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DFB LASERS AT WAVELENGTHS IN EXCESS OF 2300 NM FOR REMOTE GAS SENSING

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ABSTRACT

Remote gas sensing for atmospheric and environmental studies using single mode emitting semiconductor lasers, e.g. in LIDAR applications has gained wide interest in the last few years. This technique has been brought to sophisticated sensitivity levels and nowadays detection limits are in the range of a few ppb. However, up until recently only semiconductor laser diode sources with wavelengths below 2.3 μm have been available, which inherently limits the detection sensitivity due to the fact that the fundamental absorption band of many gases lies in the spectral range beyond 2.3 μm . With novel distributed feedback laser diodes at wavelengths up to 2.9 μm higher detection sensitivities as compared to currently available laser based sensors are possible.

1. INTRODUCTION

Tunable diode laser spectroscopy (TDLS) of trace gases is based on the optical absorption of laser light via the excitation of rotational-vibrational modes of the specific molecule(s) to be detected or monitored. Typically, gas sensors employing this technique are equipped with single mode emitting distributed feedback (DFB) lasers. These lasers are used to scan absorption features which are located in the near infra red regime usually at wavelengths below 2.3 μm . This is due to the fact that up until recently, only semiconductor laser diodes within this wavelength regime were commercially available. The maximum detection sensitivity one can achieve with this kind of sensors is inherently limited by the line strength of the specific absorption line of interest. Therefore one strategy to increase the sensitivity is to work on absorption lines having a higher oscillator strength. The absorbance usually increases as one goes to lower photon energies (see Fig. 1). The reason for this is that the quantum mechanical oscillator strength of vibrational-rotational transitions belonging to lower electronic states is generally higher than that of vibrational-rotational levels associated with higher electronic states. Up to now however, the spectral range above 2.3 μm wavelength was only accessible with lead salt lasers which usually require costly

and time consuming cooling with liquid nitrogen. Now semiconductor DFB laser diodes in this wavelength regime are available which can be operated in cw mode at room temperature. Moreover, their robustness, reliability and small size may be beneficial for many applications in remote gas sensing.

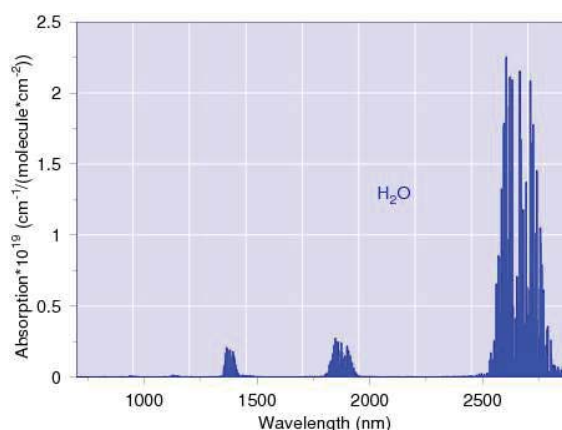


Fig. 1. Absorption Spectrum of H₂O at 296 K [1]

2. DFB PROCESS TECHNOLOGY

DFB lasers at these longer wavelengths became possible through the technology of lateral metal Bragg gratings [2]. This technology employs a nano-patterned metal grating structure in close lateral proximity to the laser ridge. Part of the light mode propagating within the laser ridge overlaps and interacts with the grating via multiple partial reflections which in turn leads to stable single mode emission of the laser. In contrast to conventional DFB lasers based on etched gratings this approach is less cost-intensive, fast, reliable and largely simplified and comprises a high single mode yield. Details of the fabrication process can be found elsewhere [2].

This technology has so far only been applied to semiconductor heterostructures that support lasing in the shorter near infra red wavelength regime. By transferring this technique to novel low band gap laser heterostructures it was possible to realize single mode emitting devices with wavelengths as far as 2.9 μm .

3. DFB LASER CHARACTERISTICS

Fig. 2 shows a typical spectrum of a DFB laser with an emission wavelength of about 2.74 μm along with the corresponding light output current curve.

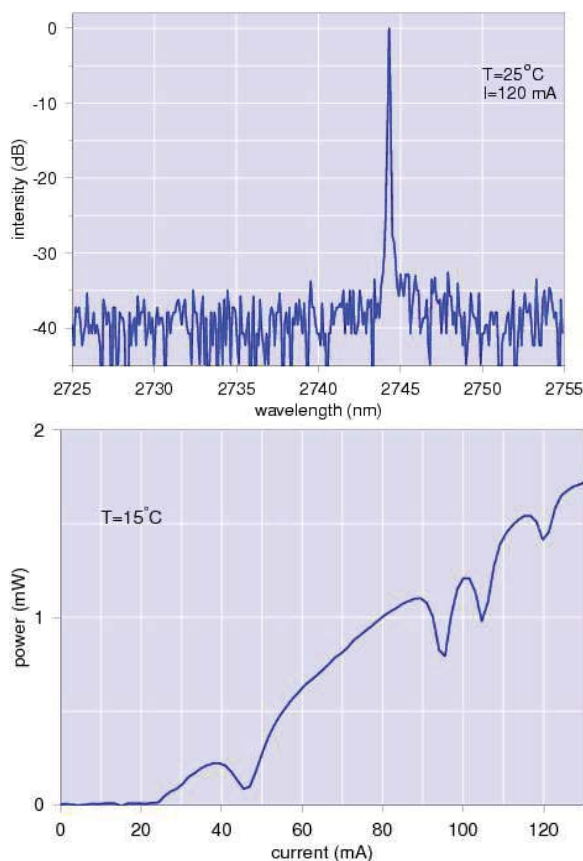


Fig.2 Spectrum of a DFB laser diode emitting at 2.744 μm at room temperature in continuous wave operation (top). Light output versus current curve for this device (bottom).

As can be seen from the top part of Fig. 2, the laser exhibits a single mode emission characteristic with a side mode suppression ratio of more than 32 dB. This laser is ideally suited for highly sensitive moisture detection.

The spectral laser line position can be tuned over water absorption lines located closely through variation of the laser temperature and/or the laser drive current. Typical wavelength tuning rates for these devices are 0.3 nm/ $^{\circ}\text{C}$ (temperature tuning) and 0.09 nm/mA (current tuning). Therefore one method to scan absorption lines of interest in TDLS applications is to first move the laser emission line close to the desired absorption feature by adjusting the laser temperature.

Then, at fixed temperature, a periodic low amplitude current ramp with typical frequencies of a few 10 kHz can be applied to the drive current sweeping the laser over the absorption line to be monitored.

The light output current curve (PI curve) in the bottom part of Fig. 2 demonstrates the effect of current tuning. The PI curve displays a series of dips reflecting multiple crossings of the laser emission wavelength with water absorption lines.

Using the known wavelength tuning rate of the laser diode one can transform the abscissa of the PI curve into the wavelength regime which yields the measured absorption spectrum of water in the wavelength range accessible by the laser.

The water absorption spectrum as extracted from the HITRAN database [1] is displayed in Fig. 3.

The one-to-one correspondence of the water absorption features with the dips observed in the PI curve of Fig. 2 is clearly visible.

One should note here, that the PI curve data was taken within a single shot (i.e. no periodic current ramp was applied to the laser) and using an absorption path length of only 10 cm in air. This demonstrates the high detection sensitivity one can achieve using these lasers in TDLS systems.

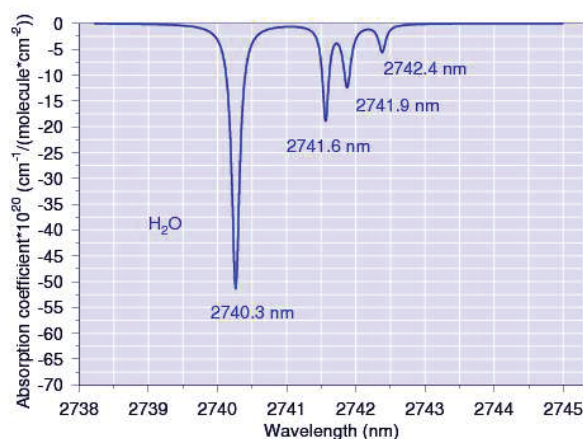


Fig.3 Absorption spectrum of water in the wavelength range around 2.74 μm .

A manifold of other prominent molecules such as e.g. CO_2 exhibit large absorption features in this spectral range. This is why the usage of novel long wavelength DFB laser diodes as the ones introduced above will open up new possibilities for previously unreachable detection sensitivities in many applications where a high spectral purity and at the same time a high reliability, robustness and compactness are required.

4. REFERENCES

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