Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

PCG008-P01 Room:Convention Hall Time:May 26 14:00-16:30

Calibration of detective sensitivity of SPRINT-A/EXCEED

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SPRINT-A/EXCEED is an earth-orbiting space telescope which carries out the Extreme Ultraviolet (EUV) spectroscopic observations for planetary plasmas. The spectral range is from 55 to 145 nm and the spectral resolution is from 0.2 to 0.5 nm. It is essential to calibrate the detective sensitivity of the instrument to determine the intensity of EUV lights. Optical components are planed to be delivered in March 2011 and the calibration facility including the vacuum chamber are being built up. In this presentation, we show the current status of the calibration of the EUV optical components.

Keywords: SPRINT-A, EXCEED, EUV

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Performance test of Micro-pore Optics (MPO) in the EUV spectral range

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It is impossible for Extreme Ultraviolet (EUV) observations to use a lens, because there is no glass material that can transmit the EUV light. Thus, we can only use the mirrors for EUV optics. Micro-pore Optics (MPO) is square or radial plates that are composed of thousands of capillaries, which consists of square glass pores having aspect ratio of several hundreds to one. It has played a lens-like role for X-ray observations. We manufactured a sample of MPO having a focal length of 35 mm, and measured the transmittance. The result shows that was more than 60% by the wavelength from 30.4 to 140.0 nm. In this presentation, we report the measured efficiency of our sample in the EUV spectral range.

Keywords: EUV, airglow, optics, remote sensing device

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Designs of multi-layer coated mirrors for remote sensing of planetary ionospheres

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According to observations of the polar orbital and the geosynchronous satellites the oxygen ions sometimes become the main component, especially during the periods of the southward interplanetary magnetic field and the high geomagnetic activity. Besides the atmosphere of the terrestrial planets has oxygen atoms as the main component, and the process of the oxygen atoms/ions escape is one of most significant issues for the evolution of the planetary atmosphere. One of the powerful tools for this study is a imagery of the oxygen ions.

The concept study of the oxygen ions imagery proposed in 1990's has been expected to make a progress about the studies on the evolution of the planetary atmosphere and on the plasma structure in the direct interaction region between the solar wind and the planetary ionosphere. However, the observations have never been performed, because a reduction of the noise produced by hydrogen atom resonance emission is too difficult to observe the signal from the oxygen ions. The members of our research team has developed the instrument with the thick indium filter to reduce the hydrogen Lyman alpha emission, and succeeded in observing the oxygen ions emission. The technical methods is adopted to the Upper-atmosphere and Plasma Imager (UPI) on the SELENE(KAGUYA) sattelite. The imager is ready for the observation of the oxygen ion distribution in the polar wind and the near-earth magnetosphere.

But we revealed that the intensity of the Lyman beta emission was not negligible. Consequently, a multi-layer coating is designed to keep the reflectivity at the oxygen ions emission and to reduce simultaneously the reflectivities at the Lyman alpha and beta emissions. There are several methods of the noise reduction, but the use of only one multi-layer mirror has an advantage of the compact and light instrument. The measured reflectivity of the preproduction sample mirror is presented, and the optical performance is discussed.

Keywords: planetary ionosphere, plasma remote sensing, soft x-ray and extreme ultraviolet light

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Effects of a light reflecting layer to the response of piezoelectric PZT elements

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We have studied responses of piezoelectric PZT elements for measuring cosmic dust. This report is aimed at a theme on effects of a light reflection layer to the response of the PZT element.

The BepiColombo mission that explores Mercury and its environment is progressed as a joint project between JAXA and ESA. Since the measurement of dust ambient Mercury is one of the approved programs, the Mercury Dust Monitor (MDM) has been developed onboard the BepiColombo mission (MPO). Because of restricted resources to the MDM, it comprises piezoelectric PZT elements and electronic circuits.

Since the MDM is to be operated around the Mercury orbit, the thermal flow around the PZT element is estimated using a thermal model. The temperature condition under which the element is operated is crucial, because the piezoelectric character should be maintained. In order to overcome this difficulty, we discussed a layer that reflects thermal flow from the sun. The layer is useful to lower temperature down at which piezoelectricity is retained. On the other hand, this layer would considerably affect the characteristic of the PZT.

The effects of the layer on the characteristic responses were experimentally studied by bombarding hypervelocity microparticles with the PZT element. The microparticles were supplied by the Van de Graff accelerator at MPI-K, HIT of University of Tokyo, and the GUN at ISAS.

The PZT element was a square of a 40 x 40 mm2 and its thickness of 2mm. One side of the element was covered with a ˜5 um thick silver layer over the entire surface. At the rear side a 5 x 5 mm2 and ˜5 um thick silver layer was embedded as a collector of induced signal. Thus then, the surface of the silver layer was painted with a paint up to ˜100 um thick. The paint was produced by Ube Kosan C.o. (PETI-330m, high heat resistance material composition polyimide resin). Hereafter we call this paint layer as a white paint.

Output signal from the collector was processed with a charge sensitive amplifier and measured with an oscilloscope. A photomultiplier was set near the element to observe light flashes immediately after collision.
The PZT element was bombarded with microparticles at room temperature. The observed signal forms measured and recorded by the scope were processed in offline analysis. A first one cycle of the signal form was interested in analysis.

The amplitude was plotted against the momentum of the incident particle. Here, let define the sensitivity of the PZT element as the ratio of the increment of amplitude dA to that of momentum dp; dA/dp. Thereby, the sensitivity clustered into three groups. The first group corresponded to the case in which the sensitivity of the PZT element overlapped with that of PZT elements without covering the white paint. There existed the second group that its sensitivity is approximately expressed as a sum of dA/dp and a certain offset. The third group clustered in a region different from those of the first and second groups, and the dA/dp values are considerably small.

At present, it is unclear why the three groups coexist. Except for the first group, the effect of the white paint to the response of PZT element is significant. As an intermediate result, we are interested in the second group that is considered to be significantly influenced by the white paint. Therefore, the present results could be worth reporting, since there are very few reports that the effects of the white paint to the system comprised white paint and the PZT element has been quantitatively discussed.

Keywords: cosmic dust, dust, BepiColombo, PZT

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Development of lightweight loop antenna for future space missions

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In space plasma physics, the polarization and wave normal direction provide key information to identify the modes and origins of plasma turbulences. Such broad-band measurements have been made by loop antennas, from 0.1 to 1000 kHz. *Okada et al.* developed a loop antenna system aboard the Akebono satellite (EXOS-D) launched in 1989. The loop was square-shaped with an area of 0.36 m^2 (0.6 x 0.6 m) and the mass of about 2 kg. The major part of its mass was due to antenna frames.

We have examined lighter loop antennas with CFRP technologies since 2007. It has an area of 0.36 m^2, which is the same as that of the Akebono antenna. The TWF-CFRP tubes are used as antenna frames. Since the CFRP tube is conductive, it is also used as an electrostatic shield of the loop element. The antenna element is rectangular (0.6 x 0.6 m) open coil with 10 turns each. The weight of the loop antenna was 438 g (frame: 72 g, wire element: 135 g, joint parts: 231g), 1/4 of the original Akebono design. As the next step, we will use CFRP joint parts. In that case, the mass will become half. The folding method of the loop antenna was examined in parallel. Then it will be tested by a model with realistic size. We expect to adopt the new loop antenna system to small-sized space missions for magnetospheric and ionospheric studies. It is also expected in landing missions, as a light sensor to detect radio waves from atmospheric discharges, subsurface radar echo, etc.

Reference
Okada et al., *Tras. IEICE*, **Vol. E70**, No. 6, 550-561, 1987

Keywords: lightweight loop antenna, ionosphere, magnetosphere, radio wave receiver

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Development of high-resolution digital fluxgate magnetometer for the SCOPE mission

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The main subject of the SCOPE (Scale COupling in the Plasma universE) project is to investigate the cross-scale coupling physics of the plasma in the magnetosphere and in the interplanetary space. The magnetic field should be measured with higher time resolution than 10 msec, to investigate the electron-scale process of the plasma. The performance requirements of the SCOPE mission are shown below.

Dynamic range : +/-4000 nT
Frequency range : DC-128 Hz
Resolution : 20 bits (Quantization step corresponds to 8 pT.)

We have developed a digital-type fluxgate magnetometer for S310-40, a sounding rocket mission, as a preliminary experimental step for the SCOPE spacecraft. The digital-type has the advantage of being small, lightweight and low power. The performance requirements for the S310-40 mission are shown below.

Dynamic range: +/-65000 nT
Frequency range: DC-60 Hz
Resolution: 16 bits (corresponding to 2 nT)

When we keep the 16-bit resolution and change the dynamic range from +/- 65000 nT to +/- 4000 nT, the quantization step corresponds to 128 pT.

The accuracy of the digital-type fluxgate is determined by the resolution of the Digital-to-Analog Converter (DAC) in the electronics package. DACs having a resolution $>$ 12 bits are not available for the space applications. We developed a sigma-delta type DAC, in order to improve the accuracy of the digital-type fluxgate magnetometer. The resolution of the sigma-delta DAC is determined by the topology of the sigma-delta modulator and analog filter. First, we designed the topology of the modulator and analog filter by numerical simulation. In the most optimized solution, they are 2nd-order 1-bit sigma-delta modulator and 4th-order analog low-pass filter, respectively. Second, we experimentally evaluated the performance of the DAC circuit build by a Field Programmable Gate Array (FPGA) and OP-amps which are tolerant of the space environment. We examined the errors in the output signal of the DAC circuit against the varying input signal. We found that the DAC circuit satisfied 16-bit resolution when the over sampling ratio is 676. The linearity error was 0.006 %, which corresponds to 4.8 nT for +/- 40000 nT range. These results showed that this DAC circuit satisfied the requirements for the S310-40 mission. We report the examination results of the fluxgate magnetometer developed for the S310-40 rocket experiment.

Keywords: SCOPE, magnetometer, digital fluxgate, sigma-delta modulation technique, Digital-to-Analog Converter

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Residual magnetism measurements needed for magnetometers onboard QSAT-EOS

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We have two 3-axis fluxgate magnetometers onboard the Kyushu Satellite for Earth Observation System Demonstration (QSAT-EOS). We call these instruments Science Magneto Sensors(SMS). The main object of SMS is to observe fluctuation of magnetic field with Field Aligned Current.(FAC)

However, residual magnetic field(of the spacecraft) and dynamic magnetic field (generated by electric currents inside the spacecraft) affect the SMS measurements. Therefore we need to separate these noises from the measurement to observe fluctuation of magnetic field with FAC accurately. Then, in this research, we devised a measuring and analysis system of residual magnetism of each onboard instrument. The object of this research is to acquire fundamental data needed for data correction.

We used MAGDAS magnetometer(3-axis fluxgate magnetometers) belonging to Space Environment Research Center of Kyushu Univ. We measured angle characteristic of magnetic field around onboard instruments, rotating them with a turntable.

In some residual magnetism measurements, calculation method was to approximate magnetic field as eccentricity dipole or quadrupole moment. On the other hand, in this research, we placed importance on the specification of the magnetic structure of each instrument. We specified them from waveform of actual fluctuation of magnetic field.

Furthermore, we will conduct another experiment using flight model(FM) of QSAT-EOS. Using this data which can be acquired by the experiment, we will define magnetic offset adopted during actual operation of QSAT-EOS. Then, using the offset, we aim to implement SMS science mission.

Keywords: residual magnetism, QSAT-EOS, Science Magneto Sensors, MAGDAS magnetometer, measurements of Earth'smagnetic fierl, Field Aligned Current(FAC)

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What does determine the resonance Q-factors in impedance probe measurements?

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The impedance probe is a powerful tool realizing highly-accurate measurements of the electron density. Detection of the upper hybrid resonance (UHR) frequency from the impedance curve provides the electron density with high accuracy. The frequency response of the antenna impedance also reflects various physical quantities and properties of a plasma in addition to the electron density. Interpretations of the antenna impedance are therefore essential for space plasma diagnostics. This paper reports on the characteristics of the ”quality factors (Q-factors)” of the UHR and sheath resonance (SHR) in impedance probe measurements.

One of the important aspects of impedance probe measurements is the ”clarity” of the resonance. The sharpness of the resonance is evaluated by the Q-factor. Sufficient insight on the Q-factor is important for evaluating the lower threshold of the electron density measurement range. Besides, the phase of the probe capacitance measured in plasma chamber indicated that characteristics of the resonance Q-factor should be examined in order to realize automatic detection of the UHR frequency. The Q-factor also has a potential to provide the electron-neutral collision frequency, which is a key parameter of the ionospheric science. However, the effect of the collision frequency on the Q-factor has not been examined. We therefore tried to evaluate the Q-factor experimentally.

We confirmed that the Q-factors of the UHR and the SHR have a clear boundary at $fpe/fce = 1$. The Q-factor indicated lower values when $fpe < fce$, while the Q-factor showed clear increases with the electron density when $fpe > fce$. This tendency was already expressed by Balmain and Oksiutik (1969). However, we also found characteristics which were not pointed out in previous works: the Q-factors were also characterized by the second harmonics of the cyclotron frequency. The effects of a hot plasma (e.g., Suzuki et al., 2009) should affects on the impedance probe measurements.

The effects of the collision frequency on the Q-factor were also examined. The impedance curves measured in the ionosphere were compared with the impedance curves measured in the plasma chamber. Contrary to expectations, the impedance curves measured in the ionosphere and in the chamber showed similar signatures in spite of the difference of 3 order magnitudes of the collision frequency. The result suggested that the mean free path is essential for evaluating the Q-factor. Careful treatments are required both for the measurements and for the numerical calculations in order to estimate the collision frequency from impedance curves.

The present study pointed out that the detailed understandings of the resonance Q-factor are necessary for further improvements of the impedance probe measurements in plasma.

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Study on real-time polarization analysis

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The amount of raw data from the plasma wave instrument is increasing as the scientific objectives require covering a wide frequency ranges with high time and frequency resolution. Furthermore a variety of operation modes are needed to meet these scientific objectives. However, it is inevitable to reduce the amount of telemetry data because it is too huge to downlink all measured data to the ground. Onboard software plays a very important role because many kinds of operational modes can be implemented without changing the hardware configuration. We have developed several software receivers for spacecraft such as NOZOMI, KAGUYA and MMO and implemented lots of intelligent functions in them making use of digital signal processing technique.

In the present study, we investigated a signal processing method to derive polarization of plasma wave using onboard software. We evaluated computation load as well as accuracy of polarization parameters under severe restrictions on telemetry and computation resources in order to find a solution for implementation to onboard software. In the presentation, we introduce the evaluation results using the waveform data obtained by the AKEBONO and KAGUYA spacecraft.

Keywords: Plasma wave instruments, Polarization analysis, Onboard software, Magnetosphere, Signal Processing

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Evaluation of co-operational observation strategy for formation-flying satellites using a magnetosphere model

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Recently multi-satellite mission is a mainstream of in-situ measurement method of the Earth's magnetosphere, because it is quite difficult to distinguish between spatial and temporal variation of plasma environment in the magnetosphere by single satellite. So far four Cluster satellites launched in 2000 and five THEMIS probes launched in 2007 are in operation, and MMS mission is in the planning stage.

The SCOPE is a Japanese future mission to investigate the multi-scale plasma physics using multiple satellites. In the SCOPE mission, formation flying will be made up of a mother satellite, a daughter satellite in the near distance, and two or three daughter satellites in the long distance from the mother.

Because it is obviously impossible to transmit all raw data measured by onboard instruments because of limitation of downlink capacity, we need to make an operation plan predicting a forthcoming observation region in order to optimize observation parameters for the purpose of data reduction.

To achieve a co-operational observation efficiently with formation-flying satellites, we developed a system using LAN-connected PCs in order to simulate inter-communication among satellites and onboard data processing functions. On the simulator, we assume that each satellite has a function of event detection such as boundary crossing in the magnetosphere, and the mother satellite makes an autonomous decision as a multi-satellite federation to grasp temporal and spatial variation of the target region.

In the present study, we introduced a magnetosphere model in the simulator and studied appropriate parameters to select the best observation mode. In the presentation, we show some experimental results under some conditions of observation configuration and discuss the performance of co-operational observation.

Keywords: Formation-flying satellite, Inter-satellite communication, Co-operational observation, Magnetosphere, Simultaneous multi-point observation