Martian atmospheric environment explored by terahertz heterodyne spectroscopy in MACO+

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We are currently advancing the design of a Terahertz Heterodyne Spectroscopy Sensor (THSS) in the context of MACO+, looking ahead to the incorporation onto sub-payload of next-generation international Mars exploration such as the Mars Ice Mapper (MIM). MIM aims at investigating the distribution of water and ice beneath the Martian surface layer using an orbiter employing a synthetic aperture radar, with an eye towards future manned activities on Mars. Meanwhile, THSS is the scientific instrument to achieve a comprehensive understanding of material cycling in the Martian atmosphere from the lower to upper layers, which is also important for understanding universal properties and varieties of the atmosphere of habitable terrestrial planets.

THSS employs Schottky barrier diode mixer detectors in the 0.4-0.9 THz range for the frontend and digital Fourier transform spectrometers for the backend. The key to development lies in the cooling of the detectors and miniaturization/low-power consumption of the system. The wavelength of terahertz band is longer than that of infrared, making it less susceptible to the absorption and scattering effects of aerosols. In Band 2 of 890 GHz this strength allows for the spectroscopy of trace molecules such as isotopes of water vapor and carbon monoxide in the lower and middle atmospheres, as well as HOx species related to atmospheric photochemical reaction processes, even during dust storm periods.

Furthermore, Doppler velocity measurements of carbon monoxide and the isotopes in Band 1 of 460 GHz and Band 2, respectively, provide us with valuable information about the atmospheric wind field. Particularly for improving the accuracy of weather forecasts and spacecraft landings, THSS plans to implement two orthogonal antennas to observe not only the meridional circulation but also the east-west wind via limb sounding mode. From the spectral profiles of carbon monoxide, it is also planned to obtain fundamental physical information about the atmosphere such as temperature and pressure, necessary for retrieval analysis. Additionally, a brief method is under consideration to capture atmospheric gravity waves predicted by General Circulation Models (GCM) as temperature disturbances from fluctuations in the absorption depth of CO spectral lines (Yamauchi et al., P-CG21, JPGU, 2024). Recent observations suggest that water vapor is transported to high altitudes. Therefore, we will try to capture water vapor above 100 km altitude (Fujimaki et al., P-CG21, JPGU, 2024) in Band 3 of 556 GHz, aiming to elucidate the mechanism of water vapor upwelling to the upper atmosphere.

THSS also has the unique feature of enabling observations across a wide range of latitudes, longitudes, altitudes, and local times without the need for a sun-like background light source. This allows for the observation of the interactions between surface-near water reservoirs and the atmosphere, as well as capturing the coupling of the atmosphere from the boundary layer to the upper atmosphere. It is expected that through data assimilation with GCM, further understandings in the dynamics/material cycling of the Martian atmosphere and meteorological and climatological predictions can be attained. In this conference, we briefly report on these overviews.

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