Mid-Infrared lasers for planetary explorations

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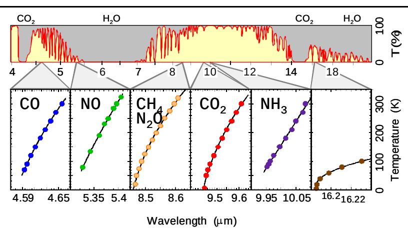
The mid-infrared spectral range (3 - 20 μm) is of particular interest for in-situ and remote sensing of material composition as many chemical species have absorption features in this wavelength range that are associated with molecular rotational-vibration transitions. These include molecules such as H_2O, CO_2, N_2O, CH_4, CO, NH_3, NO_x, HCl, and many other compounds whose absorption spectra are shown in Figure 1a and 1b. Detection of these molecules is essential for many applications in space research, atmospheric chemistry, pollution control and industrial processing. Space research applications include in-situ and remote sensing of the gases in planetary atmospheres, isotope detection and the identification of the surface composition of planetary and lunar bodies. For example, water (H_2O) has strong absorption lines in the mid-IR spectral range, and is a critical component in biological activity. Detection of these gases with ppm and ppb concentration can be straightforwardly achieved with tunable laser spectroscopy in mid-IR.

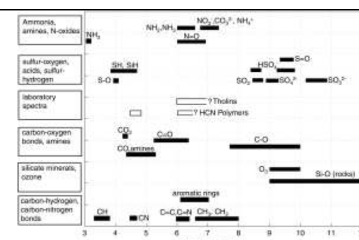
Other applications are in Laser Reflectance Spectrometer (LRS) instruments for in-situ and remote measurements of chemical composition of solids. Spectroscopy in the 3 to 20-µm region has the potential to provide an incredible amount of information about the compositions of surfaces in the outer Solar System. However, the lack of sunlight and cold conditions, make reflected solar spectroscopy and thermal emission spectroscopy difficult to perform. Both solar illumination (<4% of the level at Earth) and thermal emission (10^{-2} to 10^{-4} the level at earth) are low in the mid-IR wavelength range. Therefore, an artificial mid-IR light source is needed. Mid-IR illuminator will enable one to determine the silicate and oxide mineralogy, ice composition, and the composition of organic materials on outer solar system surfaces.

The key components required to advance the development of mid-IR instruments are the compact, efficient and wide spectral coverage laser sources operating in 3 – 20 μm wavelength region. During the last decade, quantum cascade (QC) and interband cascade (IC) semiconductor lasers have been demonstrated and have emerged with reasonable optical powers over the entire mid-IR wavelength range of interest and have operating temperatures accessible with thermoelectric (TE) coolers. Both QC and IC lasers have recently been selected for the Tunable Laser Spectrometer (TLS) instrument on the Mars Science Laboratory, which is scheduled to launch in 2009.

Here, we will discuss our effort at JPL to develop advanced and reliable mid-IR QC and IC lasers to meet instrument demands for space exploration applications. Table 1 summarizes the operational parameters of mid-IR QC and IC lasers that were demonstrated at JPL. Challenges for their further development will be discussed.



(a) Optical absorption of several gases in mid-IR and tuning range of QC lasers



(b) Spectral ranges of optical absorption in mid-IR by various chemicals

Figure 1

Laser type	**Wavelength coverage**	**Cw operating temperature**	**Output power**	**Tunability**	**Power consumption**
QC laser	5-12 μm	77-TE cooler	2- 400 mW	10-100 nm	2-5 W
IC laser	3-5 μm	77-264 K	1-12 mW for single-mode >400 mW for broad-area	>10 nm	0.02-1.2 W

Table 1