Measurement technique and description of the instrument:

The instrument consists of a source head, a detector head and the electronics package. The source head has 4 channels of LEDs out of which 3 are very narrow band and the fourth one is broad band. The three narrow band LEDs have peak wavelength of 255 nm, 290 nm and 310 nm, corresponding to absorption bands of the Hartley and Huggins band of absorption of Ozone. These LEDs are narrow band with peak power at the above-mentioned wavelengths and FWHM of 12 nm. The fourth one is a broad band LED having response in UV-VIS range. Table 1 shows some of the parameters of the LEDs. The LEDs emit in very narrow bands with high power.

Model	Peak Wavelength	Optical Power (Min)	Spectral FWHM	Viewing half Angle	Max. DC Forward Current	Package
LED250J	250 nm	1 mW	12 nm	7.5°	100 mA	TO-39
LED290J	290 nm	1.6 mW	11 nm	60°	30 mA	Φ19
LED310J	310 nm	1.5 mW	15 nm	57°	40 mA	TO-39

The detector head consists of photodiodes corresponding to each LED source. **The photodiodes are of broad band in nature. Spectral filters with narrow band pass are mounted in front of the photodiodes to filter out the other wavelengths from reaching the photodiode. This ensures that only certain wavelengths are allowed to enter the photodiodes that correspond to the absorption band of the ozone. In this way, ozone can be unambiguously detected. The instrument is a kind of multi-spectral photometer.** The photodiode is operated in photoconductive mode and the current generated by the photodiode is proportional to the power incident on the photodiode. The incident power (W) is the product of the irradiance (W/m^2) received at the active area of the photodiode and the active area (m^2) of the photodiode. This power is converted into current (A) based on the responsivity (A/W) characteristic of the photodiode. Therefore, the current generated is directly proportional to the irradiance of the received radiation. Ozone has absorption in specific bands and the received current dips in proportion to the ozone concentration. This technique is used to derive the concentration of ozone in the column formed between the LED source and the photodetector active area. With the knowledge of the Ozone absorption cross section and the attenuation in current, using Beer-Lambert's law, one can derive the concentration of ozone present in that column.

Principle of Measurement:

The sensor head and the detector head are mounted such that the source (LEDs) and the detectors (Photodiodes) face each other in a horizontal plane. The 3 narrow band LEDs are mounted symmetrically at 120°angle each and the broadband LED is mounted in the center.

Figure 1 shows the conceptual schematic of the proposed sensor and detector configurations. The LEDs are driven by LED drivers that is controlled by the Processing Electronics (PE) card sitting inside the electronics package inside the rover. Since the LEDs have half view angle of 7.5°, a collimating lens is kept in front of the LEDs to collimate the UV signals so that the spot size of the signal at the detector (photodiode) is of 5.1 mm diameter, same as the diameter of the active area of the photodiode.

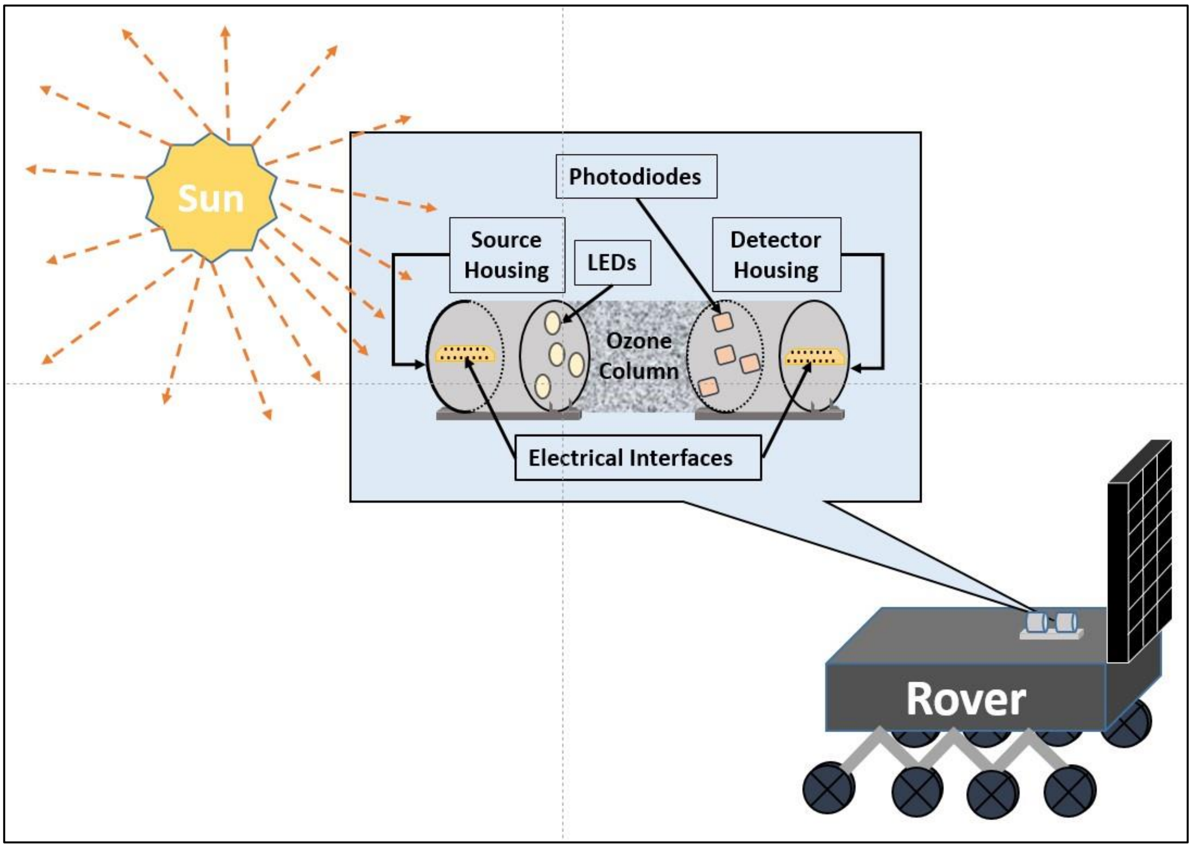

Figure 1. *Conceptual drawing of OPM on Mars Rover*

At the detector head, the collimated incoming signal from the LED is filtered by spectral filters of appropriate band pass (the Hartley and Huggins band of absorption of Ozone), and the filtered signal is received by the detector. The detector is reverse biased to operate in the photoconductive mode. The current generated is measured using a standard Trans Impedance Amplifier (TIA) circuit. The output of the TIA is a voltage inversely proportional to the concentration of the ozone. The measurements are made every 4 second and the voltage output is digitized using a multichannel ADC and the DN numbers corresponding to all the channels is passed to the Processing Electronics card.

Figure 2 shows the overall functional block diagram of the OPM. The various subsystems of the OPM experiment are briefly explained below.

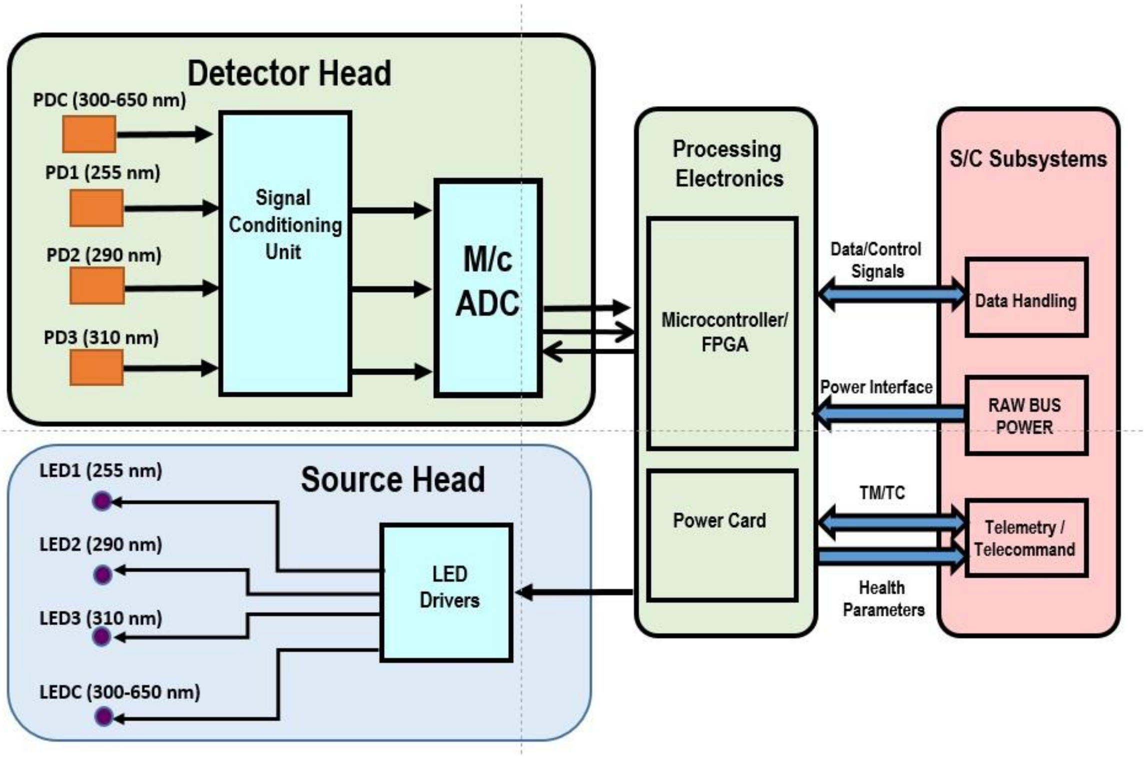

Figure 2. Functional *Block Schematic of OPM Experiment*

(i) UV Source Head (UVSH): As shown in Figure 3, the UV source head consists of the LED Driver circuits in 1 circular PCB, the LED Mounting PCB, Collimators and Dust Protector Sheet. It is shown in Figure 3. The LED driver is controlled by the inputs from the controller. The driver has provisions to program the operating current and the voltage of the LEDs thereby controlling the output power of the LEDs. The LEDs are mounted on a PCB from where the connections to the Driver PCB is made. Each LED is housed in a stepped enclosure where steps of varying step size and width are used. The first step from the outside, i.e. the area exposed to Martian environment houses the Dust protection sheet/layer. The 2nd step houses the collimator and the 3rd step houses the LED itself. The dust protector is electrically isolated from the rest of the subsystem and is cleaned electrostatically at regular intervals.

(ii) UV Detector Head (UVDH): As shown in Figure 3, each detector channel of the UV detector head consists of the dust protector sheet/layer in the first step, which is same as in the source head and will be electrostatically cleaned regularly. The second step houses the spectral filters, different for different detector channel, and the 3rd step houses the photodiode detectors. All the 4 detectors are mounted on the detector PCB. From the detector PCB, the Signal Conditioning Unit (SCU) PCB is connected to each photodiode channel. The SCU has TIAs for each channel and after suitable amplification of the voltage, it digitizes them using multichannel ADC and sends the digital data to the processing card situated inside the rover.

(iii) Processing Electronics (PE): The Processing Electronics Package is situated inside the rover and is shown in Figure 3. The package consists of the PE and Power Cards. The PE employs Microcontroller to control the LED drivers, to control the electrostatic cleaning of the dust protection layer/sheet and for other standard controls such as switching ON/OFF the instrument, LEDs, particular detector etc. The received digital data from the SCU of the detector head is processed, packaged and is communicated to the BDH of the lander. The controller also provides the interface for TM, TC and HK.

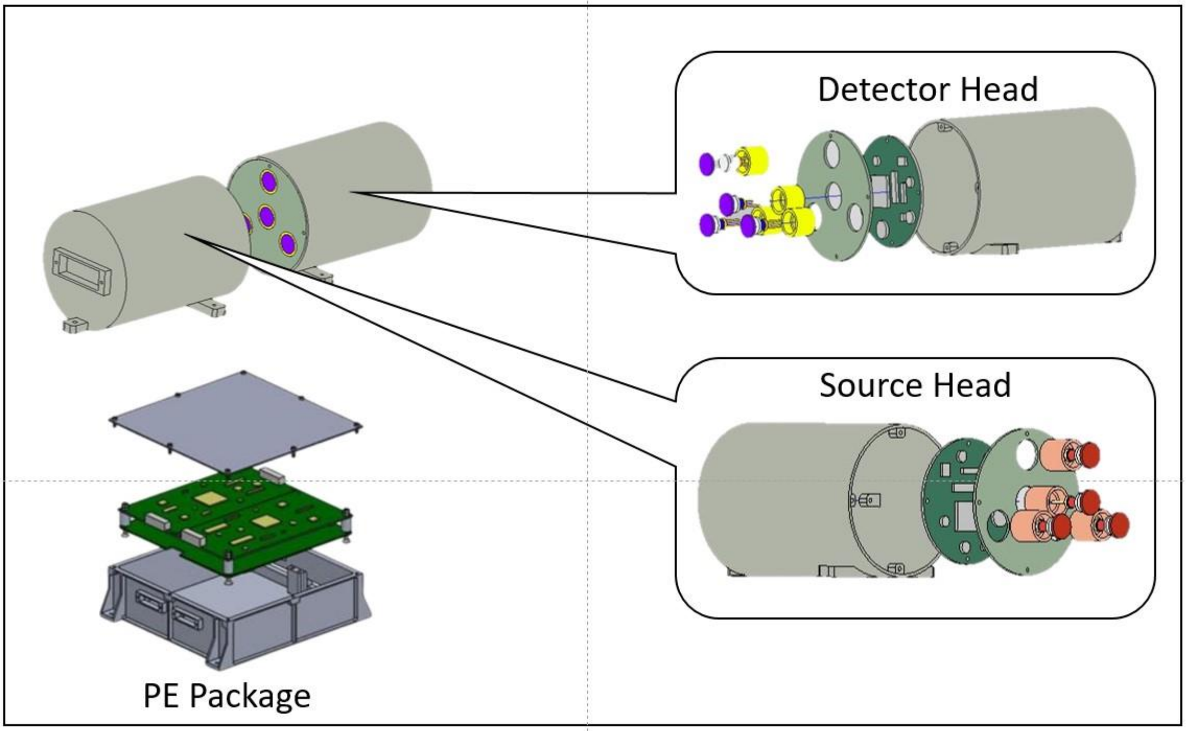

Figure 3. *Mechanical Schematic of the Source Head, Detector Head and the Processing Electronics Package*

6. How will scientific inference be made from the observations

The sampling rate for each detector channel is variable and can range from 1 sample every 4 seconds to 1 sample every 20 seconds. The voltage values received every 4 second (for sampling rate of 1 sample every 4 seconds) from each detector channel is converted into current using the equation:

$$I_{ph} = \frac{V_o}{G}$$

Where, I_{ph} is the photodiode current, V_0 and G are output voltage and gain of the particular detector channel.

The photodiode current can further be written as:

$$I_{ph} = R \times P$$

Where R is the responsivity of the photodiode in the particular band and P is the incident power in that particular band. The responsivity of the photodiode is known apriori. This leaves with P as the unknown.

The power P can be written as:

$$P = P_{LED} + (P_{sun})_{ref} + (P_{sun})_{scat} - (P_{oz})_{abs} - (P_{LED})_{scat} - (P_{LED})_{abs}$$

Where, P_{LED} is the illuminated power transmitted by the LED, $(P_{sun})_{ref}$ is the solar power received at the photodiode due to reflection from other surfaces, $(P_{sun})_{scat}$ is the solar power received at the photodiode due to scattering by dust or any other particle, $(P_{oz})_{abs}$ is the power absorbed by the ozone molecules, from other surfaces, $(P_{LED})_{scat}$is the power from the LED that is scattered by dust and other particles and, $(P_{LED})_{abs}$ is the LED power absorbed by other atmospheric constituents with absorption band within the narrow band of LED illumination spectrum. The unknown in the above equation are $(P_{sun})_{ref}$, $(P_{sun})_{scat}$, $(P_{oz})_{abs}$, $(P_{LED})_{scat}$, and $(P_{LED})_{abs}$.

Of these, the reflected powers from sun are minimized by putting the photodiode in a steeped enclosure. Moreover, the detector head is kept horizontally so that it sees minimum of solar radiation. On top of it all, the spectral filters ensure that only a very narrow band of signals pass to the detectors. Even in the worst case, the knowledge of SZA and data from other instruments and the available literature, the amount of solar power reaching the detector can very well be estimated and corrected for during analysis. For the scattered solar power reaching the photodiode, the central broadband LED and detector give us the concentration of the dust and other such particles. The data from this channel will be used to correct for the scattered power due to dust.

For LED, reflection will not be there as the LED signal is collimated to match the active area of the photodiode. The power loss due to scattering will be corrected using the data from central detector channel. With these inputs, the Power attenuation due to ozone is calculated and using the knowledge of the ozone cross section and by applying Beer-Lambert's law, one can find the concentration of the Ozone.

7. Payload specifications and scientific justification

Parameter	Principle	Range	Sensitivity/Resolution

Ozone Concentration	Beer-Lambert's Law	10^8-10^{10} molecules/cm^3	5 %
LED illumination power	Photoelectric effect	0.1- 1 mW	Variable