DFB lasers exceeding 3 µm for industrial applications

LONG WAVELENGTH DFB LASERS. **Extending the monomode emission wavelength of industrial-grade diode lasers enables new applications for gas sensing in the 3.4 µm range. Applications in particular relating to hydrocarbon detection are made possible by the new devices.**

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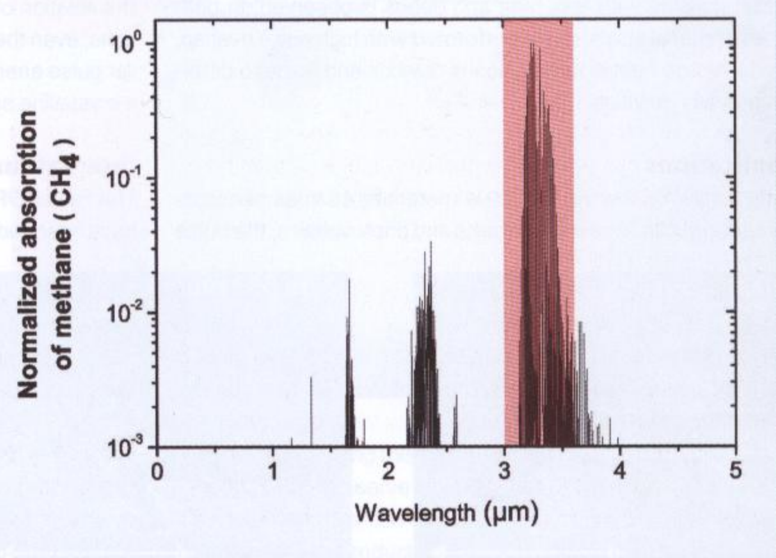
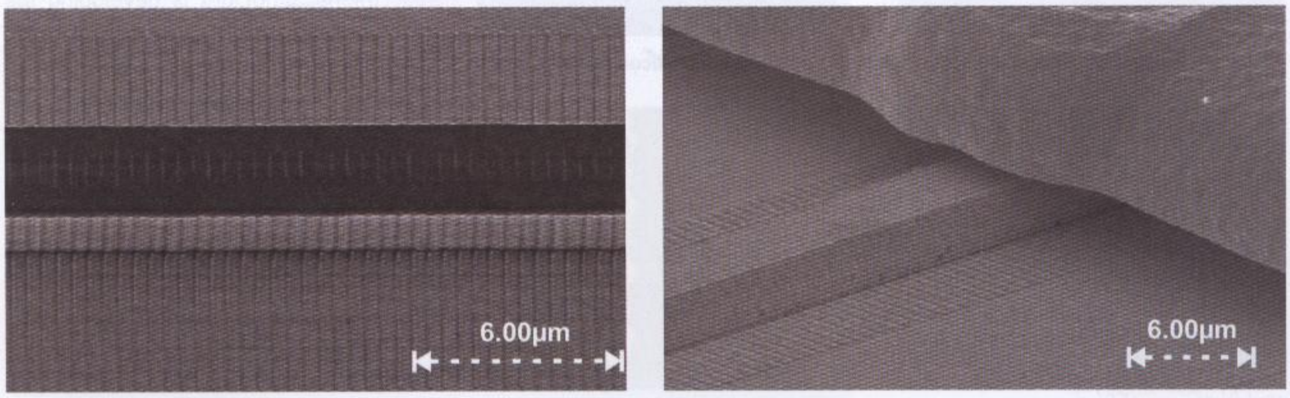
The near infrared (NIR) wavelength range up to 3 µm comprises many absorption features of gases of great relevance for industrial applications, such as water and carbon dioxide, for example. Employing tunable diode laser spectroscopy (TDLS) has proven to be a powerful concept for very fast and highly sensitive detection of gas species in this wavelength range. TDLS exploits the fact that characteristic rotational and vibrational excitation features are unique for each gas species, and, when utilizing a monomode laser, these features can be scanned very selectively.

Highly sensitive detection of hydrocarbons is especially interesting for industrial and automotive applications. Very strong characteristic absorptions (related to fundamental molecular transitions) of most hydrocarbons are located in the longer wavelength mid-infrared (MIR) range around 3.0 to 3.6 µm. They often exceed corresponding NIR absorption strengths by more than an order of magnitude (**Figure 1**) and thus permit TDLS with much higher sensitivity. This type of approach to hydrocarbon detection has so far been impeded by the lack of commercially available industrial-grade monomode laser sources in the wavelength range beyond 3 µm. For an uncomplicated and inexpensive use, suitable lasers ideally operate in continuous wave (cw) mode at room temperature. Within the scope of the European project ›SensHy‹



1 Absorption spectrum of methane
(Source: HITRAN 2004 molecular spectroscopic database)



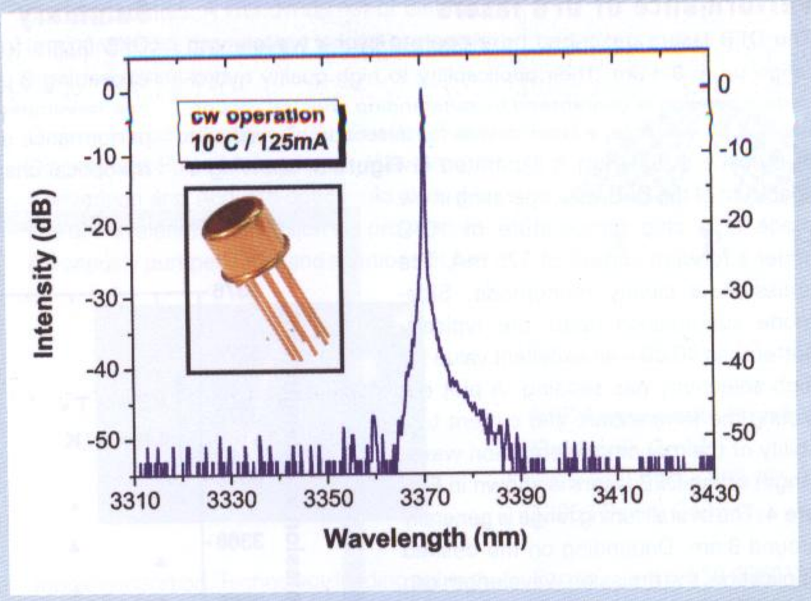
2 DFB laser: ridge waveguide with lateral metal grating (left), and the laser covered with thick gold layer (right)

(*www.senshy.eu*) suitable monomode lasers have been developed by nanoplus, demonstrating previously unattained performance. They enable a new level of qualitative monitoring techniques using TDLS up to a wavelength of 3.4 µm, for example for hydrocarbon detection.

DFB laser production technology

nanoplus is an internationally leading supplier of high quality laser sources for gas sensing applications in the visible, NIR and MIR wavelength ranges [1]. The newly developed lasers presented here are produced using the company's proprietary technology base to fabricate monomode, distributed feedback (DFB) diode lasers. Semiconductor laser material for emission >3 µm is used for DFB fabrication based on lateral metal gratings. The grating structures, with dimensions around 150 nm, are defined next to the sidewalls of etched ridge waveguide structures using highly accurate e-beam lithography. The structures are then patterned by metal evaporation, resulting in DFB laser devices as shown in **Figure 2a**.

This patented, cost-effective approach has been well-established at nanoplus for more than ten years. It shows a high DFB yield and eliminates the need for epitaxial overgrowth in the production of the laser layers. An impairment of laser performance due to the insertion of patterning-induced defects near the active region is therefore avoided. Taking increased internal losses in high wavelength diode laser structures into consideration, the processing route is customized for high performance. Therefore the laser ridge waveguides are surrounded by a gold layer of high thermal conductivity (**Figure 2b**) for improved heat removal and equipped with a highly reflective backside gold coating for increased optical output efficiency. DFB devices can be exactly matched to their designated application in TDLS sensing and are subsequently mounted onto TO-headers with internal temperature controllers (see inset of **Figure 3**). Hermetical sealing of those headers in a dry nitrogen atmosphere yields application-ready, packaged DFB laser devices protected from humidity or the hazard of mechanical destruction.



3 **Spectrum of a packaged (TO5, inset), industrial-grade DFB laser emitting around 3.37 µm in cw operation at 10°C and 125 mA [3]**

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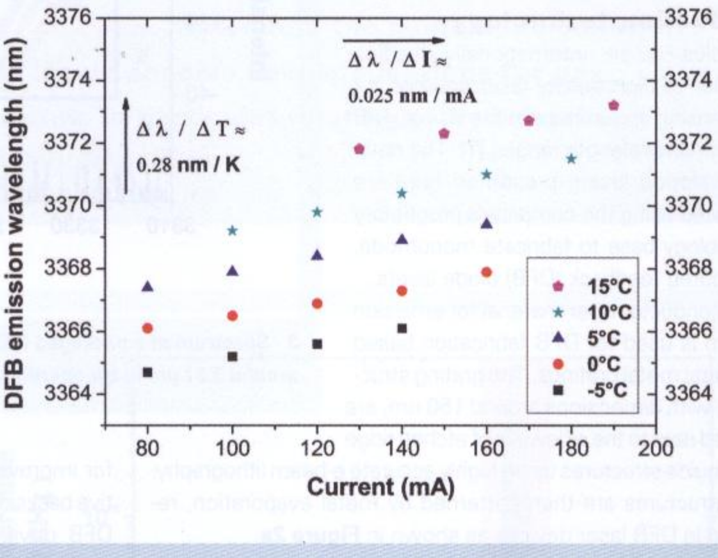
Performance of DFB lasers

The DFB lasers described here operate in the wavelength range up to 3.4 µm. Their applicability to high quality hydrocarbon sensing is guaranteed by outstanding spectral properties. As an example, a laser device for detection of methane or propane at 3.37 µm is illustrated in **Figure 3**, showing a spectrum of the DFB laser operating in cw mode at a chip temperature of 10°C under a forward current of 125 mA. The emission is clearly monomode. Side-mode suppression ratios are typically better than 40 dB – an excellent value for high selectivity gas sensing. A plot depicting the temperature and current tunability of the monomode emission wavelength of the DFB lasers is shown in **Figure 4**. The overall tuning range is generally around 9 nm. Depending on the desired application, the emission wavelength can be set by adjusting the corresponding Peltier-controlled chip temperature, exhibiting temperature tuning of around 0.28 nm/K. Very fast current tuning of the emission wavelength in a TDLS application can then be performed with a typical tuning coefficient on the order of 0.025 nm/mA. Wavelength ranges of around 2 nm can be sampled in this manner.



4 DFB emission wavelength tuning by variation of the operation current at different chip temperatures [3]

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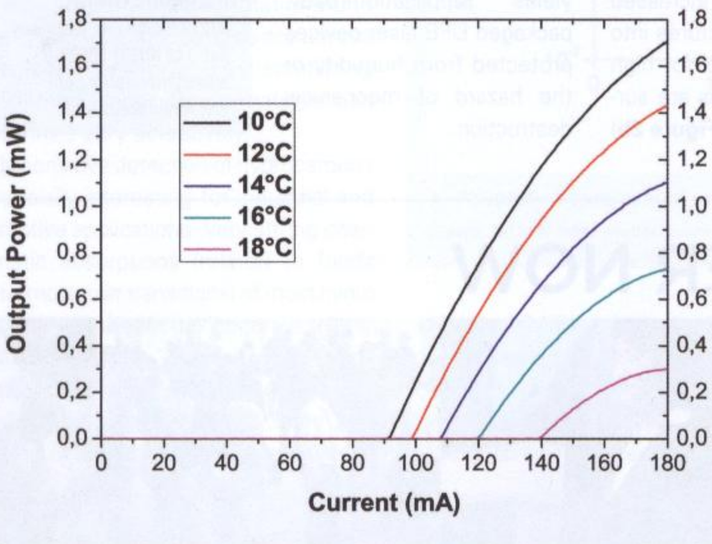

5 cw L-I characteristics of a DFB laser with emission around 3.37 µm at different chip temperatures [3]

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These long wavelength DFB lasers are capable of cw operation up to temperatures around 20°C. **Figure 5** shows typical L-I characteristics of a laser for selected chip temperatures. At an operating temperature of 10°C the laser output power exceeds 1.5 mW, enabling high sensitivity detection in TDLS applications. Higher power options are currently under development at nanoplus, as well as even larger wavelength coverage.

Summary

DFB lasers for TDLS applications in the wavelength range exceeding 3 µm are now commercially available. nanoplus has developed corresponding devices with industrial-grade performance up to wavelengths of 3.4 µm. Spectral and electro-optical characteristics of the lasers qualify them for high sensitivity and high selectivity spectroscopic applications. Their promising potential has already been demonstrated within the activities of the SensHy project, for example, in detecting acetylene impurities in ethylene and polyethylene manufacturing processes at a wavelength of 3.06 µm [2].

References

1 Zeller, W. et al: 'DFB Lasers between 760nm and 16µm for Sensing Applications', Sensors, 10, 2010, p. 2492-2510 (*www.mdpi.com/1424-8220/10/4/2492*)

2 Kluczynski, P. et al: 'Detection of acetylene impurities in ethylene and polyethylene', Applied Physics B: Lasers and Optics 105, Nr. 2, 2011, p. 427-434

3 Copyright by the Institution of Engineering and Technology: Nähle, L. et al: 'Continuous-wave operation of type-I quantum well DFB laser diodes emitting in 3.4 µm wavelength range around room temperature', Electronics Letters 47 (2011), p. 46

Lars Nähle is a PhD student at the University of Würzburg, working for nanoplus. Within his PhD work he developed DFB lasers with wavelengths larger than 3 µm for gas sensing applications. **Dr. Lars Hildebrandt** is Director of Sales at nanoplus. He received his PhD in physics in 2004 working on tunable external cavity diode lasers.