SOLAR X-RAY MONITOR (XSM) ON-BOARD CHANDRAYAAN-2 ORBITER. M. Shanmugam, S. Vadawale, Y. B. Acharya, S. K. Goyal, Arpit Patel, Bhumi Shah and S. V. S. Murty, PLANEX, Physical Research Laboratory, Ahmedabad 380009, India (shansm@prl.res.in).

Introduction: The technique of remote X-ray fluorescence spectroscopy has been employed since early days of lunar exploration to determine elemental composition of lunar surface. The experiment involves measuring spectra of fluorescent X-rays from lunar surface using a low energy X-ray detector onboard an orbiting satellite. However, it is well known that the solar X-rays are extremely variable in both intensity as well as their spectral shape; and that the flux of fluorescent X-ray lines from the lunar surface critically depend on the flux and spectral shape of incident solar X-rays. Therefore it is absolutely essential to have simultaneous measurements from both Sun and Moon for interpreting the X-ray fluorescence data and obtain the elemental abundances. Thus a typical remote X-ray fluorescence experiment consists of two components, a Moon viewing X-ray detector to measure the fluorescent spectra and a Sun viewing X-ray detector to measure direct solar X-ray spectra.

It is planned to continue the remote X-ray fluorescence spectroscopy experiment on-board Chandrayaan-2 [1] which includes both lunar X-ray observations and solar X-ray observations. The lunar X-ray observations will be carried out by Chandra Large Area Soft x-ray Spectrometer (CLASS) experiment [2]; whereas the solar X-ray observations will be carried out by another payload, Solar X-ray Monitor (XSM). Here we present the overall design of the XSM instrument as well as present development status.

Scientific Objective: The primary scientific objective of Solar X-ray Monitor is to provide real time measurement of solar X-ray spectrum for quantitative interpretation of the lunar X-ray fluorescence spectra measured by CLASS experiment. XSM will accurately measure spectrum of Solar X-rays in the energy range of 1- 20 keV with energy resolution ~200eV @ 5.9 keV. This will be achieved by using state-of-the-art Silicon Drift Detector (SDD). SDD has a unique capability of maintaining high energy resolution at very high incident count rate (of the order of 10^5 counts per second) expected from Solar X-rays and XSM onboard Chandrayaan-2 will be the first experiment to use such detector for solar X-ray monitoring. Table-1 shows comparison of XSM with Solar X-ray Monitor instruments flown in various lunar missions.

The XSM Instrument: XSM instrument will have two packages namely XSM sensor package and XSM electronics package. The XSM sensor package houses SDD along with sensitive front-end electronics circuits. XSM uses SDD module with detector active area of ~30 mm^2. SDD module with 8µm thick Be window provides low energy cut-off at 1keV. The detector module will be covered with additional Al cap to reduce the detector aperture to ~0.2mm^2. This cap will be kept at very close distance of < 0.2mm from detector to achieve the detector field of view of ±55º. The top and bottom side of the Al cap will be coated with suitable high-Z material of appropriate thickness to stop transmission of solar X-rays as well as the fluorescent X-rays due to Al cap.

One major challenge for XSM is to handle the extremely large variations in solar X-ray intensity which can range up to five orders of magnitude within few seconds. It is planned to include an active mechanism in the XSM sensor package in order to avoid saturation during very large solar flares while maintaining sensitivity for smaller flares. The XSM electronics will automatically detect occurrence of large flare and will activate a mechanism to bring in an additional Be filter of ~250 µm thickness to reduce count rate by temporarily increasing energy threshold to ~1.8 keV. This mechanism also includes onboard calibration using ^{55}Fe X-ray source. The Sensor package will be mounted on an extended bracket outside the spacecraft.

Table 1: Comparison of XSM instruments flown in various lunar missions with CH-2.

	CH-1	**SMART-1**	**SELENE**	**CH-2**
Detector/thickness (µm)	Si PIN/500	Si PIN/500	Si PIN (x2)/300	SDD/450
Detector aperture	0.15 mm^2	0.15 mm^2	< 1 mm^2	0.2 mm^2
Be window thickness (µm)	13	25	25	8
Energy range	1.8-20 keV	2-20keV	1-12keV	1 – 20 keV
FOV in degrees	105º	104º	Hemispherical (180 x 90)	110º
Calibration source	Fe-55	Fe-55	-	Fe-55
Number of channels	512	512	256	1024
Integration time (s)	16	16	16	1
Resolution (at 5.9keV)	250eV	250eV	500eV	200eV

XSM electronics package has ADC to convert analog signal to digital form with 10 bit resolution which is further processed by FPGA based digital electronics. The same FPGA will also be responsible for overall payload operation and control. This package will include all interfaces with spacecraft subsystems such as data handling (DH), TM/TC and power subsystem.

Developmental Status: Presently we have completed the laboratory model of the XSM payload. The present development follows the traditional approach of shaping the charge pulses from CSPA, followed by peak detection and A/D conversion. The sub-systems developed are CSPA, Shaper, Peak detector, ADC, HV bias, Peltier controller and FPGA based processing electronics. The CSPA has been designed with "Reset" type and shaper is designed with CR-$(RC)^2$ type network which include Base Line Restorer (BLR) to minimize the base line fluctuations at higher count rates. The ADC used in the design has 10 bit resolution. SDD requires HV bias of ~ -130V which is generated using voltage multiplier circuits. Peltier controller has been designed with PWM technique and it allows the required current through the detector peltier to get desirable ΔT and stability of <1^{o}C has been achieved within two minutes time from power-on.

Processing electronics has been developed using ACTEL PRO-ASIC based FPGA device in the laboratory setup and it will be replaced with RTAX250 device at later stage. FPGA processes the real time event data to generate 1024 channel energy spectrum for every second. Thus the data rate of XSM will be fixed 2kB/s, despite of having highly variable incident count rate. For laboratory evaluation, the spectral data is acquired using PCI and LABVIEW based interfaces. We are also exploring the possibility of digitizing the CSPA output and processing the pulse data digitally for further miniaturization.

Experimental setup and Results: SDD detector is cooled to about -35^{o}C by coupling the detector module on a 1mm thick Al wall enclosure. Developed XSM electronics has been tested for various peaking time constants and observed that the energy resolution of ≤150eV for the pulse peaking times >2μs. We also observed that the energy resolution and peak position is largely unstable for higher pulse peaking times at higher input count rates compared to lower pulse peaking times (≤1μs). Based on these observations, we have selected 1μs pulse peaking time for XSM which provides ~200eV energy resolution at 5.9keV with low energy threshold of 1keV. The spectrum is shown in fig. 1.

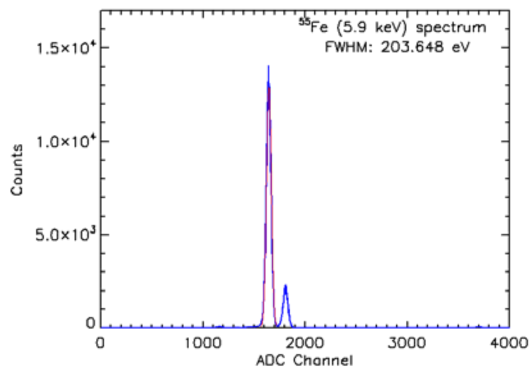
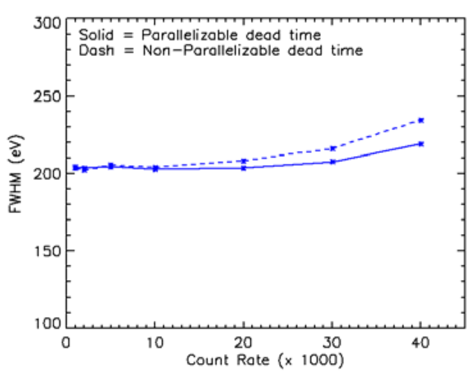


Fig. 1: Spectra obtained from SDD with breadboard model of XSM setup using ^{55}Fe X-ray source.

The system is also tested for count rates up to 40K counts/s using available laboratory X-ray source. In order to further improve the performance at higher count rates, we have implemented parallelizable dead time in the event processing, which enables to select only clean events which are not affected by previous events for generating spectra. The improved stability of both FWHM and peak position using such technique is shown in figure 2. Presently, we are making engineering model of the payload. Subsequently Qualification and Flight models will be made and delivered during second half of 2013 for integration. The total payload will be developed with mass of about 1kg with 5W power.

References: [1] Goswami J. N. et al. (2011) *LPSC 42, #2042.* [2] Radhakrishana V. et al. (2011) *LPSC 42,#1708*.



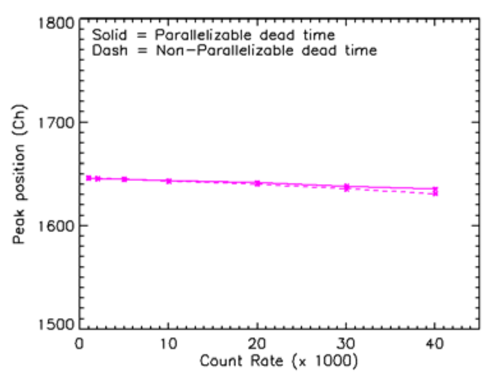


Fig. 2: Energy resolution and peak position stability obtained from the breadboard model of XSM with and without parallelizable dead time for various count rates up to 40k counts/s using ^{55}Fe X-ray source.