GaSb-based wavelength-tunable single-mode VCSELs for the 2-3 µm wavelength range

Markus-Christian Amann*, Shamsul Arafin

Walter Schottky Institut, Am Coloumbwall 3, 85748 Garching, Germany

Mid-infrared (IR) diode lasers emitting above 2 µm are currently of significant interest for applications in spectroscopy, e.g. trace gas sensing, gas leak detection and chemical gas monitoring. Tunable diode laser absorption spectroscopy (TDLAS) is one of the most powerful techniques for gas analysis due to its higher sensitivity, selectivity and faster response compared to any conventional gas sensors. For TDLAS, laser diodes must operate in true single mode with a sufficiently broad wavelength tunability. Electrically-pumped (EP) VCSELs are the best candidates for this method because they fulfill the above-mentioned requirements as well as because of their cost-effectiveness. Due to material limitations, InP-based devices will probably not reach more than 2.3 µm [1]. In contrast, the GaSb-based material system allows covering the whole mid-IR wavelength regime. Recently, Sb-based quasi-continuous wave (CW) operating EP VCSELs emitting multimode at 2.63 µm were reported [2]. Here, we present EP and CW operating GaSb-based VCSELs with emission wavelengths of 2.35 and 2.6 µm. The devices use buried tunnel junctions (BTJs) and exhibit single-mode operation with SMSR of over 28 dB.

A schematic drawing illustrating the cross-section of the top-emitting VCSEL design is shown in Fig. 1. The structures were grown in two growth steps by solid-source molecular beam epitaxy (MBE). In the first run, the base structure was grown consisting of distributed Bragg reflector (DBR), current spreading layer, active region, and tunnel junction layers. After structuring the tunnel junction, the top current spreading layer and a lattice matched contact layer were grown in the second run. A low-resistive metal-semiconductor contact is realized by evaporating Ti/Pt/Au sequentially at the top and bottom side. Finally, a dielectric DBR is evaporated at the top of the structure.

Devices were tested under CW operation on a temperature controlled heat sink. Fig. 2 shows the *L-I-V* (light output-current-voltage) characteristics of a VCSEL at 2.35 µm with 6 µm diameter denoted as D_{BTJ} in Fig. 1. The maximum CW operating temperature is obtained at 90°C. The current and temperature dependent spectra of the 2.3 µm device are displayed in Fig. 3 (a) and (b), yielding distinct single-mode emission over the entire operating range. The lasers are continuously tunable by change of current and temperature in a range of 10 nm and 20 nm, respectively. In addition, Fig. 4 (a) shows the *L-I-V* characteristics of a VCSEL at 2.6 µm with 7 µm diameter where the current tunability is found to be 0.56 nm/mA, as shown in Fig. 4(b).

The presented devices pave the way for the realization of single-mode VCSELs covering the whole mid-infrared wavelength range using GaSb-technology.

[1] M. Ortsiefer et al., Electron. Lett., 42(11), pp. 640-641, 2006.

[2] A. Ducanchez et al., Electron. Lett.,. 45(5), pp. 265-267, 2009.

* Corresponding author: email: amann@wsi.tum.de

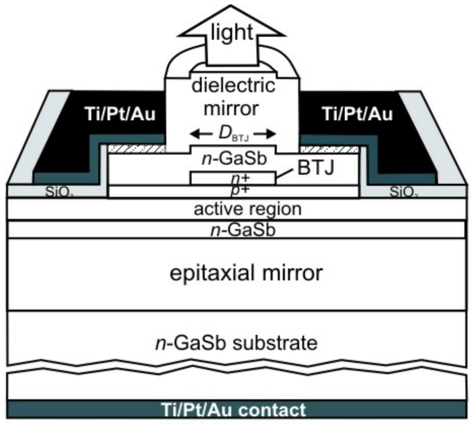

Fig. 1. Schematic cross-sectional view of the 2.3 and 2.6 µm GaSb-based VCSEL structure

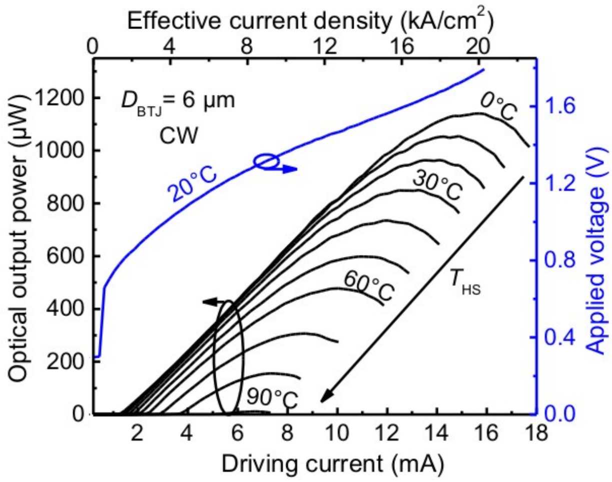

Fig. 2: Temperature dependent *L-I* characteristics of a 2.35 µm GaSb-based VCSEL

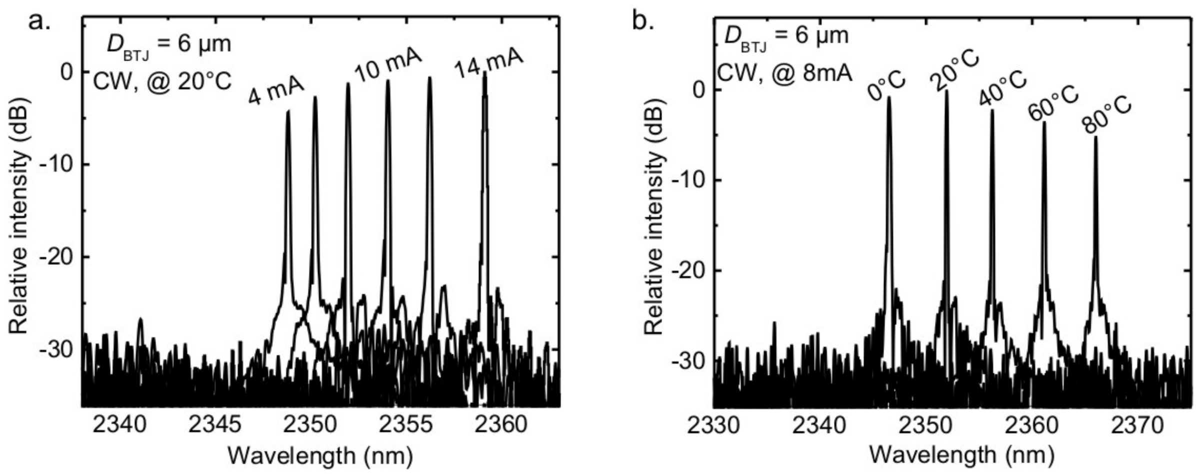

Fig. 3: (a) Spectra of VSCEL by varying driving currents at a constant heatsink temperature of 20°C, yielding a tuning rate of 1.03 nm/mA. (b) Wavelength tunability by changing the heatsink temperature at a constant driving current of 8 mA, yielding a tuning rate of 0.24 nm/K.

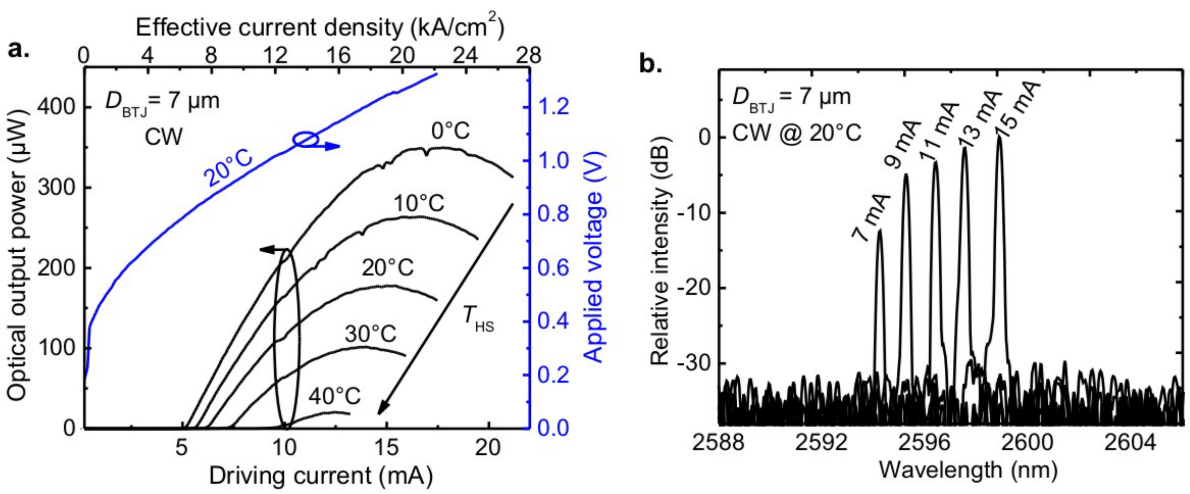

Fig. 4: (a) Temperature dependent *L-I* characteristics of a 2.6 µm GaSb-based VCSEL.(b) Wavelength tunability by varying driving currents at const. heatsink temperature of 20°C, yielding a tuning rate of 0.56 nm/mA