Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

PCG14-P11 Room:Convention Hall Time:May 23 17:15-18:30

Ultra-high resolution observations of planetary atmospheres using Mid-Infrared LAser Heterodyne Instrument (MILAHI)

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We have developed a ultra-high spectral resolution spectrometer, called Mid-Infrared LAser Heterodyne Instrument (MILAHI). It is for the applications to astronomy and planetary atmospheric science in 7-11 um wavelength at a spectral resolution resolution of up to 10^{7-8} and a bandwidth of 1GHz. We just finish the development phase of this project.

High-resolution spectroscopy in the mid-infrared regime is a versatile tool for studies of planetary atmospheres. With the highest possible spectral resolution provided by heterodyne techniques, fully resolved molecular features enables us to retrieve many physical parameters from single lines migrated in strong absorption of terrestrial atmospheric molecule bands. Because many key species in the planetary atmosphere are also abundant in the terrestrial atmosphere, high-resolution directly leads to less ambiguity. It also allows us to measure slow wind velocities with the order of 10-100m/s directly.

The heterodyne spectroscopy has been developed by our group from 1980s, in order to detect minor constituents in the terrestrial atmosphere [Taguchi et al., 1990]. The renovation with a wide-band detector, the quantum-cascade (QC) lasers and CO_2 gas laser allows us to apply this instrument to tiny planetary atmosphere.

Our performance achieved the proper level for this target. (1) System noise: At 10.3 um, we achieved 3000 K (NEP of 2.24 W/Hz$^{1/2}$ at 3MHz resolution). It leads to a minimal detectable brightness temperature difference of 37mK within 10min at 1.5 MHz bandwidth, corresponds to a minimum flux difference of 0.48 ergs/(scm2cm-1Sr) for extended source. (2) Spectral resolution: It can be achieved to be 20 MHz with a feedback using gas-cell absorption spectra.

The telluric CO_2 and O_3 absorption spectra had been obtained from the sunlight background in the lab at Sendai. On January in 2012, our equipment was mounted on the Higashi-Hiroshima 1.5m telescope, and succeeded to detect the telluric O_3 spectra obtained from moonlight. We also aimed Venus and standard stars. Unfortunately, the final success was prevented by bad weathers, but the S/N gained by these target told us that we should get the Venus and Mars spectrum with this design.

Now, we try to refine the emission spectra of the QC lasers, which provide us very wide tuneability (5cm^{-1}, and 20cm^{-1}) to operate the heterodyne system.

Although a telescope dedicated to this instrument does not exist yet, we expect to attach it to the PLANETS telescope at the top of Mt. Haleakala at Hawaii, which is now in development by PPARC / Tohoku Univ. with IfA / Univ. Hawaii (USA), Kiepenheuer Inst. f. Sonnen. (Germany), Univ. Nac. Aut. de Mexico, Univ. Turku (Finland), Harlingten Inovative Optics Co. (USA), Stan Truitt Breckenridge Astronomycal Ltd (USA), and collaborators. Its first light is, if all things are going well, in 2014.

Keywords: spectroscopy, infrared, planetary atmospheres, high spectral resolution, heterodyne, laser