P2-129第14回　宇宙科学シンポジウム

火星大気散逸探査での同位体計測を目的とした multi-turn time-of-flight型質量分析器

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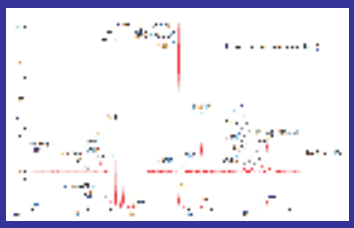
Abstract

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／Δm) of 100 is generally needed for the isotope analysis of planetary particles. However the Martian atmospheric escape and evolution science requires m／Δm＞3,000 to discriminate N2 from CO.

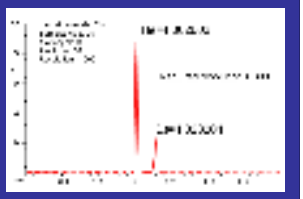
Low-energy particle measurement group of ISAS has developed a time-of-flight(TOF) ion mass analyzer with mass resolution of about 20 for KAGUYA, which succeeded in measuring ions originating from the lunar exosphere and surface. It is also preparing a TOF mass analyzer with mass resolution of 40 for 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..

Performance of the ion optics

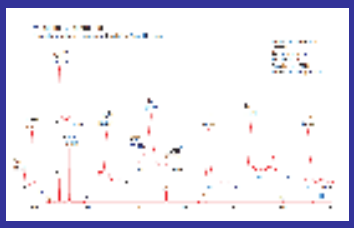


Mass spectra of the linear mode (1 cycle). In the linear mode, the entrance and exit are continuously open. Mass resolution of ~50 and relatively high transmission are achieved.

Residual gas was measured by the test model of the ion optics with external HVPS, detector and data processing system. The experimental results show that the test model of the ion optics has achieved a mass resolution 50 in the linear mode and up to 5000 in 20-cycle mode separating CO+ and NN+ clearly.



Mass spectra of He+ and D2+ in the 10-cycle mode. Multi-cycle mode extend the flight time of light species to clearly separate it from random noise counts.

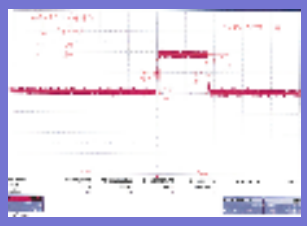


Mass spectra of the multi-turn mode (20 cycles). 20-cycle mode clearly separates two peaks of CO+ and NN+ with a mass resolution of ~5000 .

Performance of the switching HV board

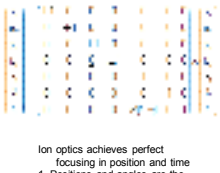
Specification of the test board of HVPS for the multi-turn time-of-flight mass spectromter

El_Float	HV_SW1&2	HV_SW3	HV_PS
Switching HV0 0 – +4kV 0.1 – 10kHz 0.5 – 10us Filament PS <300uA, <100V	Switching HV(2ch) 0 – +2kV 0 – -2kV 0.1 – 10kHz	Switching HV(2ch) 0 – +500V 0 – -500V 0.1 – 10kHz	Static HV Circular elec. 0 – +2kV 0 – -2kV MASTUDA elec. 0 – +2kV 0 – -2kV



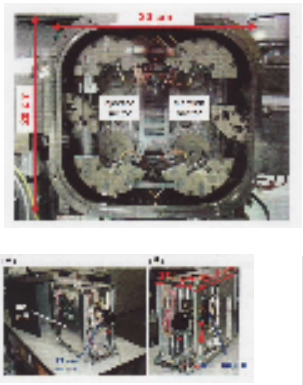
Output profile of the switching HVPS. Rectangle wave profile are obtained without overshoot. 1 kV stepping up and down complete in 50ns, quickly enough to satisfy the requirement of the MULTUM mass spectrometry. Power consumption of the switching HVPS is around 1.2W per channel.

Instrumentation of MULTUM-S Ⅱ



Ion optics achieves perfect focusing in position and time
1. Positions and angles are the same as the next ones.
2. Ions of different positions and angles complete the turning with the same period.

Increasing the number of turning makes the flight pass infinitely long and then makes the mass resolution numerously high.

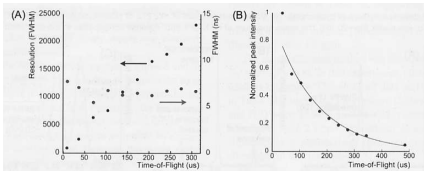


Timing chart

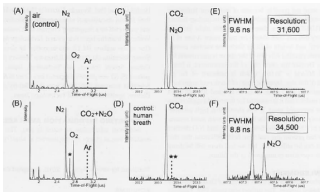
Overview of MULTUM-S Ⅱ

Paremeters of MULTUM-S Ⅱ

Electron Energy	1--100 [amu]
Emission current	100 uA
Pulse Voltage	1.5 kV
Extraction pulse length	450 ns
Total Acc. Voltage	5.5 kV
BG pressure	1.5e-4 Pa
Pressure gases	2.2e-4 Pa



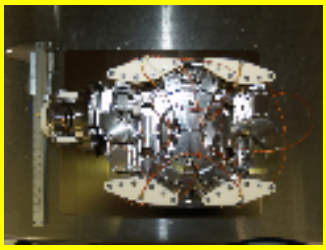
Left: Relation between flight time and mass resolution. Multi-turn increases the flight time proportionally with keeping the dispersion of flight time.
Right: Transmission vs flight time. First a couple of turning reduces the transmitted particles to blow a half.



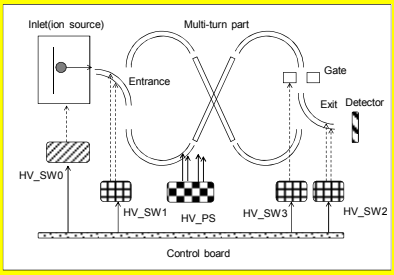
Measured results: A-C(36 turns); E-F(100 turns)

Toyoda., *EJMS*, 2010

Spaceborne multi-turn time-of-flight mass spectrometer



Ion optics



Schematic view of the mass spectrometer

Switching HV board

Assembly of the mass spectrometer

- Ion source(Ti, SUS and Ceramics)
  - Electron ionization
  - Dual filaments
  - Two acceleration
  - Vol.: 5kV
  - Einzel Lens
- Base plate (Ti)
- Optics(Ti, Ceramics)
  - Entrance electrode x1(2kV)
  - Exit electrode x1(2kV)
  - Turning electrode x4(2kV)

Schedule

2011(H23)	Design and fabrication of an ion optics of multi-turn time-of-flight mass spectrometer Performance test of the ion optics with laboratory electronics
2012(H24)	Design and fabrication of switching HVPS for acceleration and mass gate Performance test and estimation of the power consumption
2013(H25)	Performance test of the assembly of the multi-turn time-of-flight mass spectrometer