Technologies

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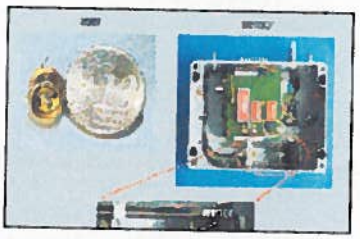
Antimony Based Tunable Diode Lasers for Trace-gas Sensing



August 16, 2010

Most laser applications in the near- and mid-infrared spectral region require low-cost laser devices with excellent spectral performance and particularly in sensing applications, emission wavelength tunability. These goals can ideally be achieved by the innovative vertical-cavity surface-emitting lasers (VCSELs) as light sources. VCSEL diodes are the youngest members of the semiconductor laser diode family. GaAs- and InPbased VCSELs recently revolutionized datacom and optical mouse applications but their wavelength is limited to about 2 µm. On the other hand, classical antimony (Sb)-based diode lasers well work up to wavelengths of at least 3.5 µm, however, their difficult and expensive technology prevented their widespread use. In the NEMIS project, aiming on the development of compact and packaged vertical-cavity surface-emitting laser diodes (VCSELs) for the 2-3.5 µm wavelength range and pilot photonic sensing systems for trace gas analysis, a demonstrator for optical CO measurement at 2.33 µm has recently been developed. These electrically pumped single-mode and tunable lasers operate continuously with very low threshold currents up to 90°C. Actually, by utilizing VCSELs' most attractive features such as efficient electronic wavelength tuning, several absorption lines of a single gas species can be scanned using the full tuning range of such lasers which already proved their suitability in gas sensing applications.

The absorption for most gases such as methane (CH4), carbon monoxide (CO) and water (H2O) is by more than one order of magnitude stronger at wavelengths above 2 µm than at shorter wavelengths. Especially for carbon monoxide (CO), only the utilization of wavelengths around 2.3 µm enables sensing with a much higher sensitivity for a typical sensor system using tunable diode laser spectroscopy (TDLS). A demonstrator for optical CO measurement at 2.33 µm has recently been developed. CO escaping from home burners is the most frequent cause for unintentional death at home with a death toll of annually 500 persons in the USA.

The common particle-detection based fire detectors have unwanted cross-sensitivities to many substances like water vapor (especially in kitchens or bathrooms), hairspray or general dust. On the other hand, gas-sensor based fire detection seems to be an interesting approach for fire detection with reduced false alarm rates. Due to its absence in ambient air and its toxicity, CO is the prominent gas to be detected for gas sensor based fire detection. In addition, the 2.6-2.65 µm wavelength region shows strong water vapor absorption lines making this range well adapted to water measurements and isotopic ratio studies. This wavelength regime especially at 2.605, 2.596 and 2.594 µm are very important for the detection of water vapor since the strongest water vapor absorption lines are found exactly at these lines. Impressive results are obtained on electrically pumped, singlemode VCSELs at abovementioned emission wavelengths with sufficient optical output power, being well-suited for the targeted application.

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Most laser applications in the near- and mid-infrared spectral region require low-cost laser devices with excellent spectral performance and particularly in sensing applications, emission wavelength tunability. These goals can ideally be achieved by the innovative vertical-cavity surface-emitting lasers (VCSELs) as light sources. VCSEL diodes are the youngest members of the semiconductor laser diode family. In fact, GaAs- and InP-based VCSELs recently revolutionized datacom and optical mouse applications but their wavelength is limited to about 2 µm. On the other hand, classical antimony (Sb)-based diode lasers well work up to wavelengths of at least 3.5 µm, however, their difficult and expensive technology prevented their widespread use. We recently achieved a breakthrough in the realization of first GaSb-based VCSELs operating at 2.3-2.6 µm wavelength paving the way for the 3 µm regime. In the NEMIS project (www.nemis.eu), aiming on the development of compact and packaged vertical-cavity surface-emitting laser diodes (VCSELs) for the 2-3.5 µm wavelength range and pilot photonic sensing systems for trace gas analysis, a demonstrator for optical CO measurement at 2.33 µm has recently been developed. These electrically pumped single-mode and tunable lasers operate continuously with very low threshold currents up to 90°C. Actually, by utilizing VCSELs' most attractive features such as efficient electronic wavelength tuning, several absorption lines of a single gas species can be scanned using the full tuning range of such lasers which already proved their suitability in gas sensing applications.

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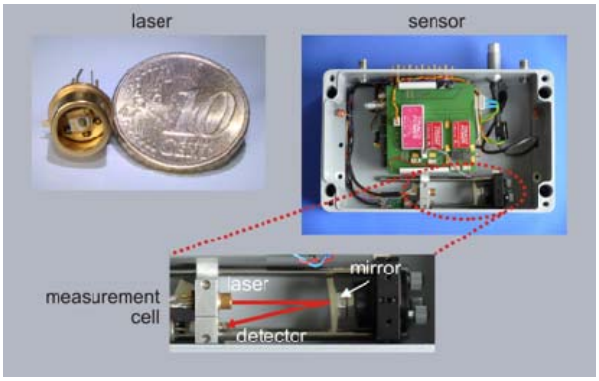

Fig. 1: TDLAS sensor for the detection of CO and packaged GaSb-based VCSEL developed by the NEMIS project consortium.

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1. M. Sigrist et al. *Appl. Phys. B*, **90**, pp. 289–300, 2008.
2. J. Chen et al. in Proc. *Eurosensors XXIII conference*, **1**, pp. 1383-1386, Sep. 2009.
3. Online electronic publication: *http://www.cdc.gov/co/pdfs/faqs.htm 2007*.
4. S. Arafin et al. *Appl. Phys. Lett.*, **95**, pp. 131120-(1-3), 2009.