SXRM - A Moon-based X-ray sensor for space weather monitoring

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Introduction

SXRM (Solar X-Rays MOONitor) is a project aimed at demonstrating the feasibility and the technological maturity of a lunar-based space weather monitor (to be part of the EMM – Earth Moon Mars mission [1]).
The SXRM project [4] benefits of the heritage of a commercially available X-Ray detector (Amptek FAST-SDD®) already used in other space missions (MinXSS and SXM, on-board Osiris-REX) and of the results of a test campaign performed in favor of Solar X[2], an analogous instrument planned to be hosted by a sail-propelled cubesat.
Our main purpose is to improve the SXRM Technology Readiness Level (TRL) producing a custom electronics that can be readily translated into a space-qualified equipment.
This poster reports the current and planned activities to implement the sensor's readout functions in an FPGA-based space-qualified electronics.

Fast-SDD

The Fast-SDD sensor chosen for our purposes is a commercial detector covering the energy range 1 keV - 30 keV. The actual energy range depends on the characteristics of the window and of the detector itself (see Fig.2).

Figure 1: FAST-SDD® (courtesy Amptek)

The sensor is actively cooled by a Peltier cell and has an effective area of $17\mathrm{mm}^2$ over a surface of $25\mathrm{mm}^2$. The readout system (X123), bundled with the sensor, is based on a Digital Pulse Processor (DPP), a methodology that allows to obtain a system highly configurable, thanks to the digital approach.

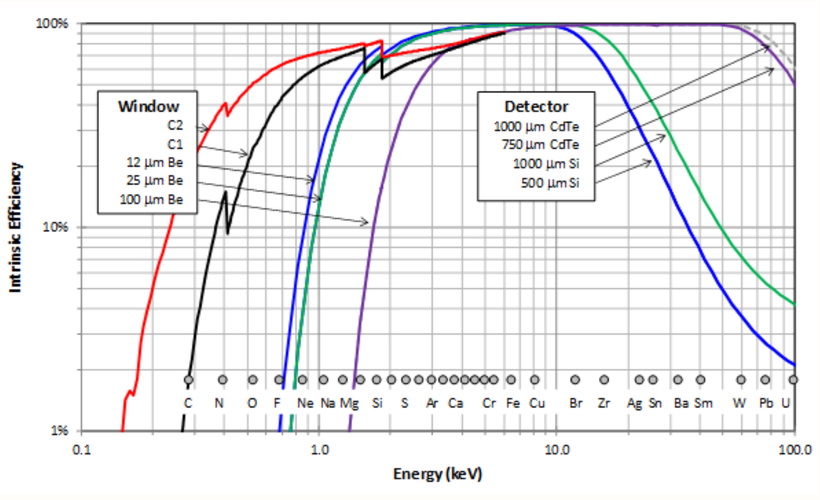

Figure 2: Detection efficiency for different combinations of window (left) and detectors' type and thickness (right)

We performed a characterization campaign for the Fast-SDD sensor during the Phase A of an analogous instrument [2]. We demonstrated that the attainable energy resolution is comparable to the Fano limit of 126 eV; a very good resolution suitable for the purposes of distinguishing between different lines characteristic of the active Sun corona.
Another important aspect that was investigated was the capability of the electronics to manage a flux variation of several orders of magnitude. The results showed that the system is capable to manage fluxes from less than 1 to almost $10^6\mathrm{ph/s}$, dealing with extreme Sun conditions: from quiet to the most energetic class-X flares.

SXRM board

Our group, in cooperation with AGE Scientific [3], is now developing a custom digital board providing:

- high voltage to bias the sensor's substrate (100-180 V)
- supply voltages to the preamplifier's electronics ($\pm$5V)
- substrate temperature control
- signal acquisition, digitization and storage

For test purposes, the readout electronics is connected to a PC with an interface that allows to accumulate, visualize, store and retrieve spectra as well as to set the sensor parameters (e.g. peak and flat times, temperature, bias voltage, etc.).

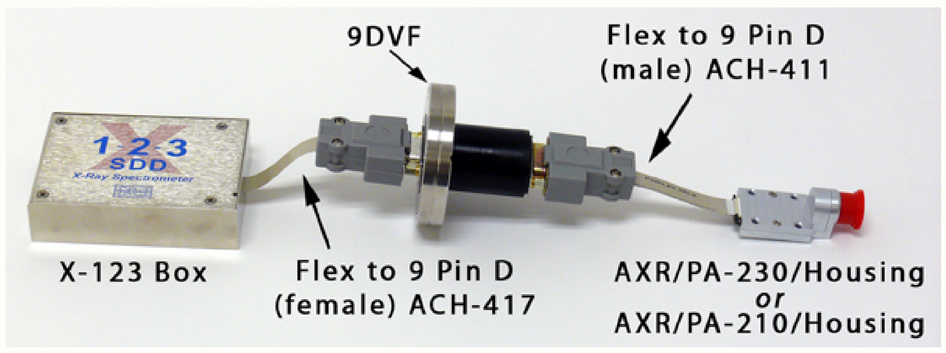

Figure 3: X123 vacuum system (Courtesy Amptek)

The core of the system resides in the FPGA code that can be easily transferred to a space-qualified design.

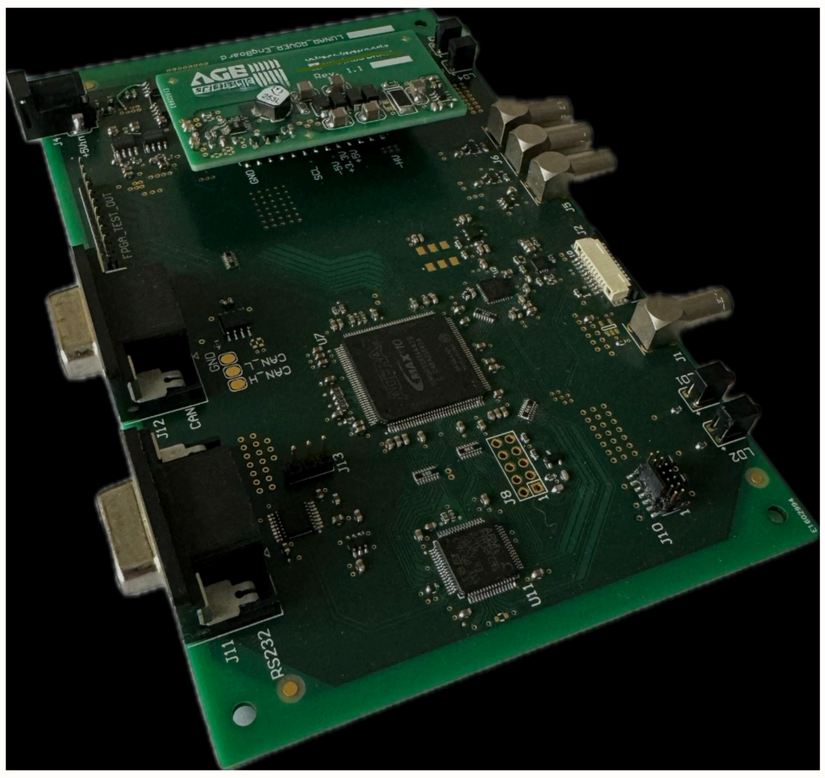

Figure 4: SXRM board (Courtesy AGE Scientific)

Forthcoming activities

Our planned future activities head in different directions:

- continue tests in relevant environment (vacuum) on the SXRM instrument to improve its technology maturity (up to TRL 4 or 5) in view of the accommodation on the lunar surface as part of the EMM mission
- identify the possible signatures of extreme solar events
- explore possible synergies with other projects, in particular a CdTe detector (more efficient at higher energies) equipped with a modified readout board will be flown on a stratospheric balloon

The activity will be pushed further, up to a space-qualified design (raising the TRL level to 7), ready for the production of a complete acquisition chain and allowing to deploy on the Moon a system capable to provide early warnings and raw data (solar spectra) at the same time.
When finally operating, the raw spectra provided by the instrument could be correlated off-line with the observations coming from other Sun observatories: SDO, GOES, etc.

Acknowledgement

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References

[1] https://pnrr.inaf.it/progetto-emm/

[2] V. Noce et al., *The space weather x-ray spectrometer for the Helianthus sub-L1 mission with solar photonic propulsion*, Proc. SPIE 121815V

[3] https://www.agescientific.com

[4] V. Noce et al., *The Solar X-Ray MOONitor (SXRM) a lunar-based sun activity monitor*, Proc. SPIE 130937F