Caliste-SO X-ray micro-camera for the STIX instrument on-board Solar Orbiter mission

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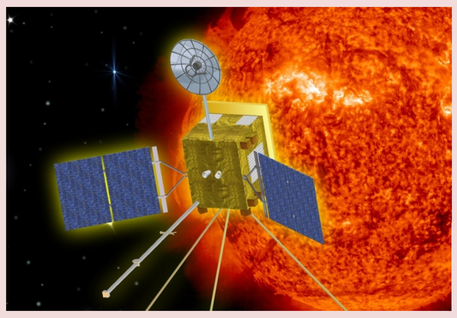
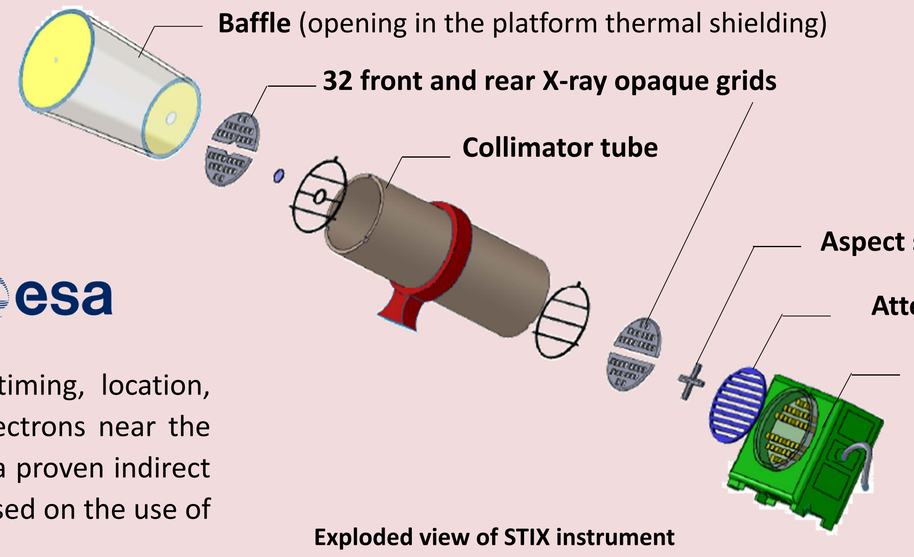
The Spectrometer Telescope for Imaging X-rays (STIX)

Solar Orbiter ESA mission



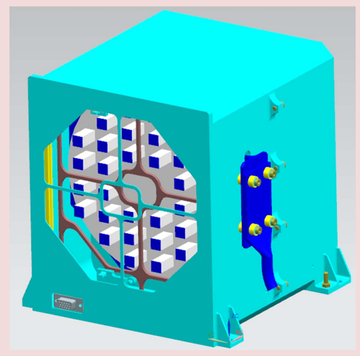
STIX will provide information on the timing, location, intensity and spectra of accelerated electrons near the Sun, in solar flares in particular. It uses a proven indirect Fourier-transform imaging technique based on the use of fine X-ray collimators.



Exploded view of STIX instrument

INSTRUMENT DEFINITION
Energy range: 4-150 keV
Effective area: 12 cm²
Field of view: 1.5°
Angular resolution: 7 arcsec
Mass: 5 kg
Power: 4 W

MISSION PROFILE
Project in implementation phase for Cosmic Vision M mission
10 in-situ or remote sensing instruments
Elliptical orbit with perihelion at 0.28 AU
10^{11} 10 MeV-equivalent protons/cm² after 7-year mission

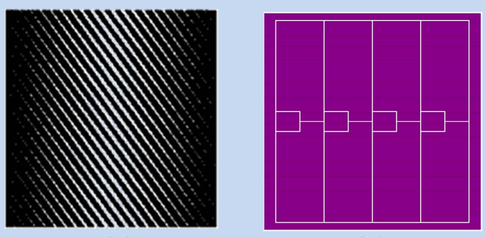


DEM mechanical design

Spectrometer requirements

Each spectrometer unit should provide photon counting information and energy measurement of one of the spatial Fourier component, with the following performance:

- 4 keV low-level threshold
- 1 keV FWHM @ 6 keV, 15 keV FWHM @ 150 keV
- 50% efficiency at 100 keV
- 20000 photon/s count capability (goal 10^5)



(a) (b)

(a) Moire pattern made by a pair of grids on the sensor.

(b) Pixel pattern of the sensor anode: the 4 bands image the Moire pattern; the small pixels are used to observe intense flares without pile-up.

Caliste-SO definition

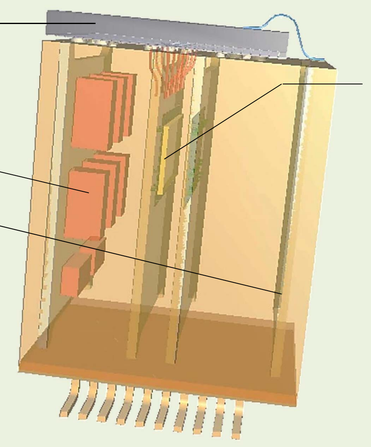
Caliste-SO is a hybrid component integrating the sensor material and dedicated front-end electronics for high resolution X-ray spectroscopy. It is based on 3D Plus technology.

Cd(Zn)Te pixel detector
ASIC connection by polymer bump bonding and flying leads

Passive filtering parts

High voltage routing

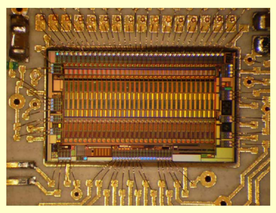
Electrical SOP interface
- ASIC power supplies
- Sensor high bias voltage
- Slow control I/O
- Test injection
- Differential analog output



Caliste-SO transparent view

IDeF-X HD ASIC
- 32 individual channels
- CSA (48..100 µA, C_F = 50 fF, C_{IN} = 2.9 pF)
- Shaper (1 to 11 µs peaking time)
- Possible channel disabling /powering off
- Individual discriminators (6-bit DAC) and global OR to trigger output
- 3 readout modes: hit channels all channels or on demand
- Temperature sensor
- Latch-up free, SEU detection

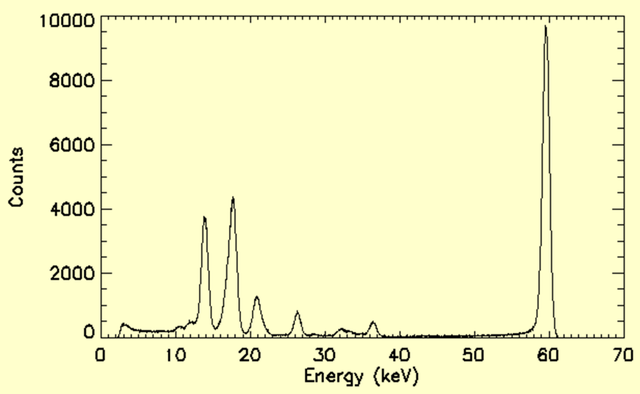
Front-end characterization



IDeF-X HD ASIC

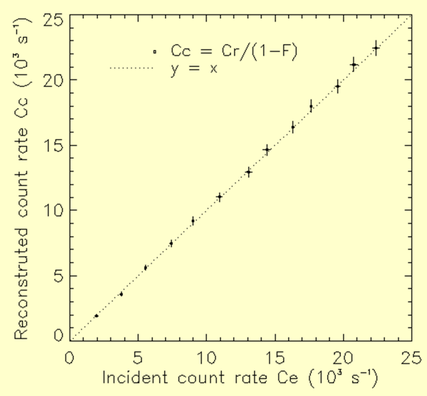
Set-up: one IDeF-X HD channel connected to one Shottky CdTe monopixel crystal, 2 mm × 2 mm pixel size, 2 mm thickness, 1000 V bias voltage, –10°C.

Spectroscopic characterization



^{241}Am spectrum. Energy resolution is 1.11 keV FWHM at 60 keV, 1.01 keV FWHM at 14 keV. Low-level threshold is 2.3 keV.

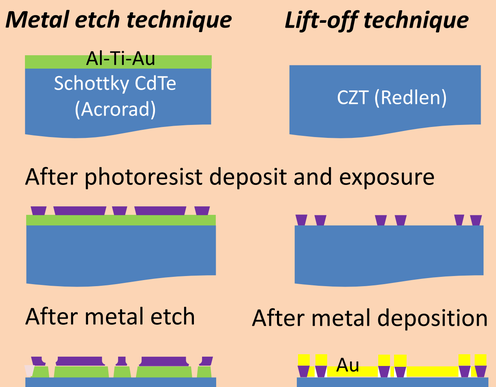
Count rate capability evaluation



Experiment with a X-ray generator and a 400 µm Ta foil (10-30 keV range). The dead time fraction F is computed and the recorded count rate Cr is corrected.

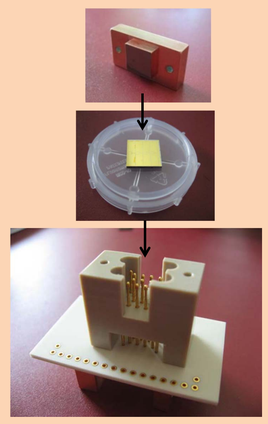
Sensor fabrication

Pixel pattern definition
- Two detector types and two processes under study
- Process optimization with silicon dummy sensors



Processes to define the segmented anode

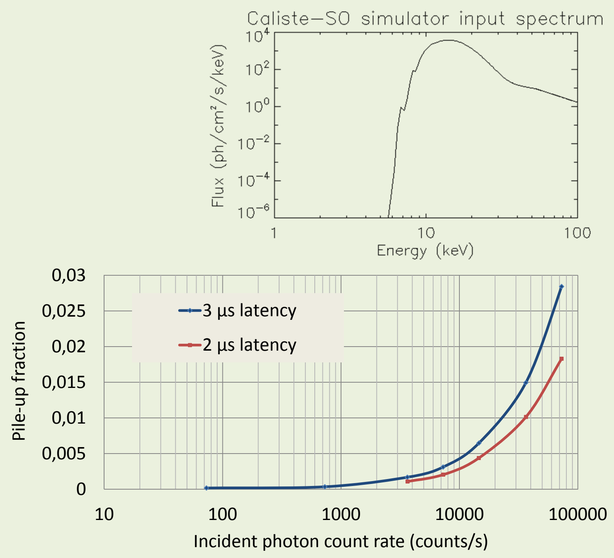
Sensor characterization
- Dark current measurement of individual pixels
- Voltage bias and current measurement with pico-ampmeter Keithley 2410



Set-up for dark current measurement

Modeling of Caliste-SO response

- Input spectrum: solar flare (July 23, 2002), 0.25 g/cm² Be window, 0.2 g/cm² Al.
- **Monte Carlo simulation** of interactions in 1 mm-thick Cd(Zn)Te detector (Geant4).
- Event time tagging and grid attenuation.
- **Readout generator**: event list {trigger time, pixel number, energy}.
- **Performance analysis**
  - ✓ Counting capability: pile-up, dead time…
  - ✓ Imaging: Moire coefficients,
  - ✓ Spectroscopy: individual histograms.



For a count rate of 20000 photon/s, less than 1% of recorded events are piled-up, for a shaping time of 2.6 µs and a latency time of 3 µs (delay ASIC trigger / readout sequence start).

Conclusions

32 Caliste-SO spectrometer units will be used in STIX to observe solar flares in X-rays on board Solar Orbiter. They should combine high energy resolution and high count rate capability in hostile radiation environment.

- **IDeF-X HD ASIC has been tested up to 25000 cts/s/channel**:
  → proper count rate evaluation after dead time correction,
  → spectral performance compatible with STIX requirements.
- **First pixel sensor prototypes** have been realized and are being characterized (dark current).
- A **first design of Caliste-SO prototype** is available.
- A **behavioral model of Caliste-SO** has been successfully implemented and will be used for scientific performance evaluation and engineering ground support equipment development.