Instrument Suite for Vertical Characterization of the Ionosphere-Thermosphere System

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A document describes a suite that provides four simultaneous ion and neutral-atom measurements as a function of altitude, with variable sensitivity for neutral atmospheric species. The variable sensitivity makes it possible to extend the measurements over the altitude range of 100 to more than 700 km. The four instruments in the suite are (1) a neutral wind-temperature spectrometer (WTS), (2) an ion-drift ion-temperature spectrometer (IDTS), (3) a neutral mass spectrometer (NMS), and (4) an ion mass spectrometer (IMS).

The instrument suite has four sensors consisting of two different types of analyzers. The first two are energy-angle spectrometers: WTS for the wind-temperature-O/N_2 ratio and IDTS for the ion drift-temperature-density ratios. The other two use a mass analyzer that allows two spectrometers to be combined into a single rectangular package, one-half for ions (IMS), the other for neutrals (NMS). The high payload velocity enables measurement of non-Maxwellian energy distributions, and also the separation of O from internal ion source products.

All instruments point in the same direction and require their common axis to point within 5° of the payload velocity vector to achieve the desired performance. In their simplest mode of operation, WTS and IDTS derive the component of the wind and ion-drift that is perpendicular to them. This is obtained from the angle of the peak of the neutral (ion) flux passing the entrance aperture. The angular distribution of the particle flux appears on the detector plane. The line passing the aperture from outside represents the total velocity vector, the vector sum of the wind, and the payload velocity. Knowledge of the payload velocity coupled with precise knowledge of the peak plus the pointing of the WTS (IDTS) axis then yields the wind vector.

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Terahertz Radiation Heterodyne Detector Using Two-Dimensional Electron Gas in a GaN Heterostructure

This detector has applications in spectroscopy of chemical species in atmospheres of planets, for detection of biochemical warfare agents, and terahertz imaging for port security.

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High-resolution submillimeter/terahertz spectroscopy is important for studying atmospheric and interstellar molecular gaseous species. It typically uses heterodyne receivers where an unknown (weak) signal is mixed with a strong signal from the local oscillator (LO) operating at a slightly different frequency. The non-linear mixer devices for this frequency range are unique and are not off-the-shelf commercial products.

Three types of THz mixers are commonly used: Schottky diode, superconducting hot-electron bolometer (HEB), and superconductor-insulation-superconductor (SIS) junction. The latter two are the most sensitive and require very small LO power to be driven to the desired operating point. These mixers require deep cryogenic cooling to at least 4 K. Schottky mixers are less sensitive and require stronger LO sources. However, they can be used at any ambient temperature.

A HEB mixer based on the two-dimensional electron gas (2DEG) formed at the interface of two slightly dissimilar semiconductors was developed. This mixer can operate at temperatures between 100 and 300 K, and thus can be used with just passive radiative cooling available even on small spacecraft. It requires small LO power (1–10 microwatt) and, therefore, can be driven by the existing LOs, even above 1 THz.

The mixer device is a micron-sized patch of the 2DEG formed in the AlInN/GaN heterostructure grown on sapphire substrate. The device operates as a bolometer with a temperature-dependent resistance (mobility of the 2DEG). Free electrons in the device absorb THz radiation received by a microantenna coupled to the mixer device. This changes the temperature of electrons and the bolometer resistance. The maximum speed of the mixer device of this type is set by the combination of the electron-phonon relaxation in the material and the diffusion of hot electrons through the device ends, and corresponds to several GHz. This is what is usually required for the intermediate frequency (IF) bandwidth of a typical THz mixer. One can say that this 2DEG HEB mixer combines the best qualities of the superconducting HEB mixer (low LO power, low noise) and of the Schottky-diode mixer (ambient temperature operation).

The main innovation here is the use of GaN-based heterostructures. Compared to the much better known GaAs-based heterostructures, the new material system