High power DFB laser diodes for gas sensing in rough environments

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Recent years have seen a considerable increase of laser based gas and liquid sensing including fields of application in medical analytics, environmental monitoring or process control.
The significant success of tunable laser diode spectroscopy (TDLS) in these areas is based particularly on its sophisticated detection limits in the range of ppm to ppb [1]. Suitable lasers are an essential pre-requisite of this technological approach. Typical devices for example used for H_2O or OH sensing operate at emission wavelengths in the 2.6 - 2.7 µm range due to the very intense absorption features of both water and hydroxide in this wavelength range. Such laser diodes have typical output power levels of 1-3 mW [2].
In harsh environments characterized e.g. by high dust loads however, the level of particle contamination leads to substantial loss in signal due to Rayleigh-scattering of the light. In this case, TDLS application requirements include a high laser output power. Therefore it can be advisable to trade more intense absorption features for higher laser output power and use corresponding laser diodes at shorter emission wavelengths.
We fabricated longitudinally single mode distributed feedback (DFB) laser diodes with continuous wave (cw) output power levels of more than 150 mW at an emission wavelength of 982 nm.
Applying the DFB concept by defining metal gratings laterally to the ridge waveguide (RWG), longitudinally single mode emission can be achieved without the need for any epitaxial overgrowth. This technique can be applied to a wide range of different material systems [3]. In this case, the RWGs were defined by optical lithography and etched close to the upper waveguide using an electron cyclotron resonance reactive-ion etching (ECR-RIE) process with an Ar–Cl_2 gas-mixture.
Using high resolution electron beam lithography and a lift-off process, first order Cr gratings were defined laterally to the RWGs. Afterwards, the structure was planarized and insulated with benzocyclobutene (BCB), followed by the evaporation, optical definition and etching of the metallic p-contact.
In order to reduce thermal roll-over often limiting achievable output power the contacts were optimized for epi-side down mounting. In a backside lapping step the sample thickness was decreased to 150 µm in order to provide better heat dissipation. Then the metallic n-contact was applied and annealed at 420℃.
After cleaving laser bars, anti- and high-reflection coatings with 5% and 90% reflectivity were applied to the laser facets. Finally the lasers were mounted epi-side down on c-mounts.
An exemplary emission spectrum of one such laser diode is shown in Fig. 1. The high side mode suppression ratio (SMSR) of 49 dB at an operating termperature of 40 ℃ ensures high spectral selectivity during gas sensing. Light output power characteristics of the same device are depicted in Fig. 2. They were measured in cw mode at temperatures of 25 and 45 ℃.

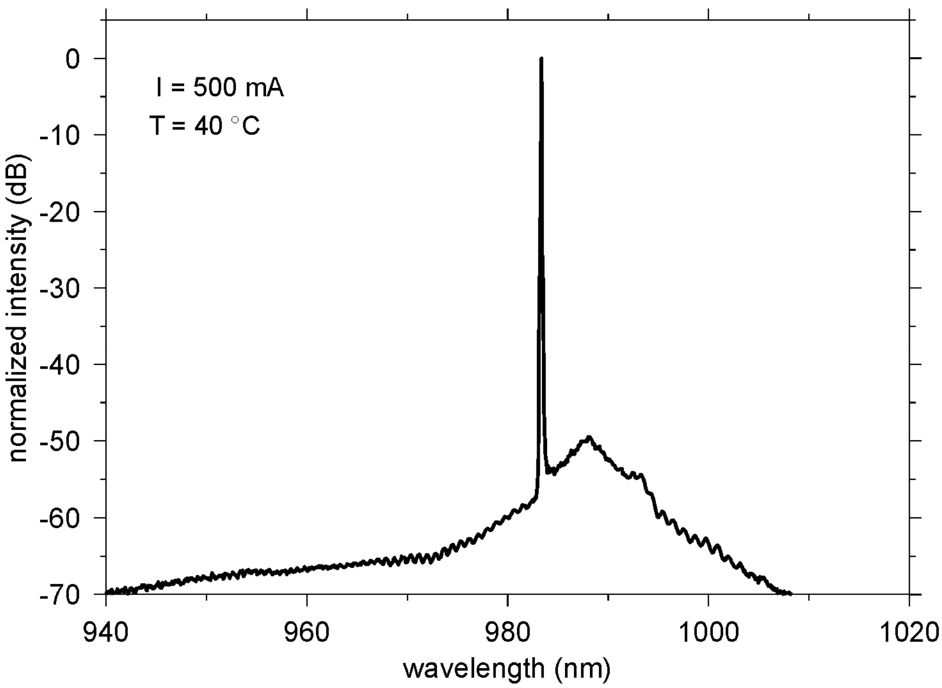

Fig. 1: Emission spectrum recorded at a drive current of 500 mA and a temperature of 40 °C, showing a SMSR of 49 dB.

Both threshold current and slope efficiency exhibit only small changes under temperature variation. The maximum cw output power level of 175 mW is higher than those of lasers typically used for water vapor or OH sensing operating in the 2.6 – 2.7 µm wavelength range by a factor of approximately 50 – 100.

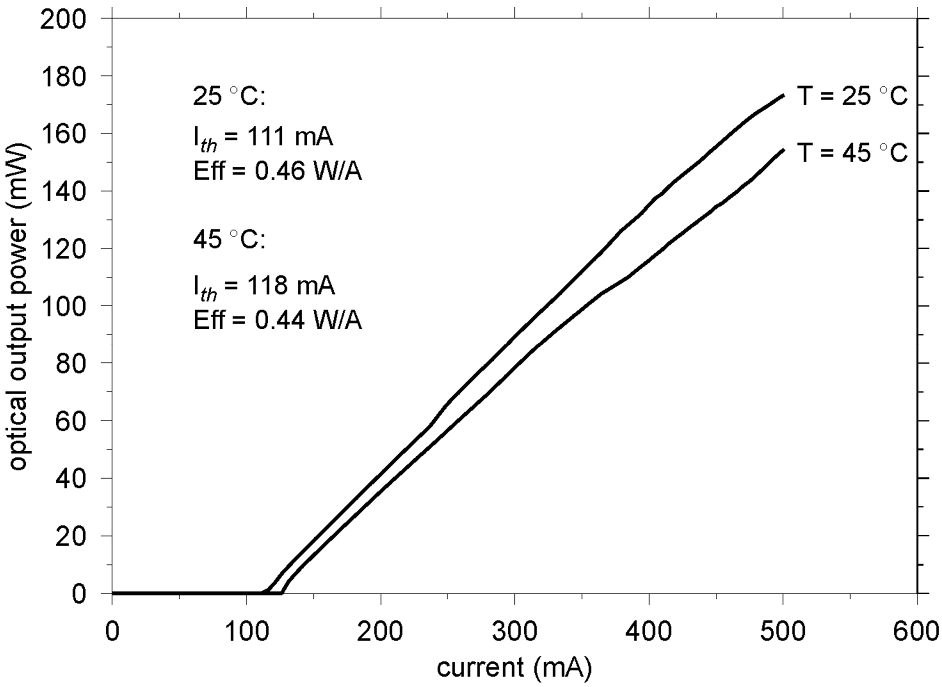

Fig. 2: Light output characteristics recorded at 25 °C and 45 °C.

Fig. 3 shows the current induced wavelength tuning characteristic obtained at an operating temperature of 40 °C. All datapoints in the figure correspond to a SMSR of at least 44 dB. By adjusting the drive current of the laser diode, the emission wavelength can be tuned over a range of 1.3 nm. Due to the epi-side down mounting of the laser diodes, a relatively small current dependency dλ/dT of 0.004 nm/K is observed.

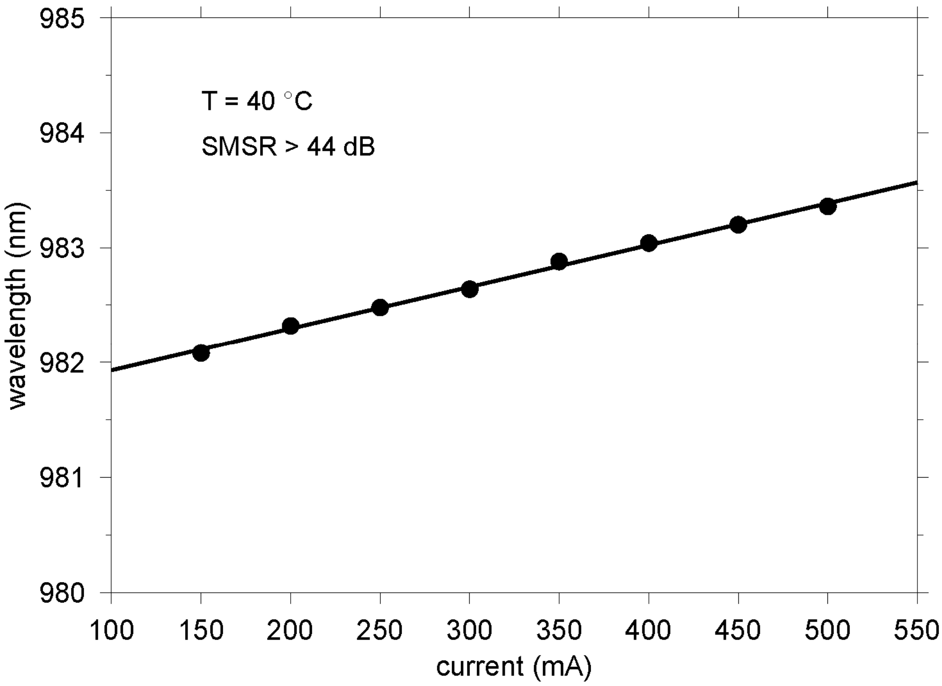

Fig. 3: Wavelength vs drive current measured at a temperature of 40 °C. A wavelength range of 1.3 nm is covered with SMSR > 44 dB.

Laser diodes operating in the wavelength range around 980 nm can be used to scan e.g. for H_2O vapor and OH. Both gas features of course exhibit significantly more intense absorption lines at wavelengths between 2.6 and 2.7 µm. However laser diodes operating at such long wavelengths are usually limited to optical output powers in the range of a few mW. In contrast, the DFB laser diodes presented here are operating with output powers approximately 50 to 100 times higher, therefore enabling the use of TDLS in environments where scattering losses are a problem.

References

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