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

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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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

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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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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.

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

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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

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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.

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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