Dual-wavelength DFB quantum cascade lasers for multi-species trace gas spectroscopy

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Abstract: We report on the design and performance of dual-wavelength distributed-feedback quantum cascade lasers emitting at several wavelengths in the mid-infrared spectrum, based on (i) neighbour QCLs or (ii) Vernier effect combined with digitalized gratings.

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Quantum cascade lasers (QCLs) are unipolar semiconductor devices based on intersubband transitions [1], offering high performance sources in the mid-infrared range, makes them the preferred choice for laser-based trace gas sensing applications [2]. In order to realize broadband spectral coverage, QCL sources with an active region gain that covers a wide spectral range with equilibrated intensity are required, as well as a mode control scheme that allows wavelength selection and tunability over this whole spectral gain. A straightforward approach is to select specific regions of interest in the mid-IR spectrum and probe them with a few multi-wavelength lasers [3].

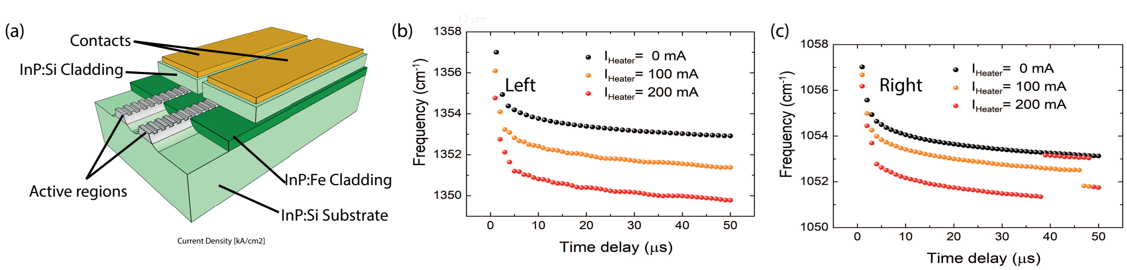

Fig. 1. (a) Schematic of NDFB lasers. (b-c) Tuning of the emission mode frequency for the left and right DFB respectively, over long pulses of 50 μs, for different CW bias currents applied on the neighbouring laser.

In this work, we propose and discuss the realization of two different designs of dual-wavelength distributed-feedback (DFB) quantum cascade lasers, as sources for a multi-species trace gas sensor, at 5.26 and 6.25 μm (1900 and 1600 cm^{-1}), and 7.4 and 9.5 μm (1352 and 1053 cm^{-1}). These spectral regions were chosen in order to measure the most important pollutant and greenhouse gases (NO, NO_2, NH_3, O_3, and SO_2) at their strong absorption lines. By reducing the number of lasers needed for all desired wavelength regions by factor of two, we simplify significantly the complexity of combination optics needed to guide the beams through the same interaction volume and onto the detector [4].

The "Neighbour" DFB (NDFB) design is comprised by two laser ridges which are very close to each other, in the order of a few tens of micrometers, i.e 20 to 35 μm, but each having different, single wavelength DFB gratings, aimed at different resonances. A concept schematic can be found in figure 1a. Figure 1b-c show the application of the neighbour ridge as an integrated heater to extend the tuning range of each DFB laser of the device.

The Vernier effect is exploited on a new type of digitized grating that allows switching between DFB modes that are 300 cm^{-1} apart (see Figure 2). Tuning is thermally induced by two heater sections, (front and back), which are made from wide ridges of the active region, etched in close proximity to the laser ridges (see finite elements simulations in 2a). The front and back heater sections are separated by a narrow dry-etched trench that allows efficient tuning as well as electrical separation between them. The performance and detail of this design can be found elsewhere [5].

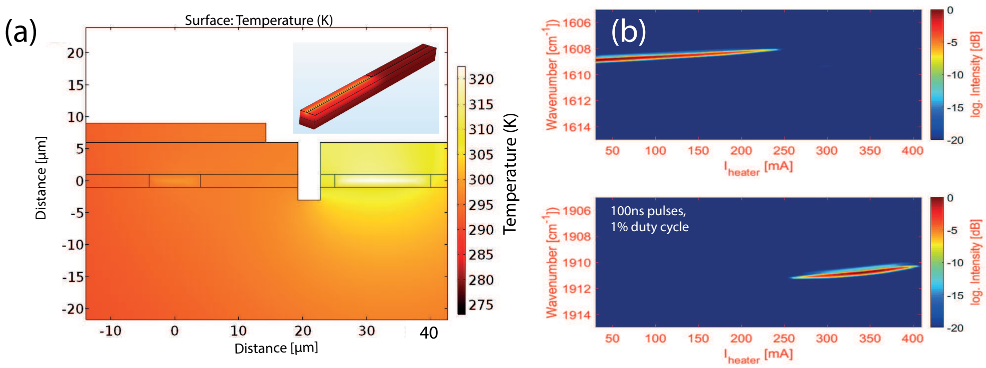

Fig. 2. (a) Finite element simulation (COMSOL) of the heat distribution inside a device, when the front heater is operated. The inset shows the simulation over the whole device. (b) Spectral map of the two channels as a function of the heat CW bias-current, where at $I_{Heater} \approx$ 250 mA, laser frequency switches from lasing at 1600 cm^{-1} channel to 1900 cm^{-1} channel.

References

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