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High spectral resolution observations of Martian atmosphere in infrared - submillimeter range from ground-based instruments.

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With increased knowledge on our “neighbor” planets Mars and Venus, based on recent aggressive explorations by the US and Europe, 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]. 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 show transitions in the mid infrared - submillimeter region. Thus, high-resolution spectroscopy in this region is significantly indispensable to study planetary atmospheres.

We searched sulfur oxide (SO2 and SO) in the Martian atmosphere by the Atacama Submillimeter Telescope Experiment (ASTE). Sulfur oxide is one of the most evident species in terrestrial volcanic gases. Although it has not yet been detected at Mars, this detection can constraint the Martian crustal and volcanic activities. We observed northern winter of Mars on 26/Dec./2007 (Ls=8.1) in 346 GHz range with $\sim$ 1h integration, and got the upper limit of the SO2 mixing ratio, 2 ppb. We concluded that the crustal or volcanic gas produced into the atmosphere is tenuous in northern winter [Nakagawa et al., 2009].

Infrared heterodyne spectroscopy has proven to be a powerful tool for astrophysical studies. To achieve highest spectral resolution and sensitivity as well as compact instrumentation heterodyne systems are advantageous over direct-detection methods. Our group in Tohoku University has developed own heterodyne system for infrared spectrometer for Earth’s atmosphere over the past 20 years. The failure of earlier attempts to build tunable systems using tunable diode lasers was due mostly to insufficient laser power. Recently, quantum cascade lasers (QCLs) offer sufficient optical output power of several milliwatts to guarantee an efficient heterodyning process and high system sensitivity. The use of QCLs in our system led to a breakthrough giving the heterodyne infrared spectrometer for planetary atmosphere. We report experiments evaluating the feasibility of QCLs at mid-infrared wavelengths for use as local oscillator (LO) in a heterodyne receiver. Performance tests with the QCL provided by Hamamatsu Photonics (operating at 7.7 um), and QCL provided by Maxion Technologies (operating at 10.6 um in room temperature) were evaluated.