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Development of infrared laser heterodyne spectrometer for remote sensing of Martian minor constituents

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With increased knowledge on our "neighbor" planets Mars and Venus, based on recent explorations, our image on them is changing significantly. In particular, Mars is called 'a frozen water planet'. It is almost certain that Mars once had duration with warm and wet climate [Head et al., 1999; Donahue, 1995; Parker et al., 1993]. It still conserves a large amount of water ice under the surface [Boynton et al., 2002; Mitrofanov et al., 2002; Feldman et al., 2002]. Moreover, methane has been detected in the Martian atmosphere by ground-based telescopes and from orbit [Formisano et al., 2004; Krasnopolsky, 2004; Mumma et al., 2009]. This discovery indicates that the planets is either biologically or geologically active. Although its temporal and spatial variations were practiced, its origin and sink in the atmosphere are still open questions. The question "Why and when did they diverge?" is essential for their environments which potentially could create and keep the life or not.
Many molecules in planetary atmospheres (H2O, CO2, O3, H2O2, NO2, CH4, C2H4, C2H6, SO2, OCS, HCl, CO, etc) show transitions in the mid infrared region. Precise measurements of those minor constituents are necessary for evaluation of their effects on evolution of the Martian atmosphere. The laser heterodyne spectroscopy is the most sensitive and highest resolution spectroscopy (1E7-8) in the middle infrared region, and has been expected to be a useful method of remote sensing of minor constituents in the Martian atmosphere from the ground. Our group in Tohoku University has developed own heterodyne system for infrared spectroscopy for the terrestrial atmosphere over the past 20 years. The failure of earlier attempts for planetary applications was due mostly to insufficient power of tunable diode lasers. Recently, quantum cascade lasers (QCLs) offer sufficient optical output power of several milliwatts to guarantee an efficient heterodyne process and high system sensitivity. The use of QCLs in our system led to a breakthrough giving the heterodyne infrared spectroscopy for planetary atmosphere. The purpose of this study is to establish the technique of remote sensing of planetary atmospheric minor constituents by the ground-based infrared laser heterodyne spectroscopy.

Keywords: spectroscopy, infrared, planetary atmosphere, high spectral resolution, heterodyne