Fine-pitch semiconductor detector for the FOXSI mission

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Abstract

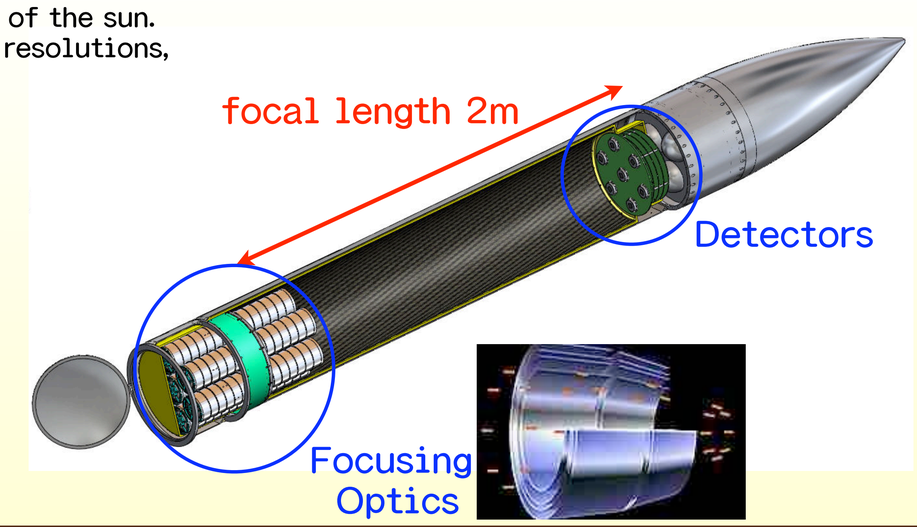
The Focusing Optics X-ray Solar Imager (FOXSI) is a NASA sounding rocket mission which will study particle acceleration and coronal heating on the Sun through unprecedented high-resolution imaging in the hard X-ray energy band (5-15 keV). With a combination of high-resolution focusing X-ray optics and fine-pitch imaging sensors, FOXSI will achieve superior sensitivity; two orders of magnitude better than that of the RHESSI satellite. To achieve such a sensitivity, we plan to use a fine-pitch Double-sided Si Strip Detector (DSSD) with a low-noise front-end ASIC as the FOXSI focal plane detector, which will fulfill the scientific requirements for the spatial resolution, energy resolution, lower threshold energy and time resolution. We have newly designed and fabricated a DSSD with a thickness of 500 μm and a dimension of 9.6 mm×9.6 mm, containing 128 strips separated by a pitch of 75 μm, which corresponds to 8" at the focal length of 2 m. The DSSD was successfully operated in a laboratory experiment under a temperature of −20 ℃ and a bias voltage of 260 V. The energy resolution was measured to be 1.0 keV (FWHM) at 14 keV, sufficient for the FOXSI mission requirement.

The FOXSI Mission

FOXSI is a NASA Low Cost Access to Space sounding rocket experiment to observe the quiet region of the sun. By using high-resolution focusing X-ray optics and imaging detectors with high energy and position resolutions, the high sensitivity and angular resolution is expected to be achieved.

FOXSI Overview

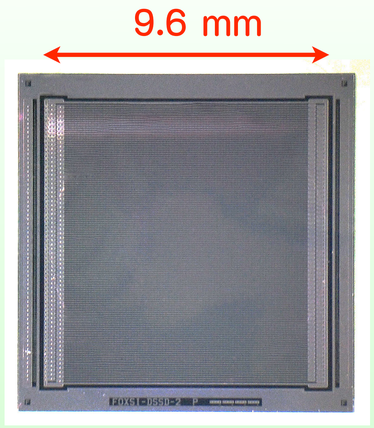
Energy range	～5-15 keV
Energy resolution	～1 keV (FWHM)
Focal length	2 m
Angular resolution	12" (FWHM)
Field of view	960" × 960"
Effective area	180 cm (8 keV), 14 cm (15 keV)
Sensitivity	0.004 cm s keV (～8 keV)
Dynamic range	100 for source separation > 30"
Observation time	～360 s
Launch site	White Sands, NM, USA
Launch date	Late 2010



Double-sided Silicon Strip Detector (DSSD) for FOXSI

To take advantage of the good angular resolution of 12" of the focusing optics, we designed and fabricated fine-pitch DSSDs. The highly doped positively charged silicon strips (p-side) and the negatively charged silicon strips (n-side) are implanted orthogonally on the n-type silicon wafer.

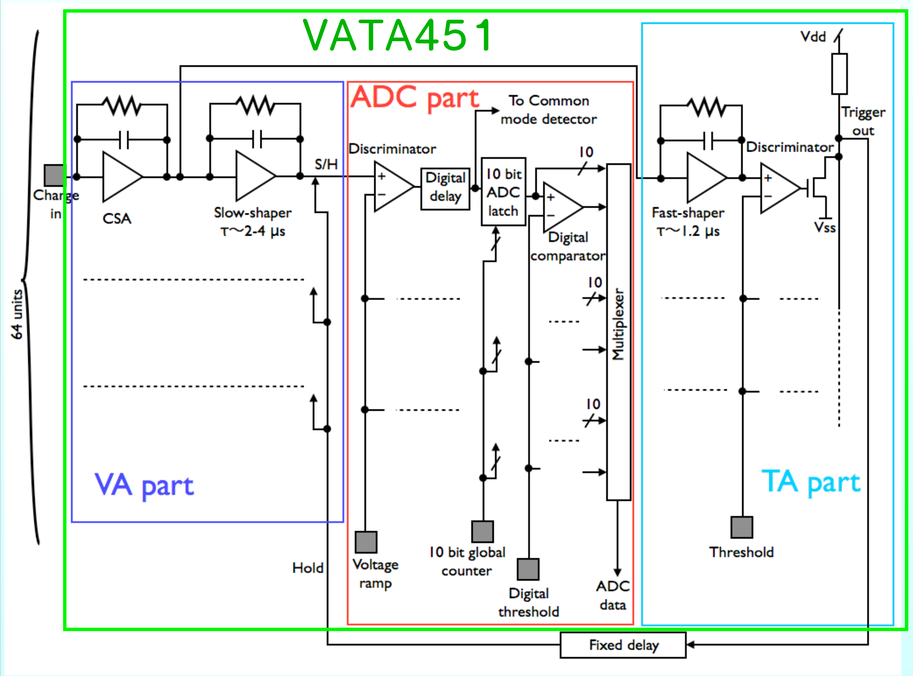
- Size 9.6 mm × 9.6 mm
- Thickness 500 μm
  (98% efficiency for 10 keV,
  68% efficiency for 15 keV)
- Strip pitch 75 μm
  (corresponds to angular resolution of 8"
  at the focal length of 2 m)
- 128 × 128 strips



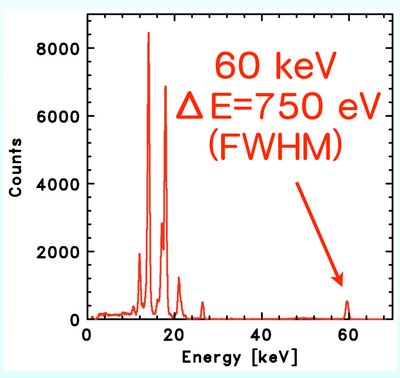
Low Noise Readout ASIC VATA451

To achieve a good energy resolution and a low threshold energy, a 64-channel analog ASIC, VATA451, has been developed by ISAS, KIPAC and IDEAS. Each channel consists of a charge sensitive amplifier, a shaping amplifier for sample and hold (VA part), and a shaping amplifier for trigger generation (TA part). A Wilkinson-type analog-to-digital convertor, by which all channels can be digitized in parallel, is also included in VATA451.

- ENC 64 electrons (designed value, at 5 pF input load and 10 pA leakage current)
- Power consumption 1 mW/channel



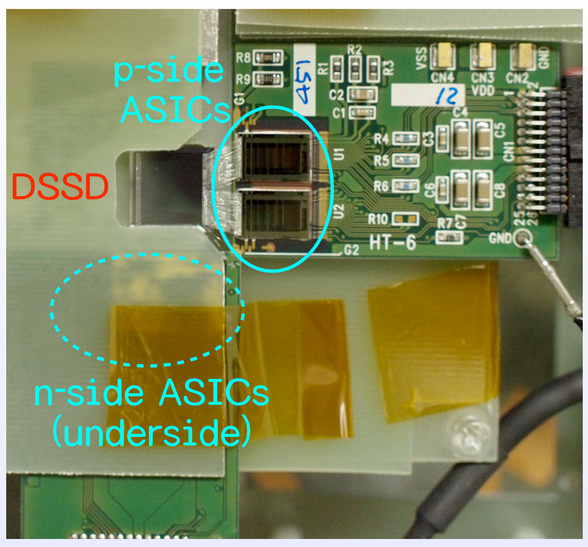
The function block diagram of VATA451.

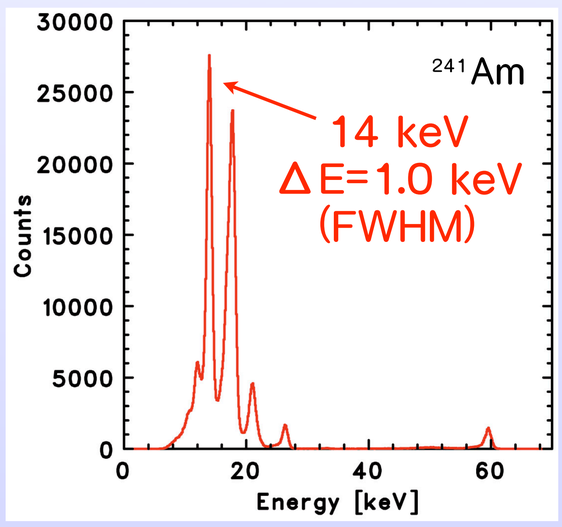


The performance of VATA451.

- Detector Single-sided silicon strip detector
  1.3 cm × 1.3 cm size,
  300 μm thick,
  400 μm strip pitch
- Readout from single channel

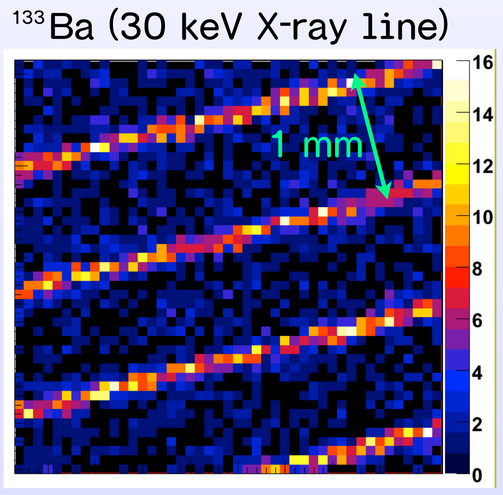
Results of the Laboratory Experiment





We integrated the DSSD and ASICs, and operated them. A spectrum was successfully obtained using a radioisotope, ^{241}Am. Energy resolutions were measured to be 1.0 keV at 14 keV, which fulfill the mission requirement. An image of a 1 mm pitch tungsten slit were also obtained successfully using ^{133}Ba.

^{133}Ba (30 keV X-ray line)



The spectrum and the image of the FOXSI DSSD with VATA451.

- Bias Voltage 260 V
- Temperature −20 ℃
- Events from
  246 out of 256 strips
  were used for the spectrum.

Summary

- FOXSI is a sounding rocket mission which will observe the Sun in the hard X-ray energy band of 5-15 keV by using X-ray focusing optics and a semiconductor imaging detector.
- We have newly developed a fine-pitch DSSD with a strip pitch of 75 μm and a low-noise readout ASIC VATA451 to achieve the superior sensitivity of FOXSI.
- The DSSD and the ASIC have been successfully operated, and an energy resolution of 1.0 keV (FWHM), which fulfill the mission requirement, has been achieved.