ALPHA PARTICLE X-RAY SPECTROMETER (APXS) ON-BOARD CHANDRAYAAN-2 ROVER.

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Introduction: Alpha Particle X-ray Spectrometer (APXS) is a well proven instrument for quantitative elemental analysis of the planetary surfaces. Several Mars rovers (MPF, MER) [1, 2] have carried APXS instruments on-board and provided elemental composition for several surface samples. Another mars rover (MSL) slated for launch in 2011, also has an improved APXS on board [3]. Here we present the objectives and status of APXS, approved for ISRO's Chandrayaan-2 rover, slated for launch in 2013.

Though lack of atmosphere on Moon offers an advantage in terms of the attenuation of Alphas and X-rays, the fluffy regolith and temperature extremes offer new challenges for the operation of APXS on lunar rovers. The landing site of Chandrayaan-2 is yet to be finalized, though it is likely to be south polar sunlit region, where the temperature excursions are expected to be in the range of -30 to -190°C (day/night) [4], more conducive for the optimum performance of Silicon Drift Detector (SDD), to achieve energy resolution of ~150eV @ 5.9 keV. The detector head needs to be kept away from touching the regolith surface to prevent dust contaminating the detector, necessitating a robotic arm to maneuver it. Table 1 gives the comparison of APXS of Chandrayaan-2 with those of MER and MSL.

Working Principle and objective: APXS involves the measurement of characteristic X-rays emitted from the sample due to α particle induced X-ray emission (PIXE) and X-ray florescence (XRF) processes. The ^{244}Cm source emits both Alpha particles and X-rays with energies of 5.8 MeV and 14.1 keV, 18 keV respectively. PIXE is dominant for low Z elements while XRF is more prominent for high Z elements, allowing the determination of elements from Na to Br, spanning the energy range of 0.9 to 16 keV. The activity of each alpha source is ~5 ± 25% mCi and the total activity of the six alpha sources is about 30 mCi. Each source is of 8mm circular disc and < 1mm thickness, with 6mm active spot at the center. These sources are coated on Si substrate [5] and sealed with 3 micron thick light tight titanium (Ti) foil. The source configuration is similar to flight sources used on Mars Exploration Rover missions. Our objective is to analyse several soil/rock samples along the rover track for the major elements composition.

The APXS Instrument: APXS instrument consists of two packages namely APXS sensor head and APXS backend electronics. APXS sensor head will be mounted on a robotic arm. On command, the robotic arm brings the sensor head close to the lunar sample (without touching it) and after the measurement, the sensor head is taken back to the rest position. APXS sensor head assembly contains SDD, six alpha sources and front end electronic circuits such as CSPA, shaper and filter circuits associated with the detector. Sensor head contains a circular disc which holds 6 alpha sources symmetrically around the detector and the detector at the centre, as shown in fig. 1.

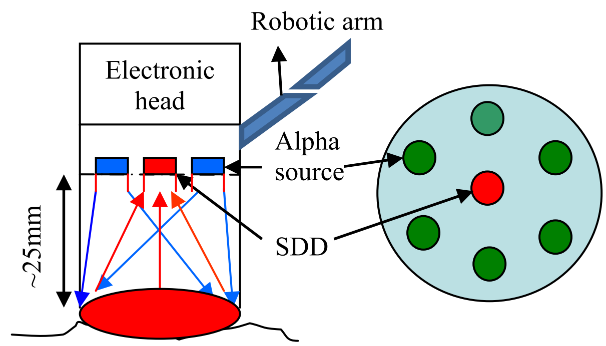

Fig. 1: APXS sensor head

SDD to be used in the experiment will have ~20 mm^2 active area detector module. This detector module contains in-built peltier cooler and heat sink to maintain the detector at ~ -30°C by providing required power and dissipating the heat by means of additional heat dissipation mechanism. The front face of the detector module is covered with 8 micron thick Be window to protect the detector from contamination. The threshold energy of the detector module due to the Be window is about 1keV. We are evaluating the performance and suitability of the SDD modules form KETEK, GmbH (20 mm^2 detector area) and AMPTEK, USA (25 mm^2 detector area). The size of the APXS sensor head is 60 mm (dia) x 80 mm (height). APXS sensor head also carries an electro mechanical door to protect the source and detector from lunar dust contamination. The detector facing side of the door will be coated with a desired material, which will be used as a calibration target during the mission. APXS backend electronics consists of PCBs having digital, power and rover interface electronics circuits, which are housed inside the Warm Electronics Box (WEB). WEB will be part of the rover where the sub-system temperatures are maintained at certain range. The interface between APXS and rover subsystems are shown in fig. 2.

Developmental Sta tus: Presently we have developed bread-board level subsystems for the APXS. We have used 20mm^2 detector (KETEK make) for the bread-board level design tests. The sub-systems developed for the APXS instrumentation are CSPA, Shaper-Peak detector-ADC, HV bias and Peltier controller.

Table 1: Comparison of APXS instrument configurations.

Parameters	MER	MSL	Chandrayaan-2
Detector (area)	SDD (10 mm^2)	SDD (10 mm^2)	SDD (~20 mm^2)
Source activity	30 mCi, ^{244}Cm	30 mCi of conventional sealed ^{244}Cm and 30 mCi of alpha emitting ^{244}Cm	30 mCi, ^{244}Cm
Detector-sample distance	30 mm	< 20 mm	~25 mm
Sample diameter	38 mm	17 mm	60 mm

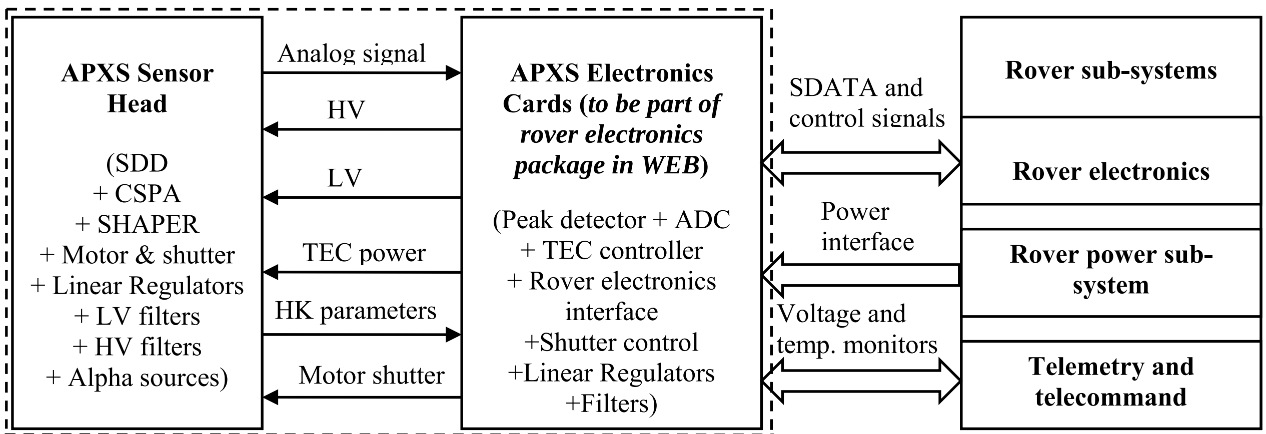

Fig. 2: APXS interface mechanism with Chandrayaan-2 rover.

CSPA, Shaper and Peak detector circuits have been developed using hybrid modules as these devices are readily available in qualified form with optimal power and packaging requirements.

The CSPA has been designed with "Reset" type and shaper with shaping time constant of 2μs. The ADC used in the design has 12 bit resolution. SDD requires HV bias of about -130V at RX (Outer ring), -20V at R1 (Inner ring) and -60V at RB (Back contact). These voltage levels have been generated using voltage multipliers as the total load current is ~20μA. Peltier controller has been designed with PWM technique and it allows the required current through the peltier to get desirable ΔT. It has been tested with stability of < 1^oC, achieved within two minutes time from power on. A sample spectra obtained from the bread-board model of the APXS electronics is shown in fig. 3. During the spectral acquisition, the detector temperature was maintained at -20^oC. The energy resolution achieved with this model is about 260 eV @ 5.9keV with low energy threshold at 1keV. We are working towards improving the spectral energy resolution by optimizing the circuit design and also developing a heat sink mechanism to cool the detector to ≤ -30^oC.

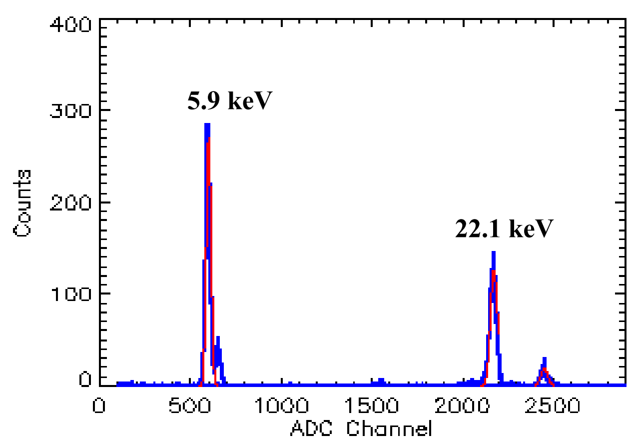

Fig. 3: Spectra obtained from SDD with breadboard level APXS setup using ^{55}Fe and ^{109}Cd X-ray sources for one minute integration time.

References: [1] Rieder R. et al. (1997) *JGR, 102(E2)*, 4027-4044. [2] Rieder R. et al. (2003) *JGR, 108(E12)*, 8066. [3] Gellert R. et al. (2009) *Lun.Planet. Sci. XXXX*, 2634. [4] Paige D. A. et al. (2010) *Science, 330*, 479-482. [5] Radchenko V. M. et al. (2010) *IOP Conf. Series*, doi:10.1088/1757-899X/9/1/01209.