Room-temperature continuous-wave single-mode quantum cascade lasers

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Team - collaborations

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Outline

• bound-to-continuum RT-CW-DFB-QC lasers fabricated with widely spaced operation frequencies on the same epi wafer around 8\(\mu\)m

• packaged RT-CW-QCL: performances trade off needed by space flight constraints
Design: bound-to-continuum

Bound-to-continuum active region:
• bound state to broad miniband
• homogeneous broadening of the gain
• suitable for CW operation at RT: demonstrated at 1830 and 1900 cm\(^{-1}\)

Should allows fabrication of single frequency devices over a wide range
-> multi-wavelengths gratings
Laser processing: gratings with multi-wavelengths

multiple gratings periodicities ranging from: 
\( \Lambda = 1.185 \ \mu m \) to \( \Lambda = 1.305 \ \mu m \)

- defined by a single photolithography step
- wet-etched (170nm-deep)
- MOVPE InP regrowth

Lasers:
- standard lithography processes and wet etching (11-17\( \mu m \)-wide ridges)
- 3\( \mu m \)-thick gold on top
- cleaved in 1.5mm-long bars
- HR back facet coating
CW DFB QCL at 7.8µm: performances

RT-CW-DFB-50-1270

\[ j_{th} = 2.62 \text{ kA/cm}^2 (+30^\circ \text{C}) \]
\[ T_0 = 113\text{K} \]
\[ T_{\text{max}} = 35^\circ \text{C} \]
\[ \lambda \sim 1206 \text{ cm}^{-1} (8.3\mu\text{m}) \]

\[ j_{th} = 1.87 \text{ kA/cm}^2 (+30^\circ \text{C}) \]
\[ T_0 = 109\text{K} \]
\[ T_{\text{max}} = 60^\circ \text{C} \]
\[ \lambda \sim 1256 \text{ cm}^{-1} (8.0\mu\text{m}) \]

\[ j_{th} = 2.45 \text{ kA/cm}^2 (+30^\circ \text{C}) \]
\[ T_0 = 98\text{K} \]
\[ T_{\text{max}} = 45^\circ \text{C} \]
\[ \lambda \sim 1302 \text{ cm}^{-1} (7.7\mu\text{m}) \]
CW DFB QCL at 7.8µm: spectra

Single-mode emission with SMSR > 25 dB (resolution limited by FTIR)

Wavelength coverage:
One laser: \( \Delta \nu \sim 10-15 \text{ cm}^{-1} \)
In total: \( \Delta \nu > 100 \text{ cm}^{-1} \)
(7.7 - 8.3 µm)

Average \( R_{th} \sim 12.4 \text{ K/W} \)
Average tuning coefficient \( \beta \sim -8.88 \times 10^{-5} \text{ K}^{-1} \)
CW DFB QCL at 7.8μm: wavelength spreading
RT-CW-DFB-50-1270

Average emission wavelength
At T = 0°C
**Alpes Lasers**

**CW DFB QCL at 7.8\(\mu\)m**

**RT-CW-DFB-50-1270**

Electroluminescence and oscillator strengths

\[ j_{th} (@+30^\circ C) \] for all measured lasers
A QCL on Mars

QCL for Tunable Laser Spectrometer integrated in the Sample Analysis at Mars Instrument Suite (SAM).
SAM: component of the Mars Science Laboratory (MSL).

MSL goal: chemical composition of different gases present at the surface of Mars
-> “suitable information to determine if the conditions of life have been previously assembled on the planet”

QCL mission: measurements of isotopic ratio at 7.79 µm
Laser / module specifications

- Wavelength: 1283.6 cm\(^{-1}\) (7.79 µm)
- Relative tuning range: 1 cm\(^{-1}\) (1283.1 - 1284.1 cm\(^{-1}\))
- Spectral linewidth: < 20 MHz (RT-CW)
- Heatsink temperature: 305 K
- Laser temperature: 20-25°C
- Max. laser I / V: 600 mA / 10 V (6 W max.)
- Output power: > 2 mW

- Max. cooler I / V: 2.1 A / 4.5 V (9.45 W max.)

Shall survive the trip!

-> MIL specifications:
5000 hours of operation, radiation, heating, thermal cycles (-40 to +85°C), mechanical shocks, acceleration (up to 20g),…
**Used technology**

Laser:
CW-RT QCL at 7.8\(\mu\)m shown previously
Fluxless soldering with AuSn
HR back-facet coating

Module:
AlN carrier
AlN heat spreader
High-performance Peltier cooler
ZnSe window
Thermistor
Hermetically sealed
Final module

Size: 47.2 x 25.4 x 11.2 mm
Preliminary lifetime measurements

Ageing module #A3, cw, 20C
Alpes Lasers