宇宙環境計測ミッション装置（ＳＥＤＡ－ＡＰ）プラズマモニタ（ＰＬＡＭ）の計測結果

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***Abstract*—In order to support future space activities, it is very important to acquire space environmental data on the causes of degraded space components and spacecraft anomalies. Such data is also useful for spacecraft design and manned space activities. Space Environment Data Acquisition equipment - Attached Payload (SEDA-AP) measures the space environment around the International Space Station (ISS) while attached to the Exposed Facility (EF) of the Japanese Experimental Module ("Kibo"). SEDA-AP was launched on July 16, 2009, and then attached to EF on July 25 by using Kibo's robotic. Initial checkout began on August 4 and successfully ended on September 17.**

The Plasma Monitor (PLAM) is one of the detectors in SEDA-AP. PLAM measures the potential, density, and electron temperature of space plasma by means of Langmuir probe analysis. Such plasma measurement is important for analyzing the charging status of surface materials and the potential of the ISS.

This paper reports on the mission objectives, instrumentation, and measurement status of PLAM.

Index Terms—**Plasma monitor, Kibo, ISS, Exposed facility, SEDA-AP**

I. Introduction

Space Environment Data Acquisition equipment – Attached Payload (SEDA-AP) was developed to measure the space environment around the International Space Station (ISS). Space environmental data is very important to avoid the risks posed by the space environment, such as total dose, single event anomalies, surface charging, and the degradation of materials. SEDA-AP measures these aspects of the space environment by using eight types of instruments as follows:

1) Neutron Monitor (NEM)
   Measures neutrons by using the Bonner Ball Detector and the Scintillation Fiber Detector.
2) Heavy Ion Telescope (HIT)
   Measures the energy distribution of heavy ions, lithium, carbon, oxygen, silicon and iron by using a silicon semiconductor detector.
3) Plasma Monitor (PLAM)
   Measures the plasma density and electron temperature by means of Langmuir probe analysis.
4) Standard Dose Monitor (SDOM)
   Measures the energy distribution of high-energy light particles such as electrons, protons, and alpha particles by using a system that combines three semiconductor detectors (SSDs) and a scintillator.
5) Atomic Oxygen Monitor (AOM)
   Measures the amount of atomic oxygen in ISS orbit from changes in resistance in response to variations in carbon film thickness.
6) Electric Device Evaluation Equipment (EDEE)
   Measures single event effects and the degradation of electronic devices used on Kibo.
7) Micro-Particles Capture (MPAC)
   Captures micron particles that exist in ISS orbit by using silica aerogel and a golden plate.
8) Space Environment Exposure Device (SEED)
   Measures the degradation of materials for space use caused by the space environment, such as high energy radiation, atomic oxygen, and UV.

SEDA-AP is attached to port #9 of the Exposed Facility (EF) of the Japanese Experimental Module ("Kibo"). Figure 1 shows a photo of Kibo and SEDA-AP.

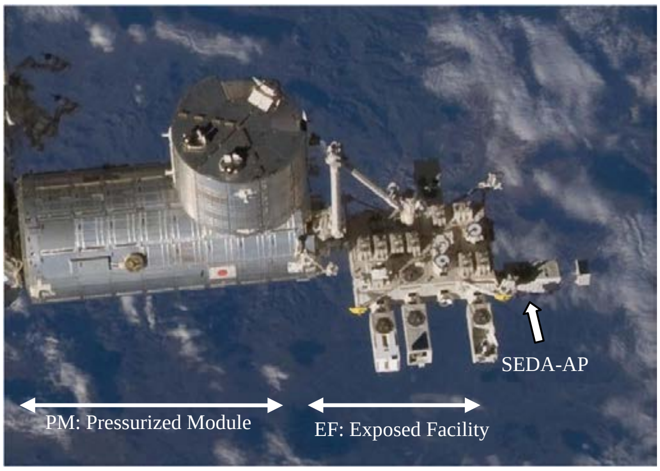

Fig. 1. Photo of "Kibo" and SEDA-AP (modified NASA image)

Figure 2 shows a diagram of SEDA-AP and the location of each instrument.

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PLAM is designed to measure the floating potential and plasma properties of density and electron temperature.

This paper reports on the instrumentation of PLAM and the initial results on orbit.

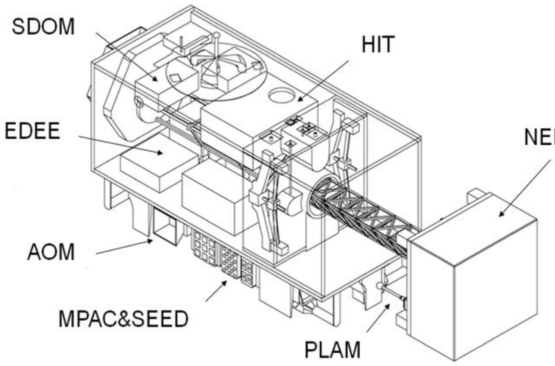

Fig. 2. Diagram of SEDA-AP

II. Overview of SEDA-AP operation

SEDA-AP is one of the first missions of Kibo's Exposed Facility (EF), and was launched aboard the Space Shuttle as a part of Kibo construction #2 (mission 2JA) on July 16, 2009. SEDA-AP is mounted in the Experiment Logistics Module-Exposed Section (ELM-ES), along with Monitor of All-sky X-ray Image (MAXI) and the Inter-orbit Communication System (ICS), in the Space Shuttle's cargo bay.

SEDA-AP was attached to Kibo on July 25 by using Kibo's JEM Remote Manipulator System (JEMRMS). Initial checkout began on August 4 and successfully ended on September 17. After initial checkout, SEDA-AP began conducting space environment measurements.

III. Description of PLAM instruments

PLAM measures the plasma density, temperature, and floating potential by using a Langmuir probe. Table I lists the four measurement modes. Figure 3 shows a diagram and a photo of the PLAM sensor. PLAM design is based on the plasma measurement instruments of the Space Flyer Unit (SFU).[1]

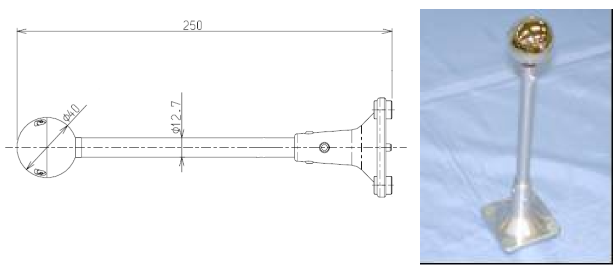

Fig. 3. Diagram (left) and photo (right) of the PLAM sensor (dimensions in mm)

The PLAM sensor employs a gold-plated sphere as its probe, having a radius of 40 mm and a length of 250 mm. Gold was selected as the surface coating material, given its uniform work function and stability in the atomic oxygen environment of ISS orbit. As the probe contains no built-in heater, there is no active cleaning mode. PLAM has five measurement modes. Mode 0 (a repetition from Modes 1 to 4) is used for nominal cases of measurement. A mechanical relay is used to change the modes.

Table I.
Measurement modes of PLAM

Mode No.	Probe mode	Time of measurement (sec.)	Applied voltage
0	LP, FP*)	64	Repetition from Modes 1 to 4
1	LP	16	-2 to +2V sweep/16 sec.
2	LP	16	-50 to +50V sweep/16 sec.
3	LP	16	+10V fixed
4	FP	16	(Voltage measurement)

*) LP: Langmuir Probe, FP: Floating Probe

A. *Mode 1*

A voltage sweep is conducted from -2 to +2V (sawtooth wave) relative to the chassis ground and structure of SEDA-AP (as well as the ISS). The sweep time is 16 seconds, with 320 sampling steps (at equal intervals) and 8-bit quantization. Mode 1 has two types of current measurement mode, high gain (from -0.2 μA to +2 μA), and low gain (from -0.04 mA to +0.4 mA).

B. *Mode 2*

A voltage sweep is conducted from -50 to +50 V relative to the chassis ground. The sweep time, sampling steps, quantization, and current mode are the same as in Mode 1.

C. *Mode 3*

Voltage is fixed to +10V. There are 512 sampling steps (at equal intervals) with 8-bit quantization. The current mode is same as in Modes 1 and 2.

D. *Mode 4*

The sphere is isolated from the chassis ground by a high impedance circuit (at approximately $10^9 \Omega$). There are 512 sampling steps (at equal intervals) with 8-bit quantization.

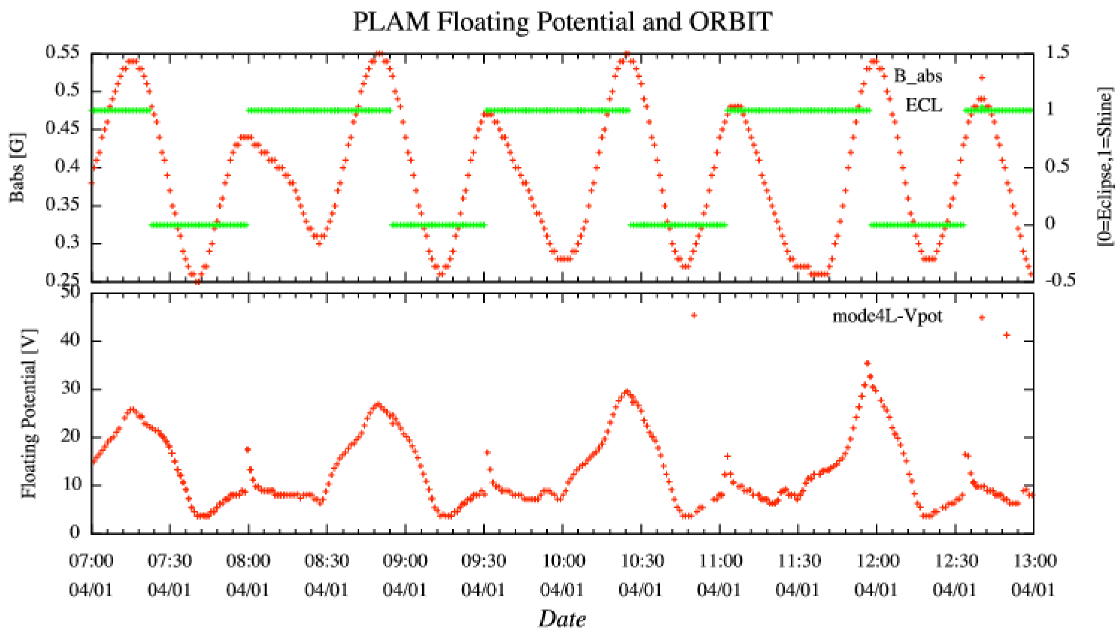

Fig. 4. Floating potential and orbit data

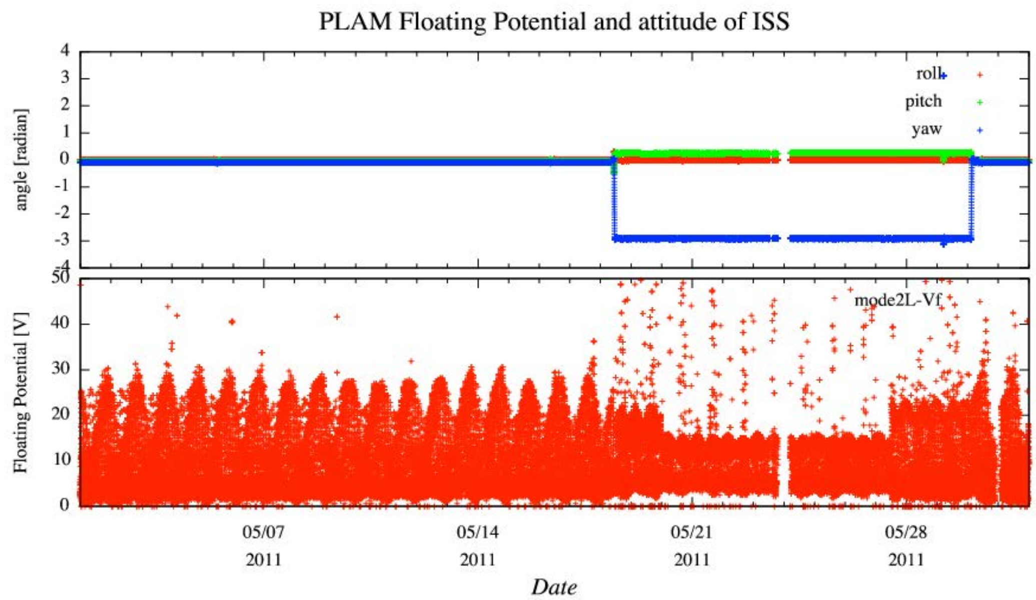

Fig. 5. Floating potential and attitude data

IV. FLIGHT DATA

Initial checkout was successfully completed on August 6, 2009. PLAM was then placed into continuous measurement mode. Data processing is based on general Langmuir Probe theory.[2]

A. *Floating potential*

Floating potential is obtained from Modes 1, 2, and 4. Figure 4 shows data covering six hours on April 4, 2011. Floating potential is shown in the lower part of the figure. Mode 4 (floating probe mode) obtains Vpot. L and H denote Low and High gain mode, respectively. The upper part of the figure shows the absolute value of the magnetic field (red line); the green lines show a solar eclipse [0=eclipse, 1=shine]. When the ISS exits an eclipse, floating potential is increased by the power generated by the PV array module. Variations in floating potential are synchronized with the absolute value of the magnetic field due to induced electromotive force. These results are in good agreement with data obtained by the Floating Potential Measurement Unit (FPMU) onboard the ISS.[3]

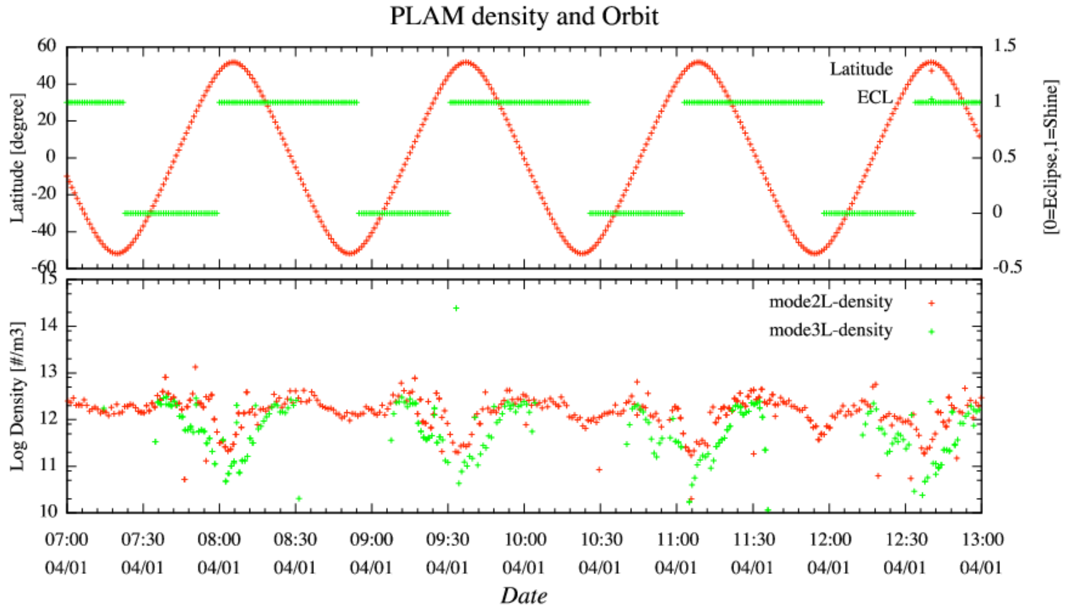

Fig. 6. Plasma density and orbit data

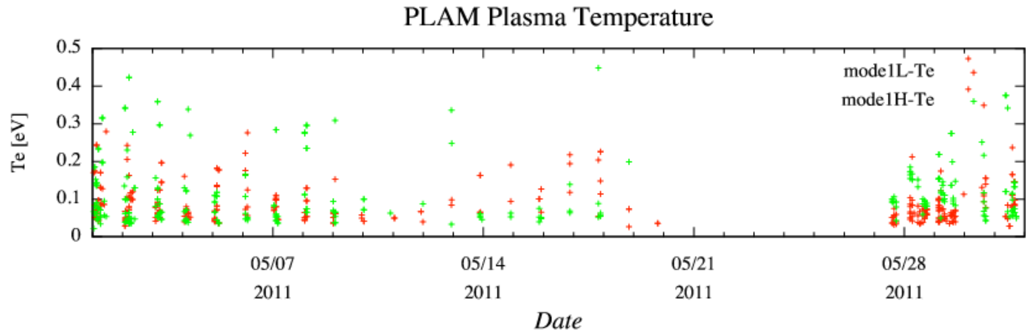

Fig. 7. Plasma Temperature data

Figure 5 shows one month of data on floating potential and attitude of the ISS in May 2011. The lower part of the figure shows floating potential; the upper part shows roll, pitch, and yaw. Vf is obtained by determining the voltage at which the current changes polarity in Mode 2 (Langmuir Probe mode). The Space Shuttle was docked at the ISS from May 18 to May 30. During this period, the attitude of the ISS was changed from +XVV (yaw=0) to –XVV (yaw=-π) to avoid space debris from striking the insulation tiles of the Space Shuttle. A lower potential resulted from this change in attitude. The data on floating potential is erratic during this period, as the location of PLAM was changed from ahead of the ISS to behind it.

B. Plasma density

Plasma density is obtained from Modes 1, 2 and 3. Figure 6 shows the plasma density and orbit data of ISS covering six hours on April 4, 2011 (same period as in Fig. 2). The lower part of the figure shows the plasma density obtained from Modes 2 and 3 at low gain. The upper part shows the latitude and solar eclipse and sunshine. There is good agreement regarding the plasma density obtained by Modes 2 and 3.

C. Plasma temperature

Plasma temperature is obtained from Modes 1 and 2. Given the roughness of the voltage sampling rate in Mode 2, the accuracy is very low. In Mode 1, the applied voltage is narrow (±2V); therefore, data on plasma temperature can only be obtained when Vf is under 2V. Figure 5 shows one month of Mode 1 data obtained in May, 2011. Vf is almost greater than 2V, thereby limiting available data. The data obtained in Mode 1 is now being evaluated and its quality improved.

V. Summary

PLAM has successfully been engaged in continuous measurement since August 2009. The data on floating potential and plasma density are in agreement with another observation data obtained at the ISS. Given the currently limited and low quality data on plasma temperature, we will continue making efforts to resolve this problem. For future work, we will compare the data on plasma density and temperature with that of the International Reference Ionosphere (IRI) model and data on floating potential through $V_{ISS} \times B \cdot l$ analysis.

ACKNOWLEDGMENT

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