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

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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 cm^3 (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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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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The space particle instrument calibration facility at PSSC/NCKU and development of a neutral particle analyzer

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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