Design and Performance of the Langmuir Probe on the MAVEN Mission. G. T. Delory[1], L. Andersson[2], R. E. Ergun[2], M**.** W. Mooroka[2], C. Fowler[2], T. McEnulty[2], T. Weber[2], A. Eriksson[3], D. Andrews[3], D. L. Mitchell[1], J. P. McFadden[1], J. S. Halekas[4] , D. Larson[1], J. E. P. Connerney[5], J. Espley[5], and F. Eparvier[2], [1]Space Sciences Laboratory, University of California, Berkeley CA 94720 (gdelory@berkeley.edu), [2]Laboratory for Atmospheric and Space Physics, University of Colorado, Boulder, CO, 80303, [3]Swedish Institute for Space Physics, Uppsala, Sweden, [4]Department of Physics and Astronomy, University of Iowa, Iowa City, IA 52242, [5]NASA Goddard Space Flight Center, Greenbelt, MD 20771.

Introduction: The Langmuir Probe and Waves (LPW) instrument was developed for the Mars Atmosphere and Volatile EvolutioN (MAVEN) mission to provide fundamental measurements of ionospheric properties and dynamics at Mars. The LPW instrument is a dual purpose sensor designed to measure the electron temperature and density using current-voltage sweeps, and plasma waves emissions in receiver mode. Here we discuss the rationale behind the Langmuir Probe (LP) design and operation, and discuss the instrument performance in various plasma regimes ranging from cold dense ionospheric conditions, sunlight vs. shadow, and in more tenuous plasmas at higher altitudes.

Background: Electron temperature and density are critical quantities in understanding an upper atmosphere. Approximately 40 years ago, the first and only two temperature profiles of the Martian ionosphere were obtained during the descent of the Viking landers [1]. All spacecraft that have visited the red planet thereafter have had limited plasma packages and high altitude orbits, preventing the acquisition of detailed *in situ* information about Mars' upper atmosphere and ionosphere. Much of our knowledge about the upper atmosphere and ionosphere of Mars has been limited to remote measurements by the MARSIS sounder on Mars Express (MEX) [2], and Electron Reflectometer and radio occultation observations on Mars Global Surveyor [3,4].

The MAVEN mission is the first satellite sent to Mars with a complete plasma package. The Particle and Fields Package (PFP) consists of 7 instruments: LPW, an Extreme Ultra Violet sensor (EUV), a magnetometer (MAG), two ion instruments (SWIA and STATIC), an electron instrument (SWEA), and an energetic particle instrument (SEP). Together, these instruments will provide the first comprehensive characterization of the upper atmospheric and plasma environment at Mars.

The MAVEN Langmuir Probe: The LPW instrument has two sensors located on ~7 m booms that can be operated both as two separate Langmuir probes or as an electric field instrument. The LPW instrument makes fundamentally different measurements in LP mode versus Electric Field (Waves) mode. When the sensors are operated in LP mode, the potential is swept over a set of voltage steps, and the current to the sensor at each voltage step is measured. In waves mode, the LPW sensors act as voltmeters and measure the DC and AC voltage fluctuations in the ambient plasma (Figure 1 and [5].)

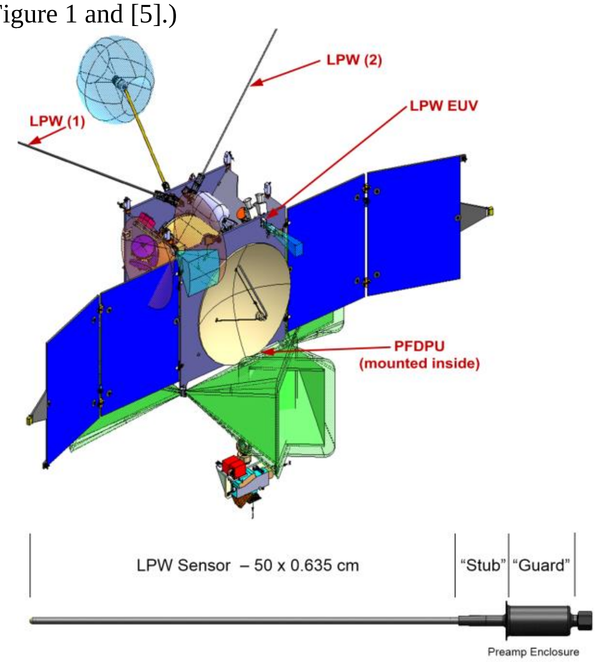

Figure 1: MAVEN LPW Instrument and sensor assembly

The MAVEN LPW sensors are linear rods, similar to previous LP designs such as the instrument flown on the Pioneer-Venus Orbiter (PVO) [6]. At the base of the rod is an active preamplifier assembly that controls the voltage and current modes. In LP mode, a potential is applied to the rod over a range of ± 50 V or less, and the current collected from the plasma is monitored. The voltage-current profile yields the electron density and temperature for the most dense, lowest energy component of the ionosphere. In addition to current-voltage sweeps, observations of Langmuir wave emissions in the ionospheric plasma allows for an independent measurement of electron density. A unique feature of the LPW instrument is the ability to stimulate ionospheric Langmuir emissions by broadcasting a low power white noise source.

The LP sensors consist of Titanium and are coated with Titanium-Nitride (TiN). Guard and Stub surfaces near the sensor are voltage biased to minimize end effects, and screen out photo-electrons from the spacecraft, which can interfere with measurements of the pristine Martian ionosphere. Changes in these surfaces over time will also affect the LP instrument performance.

In general, LP data interpretation depends on many factors ranging from the properties of the instrument itself, various environmental factors such as photoemission, and the characteristics of the MAVEN spacecraft. One of the advantages of the MAVEN LP mode is the ability to send back entire current-voltage sweep profiles in telemetry, such that many subtle effects resulting from photo-currents, changes in surface properties, bi-modal electron distributions, and other details can be discerned on the ground.

Equally important for LP measurements are the electrical properties of the MAVEN spacecraft itself, which mediates the plasma return current during LP mode voltage sweeps. Under ideal conditions, the spacecraft would have over several hundred times the current collection area as each LP sensor, such that the spacecraft potential is stable during LP voltage sweeps. Due to the properties of the MAVEN solar arrays and High Gain Antenna (HGA), the ability of the spacecraft to collect return currents is heavily attitude dependent. This has resulted in spacecraft charging in some attitudes which the LPW and other PFP instruments have to contend with.

MAVEN observations: Thus far the MAVEN LP mode is measuring electron temperature and density under a wide range of conditions, including the low-altitude ionosphere (below 400 km), and lower density, hotter populations at higher altitudes and in darkness. Inclusion of Langmuir wave emissions in the density calculation brings the LP mode accuracy to better than 5%. While spacecraft charging is occasionally an issue, the wide dynamic range of the LP mode voltage sweep enables measurements of electron density and temperature under these conditions as well. As the MAVEN orbit precesses over different latitudes and local times, the LPW observations will provide critical information to drive models that can demonstrate how the upper atmosphere varies and what processes are critical for atmospheric escape at Mars.

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