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

PCG008-01 Room:202 Time:May 26 08:30-09:00

Space Plasma Research and Instrument Development at SPDL, NCU

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Space plasma is profoundly different from laboratory plasma in that it is highly collisionless and thus may develop many interesting nonlinear phenomena. In-situ measurement and observation of space plasma requires specially designed and high-quality instruments onboard satellites. Theoretical understanding and interpretation of spacecraft data is equally challenging. In this talk a brief overview is presented of the theoretical research on collisionless magnetized plasma and the efforts on the instrumentation conducted at the Satellite Payload Development Laboratory (SPDL), National Central University.

Keywords: space plasma, collisionless plasma, instrumentation

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PCG008-02 Room:202 Time:May 26 09:00-09:30

STSAT-1 observations of the polar region

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STSAT-1 is the fourth satellite developed by Korea Advanced Institute of Science and Technology (KAIST), following the two 50 kg-size KITSATs and 100 kg-size KITSAT-3. The development of these microsatellites is part of the efforts at KAIST to promote space education as they were built with involvement of graduate students and relatively inexpensive parts were used. The purpose of the first three satellites was to establish satellite technology at KAIST while the main focus shifted to space science in the case of STSAT-1. STSAT-1, a three-axis stabilized satellite, was launched on September 27, 2003 into a sun-synchronous polar orbit at 685 km altitude and operated until May 2005. The main scientific mission of STSAT-1 was astrophysical observation while geophysical observations were also made when they did not interfere with scheduled astrophysics observations. The main scientific payload was an imaging spectrograph, capable of measuring far ultraviolet (FUV) emission lines from 90.0 to 115.0 nm (S-band) and 134.0 to 171.5 nm (L-band) with 0.15-0.2 nm and 0.25-0.3 nm spectral resolutions, respectively. The payload was primarily used for the observation of Galactic hot gas through sky survey mode operations. Geophysical observations of the spectrograph were usually made during eclipses when the geomagnetic conditions were not severe to protect the instrument. The spectrograph was directed toward the ground during geophysical observations so that it naturally observed auroras and nighttime airglows in the nadir direction. Over the polar region, precipitating electrons were simultaneously measured using the Electrostatic Analyzer (ESA) and Solid State Telescope (SST), whose energy ranges were 100 eV - 20 keV and 170 keV - 360 keV, respectively, on board the same spacecraft. For the auroral observations, the satellite was further maneuvered so that the designated one of the satellite's three axes became aligned with the local geomagnetic field line so that the ESA could provide pitch angle information of the precipitating electrons. With such a configuration, one of the SST's two telescopes was aligned along the geomagnetic field line and the other perpendicular to it. I would like to discuss some of the results obtained from this operation of STSAT-1 over the polar region. For example, electron microbursts were detected by SST at magnetic latitudes corresponding to the outer radiation belt zone. The observations showed that the microbursts occurred very fast with the time scale of less than 50 msec, much faster than the proposed pitch angle diffusion time scales. Furthermore, the energy dispersion showed that higher energy electron precipitation occurred at lower L values, indicating that precipitation might be related to the magnetic moment scattering in the geomagnetic tail. In another example, the auroral spectrum will be compared with the ESA spectrum of precipitating electrons measured simultaneously. It will be shown that the auroral FUV spectrum for inverted-V events has significant energy dependence with the long wavelength region of the L-band increasing faster than the short wavelength region with increasing peak electron energy.

Keywords: FUV obervation, aurora, microburst

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PCG008-03 Room:202 Time:May 26 09:30-09:45

Development of the Analog ASIC for Miniaturized Waveform Receiver

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Since space plasmas are essentially collisionless, kinetic energies of the plasmas are exchanged via plasma waves. Observations of the plasma waves are very important to study space plasma physics. Waveform observation of the plasma waves have been conducted since the GEOTAIL satellite. The phase information of the plasma wave unveils various features of plasma such as structure of electric potential, and propagation velocity etc.

On the other hand, plasma wave receivers have been required to be miniaturized toward simultaneous multi-point observation missions, and deep space explorer missions. Although weight budget of the instruments in these missions are limited, the plasma wave receivers need high-sensitive, low-noise, and wide-dynamic range analog circuits which lead to heavy instruments in general.

We have developed analog Application Specific Integrated Circuits (ASICs) dedicated to the plasma wave receiver. The ASIC observes six-channel of plasma wave (each three channels for electric and magnetic fields, respectively) up to 100 kHz. The dimension of the ASIC and the package enclosing the ASIC are 5 mm by 5mm, and 15 mm by 15 mm, respectively. The single channel contains a band-limiting filter, a differential amplifier, and anti-aliasing filters. The ASIC have not only six-channel circuits for the waveform observation but also a compensation circuit for temperature drift. We also develop a business-card-size board. The board works as an instrument by which six analog differential input pairs are treated to six digital serial bit strings. The developed ASIC and the board lead to success of realization of the miniaturized waveform receiver for the-simultaneous multi-point observations, and the deep space explorer missions.

Keywords: Plasma Wave, Waveform, WFC, ASIC

PCG008-04 Room:202 Time:May 26 09:45-10:00

Design and development of miniaturized sweep frequency analyzer using ASIC technology

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Space plasma is essentially collisionless, and its kinetic energy is transferred through plasma waves. Plasma wave receivers, which capture these waves, have contributed to the investigation of electromagnetic environment in space. Sweep frequency analyzer (SFA), one of the types of the plasma wave receivers, provides spectral information on plasma waves with good frequency resolutions. General SFA is basically a heterodyne receiving system, provides the spectrum information with the good signal to noise ratio. The SFA has a PLL, a frequency synthesizer. This PLL makes a number of fine sweep frequency steps. It takes several seconds to complete all sweep steps. Thus, this type of SFA generally has disadvantage in temporal resolution.

We propose a new kind of the SFA combined with FFT in FPGA (Field Programmable Gate Array). To improve the temporal resolution, we widen frequency range of each sweep step and decrease the number of sweep steps. The bandwidth brought out of the double-superheterodyne receiving is also widened. Observed signals are converted into digital signals and input to the FPGA. Logic FFT blocks in the FPGA apply the FFT to these digital signals. Thus, we can obtain the frequency resolution which is equals to the widened bandwidth divided by the FFT points. This new type of SFA realizes low noises, high frequency resolution, and high temporal resolution at the same time.

Plasma wave receivers, include SFA, are required to have low noise and wide dynamic range with amplification in wide band. These requirements lead analog circuits in each receiver to be large and make it difficult to realize small plasma receivers with discrete parts or commercial integrated circuits. We use ASIC (Application Specific Integrated Circuit) technology to make breakthrough in this present state. The ASIC technology enables extreme miniaturization of analog circuit. We have developed several analog circuits in the SFA, such as a differential amp, a low pass filter, PLLs, and a band pass filter using ASIC. In the session, we will introduce the new SFA and development of required circuits with showing each performance.

Keywords: Space electromagnetic environment, Space plasma, Plasama wave, Plasama wave receiver, Sweep frequency analyzer, ASIC technology

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PCG008-05 Room:202 Time:May 26 10:00-10:15

Particle simulations on the photoelectron environment around an electric field sensor

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For more sophisticated electric field measurement planned in future magnetospheric missions, a strong demand arises regarding better understanding of the behavior of an electric field sensor in space plasma environment. In low-density space plasmas, photoelectron emission due to solar illumination creates a high-density electron cloud around a sensor aboard scientific spacecraft. Considering the fact that such a photoelectron cloud occasionally causes spurious electric field and unexpected change of sensor properties, we require quantitative evaluation of the photoelectron environment around the sensor and its influence on the sensor properties. Particularly, it is necessary to develop a numerical approach, which is applicable to a wide range of presumable situations of photoelectron environment around spacecraft.

In the current study, we applied the particle-in-cell (PIC) plasma simulation to the analysis of the photoelectron environment around spacecraft and its influence on sensor characteristics. The PIC approach enables us to reproduce the formation of the photoelectron cloud as well as the spacecraft and sensor charging in a self-consistent manner. Based on the PIC approach, we have developed a numerical model of a modern electric field sensor MEFISTO for the BepiColombo/MMO spacecraft. The model includes the photoelectron guard electrode and current biasing, both of which are realized in the simulation as a potential control of the instrument surfaces.

We report the progress of our analysis on photoelectron environment around MEFISTO and its influence on the sensor behavior. In considering photoelectron environment, the photoelectron guard electrode is a key technology of MEFISTO for producing an optimum condition of the photoelectron distribution. We show some simulation results regarding the photoelectron guard effect on the photoelectron distribution in the vicinity of the sensor. We also report the recent progress of our numerical tool toward the inclusion of more practical sensor model and plasma parameters.

Keywords: Electric field sensor, Photoelectron, PIC simulation

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PCG008-06 Room:202 Time:May 26 10:15-10:30

Nondestructive analysis of single dust particle based on observation of free magnetic motions in microgravity

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It is expected that the ensemble of dust samples collected by various space missions are generally mixture of various primitive grains which have different origins. For such samples, it is desirable to identify the material of individual grain by a simple and non-destructive method, before performing various refined analysis, such as isotopic, chemical or optical analysis. The situation may be the same for the grain materials that compose the primitive meteorites.

A new principle to identify the material of a single grain is proposed, which is based on magnetic susceptibility data obtained from magnetically induced translation of the grain; when solid grain is released in an area of magnetic field-gradient with negligible initial velocity, a translation caused by field-gradient force is induced on the grain; here the field is located in a micro-gravity condition. In general, every material possesses an intrinsic value of magnetic susceptibility, and the values are compiled in a data book [1]; hence the material of a solid particle is directly identified from the measured susceptibility data.

Previously, the above translation was observed in a large-scaled facility of microgravity for millimeter sized crystal of corundum, diamond, forsterite, MgO and graphite [2][3]. It was deduced from motional equation that acceleration of translation is independent to mass of particles; it uniquely dependent to intrinsic susceptibility assigned to the material, in a given field distribution. Value of susceptibility was obtained from observed acceleration, which agreed well with published values [1]. The measurement was free of a back ground signal of a sample holder; it does not require mass measurement. This means that, in principle, susceptibility is obtained for samples with a limitlessly small size, provided that motion of sample is observable [2]; material identification is also becomes possible for these grains. Specific translation due to magnetic field has not been recognized before for ordinary diamagnetic solid particles; at present, such motions are publically recognized only for materials that contain spontaneous magnetic moment.

Observation of the above translation was extended to micron-sized samples in the present work for the purpose of developing a practical system to identify the above-mentioned primitive grains. The mass independent properties are examined by varying the grain size of the measured materials between 5mm to 0.05mm in diameter.

In general, the conventional facilities of microgravity require long machine time and large running cost. Hence they are not suitable for a routine analysis such as the present measurement of susceptibility. Hence compact microgravity system was newly developed, which can be introduced in an ordinary laboratory. The length of the drop shaft is 1.5m, and the duration of microgravity was 0.62 second. The compact system was realized by designing a small NdFeB magnet circuit. Maximum field intensity of the circuit was 0.7 T at field center. It is noted that this compact apparatus will be the basis to construct a system that can be loaded on a space probe to investigate dust particles. At present, size of system can be reduced to 100 cmˆ3 (2x5x10) in volume, and 1 kg in weight. Specific problems in loading the system in various space missions will be discussed.

[1] K. Hisayoshi et al: J.Phys.: Conf. Ser., in press. [2]C.Uyeda et al: J.Phys.Soc.Jpn. (2010) 79 064709 [3] R. Guputa: Landort Bornstein New Series II (1983) 445.

Keywords: magnetic ejection, microgravity, field gradient force, diamagnetic susceptibility, material identification, nano sized material

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PCG008-07 Room:202 Time:May 26 10:45-11:15

Development of space plasma instruments onboard Taiwan sounding rocket

Alfred Bing-Chih Chen[1*], Frank Cheng[1], Kohichiro Oyama[1], Nobuko Fujikawa[1], Marko Istenic[1], Eiichirou Kawamori[1], Albert Peng[1], Hui-Kuan Fang[1], Jheng-Jie Wong[1]

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Four space plasma instruments were proposed to National Space Organization (NSPO), Taiwan as the scientific payload of Sounding rocket experiment to observe temporal and vertical variations of these parameters in order to study plasma irregularities produced by instabilities in E and F regions and to understand coupling processes of particle, momentum and energy between the ionosphere and the thermosphere. The four instruments are Langmuir Probe, Ion Energy Analyzer (Faraday cup), Neutral Particle Analyzer, and magnetoresistive magnetometer. Two instruments, Sun Aspect Sensor and Flux-gate magnetometer, are contributed by Japan colleagues to tone up scientific merit. The development of these instruments are reported in this presentation.

Keywords: Sounding rocket, ionosphere, thermosphere, plasma irregularity

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PCG008-08 Room:202 Time:May 26 11:15-11:30

Gain-temperature relationship of an Avalanche Photodiode developed for the ERG mission

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We have been developing an instrument for the observations of the medium-energy electrons (8-80 keV) in our coming radiation belt mission ERG (Energization and Radiation in Geospace). The mission goal is to understand the radiation belt dynamics during space storms. The medium-energy electron measurement is one of the most important issues in this mission since these electrons generate whistler chorus wave, which is believed to play significant roles in the relativistic electron acceleration and loss during storms. On the other hand, the medium-energy electron measurement has been a challenging issue since the quantum efficiencies of classical detectors (CEM, MCP, and conventional SSDs) are generally low and ambiguous in this energy range. Avalanche photodiode (APD) is a promising device for medium-energy electron detection, and we have developed a new APD particularly for the ERG mission. The area and thickness of the detector were optimised to cover the medium-energy range and minimise the gamma ray background at the same time. We report the performance of this new device obtained through laboratory tests, with a special emphasis on the gain dependence of the temperature, which is essential for the calibration sequence in energy determination.

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PCG008-09 Room:202 Time:May 26 11:30-11:45

Development of a low energy electron spectrometer for SCOPE

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We are newly developing an electrostatic analyzer which measures low energy electrons for the future satellite mission SCOPE (cross Scale COupling in the Plasma universE).

The main purpose of the SCOPE mission is to understand the cross scale coupling between macroscopic MHD scale phenomena and microscopic ion and electron spatial scale phenomena. In order to understand the dynamics of plasmas in such small scales, we need to observe the plasma with an analyzer which has high time resolutions. In order to conduct electron spatial scale observations, we have to develop a Fast Electron Spectrum Analyzer (FESA) which has a very high time resolution ($<$10 msec).

Observations using multiple analyzers which have three nested deflectors are the secrets to achieve 8 msec time resolution. We will set 8 FESAs on the SCOPE satellite, which enables us to secure 4 pi str FOV at the same time. FESA has three nested spherical/toroidal deflectors, which enables us to measure electrons of two different energies simultaneously and make the time resolution higher.

In this study, we designed the second testmodel of FESA (TM2) . The sensitivity (g-factor) of TM2 is designed so that the same amount of counts within 0.5 msec as GEOTAIL LEP-EAe should be obtained. TM2 should also have an energy resolution that is appropriate for measuring electrons from 10 eV to 22.5 keV with 32 steps, and have an angular resolution that is appropriate for secure 45 deg. FOV along the spin direction of the satellite. We built a numerical model of TM2, and calculated the characteristics of it using numerical simulation. From the calculation, we found that TM2 has g-factor of 6.37e-^{3} [cm^{2} str eV/eV /22.5deg.] (Spherical part, Inside) and 9.12e^{-3} [cm^{2} str eV/eV /22.5deg.] (Toroidal part, Outside), energy resolution of 25.4% (Inside) and 18.6% (Outside) [Full Width at the Half Maximum : FWHM], and angular resolution of 14 deg.(Inside) and 9 deg.(Outside) [FWHM].

We built numerical models of electron velocity distribution function, and using these models we calculated the counts that TM2 will obtain in plasma sheet, lobe, and solar wind regions. From the calculation, we found that 20 msec sampling time is appropriate for observations in solar wind regions, and 50 msec is appropriate for observations in lobe regions. The sampling time of the observation in plasma sheet regions should be 0.5 msec. However, we found that statistical error of obtained counts within the sampling time severely affects the observation. So careful analysis of the obtained counts is necessary for more precise observations in this region.

We estimated counts that will be obtained in the magnetotail reconnection region using the result of a three-dimensional full kinetic simulation. From these estimated counts, we calculated the velocity distribution function, and found out how precisely these calculated distribution function shows thermal anisotropy of this region. We found that distribution function obtained within 8 msec can show these anisotropies to some extent, and we could calculate the velocity moments of this region using the function.

It is not simple to obtain a flux from one direction using data from multiple analyzers. That is because Field of views (FOVs) of these analyzers rotate as the satellite spins. Therefore it is not simple to draw Energy-Time (E-T) spectrogram from the observation. In this study, we suggested a method to make E-T spectrogram from the counts obtained by FESA. Using the method, we drew E-T spectrum from the estimated counts, and verified the validity of the method. In order to estimate the accuracy of calculated differential energy flux, we also drew E-T spectrogram from estimated counts obtained by the dummy satellite that does not spin during the observation. Comparing these two E-T spectrograms, we found out how precisely we can calculate the differential energy flux with the proposed method.

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PCG008-10 Room:202 Time:May 26 11:45-12:00

Development of the High Energy Particle instrument for Ions (HEP-ion) on BepiColombo/MMO

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In the past, Mercury has been investigated by Mariner 10 in 1970s. It discovered a dipole-type magnetic field and high-energy particle bursts through three times fly-by. However, due to the limited conditions, the observational results are not sufficient. Recently Messenger explored Mercury through three times fly-by in 2008-2009 and it has detected the substorms, but it has not detected any high-energy particle bursts. In order to reveal the structure and dynamics of the magnetosphere of Mercury, it is crucial to observe plasmas and high energy particles directly. Therefore, the next Mercury exploration, BepiColombo mission is planned to launch in 2014, which is a collaborate project between JAXA and ESA.

Mercury Magnetospheric Orbiter (MMO), one of the two spacecraft of this mission, carries the High Energy Particle instrument for ions (HEP-ion) which has two techniques for high energy particle measurements, namely a Time-of-Flight (TOF) and a Solid-State Detector (SSD). They can measure velocity (v) and energy (E) of incoming ions respectively and the ion mass can be derived from v, E, so the ions are discriminated such as H, He, C-N-O, Na-Mg, K-Ca and Fe. Energy range is required from 30KeV to 1.5MeV.

In order to measure these particles, the characteristics of the TOF unit of HEP-ion have been studied about electrical potential distribution and particle trajectories with numerical simulations. Additionally we calibrate its prototype model in our laboratory by using the high-energy ion beam line which provides 10keV-150keV ion beam of H+, He+, He++, N+. Its performance of a coincidence rate and mass resolution is checked by comparisons with the simulation results. The experiment results of a coincidence rate are consistent with simulations. As for mass resolution, the results of experiments and simulations show good agreement and sufficient mass resolution in the energy range of 55keV to 100keV and we obtain information of mass resolution from 100keV to 1.5MeV with simulations. In this presentation, we report the performance of the TOF unit of HEP-ion.

Keywords: BepiColombo, MMO, HEP-ion, TOF

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PCG008-11 Room:202 Time:May 26 12:00-12:15

The space particle instrument calibration facility at PSSC/NCKU and development of a neutral particle analyzer

Chio Z. Cheng[1*], N. Fujikawa[1], Y. Kazama[1], K. M. Peng[1], C. H. Ho[1], K. Oyama[1], E. Kawamori[1], A. B. Chen[1], M. Hirahara[2]

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The Plasma and Space Science Center (PSSC) Space Instrument Laboratory developed a test and calibration facility for space plasma instrument development. With a high-energy ion beam (1 -130 keV) and 3-axis turntable, the facility is capable of calibrating particle analyzers that can measure 3-dimensinal velocity distributions with a wide energy range. The ion beam is produced by electron impact on neutral gas introduced to the ion source chamber and ions with a specific mass/charge value are selected by the ExB mass spectrometer. After the beam expander, the ion beam is accelerated by an electric potential drop in the accelerator tube and directed to the drift tube where a beam monitor is located. In the main chamber the 3-axis turntable is set up to house particle instruments for test and calibration. The property of the ion beams will be presented. One of the space particle instruments we are developing using this facility is a Neutral Particle Analyzer (NPA), which is one of the instruments for a sounding rocket experiment to observe the ionosphere and thermosphere. The NPA measures the neutral energy distribution function as neutral particles enter into the instrument as the rocket proceeds. Then, neutral particles are ionized by an electron beam and accelerated by a uniform electric field perpendicular to the incident velocity towards the detector plane. Only the particles with an incident energy selected by the acceleration electric field can reach one of the two detectors through a slit in the detector plane. By sweeping the electric field strength, the full energy spectrum is obtained. Test results of the NPA will be presented.

Keywords: space instrument, instrument development facility, neutral particle analyzer

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

Calibration of detective sensitivity of SPRINT-A/EXCEED

Kouichi Sakai[1*], Go Murakami[1], Tatsuro Honma[1], Hiroaki Ishii[1], Ichiro Yoshikawa[1], Kazuo Yoshioka[2], Munetaka Ueno[3], Atsushi Yamazaki[3], Masato Kagitani[4], Fuminori Tsuchiya[4]

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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

PCG008-P02 Room:Convention Hall Time:May 26 14:00-16:30

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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PCG008-P03 Room:Convention Hall Time:May 26 14:00-16:30

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

Maki H. Nakamura[1*], Hiromi Shibata[3], Masayuki Fujii[6], Sunao Hasegawa[6], Takayuki Hirai[7], Takeo Iwai[1], Hiroshi Kimura[10], Masanori Kobayashi[2], Takashi Miyachi[2], Hideo Ohashi[5], Nagaya Okada[9], Osamu Okudaira[6], Sho Sasaki[8], Seiji Sugita[1], Seiji Takechi[4], Hajime Yano[6], Ralf Srama[11], Eberhard Gruen[11]

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

PCG008-P05 Room:Convention Hall Time:May 26 14:00-16:30

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