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PCG008-01 会場:202 時間:5 月 26 日 08:30-09:00

Space Plasma Research and Instrument Development at SPDL, NCU
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.

キーワード: space plasma, collisionless plasma, instrumentation
Keywords: space plasma, collisionless plasma, instrumentation

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PCG008-02 会場:202 時間:5 月 26 日 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.

キーワード: FUV obervation, aurora, microburst
Keywords: FUV obervation, aurora, microburst

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小型波形受信器に向けたアナログ ASIC の開発
Development of the Analog ASIC for Miniaturized Waveform Receiver

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Hajime Fukuhara[1*], Hirotsugu Kojima[2], Satoshi Okada[1], Hirokazu Ikeda[3], Hiroshi Yamakawa[2]

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宇宙プラズマは無衝突であるため、プラズマの運動エネルギー交換はプラズマ波動を介して行われるため、プラズマ波動の観測は宇宙プラズマ物理を解き明かす上で非常に重要である。GEOTAIL 以降の科学衛星では波形観測が行われており、波形観測から得られるプラズマ波動の位相の情報がスペクトル観測のみからでは得られなかった知見を与えている。

一方、プラズマ波動の観測器は同時多点観測ミッションや深宇宙探査ミッションに向け小型化の要求が高まっている。しかし、プラズマ波動の観測器は高感度・低雑音・広ダイナミックレンジであるアナログ回路が不可欠であり、小型化が困難であった。

我々はこれまで特定用途向け集積回路技術（Application Specific Integrated Circuit: ASIC）技術によってアナログ回路の小型化を進めており、100kHz までのプラズマ波動の電磁界 6 成分全てのアナログ信号処理が可能な回路の開発に成功した。ASIC の寸法は 5mm 角であり、ASIC が封入されているパッケージまで含めると 15mm 角である。ASIC には、帯域制限フィルタ、差動アンプ、アンチエイリアシングフィルタ、という 1 連の回路を 1 チャンネルとしてそれを合計 6 チャンネル搭載しており、また温度ドリフトの補償回路も同時に搭載している。また開発した ASIC を搭載し、6 チャンネルのアナログ差動入力からそれぞれの AD 変換を行いシリアルビット列として出力する名刺サイズの受信器の開発も行った。これらは、今後の同時多点観測ミッションや深宇宙探査ミッションにおけるプラズマ波動観測において非常に大きな効果を発揮すると見込まれる。

キーワード: プラズマ波動, 波形, WFC, ASIC
Keywords: Plasma Wave, Waveform, WFC, ASIC

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PCG008-04 会場:202 時間:5月26日 09:45-10:00

ASICを用いた小型周波数掃引受信器の設計・開発
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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科学衛星搭載用電界センサー周辺の光電子環境に関する計算機実験
Particle simulations on the photoelectron environment around an electric field sensor

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将来磁気圏探査衛星で計画される定常および波動電界の精密測定に向け、宇宙プラズマ環境における電界センサーの振る舞いをより詳細に把握する必要がある。磁気圏および太陽風プラズマ中では、衛星の太陽光照射面から放出される光電子の密度が背景プラズマ密度に対して非常に高く、電界センサーの日照面周辺に高密度の光電子雲が形成される。特に一対のセンサー間の光電子分布が非対称な場合に、こうした光電子雲が電界センサー特性に重大な影響を及ぼし得るといった報告例もあり、センサー周辺の光電子環境およびそれが電界センサー特性に及ぼす影響を詳細に解析する必要がある。こうした解析は、限られたケースを除いては理論や地上実験で取り扱う事が困難であり、数値的手法の確立が急務となっている。

本研究では、電界センサー周辺プラズマ環境、およびその環境下でのセンサー特性評価にプラズマ粒子計算機実験を適用する。粒子モデル計算機実験は個々のプラズマ粒子の運動方程式を解き進めていくため、原理的には光電子雲の形成過程を運動論効果も含めて矛盾なく再現することができる。

本発表では特に水星磁気圏探査衛星 BepiColombo/MMO に搭載予定のパック式電界センサー (MEFISTO) の数値モデリングおよびセンサー周辺の光電子環境解析について報告を行う。MEFISTO の特徴として、電界センサー特性への光電子の影響の軽減を目的としたガード電極の搭載があげられる。本発表ではセンサー周辺光電子分布に対するガード電極の影響やその結果として得られるセンサー電気特性について、計算機実験の結果を示す。また、現実的なセンサー形状のモデリングやプラズマパラメータの取り込みなど、センサー特性評価数値ツールとして克服しなければならない課題に対する取り組みの進捗や今後の展望についても紹介する。

キーワード: 電界センサー, 光電子, 粒子シミュレーション
Keywords: Electric field sensor, Photoelectron, PIC simulation

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磁場誘導型自由運動に基づく単一ダストの非破壊分析
Nondestructive analysis of single dust particle based on observation of free magnetic motions in microgravity

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

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

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

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

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

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

キーワード: 磁気放出, 微小重力, 磁場勾配力, 反磁性磁化率, 物質同定, ナノ材料
Keywords: magnetic ejection, microgravity, field gradient force, diamagnetic susceptibility, material identification, nano sized material

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Development of space plasma instruments onboard Taiwan sounding rocket
Development of space plasma instruments onboard Taiwan sounding rocket

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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.

キーワード: Sounding rocket, ionosphere, thermosphere, plasma irregularity
Keywords: Sounding rocket, ionosphere, thermosphere, plasma irregularity

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PCG008-08 会場:202 時間:5 月 26 日 11:15-11:30

ERG 衛星搭載用アバランシェフォトダイオードのゲイン-温度関係
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 会場:202 時間:5 月 26 日 11:30-11:45

SCOPE 衛星搭載用超高時間分解能電子計測器の開発
Development of a low energy electron spectrometer for SCOPE

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地球磁気圏観測を目的とした将来ミッションとして、SCOPE（cross Scale COupling in Plasma universE）計画が 2019 年の打ち上げを目標に企画されている。SCOPE 計画の主目的は、プラズマの MHD スケールのマクロな現象と、電子・イオンの特徴的なスケールのミクロな現象を同時に観測することである。既存の磁気圏観測衛星における電子計測では、観測時間分解能が 1 sec オーダーであるため、電子の特徴的なスケールの観測ができなかった。計画の実現には、10 msec 以下の時間分解能での観測の実現が必須となる。本研究では、このような超高時間分解能での観測が可能な電子計測器 FESA（Fast Electron Spectrum Analyzer）の設計、並びに FESA を用いた観測の精度評価を行なった。

SCOPE 衛星には、８台の FESA を搭載し同時に 4 π str の観測視野を確保することを検討している。これにより、観測の時間分解能は衛星スピンに依存しなくなる。また FESA には、Spherical Top-hat 型と Toroidal Top-hat 型の静電分析器を組み合わせた三重球型静電分析器を採用する。二種類の極板間電圧を与えることができるこの分析器を用いれば、同時に２つのエネルギー帯を測定でき、電圧掃引回数を半減させせることができる。以上の試みによって、最高で 8 msec という超高時間分解能を実現することができる。

本研究で設計するセンサーは、先行研究（Saito et al., 2009）によって製作された FESA の第一世代テストモデルを改良した、第二世代テストモデル（Test Model 2,TM2）という位置付けになる。計算機上で TM2 の設計モデルを構築し、数値シミュレーションによって設計した TM2 の感度特性を求めた。TM2 の感度（g-factor）は、サンプリングタイム 0.5 msec 中に GEOTAIL LEP-EAe と同等の統計精度でカウントレートを取れる値を目標に設定し、Spherical 部（Inside）で $6.37e^{-3}$ [cm^2 str eV/eV /22.5deg.]、Toroidal 部（Outside）で $9.12e^{-3}$ [cm^2 str eV/eV /22.5deg.] となった。またエネルギー分解能は、10 eV～22.5 keV のエネルギー帯を 32 ステップで十分なカバレッジで測定できる分解能を目標に設定し、Inside で 25.4%、Outside で 18.6% [Full Width at the Half Maximum : FWHM] となった。α方向角度分解能については、１つのセンサーヘッドで衛星スピン方向に 22.5deg. の視野幅を確保できる角度分解能を目標に設定し、Inside で 14deg.、Outside で 9deg.[FWHM] となった。

設計した TM2 の観測精度を求めるため、またローブ・太陽風観測時の観測のサンプリングタイム (dt) の長さを決めるため、各観測領域におけるプラズマ電子の速度分布関数モデルを構築し、モデル計算によって取得されるカウントを再現した。モデル計算には、取得カウントの統計誤差の影響が考慮されている。モデル計算の結果から、ローブ観測で 50 msec、太陽風観測では 20 msec の dt を採用するのが、統計誤差を押さえつつ高時間分解能で観測を行うのに適当であると判断した。プラズマシート観測では、0.5 msec の dt で観測を行うことが検討されている。モデル計算から、この dt では取得カウントの統計誤差が温度・密度の計算結果に 1%オーダーの誤差を与えること、またバルク速度の計算は統計誤差の影響が大きいため計算精度が悪くなることが確認できた。8 msec の時間分解能で取得した分布関数から精度良く速度モーメントを求めるには、取得した分布関数に対して関数形を仮定してフィッティング関数を求める必要がある。

SCOPE 衛星の観測対象の一つである磁気圏尾部リコネクション領域を、8 msec の時間分解能で観測を行なった前例は無い。8 msec の時間分解能で取得される速度分布関数の再現性を評価するため、３次元粒子シミュレーションの結果を用いてこの領域で取得されるカウントを再現し、速度分布関数を計算した。8 msec で取得した分布関数から速度モーメントを計算すると、シミュレーションで再現されているリコネクションポイント付近の特徴的な速度モーメントの変化を再現できることがわかった。またこの分布関数から、リコネクションポイント付近で見られる分布関数の温度異方性も確認できた。

複数センサーによる同時観測では、衛星スピンの影響で各センサーの観測視野が回転してしまう。このため Energy-Time Spectrum（E-T 図）の作成するためには、あるサンプリングタイムに観測方向を向いているセンサーを選び出す、センサーセレクションが必要となる。本研究では、このセンサーセレクション方法を提案した。３次元粒子シミュレーションの結果から再現した取得カウントから E-T 図を作成し、提案した方法によって E-T 図の作成が可能であることを示した。また同時に、スピンを行わず同じ時間分解能で観測を行う衛星によって取得されるカウントからも E-T 図を作成し、両者を比較して Differential energy flux の計算精度を比較した。

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PCG008-10 会場:202 時間:5 月 26 日 11:45-12:00

水星探査計画BepiColombo/MMO搭載用高エネルギーイオン粒子観測機器(HEP-ion)の開発
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

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.

キーワード: space instrument, instrument development facility, neutral particle analyzer
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