Singlemode Room-Temperature CW operation and high power pulsed operation of Quantum Cascade Lasers

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Abstract: singlemode 1900 cm^{-1} laser operating in continuous wave based on bound to continuum design is reported, it exhibits a maximum power of 60 mW at -30 °C. Fabry Pérot devices exhibiting 200 mW of average power centred at 2240 cm^{-1} at -30 °C.

OCIS codes: (140.3070) Lasers and laser optics Infrared and far-infrared lasers

1. Introduction

Quantum Cascade Lasers (QCL) have been demonstrated for the first time in 1994[1] at that point devices were operating at cryogenic temperature only. After about 10 years of continuous development it is now a mature field where devices are commercially available. Devices have been shown to operate pulsed or CW up to and above room temperature[2-4]. QCLs have been demonstrated to operate in a vast region of the mid-IR spectrum. Lasers have been demonstrated to operate at wavelength as short as 3.44 μm and up to 19 μm.

In this paper we report on two specific class devices based on the so called "bound to continuum"[5] design and applied to strained compensated devices.

2. QC Lasers for spectroscopy

Chemical spectroscopy is natural field of application of the QC Lasers as it can take advantage of most of the features provided by the technology[6-9]. First, the range of wavelength where the laser emits is overlapping the region of the spectrum known as the fingerprint region. In this region most of the fundamental absorptions lines of molecules are located giving access to high absorption cross section and high selectivity from the uniqueness of these lines. Second, QC lasers provide high power levels with singlemode operation at room temperature, this can be advantageous for photo-acoustic measurements where sensitivity is linear with power. Third, pulsed QC Lasers exhibit linewidth that are compatible with atmospheric pressure broadened lines. In the case of pulsed devices, the measurement system will be of highest importance as it will determine the usable linewidth. A pulsed laser sweeps across a wavelength range due to the heating of the active region that induces an index of refraction change that changes the optical period of the grating selecting the emitted mode. If the measurement system is slow compared to the pulse length, it will observe an average of the emitted wavelength that may be as broad as several wave numbers. Using short pulses, in the order of 10 nanoseconds or long pulses and a fast detection system, it is possible to reduce the linewidth down to about 200 MHz.

It is not always possible to realise the desired measurement with this type of linewidth for example for trace gas measurements in mixtures exhibiting close overlapping lines. In this case the usual approach is to lower the pressure to avoid the overlapping and choose a laser with a linewidth that is smaller than the line separation. In this case only continuous wave operating lasers will provide sufficiently narrow lines[4,10,11].

The laser example presented in figures 1 and 2 is a DFB laser based on a bound to continuum active region design[11]. It exhibits output power of up to 60 mW and operates up to 27 °C. The laser operates singlemode over the temperature range from -30 °C to 27 °C. The measured linewidth is limited to 0.2 cm^{-1} by the FTIR instrument used (Bruker vertex 70).

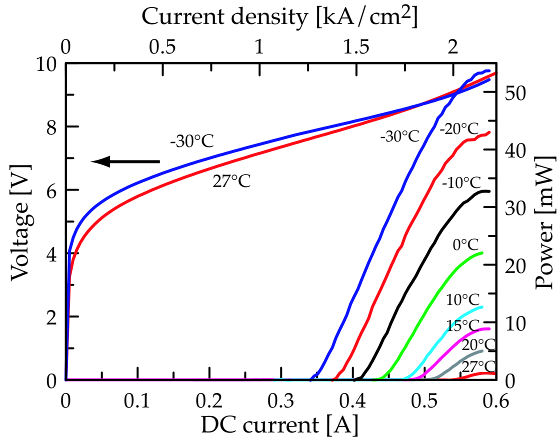

Fig. 1. Light (right vertical axis) and bias voltage (left vertical axis) versus current injected plotted for heat sink temperatures spanning from -30 °C to 27 °C.

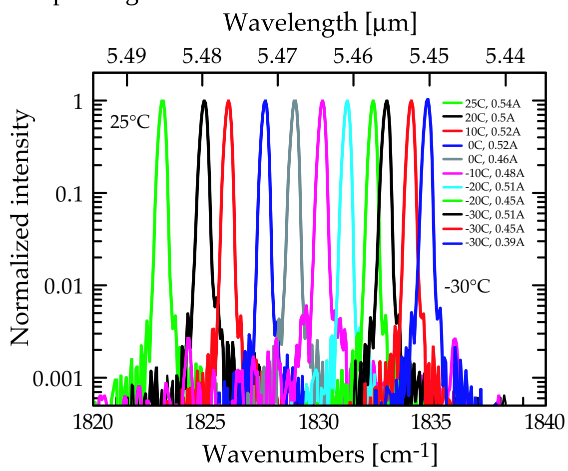

Fig. 2. FTIR spectra plotted for heat sink temperatures spanning from -30 °C to 27 °C.

3. High power QC Laser

Applications such as measurement of broad spectral features in highly absorbing media, for example CO_2 dissolved in water or energy deposition for blinding detectors or photo-acoustic measurements, may require multimode high power lasers. The example presented in figures 3 and 4 is a device based on a two phonon design using strained compensated material and a large optical resonator. The laser was back facet coated with Al_2O_3 and gold, its length was 5 mm, it was mounted epi up with two µm electroplated gold on the stripe.

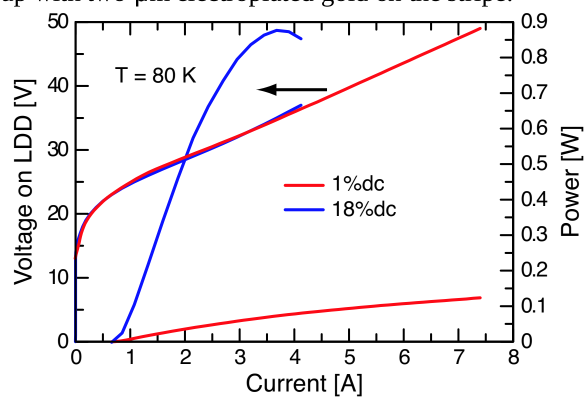

Fig. 3. LDD 100 (Alpes Lasers) bias voltage (left vertical axis) and light (right vertical axis) versus injected current for 1% and 18% duty cycle. The measurement temperature was 80 K and a geometrical calibration was used to compensate for the incomplete collection of the power meter. The measured optical power was multiplied by a factor 1.3 to account for the collection.

The maximum instantaneous power observed at 80 K was 12 W at at maximum power and 1% duty cycle and reduced to 4.7 W when increasing the duty cycle to 18%. The bias voltage indication is overestimating the laser bias voltage by at least 10 volts as in series with the laser are a mosfet transistor with an on resistance of .15 Ω, a ballast resistance of .85 Ω and an imperfect low impedance line composed of four cryogenic 50 Ω wires.

The thermo-electrically cooled measurements at -30 °C, were performed in an Alpes Lasers LLH 100 housing and the pulses were provided by a LDD 100. Optical power was measured using a polished tube to conduct the light to an AN/2 Ophir thermopile head.

The measured peak power at 1% duty cycle was 4 W and reduced to 2.2 W at 8.3% duty cycle.

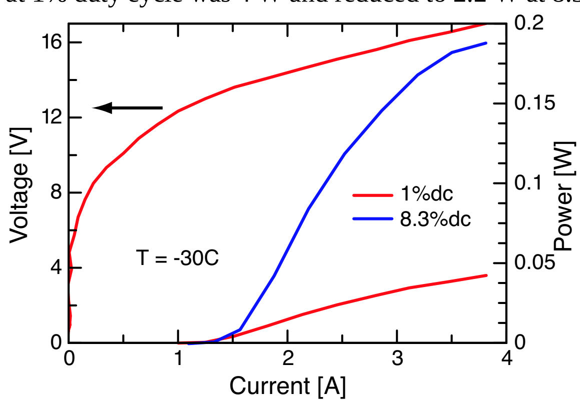

Fig. 4. Bias voltage (left vertical axis) and light (right vertical axis) versus injected current for 1% and 8.3% duty cycle. The measurement temperature was -30 °C.

4. Conclusion

A device suitable for trace gas analysis providing CW light with singlemode spectrum tuned at the NO absorption is presented. A device emitting in the 4 to 5 μm exhibiting up to 800 mW at 80 K is presented.

5. References

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