Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

PCG10-01 Room:102A Time:May 24 09:00-09:20

Requirements for Observation Equipment Development on Small Satellite from Bus Side

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1: Introduction

Artificial satellites are getting larger and larger every year and reached to several tons. This induces satellite high cost, long term development and high reliability requirements and large satellite development stalled. In this situation small satellite which weighs 1 to 100kg become conspicuous in astronautics. Especially, Japan is leading 1kg nano-satellite class in the world since we have developed and verify them first in the world. Mission at first stage was simple satellite bus performance check. Now there are technical demonstrations and high-level science observation missions similar to large satellites are taken place. This time, requirements from satellite side to observation equipment developers are reported.

2: Nano-satellite specifications

In this paper, nano-satellite means 1-50kg, 10-50 cm cubic size and it generates 1-50W power. (Common large satellite is several meter size.) Nano-satellite can provide 30 to 50 % resource for mission side.

In Japan, university one laboratory is a major player for nano-satellite development. And this means students are main force.

As referred in the above, usually nano-satellite has a single mission because of limited resources. And that means observers can use the satellite exclusively.

3: Requests for observation equipment developers

3-1: Interface and use of resources

Nano-satellite developers are not bureaucratic. Interface can be determined based on discussion between bus and mission side and it can be changed it is needed.

3-2: Information and motivation

For precise interface draw up, both sides should exchange design and development information each other. Since we work in a different area, we will start from understanding of terms of other side. Announcement of observation purpose, method and achievements are strongly welcome, it help to raise motivation. Main members of bus side are students, they are curious in science. When the explanation is enough, bus side will start to develop observation equipment part. This helps further mutual understanding and union of organization and knowledge speeds up.

3-4: Development strategy

Ambition for precise observation deserves to be acclaimed. There is performance limit for nano-satellite. Future plan should be considered. Successive small satellite project or combination use of large satellite (high low mix) will be easy rather than on extremely high specification satellite.

3-5: Redundancy

Since nano-satellite bus has little redundancy, too much careful design in mission side is useless.

3-6: Launch delay

Small satellites are often launched as a piggy-back of large satellite. So launch will postpone in many cases by irresistible force. Prepare for launch delay on ahead.

3-7: Ground test

The equipment tests are difficult since it will be used in vacuum and zero-gravity environment. But we can't fix them after the satellite in on the orbit. Verification for validation must be done before the launch no matter how hard it is.

4: Conclusion

Requirements for mission side from bus side are described in this paper. In recent years, many universities star satellite projects. You can contact UNISEC (University Space Engineering Consortium) for introducing satellite projects.

Keywords: nano-satellite

PCG10-02 Room:102A Time:May 24 09:20-09:35

Compact Instrument to measure Te and Ne for Pico /Nano satellite

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An instrument has been developed for Pico/nano satellite to measure electron density and electron temperature simultaneously. Electron temperature probe(ETP) which has been developed about 40 years ago is modified. ETP has been accommodated in Japanes 5 scientific satellites (TAIYO, HINOTORI, OZORA, KYOKKO, and AKEBONO), and 3 foreign satellites(Korea, Brazil, and Russia). ETP was also installed in more than 50 Japanese sounding rockets including Showa base, West Gemany, Brazil, and Russia. Its performance is well established. In ETP, 30KHz sine wave oscillator which has been used so far is replaced by an oscillator which generates 200Khz-7Mhz sweep frequency signal.

Keywords: Pico.Nanosatellte, Topside ionopshere, Electron density, Electron temperature

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PCG10-03 Room:102A Time:May 24 09:35-09:50

Detecting Electrons and Ions with a Single Detector in Miniaturised Low Energy Particle Analysers

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Electrostatic energy analysers for eV to low keV particles typically analyse either electrons or positive ions. Instruments that do study both usually use separate detectors. Using a single detector for both electrons and ions potentially enables more compact instruments with reduced spacecraft resource requirements.

CATS (Cylindrical And Tiny Spectrometer) is one such approach to this challenge. It is a prototype highly miniaturised instrument that uses a concentric cylindrical geometry to measure multiple energies of electron and ion simultaneously. It has been demonstrated experimentally with 0.5-8 keV electrons using an ion-implanted CCD for a detector. It is being adapted for use in PoleCATS: a student-led experiment on the REXUS (Rocket EXperiments for University Students) European sounding rocket programme. The current geometry has ~7% energy resolution and ~7 degree by ~3 degree angular resolutions. Conceptually the design can be adjusted to tune the instrument parameters for a range of applications.

An alternative approach to the challenge is to adapt a conventional top hat geometry instrument so that it can sample alternately electrons and ions in continuous positive to negative inner hemisphere electrode voltage sweeps. While, unlike CATS, the electron and ion measurements would not be made simultaneously, the elegant focussing properties of the powerful and well-understood top hat geometry are preserved and existing, well-evolved instrument designs can be leveraged. By placing suitable dynodes (secondary electron emitters) at the exit of the analyser it is intended that a single MCP can be used to study electrons and ions over a wide range of energies. Initial simulations and development work on this project will be discussed.

Keywords: plasma analyser, miniaturised instrumentation, direct detection of low energy electrons with a CCD, SIMION simulations, low energy electron and ion spectrometer, CATS Cylindrical And Tiny Spectrometer

PCG10-04 Room:102A Time:May 24 09:50-10:10

The Fast Auroral Imager Experiment to Investigate the Dynamics of Nighttime Optical Aurora

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The Fast Auroral Imager (FAI) consists of two CCD cameras: one to measure the 630 nm emission of atomic oxygen in aurora and enhanced night airglow; and the other to observe the prompt auroral emissions in the 650 to 1100 nm range. Good optical throughput (etendue) will be realized through the combination of fast lens systems (f/0.8) with CCDs of high quantum efficiency. Both cameras have a common 27 degrees field-of-view, to provide circular images of about 650 km diameter from apogee at 1500 km.

In the nadir viewing mode, the near infrared camera will provide multiple images per second at a spatial resolution of a few kilometres, for studies of dynamic phenomena such as substorm onset, vortices and multiple narrow arcs, and for monitoring the auroral context for the complementary *in situ* measurements onboard. The 630-nm camera will produce images once per minute with an exposure time of 0.5 sec, which is compatible with the radiative lifetime of the $O(^1D)$ atom in the atmosphere. Not only will this camera image auroral forms such as discrete arcs that are produced by soft electrons, it will also measure the locations of the auroral oval and polar cap boundaries. With on-chip pixel binning it will be possible to investigate weak emission phenomena such as polar arcs and patches, midlatitude SAR arcs and detached arcs, and enhanced airglow from artificial ionospheric heating. Overall, the FAI instrument represents a major advance in the application of new technology to the study of nighttime auroral phenomena.

Keywords: auroral imaging, nighttime optical aurora, night airglow, CASSIOPE/ePOP Mission, Fast Auroral Imager (FAI), discrete aurora

PCG10-05 Room:102A Time:May 24 10:10-10:25

Observation plan of pulsating aurora with a monochromatic camera on a rocket experiment

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To understand the small-scale variation of pulsating aurora and its cross-scale coupling to large-scale feature, we plan a S520 sounding rocket experiment to carry out the high-time resolution wave-particle measurements as well as optical imaging. This rocket experiment is characterized by the simultaneous measurement among plasma particle in the wide energy range up to more than 200 keV, VLF and high-frequency plasma waves, magnetic field, electron temperatures and monochromatic auroral image at the N2 1st positive band. Ground-based instruments, such as EISCAT radar, optical imager, and SuperDARN radar, will join this experiment. The rocket will be launched into pulsating auroras from Andoya, Norway during a new moon period in winter of 2017 to achieve the conjugate measurement with the ERG satellite. The launch window is 01-06 MLT, and the apex altitude of rocket will be more than 300 km in altitude. The total mass, electric power and data rate are estimated to be 48 kg, 110 W, and 3.1 Mbps, respectively.

We are developing a monochromatic camera for this project. The auroral imaging data at the N2 1st positive band (670 nm) is useful since the time response of N2 emission to the precipitating electrons is prompt, and its emission intensity is proposal to the total energy flux of electrons that cause the pulsating aurora. The optical and electrical designing is still in progress. At the present design, the field-of-view (FOV) is 45 degrees covering the ontological to downward directions, time resolution is several frame-per-second, and spatial resolution is 1 to a few km. Using successive image data in the vicinity of pulsating auroral emission layer, we expect to estimate the thickness of emission layer. In addition, we will achieve simultaneous image-particle measurement using the data when the FOV of camera is pointed to the magnetic footprint threading the rocket during the apex period. In this presentation, we give the current status of optical and electrical design of monochromatic camera, its detailed specifications and operation plan.

Keywords: pulsating aurora, rocket, camera, optical, development, ERG

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PCG10-06 Room:102A Time:May 24 10:25-10:45

Discussions of Electrode Contamination Effects on a Retarding Potential Analyzer on-board Sounding Rocket

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Electrode contamination of a Langmuir probe in space is a serious problem even now although laboratory experimenters were aware of this problem for a long time. Surface contamination layer form extra capacitances and leads to a I-V curve distortion, which leads erroneous measurements, especially of electron temperature. Similar effects exist on electro-static analyzers, such as a retarding potential analyzer (RPA). Error caused by contaminations of a RPA is considered small for satellite experiments because satellite velocity is high (7 km/sec), and plasma density is low. While for sounding rocket experiments, error caused by contamination gets larger when we try to measure low ion temperature of 200-300K. We discussed several contamination effects on a RPA based on the experiments performed in a space plasma chamber. And development of a contamination-free RPA for rocket missions is also demonstrated.

Keywords: Retarding Potential Analyzer, Electrode Contamination, Sounding Rocket, Ion Temperature

PCG10-07 Room:102A Time:May 24 11:00-11:20

Study of Space Storms using Next Generation Small Satellite of Korea

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Korea Advanced Institute of Science and Technology (KAIST) is developing its 8th satellite as the first of the Next Generation Small Satellite series. The satellite will be launched in early 2016 into a polar orbit with an altitude of ˜700 km. While the main mission of the satellite is to test engineering payloads, scientific instruments were also selected for space science and astrophysical investigations. The scientific goal of the space science payloads is to understand the behavior of the radiation belt and the ionosphere during space storms. Two of the space science payloads, Medium Energy Particle Detector (MEPD) and High Energy Particle Detector (HEPD), will be operated in the polar region to observe precipitating and trapped energetic particles, in the energy range from ˜40 keV to ˜1 MeV. Electrostatic deflectors will be employed in these instruments to reduce the cross-contamination between electrons and protons. A Langmuir Probe (LP), a Retarding Potential Analyzer (RPA), and an Ion Drift Meter (IDM) will also be on board the satellite for the operation in the mid- and low-latitude regions by sharing the orbits with the infrared astrophysics mission. Instruments and their operation scenarios will be discussed.

Keywords: Space Storms, Next Generation Small Satellite

PCG10-08 Room:102A Time:May 24 11:20-11:35

Seismo-Electromagnetic Research by Small Satellite Constellation

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Seismo-electromagnetic research by satellite observation started in Soviet Union in the 1980. After the collapse of USSR, France took over the initiative and its small satellite: DEMETER has already clarified, by statistical analysis of 9000 cases, that night-time attenuation of VLF range electromagnetic emission occurs 4 hours before earthquakes larger than M4.8 that would have required some 100 years for it by ground observation. Recently, satellite observation has followed in Ukraine, Italy, Taiwan, etc. and similar projects are being planned in China, Russia, UK, Mexico, Kazakhstan, India, Peru, South Korea and Iran.

The advantage of observation from space is that statistical research on the correlation between precursory phenomena and earthquakes is possible in a dramatically short-time compared with ground observation which is limited in the spatial coverage. Beyond this, the studies on the mechanism of observed phenomena will be facilitated by adoption of various instruments.

However, most existing and planned missions are single satellite or a few satellites, it is difficult to establish reliable ”time and space” ionospheric model which is indispensable for identification of precursory phenomena. Therefore, it is a logical conclusion that we should conduct comprehensive observations of space-time variations of ionosphere by satellite constellation with reliable instruments by international cooperation.

Keywords: Seismo-Electromagnetic, Small Satellite Constellation, Earthquake Precursor, Ionosphere

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PCG10-09 Room:102A Time:May 24 11:35-11:50

The current status of EUV spectroscope, EXCEED on board the SPRINT-A

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[1]JAXA/ISAS, [2]The University of Tokyo, [3]The Tohoku University

EXCEED is the Extreme ultraviolet spectroscope on board the Japanese small scientific satellite, SPRINT-A. The mission will carry out spectroscopic and imaging observation of EUV (50-150 nm) emissions from tenuous plasmas around the planets (such as Venus, Mars, Mercury, and Jupiter) from the Earth orbit at the altitude of around 1000 km. It is essential for EUV observation to put on an observing site outside the Earth's atmosphere in order to avoid the absorption. In addition, because the emissions from the targets are very faint, the effective are should be as large as possible and needs long observation period. Since EXCEED is developed mainly for the planetary science, we can use the observation window as long as possible on the geometrical point of view. In this presentation, the specification and performance of the instrument according to the FM final calibration, and possible observation scenario are discussed.

Keywords: SPRINT-A, EUV, Jupiter, Escaping atmosphere, Io plasma torus, Spectroscopy

PCG10-10 Room:102A Time:May 24 11:50-12:05

Development of a Low-Energy Electron Instrument LEP-e for the ERG Mission

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Plasma and Space Science Center (PSSC) at National Cheng Kung University (NCKU) in Taiwan is now developing a low-energy electron instrument LEP-e for JAXA's radiation belts observation mission ERG (Energization and Radiation in Geospace). The LEP-e instrument measures electrons in the inner magnetosphere with energies from ~10eV to ~20keV to give key information on background plasmas, in which electron accelerations to a MeV range take place. The instrument is a tophat-type electostatic analyzer with multi-channel plates, similar to those on the NOZOMI and REIMEI missions. In the ERG mission, the keypoint of plasma instruments is to suppress effects due to background radiations. LEP-e employs 6mm-thick aluminum shields for the analyzer, and 5mm-thick shields for the electronics. In addition, LEP-e has a background noise channel, and an electron count is estimated by subtracting a noise count. In the presentation, instrument performance, estimated radiation effects and the current status of the development will be discussed.

Keywords: plasma analyzer, ERG mission

PCG10-11 Room:102A Time:May 24 12:05-12:20

Ionosphere Profiling Based on FORMOSAT-3/COSMIC Radio Occultation Experiment

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FORMOSAT-3/COSMIC (F3/C) is a Taiwan-US collaborative satellite mission for sounding Earth's atmosphere and ionosphere in recent years. The primary payload of each F3/C satellite is a GPS radio-occultation (RO) receiver, which measures the phase delay of radio waves from GPS satellites occulted by the Earth's atmosphere or ionosphere. By estimating the bending angles of radio wave trajectories, accurate and precise vertical profiles of the global troposphere, stratosphere and ionosphere are obtained. This presentation reveals data processing from F3/C RO phase measurements to ionospheric electron density profiles by means of single-difference excess phase estimation, bending angle estimation and ionosphere inversion technique. In addition, related RO experiments on board the next generation of F3/C, FORMOSAT-7, to be launched in 2016 and 2018, will be mentioned.

Keywords: FORMOSAT-3/COSMIC, radio occultation, ionospheric electron density, GPS

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PCG10-P01 Room:Convention Hall Time:May 24 16:15-17:30

Development of the ASIC for miniaturizing the digital fluxgate magnetometer onboard future magnetospheric satellites

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[1]Sokensai, [2]ISAS/JAXA

The main subject of the SCOPE (cross-Scale COupling in the Plasma universE) mission examined by ISAS/JAXA is to investigate the cross-scale coupling physics of the plasma in the magnetosphere and interplanetary space by using 5 spacecrafts. The total weight of the spacecrafts is severely limited due to the limitation of the capability of the launch vehicle. It is required to further reduce the resources of the payload instruments to achieve the mission.

Fluxgate magnetometers have many advantages as a method to measure the magnetic field by spacecraft; relatively simple principle, good accuracy, and low power consumption. Therefore they have been most often used for the magnetospheric observation missions since the 1950s. Because the electronics of conventional fluxgate magnetometer mostly consisted of analog devices, it was hard to reduce the resources. On the other hand, so-called digital-type fluxgate magnetometers have been developed since 1990s. For the digital-type fluxgate magnetometer, digital signal processors, e.g. FPGA (Field Programmable Gate Array), undertake the signal processing, which has been performed by analog devises for the conventional type. In previous studies, digital-type fluxgate magnetometers have been successfully reduced the size, mass, and power consumption with keeping good measurement accuracy. However, the preamplifier (AMP) and the Band-Pass Filter (BPF) in the electronics circuit of the digital types should be built by discrete analog devices. Moreover, digital-to-analog and analog-to-digital converters are built by the commercial IC chips, and hard to be reduced in size.

Application Specific Integrated Circuit (ASIC) chip is a device which can be designed for specific function. Using ASIC in the analog part of the digital-type fluxgate magnetometer would enable the further reduction of the resource keeping good performance.

We designed an ASIC chip which contains an AMP and a BPF. The gain of the amplifier is controlled (2, 3, ... ,10 times) by the external signals given to the ASIC. The BPF is the second-order Butterworth filter and the center frequency can be precisely adjusted to 22 kHz, the frequency of the fluxgate sensor output signal, by adjusting the external resistor.

The performance and the temperature dependence of the designed circuit were evaluated by the circuit simulator. The output dynamic range is 0.24 F.S.(corresponding to 1.2 V). The frequency characteristic of the BPF satisfies the requirement. The noise density in the output signal is less than 600 $nV/Hz^{1/2}$ at 1 Hz(corresponding to 2 $pT/Hz^{1/2}$) in the temperature range between -30 degrees C and 50 degrees C. The simulation results indicated that the overall performance of the designed ASIC satisfies the requirements.

We experimentally examined the characteristic performance of the ASIC chip. In our presentation, we will focus on the evaluation results of the ASIC performance.

Keywords: Space plasma, Magnetosphere, The SCOPE mission, Fluxgate magnetometer, ASIC

PCG10-P02 Room:Convention Hall Time:May 24 16:15-17:30

Study on Miniaturization of Plasma Wave Receiver Using Analog ASIC

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Plasma filling the space is very rarefied. Ions and electrons in space plasma don't exchange their kinetic energy through their collision but through plasma waves. Hence observing plasma wave is essential for measuring space electromagnetic environment. The characteristics of plasma waves appear especially in the frequency range below electron plasma frequencies, which are typically a few tens of MHz at maximum in the terrestrial magnetosphere. On the other hand, the signal dynamic range of plasma waves is very wide. There exist plasma waves with their intensities of a few uV/m to a few hundreds of mV/m. Then the plasma observation device should have high sensitivity as well as a wide dynamic range in wide frequency bands. The device of observing plasma waves is so-called plasma wave receiver. In order to achieve the above requirements to the frequency range, the sensitivity, and the dynamic range, typical plasma wave receivers tend to be large because they need large analog circuits such as filters and amplifiers. However, recent space missions require miniaturization of onboard observation device in order to reduce mass and power budgets. Plasma wave receivers cannot run away from the miniaturization of their analogue circuits. In this study, we will try to miniaturize the plasma observation receiver using ASIC(Application Specific Integrate Circuit).

SFA(Sweep Frequency Analyzer) and WFC(Wave Form Capture) are used in plasma observation device. The SFA is one type of spectrum analyzer, which has poor time resolution and fine frequency resolution. The SFA is a double super heterodyne receiver and operate frequency conversion two times. In usual SFA, we swept the frequency very finely, so it takes long time to sweep all frequency and time resolution becomes worse. However, SFA which we design operate A/D conversion and FFT after sweeping frequency roughly. By using this method, we can realize both good frequency resolution and good time resolution. Thus we need to implement a frequency synthesizer, mixer, and band pass filter inside an ASIC chip. We developed test circuits of the each component and evaluated their performance. On the other hand, the WFC observes plasma waves in the time domain. It provides phase information of the observed plasma waves. Then the WFC should be calibrated in its phase as well as its gain. The transfer functions of the electric field sensors strongly depend on the surrounding plasma conditions. Because the change of transfer functions affect observed waveforms, we need to measure transfer function by onboard system in space. We realized miniaturization of waveform receiver, measurement system and preamplifier using analog ASIC and developed the miniaturized waveform receiver with the built-in preamplifier and onboard measurement system.

In the present paper, we show our attempts in developing both types of ASIC, i.e., SFA chip and WFC chip.

Keywords: Plasma Wave, Downsizing, Integrate Circuit, ASIC, Sweep Frequency Analizer, Waveform Capture

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PCG10-P03 Room:Convention Hall Time:May 24 16:15-17:30

The development of an InSb array driving electronics for the infrared imager and the echelle spectrometer

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The Atmospheres, Ionospheres and Magnetospheres of planets change with various time scale. The prominent example is auroral phenomena on the planets including Jupiter. Especially, infrared H3+ emissions are suitable for long-term observation because only the IR emissions are observable at the ground through the optical-window at the 2 um or 4 um. The time limitation of space telescopes such as HST and the largest ground-based telescopes such as SUBARU make it difficult to observe long-term variation of the planetary phenomena. So, it is the only solution to probe the temporal variation of planetary aurorae that uses the small- to mid-size own telescope for longer machine-times combined with own IR instrument.

Our group has been developing the infrared imager which widely available to planetary observation (Takahashi, 2005; Kobuna, 2008; Kitami, 2010) and the infrared echelle spectrometer (Uno, 2009), as a primary goal to conduct monitoring of Jupiter's magnetosphere from observations of aurora of Jupiter and volcanic Io activity. These devices are both using an InSb array sensor of 256x256 pixel, with high sensitivity in the 1-5 um. The infrared imager is a refractive optical system using achromatic lens. Infrared narrow band filter, of which center wavelength is 3.414 um and half-width about10 nm, is installed onto the filter turret for the observations of infrared H3+ aurora. On the infrared echelle spectrometer, it adopts the reflective optics with parabolic mirrors, and its wavelength resolution is about 20,000. These will be install on our Tohoku University 60 cm telescope at the summit of Mt. Haleakala in Hawaii (operations will be started in 2013) and the 1.8 m PLANETS telescope (operation will be started in 2014). We will make continuous observations of Jupiter and other planets. This study is focusing on the development of InSb sensor driving electronics for these instruments. In this research, we verified multiplexer of imager, and define adequate bias voltage and high-level time of clock. This development succeeded the infrared imaging test, and the rest thing is calibration of infrared imager including noise evaluation. On the other hand, we are proceeding designing and production of fan-out-board. Now, making model of element, simulation, and production of demonstration equipment are proceeding. This presentation will mention about the drive system developed.

PCG10-P04 Room:Convention Hall Time:May 24 16:15-17:30

A multi-turn time-of-flight isotope analyzer for space application

Shoichiro Yokota[1*], Michisato Toyoda[2], Jun Aoki[2], Junichi Kurihara[3], Yoshifumi Saito[1]

[1]ISAS/JAXA, [2]Osaka Univ., [3]Hokkaido Univ.

In order to study terrestrial or planetary plasma environment in situ low-energy ion measurements are indispensable and thus have been done by a variety of ion analyzers. Detailed studies of plasma characteristics demand mass analyses as well as energy analyses. In case of measuring a variety of ions originating from planetary atmospheres, we need to measure the ion composition with high mass resolution. Although we have achieved the measurements of the ion composition by mass analyzers around planetary environment, higher mass resolution is now needed in order to distinguish heavy species and isotopes. For the future isotope measurements around moons, planets and asteroids, we are developing a high-mass-resolution mass analyzer. One of our scientific objects is to measure the Martian atmospheric escape and evolution. Mass resolution (m/dm) of 100 is generally needed for the isotope analysis of planetary particles. However the Martian atmospheric escape and evolution science requires m/dm>3,000 to discriminate N2 from CO.

Low-energy particle measurement group of ISAS has developed a time-of-flight(TOF) ion mass analyzer with mass resolution of about 20 for KAGUYA, which succeeded in measuring ions originating from the lunar exosphere and surface. It is also preparing a TOF mass analyzer with mass resolution of 40 for the BepiColombo mission. Multi-turn TOF mass spectrometers(MULTUM), where ions are stored in a fixed orbit within electrostatic sectors and allowed to propagate the same orbit numerous times, have been developed by Osaka Univ. mass spectrometry group. One of the MULTUM series achieves the mass resolution over 30000 with the size of 20cm x 20cm. We have prepared a test model of the ion optics of the isotope analyzer which employs the MULTUM technique. We are also developing a pulsive high voltage power supply(HVPS) for the test model of the ion optics. We will report test results of the MULTUM optics and the HVPS performance.

Keywords: mass analysis, isotope, planetary exploration

PCG10-P05 Room:Convention Hall Time:May 24 16:15-17:30

Detailed design and performances on radio frequency mass spectrometer for development of Atmospheric Neutral Analyzer

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Neutral Mass Spectrometer (NMS) has been onboard several satellites and sounding rockets to observe neutral upper atmosphere of the Earth and other planets. However physical processes of neutral atmosphere are not fully understood because of limitations of observation time and NMS capabilities to observe neutral particle motion such as wind or temperature. Since in almost NMSs quadrupole mass spectrometer was applied to analyze particle species, it is difficult to obtain information on detailed velocity distributions for specific species. Neutral particles interact with plasma through collisions with ions in the upper atmosphere. Behavior of neutral particle motion thus varies by conditions in the ionosphere or the magnetosphere. In order to understand physical processes of neutral atmosphere response to the ionosphere and magnetosphere variation, it is necessary to achieve velocity distribution function for each atmosphere species.

We are developing new NMS which is called Atmospheric Neutral Analyzer (ANA). In ANA, radio frequency (RF) electric field is applied for mass analysis. After ionization of incident neutral particles, the particles are uniformed in a certain energy perpendicular to the entrance slit plane and then the particles through RF fields in three times. While passing through RF sections, the velocity perpendicular to the entrance slit plane is accelerated or decelerated by RF fields, and only particles with specific mass which have the resonant velocity can gain maximum energy in comparison with other particles. The particles which gained maximum energy can pass through the retarding potential analyzer (RPA) which is placed after the exit of the RF section to detection section. Counts and locations of the accelerated particles are detected by combination of MCP with fluorescent plate and CCD as a 2D image. The image represents 2D velocity distribution parallel to the plane of entrance slit and winds and temperatures are derived.

The detection efficiency and mass resolution of ANA depends on the potential on RPA and characteristics of energy gain. We improve mass resolution and detection efficiency by optimizing the geometry of RF analyzer. We will show performances of the RF analyzer estimated from numerical simulation.

Keywords: Upper atmosphere, In-situ observation, Neutral particle, Radio frequency, Ion mass analyzer

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Design of a ToF type ion mass spectrometer with high mass resolution for future planetary in-situ observations

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Many investigations of ion three-dimensional velocity distribution functions (VDFs) have been conducted with spacecraft-borne ion mass spectrometers (IMSs) to clarify plasma dynamics around terrestrial/planetary ionospheres and magnetospheres. According to numerical simulations, it has been considered that molecular ions exist around ionospheres of non-magnetized planets (e.g. Kransnopolsky et al., JGR, 2002). But there is a problem that conventional time-of-flight (ToF) type IMSs applying carbon foils (CFs) require high acceleration voltages to measure molecular ion VDFs with high mass resolution. Generally, acceleration voltages are limited due to sizes of power supplies which can be applied to spacecraft. A limitation of acceleration voltages is critical for this problem because mass resolution depends on the acceleration voltages. Therefore, developments of IMSs that can also measure VDFs of the molecular ions without high acceleration voltages are necessary for future investigations of plasma dynamics around the ionospheres of non-magnetized planets.

Our ToF type IMS is supposed to installed on spin-stabilized spacecraft. It consists of two analyzers: a top-hat type electrostatic analyzer (ESA) and a ToF analyzer. Firstly, the ESA discriminates kinetic energy per charge (E/q) of incident ions by applying sweep voltages to spherical electrodes. Secondly, information of ion velocities (v) can be derived from ToFs of accelerated ions with a high uniform energy (Eacc) at the ToF analyzer. Finally, from a relationship between Eacc/q and v, we can get information of incident ion mass per charge (M/q).

In this study, we designed the ToF analyzer by adopting new applications, conversion surfaces (CSs), instead of the conventional applications, the CFs, to realize measurement of the molecular ion VDFs with high mass resolution. A particle ToF is defined as a time difference between a START signal and a STOP signal. In the case of our ToF analyzer, secondary electrons emitted by collisions of the incident positive ions with the CSs, are treated as the START signals. The STOP signals can be generated by only reflected particles which can pass through a slit. Due to the collisions, charge-exchange reaction occurs, and most of the incident positive ions are converted into neutral particles. Electrode structures which produce linear electric fields (LEFs) are adopted to make it possible to analyze ToFs of reflected positive and negative ions with high accuracy. In the case of molecular ion collisions, dissociative reaction occurs with high probability, and the molecular ions split up into positive, negative, and neutral particles. Thus, three types of STOP signals may be generated in response to one START signal. Our ToF analyzer can also identify positions where the incident ions collide with the CSs by detecting incident positions of secondary electrons on START micro-channel plate (MCP). We firstly designed simple electrode model of the ToF analyzer with SIMION. Secondly, we analyzed a specification of the ToF analyzer with numerical simulations. As a result, we finally concluded that mass resolutions of the reflected positive ions are high enough to identify CO_2^+ and HCO_2^+ respectively at full width half maximum.

In this presentation, we will show numerical simulation results of the ToF analyzer, and will describe its total specification.

Keywords: Suprathermal ion, Ion mass spectrometer, Electrostatic analyzer, ToF analyzer, Carbon-foil, Conversion surface

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Development of 0.01-25keV/q ion mass spectrometer (LEPi) for ERG spacecraft

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We are developing a low-energy ion mass spectrometer (0.01-25keV/q) to be onboard ERG spacecraft. Measurements of plasma partciles with energies lower than 100keV is not easy in the terrestrial inner magnetosphere, since fluxes of high-energy particles are large. High-energy particles can penetrate through, or kick out the secondary particles when they hit materials. This means they can be detected by a detector inside an instrument without any analysis, namely, noise. In order to reduce the noise generated by the high-energy particles, we apply a time-of-flight (TOF) technique. In addition, we try to minimize size of the detector. We will discuss how an instrument in the current design can survive under severe environment under terrestrial inner magnetosphere.

Keywords: low-energy plasma analyzer, mass spectrometer, ERG

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Design and verification plan of MEP-e and MEP-i onboard ERG

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We have been developing instruments for the observations of the medium-energy electrons (10-80 keV) and ions (10-180 keV/q) in our coming radiation belt mission ERG (Exploration of 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 waves, which are believed to play significant roles in the relativistic electron acceleration and loss during storms. On the other hand, such a measurement has been a challenging issue due to the harsh radiation environment, where penetrating particles and secondary particles result in significant background. Our strategy for enhancing signal-to-noise ratio is to combine an electrostatic analyzer and silicon detectors, which provide energy coincidence for true signals. In parallel with the electron instrument, we also have designed and tested a medium-energy ion mass spectrometer. This instrument is comprised of an electrostatic analyser, time-of-flight (TOF) mass spectrometer, and solid state detectors, hence it can measure energy, mass and charge state of medium-energy ions. It provides significant information of particle flux and pitch angle distribution of ring current core components, which contributes to the radiation belt dynamics via electromagnetic waves and global magnetic field deformation.

PCG10-P09 Room:Convention Hall Time:May 24 16:15-17:30

Extremely High-Energy Plasma/Particle Sensor for Electron (XEP-e)

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It is well known that satellites are always in danger in space and especially high-energy radiation damages them. One of the sources that cause them is the radiation belt (the Van Allen belt). It was thought to be static, but in the 1990s it rediscovered the radiation belt fluctuates greatly. There are some reasons to occur this phenomenon, but we have not understood a clear reason of this yet. On the other hand, it is well known that the energetic particle flux vary during geomagnetic disturbances and the relativistic electrons in the other radiation belt change with solar wind speed. Recently solar activity is getting larger, so now we are trying to develop the satellite (ERG) to reveal this mechanism in this solar maximum phase. ERG (Energization and Radiation in Geospace) satellite is the small space science platform for rapid investigation and test satellite of JAXA/ISAS, and our group is developing the instrument (XEP-e) to measure high-energy electrons (200keV~20MeV), that is one of many ERG satellite instruments. XEP-e (eXtremely high Energy Plasma/ particle sensor for electron) is consists of three SSDs (Solid-State Silicon Detectors) and a GSO single crystal scintillator. It has one-way conic sight and an electric part is unified with a part of sensor that is covered with aluminum to protect from contamination. The front part of the SSDs discriminate a radiation enters into the sensor and the back part of the plastic scintillator get the value of its energy. We can get the data of high-energy electron by using this sensor and it will be useful to reveal the detail of the radiation belt's fluctuation.

Keywords: ERG

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Current status of development of the high-speed digital processing system by ASIC for HEP-e on board the ERG satellite

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ERG (Energization and Radiation in Geospace) satellite will be launched in 2015 to understand the acceleration process of relativistic electrons and dynamical variations of the space storm in the inner magnetosphere. In efforts to understand the cross-energy coupling process generating relativistic electrons, the satellite is equipped with instruments for comprehensively observing plasma/particles, fields and waves. The Plasma and Particle Experiment (PPE) utilizes four electron sensors and two ion sensors in order to cover the wide energy range. HEP-e is one of the four electron sensors and uses sets of SSSD (Single-sided Silicon Strip Detector) to detect energetic electrons. HEP on board MMO (Mercury Magnetospheric Orbiter) also employs an ASIC called VATA for read-out system from the detector, but HEP-e on board the ERG satellite aims at handling data with higher speed and has VATA which can process simultaneously signals from 32 channels with ADC function. We present the current status of development of the high-speed digital processing system for HEP-e on board the ERG satellite.

Keywords: ERG, HEP-e, ASIC

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Development of high time resolution ion sensors (FPI-DIS) on MMS

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The NASA's Magnetospheric Multiscale (MMS) mission is scheduled for launch in October 2014. According to the in-situ observations of the recent spacecraft including GEOTAIL, Cluster, and Themis, it is essential to resolve the ion / electron scale phenomena in order to understand the driving mechanisms of the magnetic reconnection. The purpose of the MMS mission, consisting of four identically instrumented spacecraft, is to observe Earth's magnetosphere in order to study magnetic reconnection, a fundamental plasma-physical process. MMS will observe the diffusion regions using four satellites with high (millisecond order) time resolution low energy particle sensors. Four sets of low energy electron and ion sensors are installed on one satellite, which enables us to obtain 3-D data independent of the satellite spin motion.

In order to realize the low energy ion measurements on MMS, we are developing high time resolution ion sensors (FPI-DIS: Fast Plasma Instrument Dual Ion Sensors). FPI-DIS measures 3D ion flux distributions over the energy range between 1 eV/q and 30 keV/q with an energy resolution of 20%. The time resolution to observe 3-D ion distribution function using four DIS sensors is 150msec.

So far, we have completed calibration of all the flight model DIS sensors (16 DIS sensors / 4 spacecraft). We have confirmed that all the DIS sensors satisfy the required performance. We will report the expected observation performance of FPI-DIS based on the results of the calibration.

Keywords: MMS, FPI-DIS, reconnection, high time resolution ion sensor

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High time resolution low energy electron spectrometer LEP-ESA on Norwegian sounding rocket ICI-4

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Strong coherent HF radar backscatter is a well-known characteristic of the polar cusp ionosphere. The echoing targets for the coherent HF radars are decametre scale electron density structures. The main purpose of ICI (Investigation of Cusp Irregularities) project is to understand the generation mechanism of this decametre scale electron density irregularities. Although the generation mechanism of the backscatter targets has not yet been agreed, the gradient drift instability (GDI) has been regarded as the dominant mode for driving the plasma instability in the F-region auroral ionosphere under conditions when the plasma flow has a component in the direction of a density gradient.

In order to understand the role of the precipitating electrons on the plasma irregularity generation, we have developed a high time resolution low energy electron spectrometer LEP-ESA for ICI-2 and ICI-3 sounding rockets. ICI-2 was successfully launched from NyAlesund, Svalbard into a sequence of Poleward Moving Forms (PMAFs) separating from the cusp proper on 5 December 2008. ICI-2 had a direct encounter with HF cusp backscatter in the vicinity of an inverted-V structure and elevated electron density near the poleward boundary of the cusp flow channel. ICI-2 succeeded in obtaining absolute electron density measurements of decametre scale plasma structures for the first time. ICI-3 was launched on 3 December 2011 and its trajectory successfully intersected an RFE (Reverse Flow Event). By analysing ICI-3 data, the effect of the two-step Kelvin Helmholtz Instability - Gradient Drift mechanism will be resolved. Following the successful flight of ICI-2 and ICI-3, ICI-4 will be launched in November 2013 so that the trajectory should intersect a Flow Channel Event.

Low energy electron spectrometer LEP on ICI-2, ICI-3, and ICI-4 consists of sensor head LEP-ESA (Electron Spectrum Analyzer), deployment mechanism, and electronics box LEP-E. LEP-ESA measures the electron distribution function in the energy range between 10eV and 10keV. LEP-ESA is a top-hat type electrostatic analyzer with a pair of disks that works as a collimator at the entrance and toroidal electrodes inside. The inner toroidal electrode is supplied with high voltage swept between 0V and +3kV. The electrons coming through the collimator are attracted down toward the inner electrode. Only the electrons with specific energy range can further travel down to the exit of the electrodes. The electrons passing through the deflector plates enter to Micro-Channel Plate (MCP) and are intensified to detectable charge pulses. The intensified charge pulses are received by annular discrete anodes that are divided into 16 parts. The positions where the charge pulses are detected correspond to the incident polar directions of the electrons/ions.

Although LEP on ICI-2 and ICI-3 succeeded in obtaining the high time resolution electron energy spectra in the plasma irregularity region, it does not necessarily mean that the flight performance of LEP on ICI-2 and ICI-3 was perfect. We used triangular voltage waveform for the energy sweep. Our original plan was to obtain 11msec high time resolution data using 16 rising / falling energy steps. However, there existed difference between the rising 16 steps data and falling 16steps data except when the electron energy distribution was broad. This may be caused by the slow temporal response of the stepper high voltage power supply that was connected to the analyzer sphere. We are going to modify the previous high voltage power supply used for ICI-2 and ICI-3 LEP in order to realize the 11msec time resolution measurements of the low energy electrons by ICI-4 LEP.

ICI-4 is the first mission included in the 10-year plan for Japan-Norway sounding rocket experiment program whose main goal is to achieve collective understanding of the microphysics and its role (scale coupling) in the global to meso scale phenomena in the polar ionosphere.

Keywords: sounding rocket, charged particle, detector, ASIC, MCP anode, cusp

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BepiColombo Euro-Japan Joint mission to Mercury: MMO Project Status update

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BepiColombo is a ESA-JAXA joint mission to Mercury with the aim to understand the process of planetary formation and evolution in the hottest part of the proto-planetary nebula as well as to understand similarities and differences between the magnetospheres of Mercury and Earth.

The baseline mission consists of two spacecraft, i.e. the Mercury Planetary Orbiter (MPO) and the Mercury Magnetospheric Orbiter (MMO). JAXA is responsible for the development and operation of MMO, while ESA is responsible for the development and operation of MPO as well as the launch, transport, and the insertion of two spacecraft into their dedicated orbits.

MMO is designed as a spin-stabilized spacecraft to be placed in a 400 km x 12000 km polar orbit. The spacecraft will accommodate instruments mostly dedicated to the study of the magnetic field, waves, and particles near Mercury. While MPO is designed as a 3-axis stabilized spacecraft to be placed in a 400km x 1500 km polar orbit. Both spacecraft will be in same orbital plane.

Critical Design Review(CDR) for MMO project is completed in November 2011. Electrical Interface Check (EIC)/ Mechanical Interface Check (MIC) for MMO has been completed in January 2012. MMO stand alone FM AIV is started from September 2012. MMO Mechanical Test Model(MTM) has been transported to ESA/ESTEC on November 2011 and attended for the stack (MCS) level mechanical test which was completed in last August.

7th BepiColombo science working team (SWT) meeting, which discusses science related matters, was held on September 2012 at Stockholm. In this paper, we will report the latest information of BepiColommbo MMO project status.

Keywords: Mercury, Planetary Exploration, International Collaboration

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Final calibration results of MIA/MMO sensor characteristics

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The Mercury Ion Analyzer (MIA) on board Mercury Magnetospheric Orbiter (MMO) measures the velocity distribution of low-energy ions (5 eV to 30 keV) by using a top-hat electrostatic analyzer for half a spin period (2 s). By combining both the mechanical and electrical sensitivity controls, MIA has a wide dynamic range of count rates expected in the solar wind around 0.3 AU from the sun, and in the Mercury's magnetosphere. The entrance grid for the sensitivity control of ions is also expected to reduce significantly the contamination of solar UV radiation, whose intensity is about 10 times larger than that around Earth's orbit. In this presentation, we will summarize final results of the MIA sensor calibration experiment.

Keywords: MMO, sensor characteristics