First structural tests of the CryoAC Detector silicon chip of the Athena X-ray observatory

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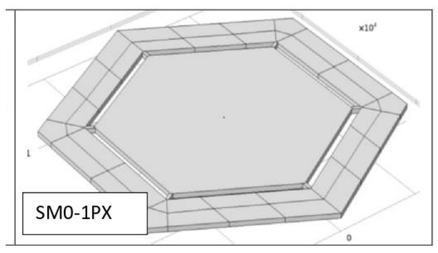
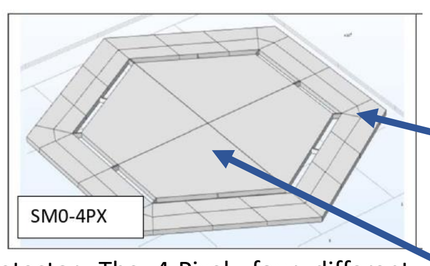
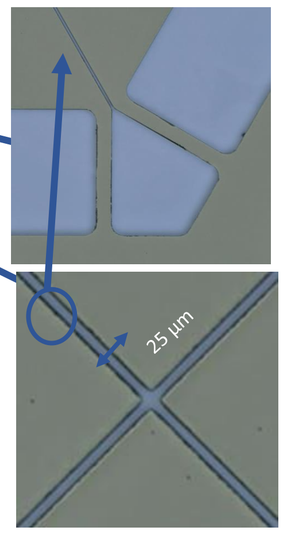
The 50 mK cryogenic focal plane anti-coincidence detector of the Athena X-ray observatory (CryoAC) is a silicon suspended absorber sensed by a network of 400 Ir/Au Transition Edge Sensors (TES) and connected through silicon bridges to a surrounding silicon frame plated with gold (RIM). The device is shaped by Deep Reactive Ion Etching (DRIE) from a single silicon wafer of 500 µm. There are two different possible geometries: A single Monolithic absorber and a Segmented one with 4 distinct absorber structure. As part of the payload of space mission the detector must resist to several mechanical excitations. We have tested a set of prototypes of the CryoAC vibrating several hexagonal Silicon samples. This vibrating them using the vibrational mask provided by CNES for the future ARIANE 6. The aim is to have a first information on the mechanical response of the Silicon bridges that connect the absorber to the RIM, to start a tradeoff over the two geometries and to validate the elastic-mechanical response.

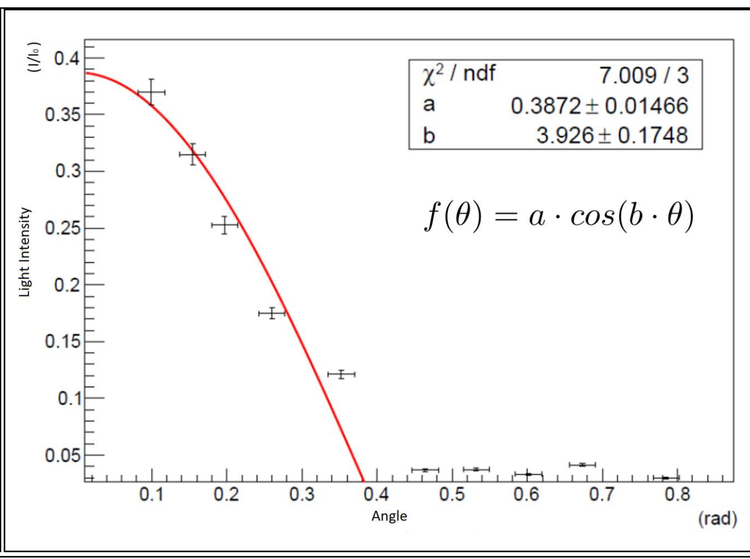




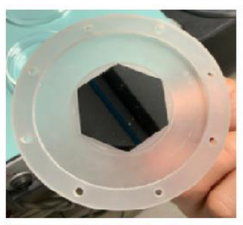
Two possible geometries for the Detector. The 4-Pixel, four different trapezoidal freestanding silicon absorber of 500 µ m thickness separated by a narrow trench of 25 µm and the 1-Pixel a Monolithical hexagonal freestanding silicon absorber of 500 µm thickness.
The two geometries have different advantages and disadvantages.
The 1-Pixel is easier to fabricate but with a single absorber will led to a slower detector. The 4-Pixel is much more demanding for its high etching aspect ratio.

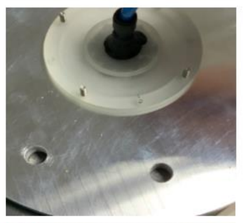


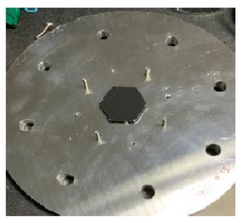
Trench between the absorbers and the external RIM in the 4-Pixel configuration. Is clearly visible the Silicon bridges that hold the absorbers and the 25 µm separation between the four absorbers.



Measurement on vibration response have been taken with a Laser so we had to increment the diffusivity of Silicon or the reflected Signal won't have been detectable.
We had used CGM ROTRIVEL U white powder. In figure is possible to see the lifght diffused at different angles.

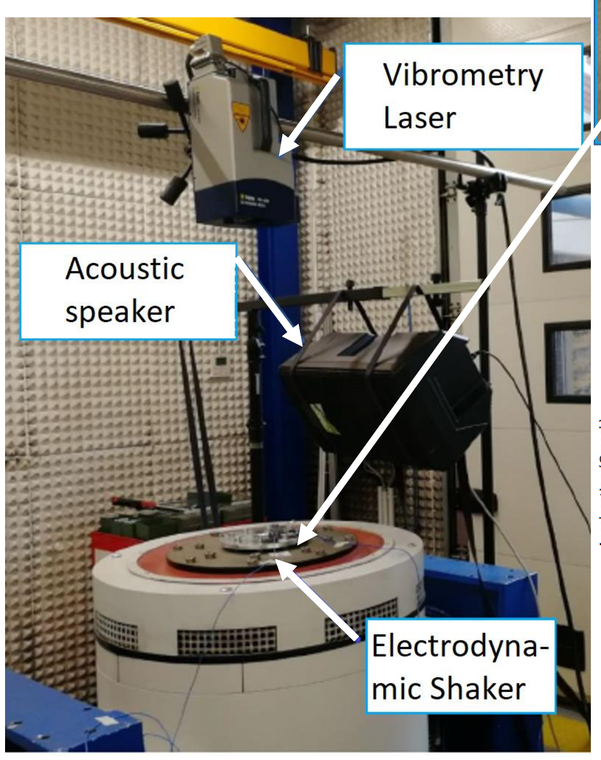


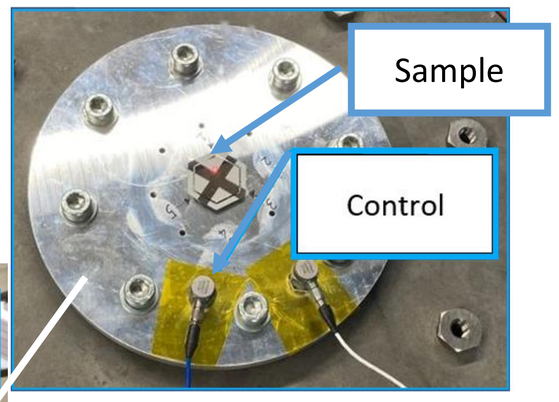




These first tests aim to characterize only the Silicon chip substrate without electronic connections or film deposited. In order to have informations on the chip structure.
So, we fixed the Samples in three point with STYCAST 2850 FT to reproduce the Focal Plane Assembly mounting.
Curing was a crucial part as we observed that stresses due to curing at high temperature led to samples fragility. The 1-Pixel broke during tests and the 4-Pixel during thermal relaxation.

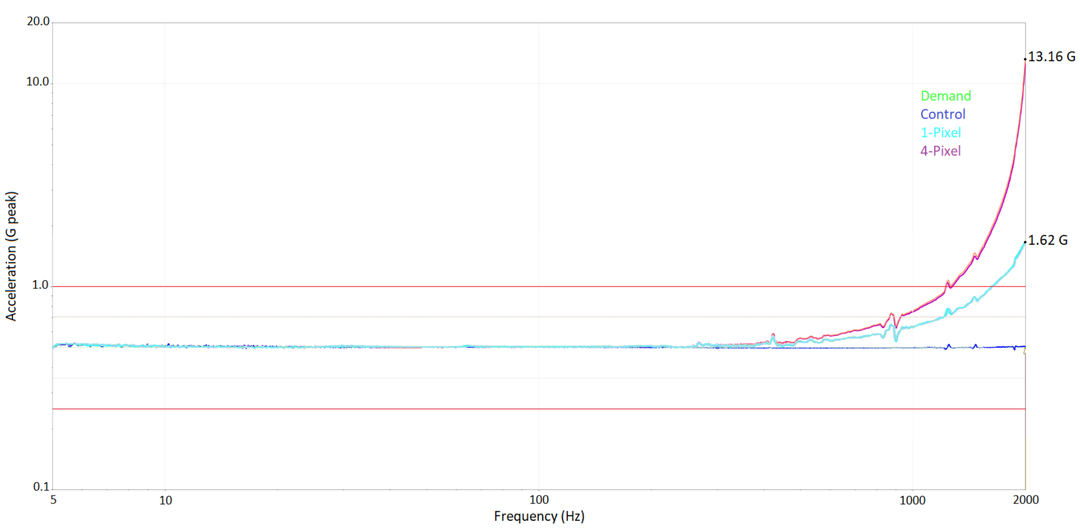
Measurement setup, samples have been accelerated with and electrodynamic shaker and displacements read by Laser. To check vibration modes and coupling also control accelerometers have been mounted Shaker coupling on flange.
The Acoustic speaker was used to find resonances at high frequency.

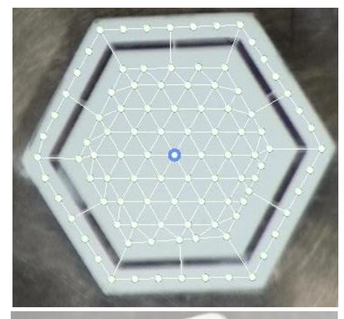


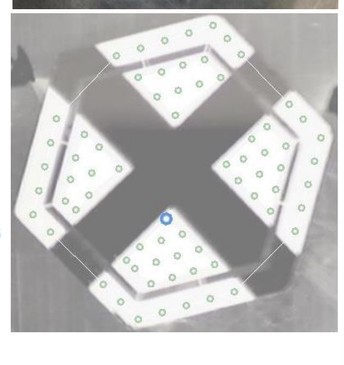


The harmonic spectra acceleration profile represents the response to 0.8 G sine excitation in the 5 Hz – 2 kHz range.
Qualification vibration masks are in this region. The test shows a flat response at low frequency and an amplification gain at higher ones. This due to first resonance mode approaching.

Harmonic Spectra Acceleration Profile

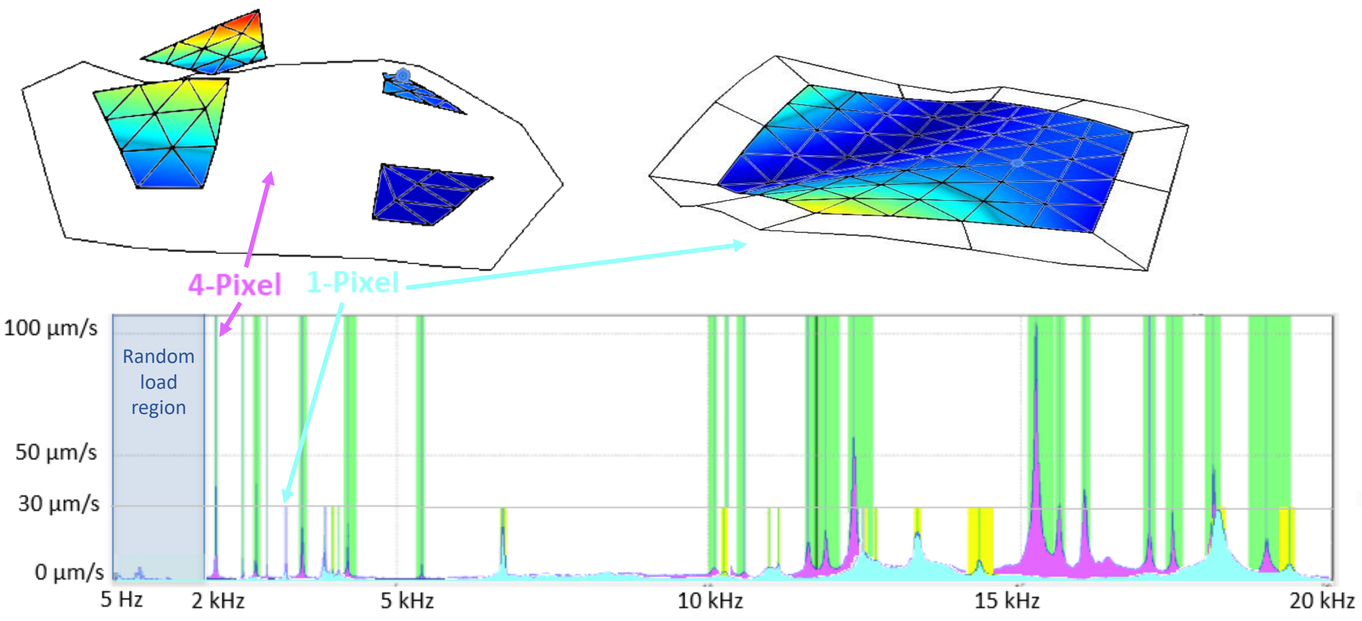




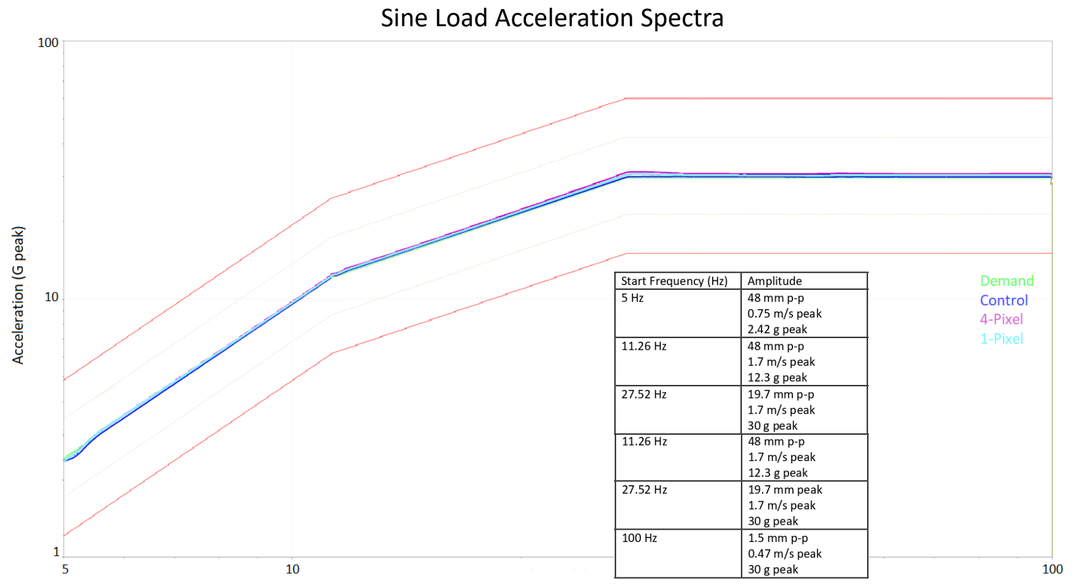


Software reconstruction of the sample geometry. Each point is a sampling point of the laser.

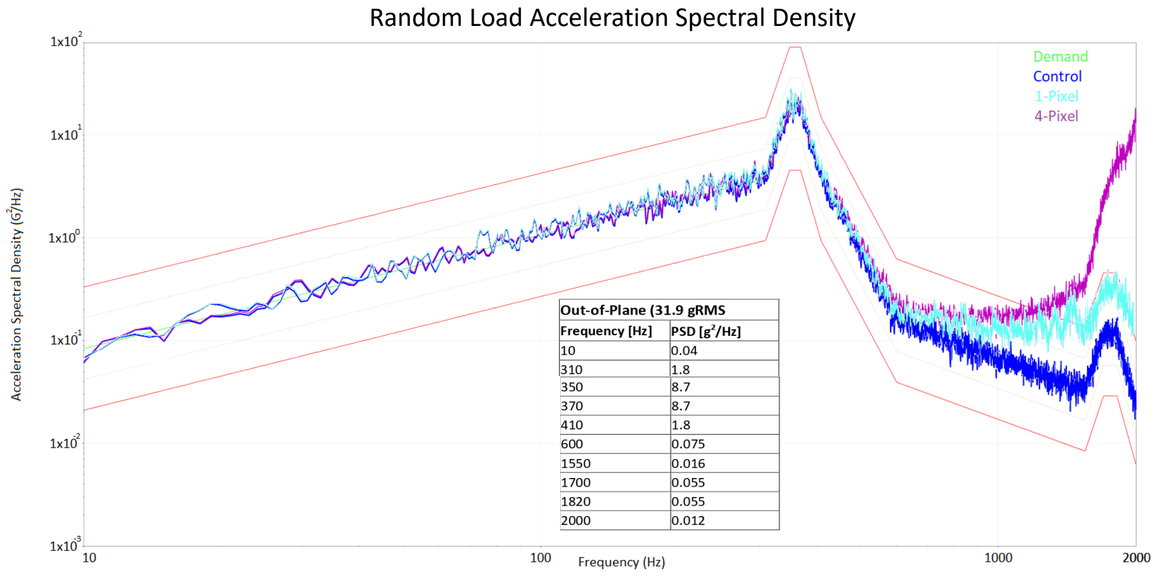
Operating deflection shapes shows different resonance modes between the two geometries with a bigger response in the 4-Pixel and a first mode dangerously near to the 2 kHz random load test region.
In the response to acoustic speaker excitation is clear the higher factor of merit of the 4-Pixel resonances.



Sine Load Acceleration Spectra



Random Load Acceleration Spectral Density



We have finally tested several chip for each geometries with qualification vibration masks provided by CNES for the ARIANE 6 project:

- Sine load test at low frequency (5 Hz – 100 Hz) where response are the same of the expected ones as in that region the Silicon response is flat as shown by the harmonic spectra acceleration profile. The maximum acceleration provided was 30 G.
- Random load test between 10 Hz and 2 kHz. Here the effect by the first resonance mode produce an evident increment in silicon acceleration in respect to the flange.

All the sample of both geometries passed the qualifications vibration tests without any crack. So, both the geometries are valid from a structural point of view to build the detector.
The 4-Pixel configuration have been demonstrated less safe as the first resonance peak is just above 2 kHz and has a gain factor of 1500 on accelerations. Direct excitation of the first resonance mode led to sample breakage. Simulations shows that the real setup should reduce the frequency of the first mode. So, we are going to test both geometries in a more representative setup and understanding if is possible to use the 1-Pixel configuration from a detector performance point of view.