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Solar-wind Magnetosphere Ionosphere Link Explorer (SMILE)

An array of imaging systems will focus on the Earth's geometric variations using measurements of the global system response to solar winds.

A combination of soft X-ray imaging of the Earth's magnetopause and magnetospheric cusps with ultraviolet imaging of the Northern aurora.

SMILE is a collaborative space mission between the European Space Agency (ESA) and the Chinese Academy of Science (CAS). The launch is planned for late 2021.

X-ray Detection in SMILE CCDs

- A CCD is a silicon wafer that has metal-oxide-semiconductor capacitors constructed into the surface, which create an array of pixels.
- Incident photons are converted into electrical charge by liberation of bonding electrons, thus generating electron-hole pairs in the silicon; a phenomenon known as the photoelectric effect.
- Pixel charge is transferred one row at a time from the image array into a serial register, which is sequentially read out between transfers. Charge is then converted into voltage by a sense node at the end of the register.
- Voltage is converted into a digital number by an electronic device, known as an Analogue-to-Digital Converter (ADC), which can then be translated and analysed by a computer.
- X-rays are produced by a Manson Source for testing in the laboratory (Figure 5). An experimental set-up under vacuum (Figure 4) is required and the CCD must be cooled to reduce image noise from dark current due to thermally generated electrons.

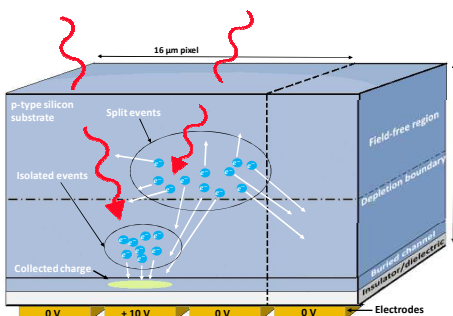


Figure 1. X-ray interactions in a back-illuminated CCD pixel.

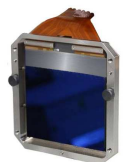


Figure 2. Artists impression of a SMILE CCD.

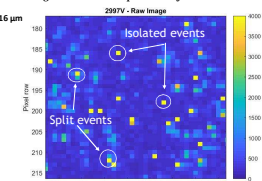


Figure 3. Zoomed image captured with the CCD exposed to the Manson Source

Experimental Set-up

Figure 4. CCD testing equipment

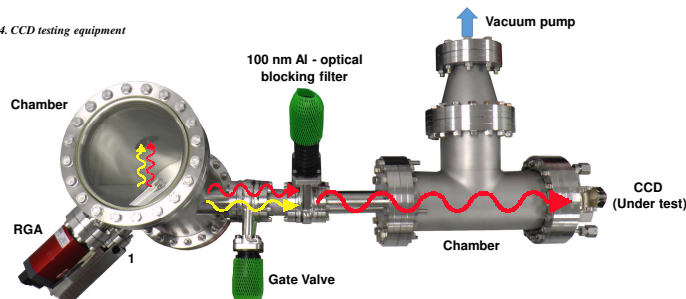
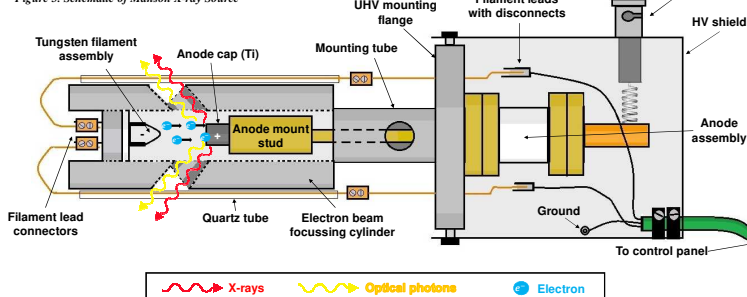


Figure 5. Schematic of Manson X-ray Source



Results & Discussion

Data in the form of images was collected and analysed using MATLAB. Various experimental configurations were used to investigate the tolerances and limitations of the Manson Source and to categorise the CCD under test. Studies thus far has produced data that suggests that the Manson Source is producing X-Rays primarily in the K- α energy region of the anode material (Figure 6).

We are interested in the soft X-ray region between 0.2 keV and 5 keV, it is important to investigate the CCD and the filter being used between, and above this energy range.

The attenuation factor and transmittance behaviour of the aluminium filter were modelled using the Beer-Lambert law:

$$I = I_0 e^{-\mu x}$$

I = intensity of photons transmitted; I_0 = initial intensity of the photons; μ = linear attenuation coefficient; x = distance travelled.

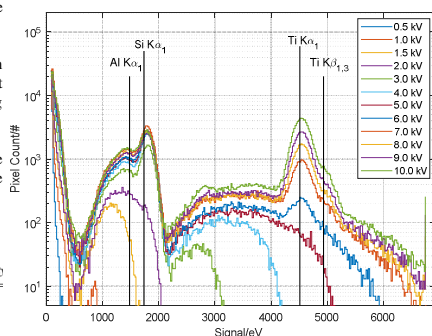


Figure 6. The peaked transmission spectra for the main materials expected to fluoresce in the equipment.

Figure 8 shows the transmittance for different filter thicknesses and X-ray energies. An expected exponential decay was observed.

This will help determine the optimum thickness of filter to use for further investigations with the Manson Source facility.

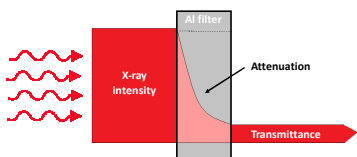


Figure 7. Illustration showing the attenuation and penetration of X-rays through aluminium.

A sharp increase in X-ray flux was observed when increasing the cathode current above 4.6 A to 5 A. From this point the flux started to increase in a linear fashion (Figure 9). This is due to the work function of the tungsten cathode (4.50 eV), which prevents electrons from being emitted below a certain thermal energy.

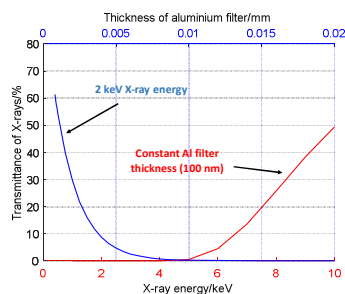


Figure 8. Transmittance through an Al filter of varying thickness at constant X-ray energy (blue) and increasing X-ray energy at constant filter thickness (red).

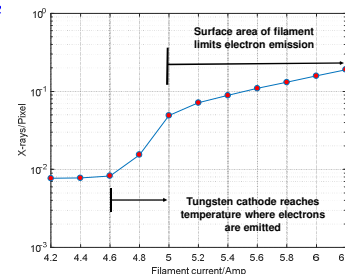


Figure 9. X-ray flux as attenuation of filament current.

Conclusions & Future work

Due to the work conducted here we have a better understanding of the Manson Source and how it operates. It will be used in future test campaigns with SMILE CCDs and the data analysis techniques used will feed into the baseline algorithms that will be used on-board SMILE.

SMILE's Soft X-ray Imager (SXI) will take spectral images of the Earth's magnetosphere which will enable researchers to observe the dynamical properties of the dayside magnetospheric boundaries within the soft X-ray range, between 0.2 and 5 keV.

- W. Raab, G. Branduardi-Raymont, C. Wang, et al., "SMILE: a joint ESA/CAS mission to investigate the interaction between the solar wind and Earth's magnetosphere," Proc. SPIE 9905, Space Telescopes and Instrumentation 2016: Ultraviolet to Gamma Ray, 990502 (11 July 2016).
- <http://www.open.ac.uk/science/research/cei/missions/smile>