminary tests have been carried-out in a vacuum enclosure with electron gun and UV LED.

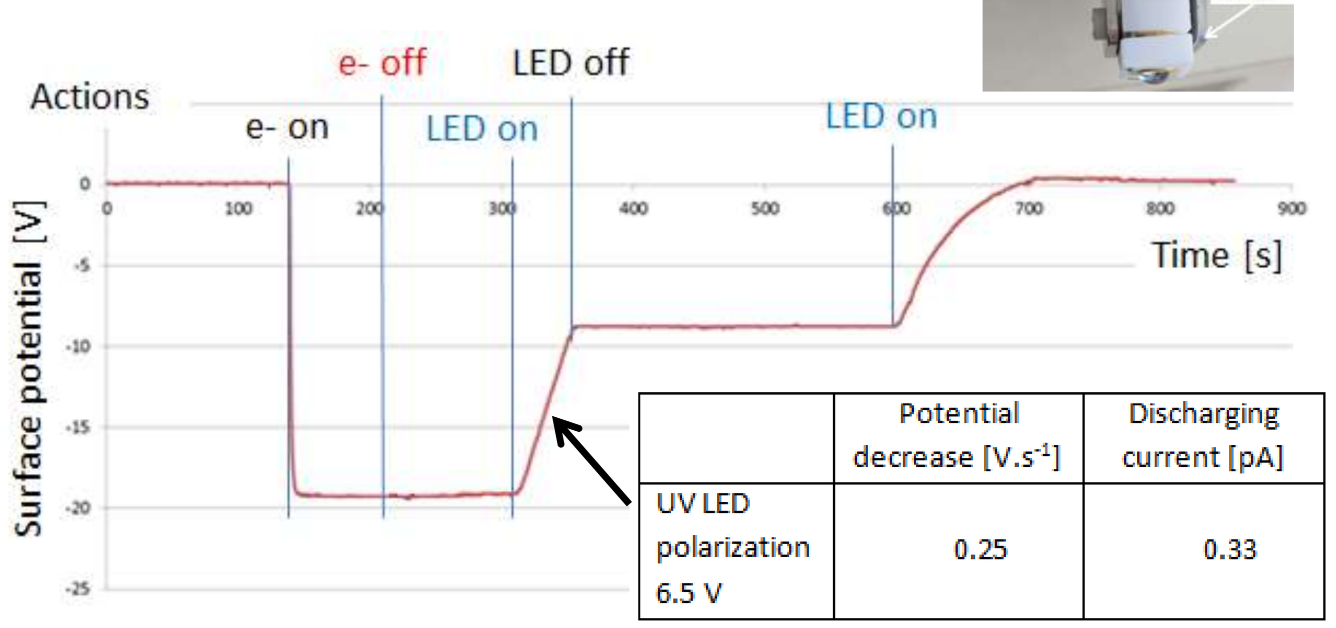


A floating metallic sample is put to a potential of -20V via the electron gun. Then the sample is lighted by a 240 nm UV LED. The current measurement is performed by the determination of the capacitance and the surface potential variation over time :

$$I_{dech} = \frac{dQ}{dt} = C\frac{dV}{dt}$$





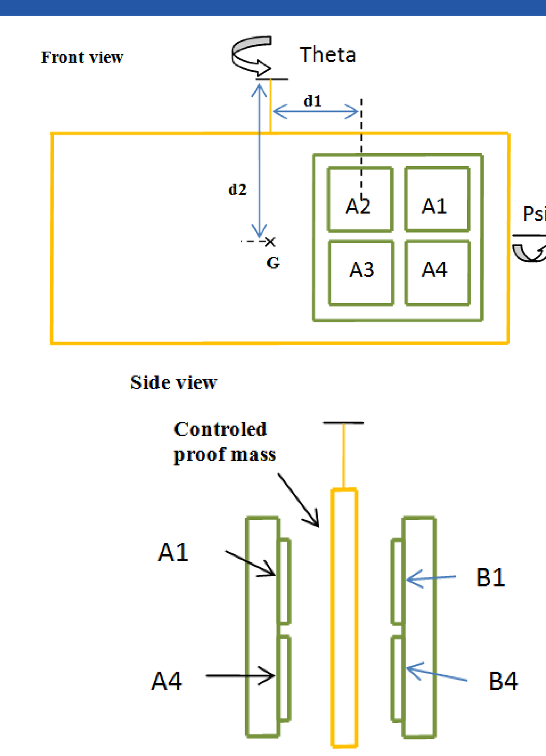


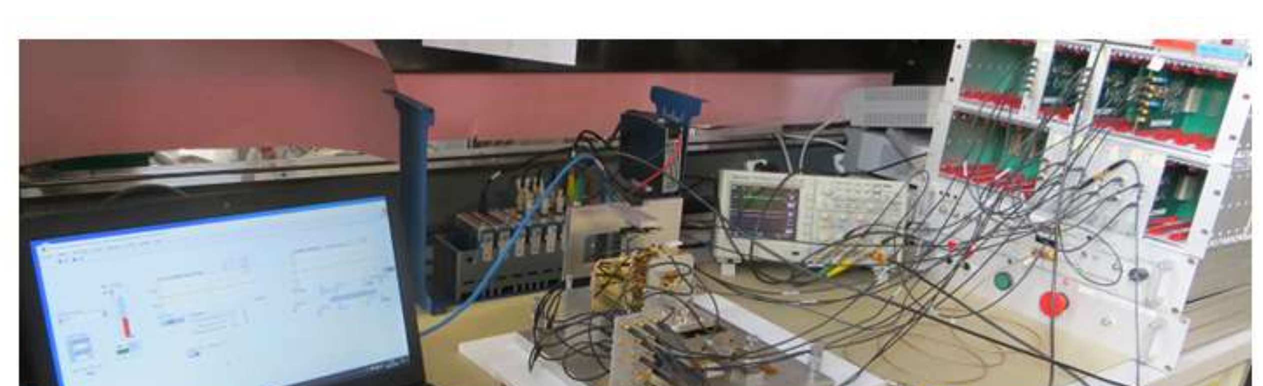
	Potential decrease [V.s-1]	Discharging current [pA]
UV LED polarization 6.5 V	0.25	0.33

Prototype

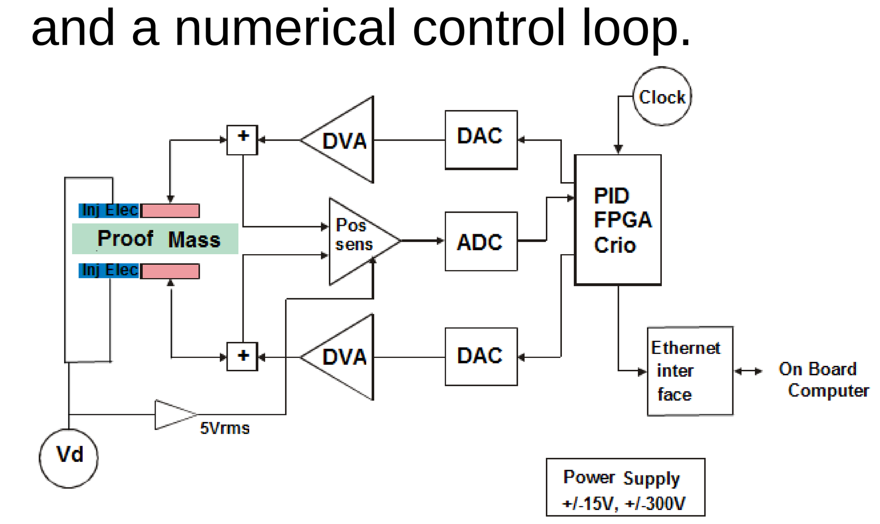
A prototype has been designed and manufactured to investigate:

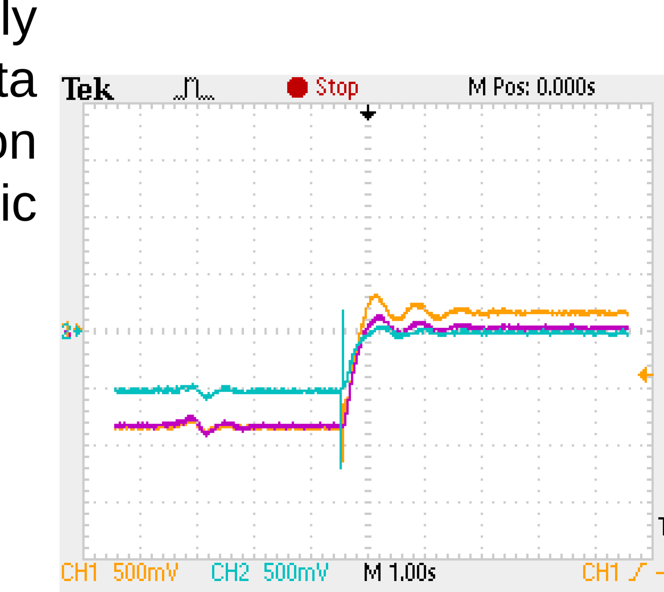
- Charge determination on the proof mass.
- Charge control via UV LED or electron gun.
- Low force measurement to characterize perturbation induced on the proof mass.





The prototype has been successfully controlled around the rotation Theta using a dedicated analogic position detector and amplifying electronic and a numerical control loop.





This oscilloscope screenshot shows the 3 capacitive position detectors behavior on the control loop start.

The blue and pink detectors are used in the control loop. Yellow detector is used only as a monitoring.

The system performances are still under evaluation.

Perspectives

The following tasks will be performed in 2020 and 2021:

- Charging simulation for the MICROSCOPE and E-GRASP-like orbits.
- Tests on electron gun and UV parameters sensitivities (Materials, relative angular position, distance between source and sample, etc.)
- Finally the prototype will be tested under ONERA test facilities with an equivalent space environment.

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