Advanced Plasma Analyzer for Measurements in the Magnetosphere of Jupiter

Joan Stude

Akademisk avhandling

som med vederbörligt tillstånd av Rektor vid Umeå universitet för avläggande av filosofie doktorsexamen framläggs till offentligt försvar i aulan vid Institutet för rymdfysik, Rymdcampus 1, Kiruna, tisdagen den 1 juni, kl. 14:00.
Avhandlingen kommer att försvaras på engelska.

Fakultetsopponent: Dr. Joseph H. Westlake,
The Johns Hopkins University Applied Physics Laboratory, Maryland, USA.
The Jupiter Icy Moons Explorer is a planetary exploration mission that aims to study the moons of Jupiter in the planet’s vast magnetosphere. Among the various instruments on board is the Particle Environment Package (PEP), that is led by the Swedish Institute of Space Physics (IRF) in Kiruna. The Jovian plasma Dynamics and Composition analyzer (JDC) is one of six sensors within PEP and focuses on the characterization of positive ions. To be able to measure their three-dimensional distribution and composition, in-situ and in high time resolution, JDC has to cover a large field of view of 2p sr, for the desired energy range, in just a couple of seconds. An electrostatic analyzer within the sensor determines the energy per charge of such particles and a time-of-flight mass spectrometer measures their mass per charge. Constraints on weight and the radiation environment of Jupiter drive the design of the sensor: small and lightweight to allow extra shielding, but still large enough to accomplish measurements in the harsh radiation environment of Jupiter.

This work focuses on a new type of compact, electrostatic analyzer using spherical wedges and the start signal generation for the time-of-flight measurement using new venetian blind-type surfaces. Simulations on the electrostatic analyzer showed that the most promising design is a hybrid variant, using an inner shell with spherical wedges and a spheroidal outer shell. A prototype sensor was built and tested with successful results. A reflectron-type time-of-flight cell measures the time it takes for a particle to pass a linear electric field. The time measurement has to be very accurate and requires that all ions enter the reflectron from the same start position. Commonly this is achieved with thin carbon foils of some nanometer thickness to provide a very accurate start position. Upon impact and after leaving a foil, ions generate secondary electrons that act as start signals for the time measurement. Foils require a substantial pre-acceleration of several kilovolts for the ions to penetrate the foil, thus increasing the size and mass of the instrument.

When incident ions are reflected at grazing angles from a surface, secondary electrons are released in the same way as with foils. To increase position accuracy during this reflection process, venetian blind-type start surfaces are investigated, where many smaller surfaces replace a large flat surface. The most promising sample was found to be micro pore optics, that were initially designed to focus gamma rays. In several experiments it could be shown that micro pore optics show good reflection properties when used as start surfaces in the time-of-flight measurement.

Both improvements allow a more compact and lightweight sensor that can be better shielded against the harsh radiation environment in Jupiter’s system.

Jupiter hosts the strongest radiation environment in the solar system, that could kill an unprotected human thousand times over.

Keywords

plasma instrumentation, time-of-flight, space, Jupiter, JUICE, PEP, JDC, start surface, charge fraction, the final frontier, accidental counts, chance counts, micro pore optics, spherical-wedge electrostatic analyzer