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Advanced Ion Mass Spectrometer for Giant Planet Ionospheres, Magnetospheres and Moons

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Abstract

The Advanced Ion Composition Spectrometer (AIMS) has been under development from various NASA sources (NASA LWSID, NASA ASTID, NASA Goddard IRADs) to measure elemental, isotopic, and simple molecular composition abundances of 1 eV/e to 25 keV/e hot ions with wide field-of-view (FOV) in the 1 – 60 amu mass range at mass resolution $M/\Delta M \leqslant 60$ over a wide dynamic range of intensities and penetrating radiation background from the inner magnetospheres of Jupiter and Saturn to the outer magnetospheric boundary regions and the upstream solar wind. This instrument will work for both spinning spacecraft and 3-axis stabilized spacecraft with wide field-of-view capability in both cases. It will measure the ion velocity distribution functions (IVDF) for the individual ion species; ion velocity moments of the IVDF will give the fluid parameters (density, flow velocity and temperature) of the individual ion species. Outer planet mission applications are Io Observer, Jupiter Europa Orbiter/Europa Clipper, Enceladus Orbiter, and Uranus Orbiter as described in the decadal survey, but would also be valuable for inclusion on other missions to outer planet destinations such as Saturn-Titan and Neptune-Triton and for future missions to terrestrial planets, Venus and Mars, the Moon, asteroids, and comets, and of course for geospace applications to the Earth.

1. Introduction

The AIMS approach has a multi-mission capability in sub-systems can be removed or added in order to meet the planetary mission requirements. Emphasis is on Europa class mission due to its most demanding environment, since if this can be achieved one has the capability to do missions with less demanding environments. The least capable and lowest resource requirements with major ion detection emphasis but applicable, for example, to support magnetometer measurements of Europa's ocean, to the most capable higher resource option for which ion composition has the greatest emphasis with both major ion and minor ion detection capabilities along with wide dynamic range for measurements of the more tenuous magnetospheric plasmas to the denser plasmas within planetary ionospheres. The design of AIMS can be optimized for science operations in extreme radiation environments as would be encountered at Io and Europa, while also allowing full measurements in the more quiescent environments of the outer magnetospheric boundary regions and the upstream solar wind.

2. Summary and Conclusions

Our approach to increase signal to noise within the instrument is to 1) reduce foreground noise so scattering by major ions cannot hide the peaks of the minor ions by using our Circular Wien Filter (CWF) design with tophat electrostatic analyzer for wide field-of-view capability and 2) reduce background noise due to penetrating particles by reducing the effective area of the detectors without reducing geometric factor (GF) or sensitive area and then using sufficient shielding; reducing detector area allows shielding mass to be reduced. We have been measuring the response of microchannel plates to penetrating electrons from 100 keV to 1.5 MeV electrons using the NASA Goddard Van de Graaff and 8 MeV to 27 MeV using the National Institute of Standards and Technology (NIST) linear accelerator with and without shielding. Other mitigating techniques can also be used. By combining the mass-per-charge (M/Q) selection capabilities of the CWF + ESA, and the Linear Electric Field (LEF) time-of-flight (TOF) sub-assembly, we can separate ions of similar M/Q like O+/S++ and O2+/S+; our LEF can use novel tapered design whose concept was originated by the Goddard AIMS group. Solid state detector is included for high charge state ion measurements. We also have the capability to detune the instrument's GF by > 1000. Laboratory measurements of the AIMS prototype instrument performance will be presented.

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