Long wavelength Distributed Feedback Tapered Quantum Cascade Lasers

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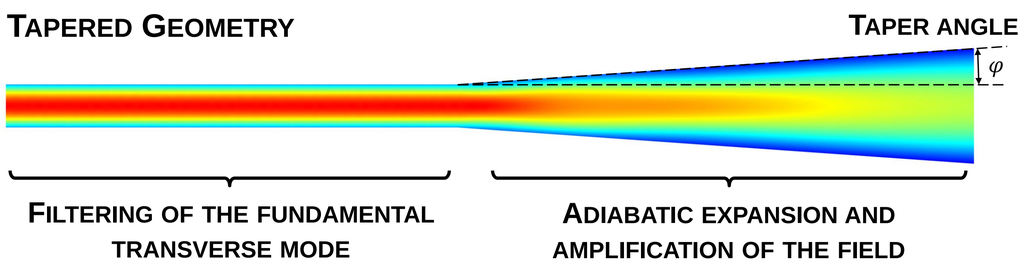
1. Introduction & motivation

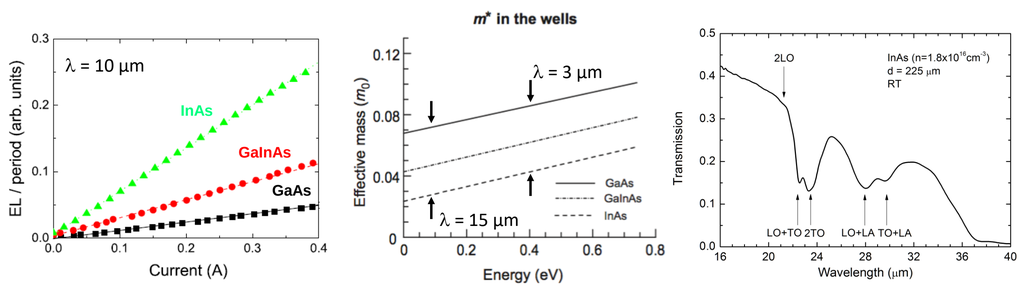
- Long-wavelength Quantum Cascade Lasers (LW-QCLs) find application in several fields, such as in **molecular spectroscopy**
- The small photon energy reduces the output power, requiring strategies to overcome this limitation: **high-power** and **good beam quality** are often desired for better performances
- **Tapered lasers** deliver higher output power, preserving beam quality and reducing beam divergence along the slow-axis



2. LW-QCLs features and fabrication protocol

2.1 InAs/AlSb system

- LW-QCLs are based on **InAs/AlSb system** to exploit small m_e^* of InAs quantum wells
- Weak multiphonon absorption below 20 µm due to small phonon energies considerably reduces waveguide losses



E. Benveniste et al., Appl. Phys. Lett. 93, 131108 (2008) - MPQ

2.2 Fabrication protocol of DFB Tapered LW-QCL

1. E-beam lithography and ICP etching define the grating on top of the waveguide
2. Photolithography is used for tapered MESAs, followed by wet chemical etching
3. Photolithography for insulation aperture via photoresist hard baking
4. Top contact metallization via Ti/Au/Cr/Au e-beam evaporation

***Figure 1**. Tapered LW-QCLs with angles of 0°, 0.5°, 1° and 1.5° - indicated with A, B, C and D, respectively.*

***Figure 2.** Straight-side facet of DFB-LW-QCL under SEM.*

3. Results

3.1 Electrical Characterization

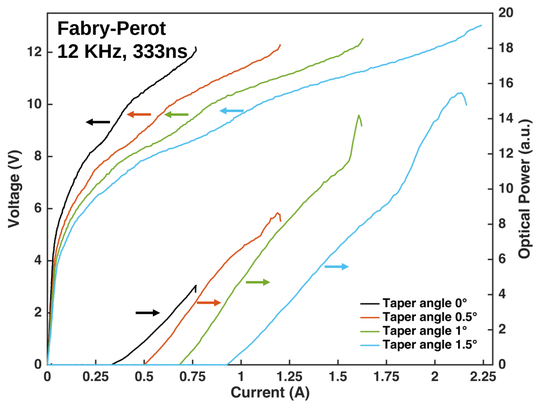


***Figure 3.** LIV curves of Fabry-Perot devices.*

- Tapered lasers exhibit **increased optical power** output compared to straight lasers
- Slope efficiency can be affected by the measurement's **collection efficiency**

3.2 Spectral Characterization

- **Single-longitudinal mode** was obtained for every taper angle
- Side-mode suppression ratio (SMSR) greater than 20 dB was achieved
- Suitable for **spectroscopic applications** for BTEX detection

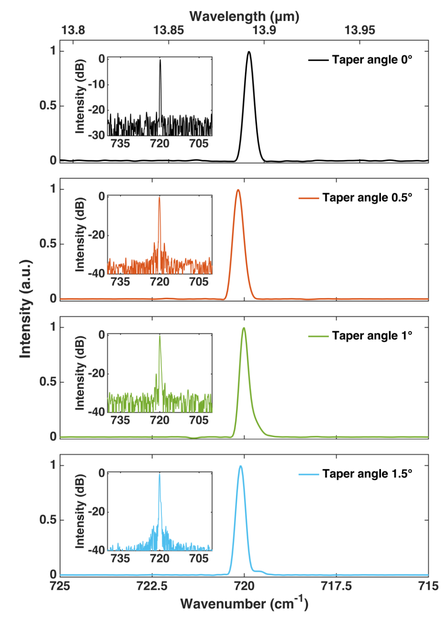


***Figure 4.** Spectral characterization of the DFB-tapered QCLs.*

3.3 Beam Quality

Beam quality factor

$$M^2 = \frac{4\pi\sigma_0\sigma_\theta}{\lambda}$$

$\sigma_{0(\theta)}$ standard deviation of spatial (angular) intensity distribution

Taper angle	σ_θ	M^2
0°	~ 26°	~ 1
0.5°	8.1°	1.05
1°	5.1°	1.07
1.5°	3.6°	1.09

***Table 1.** Summary of the angular emission-field properties of the tapered lasers.*

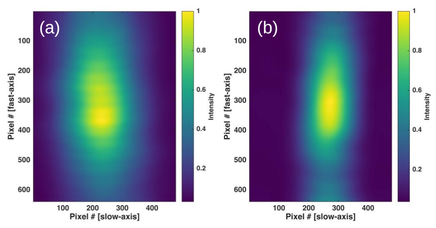


***Figure 5.** Far-field intensity profile recorded with IR-camera of 0.5° (a) and 1° (b) lasers.*

- **Reduced slow-axis divergence** in tapered devices
- Excellent **beam quality factor**
- Insurgence of side lobes at higher operative currents

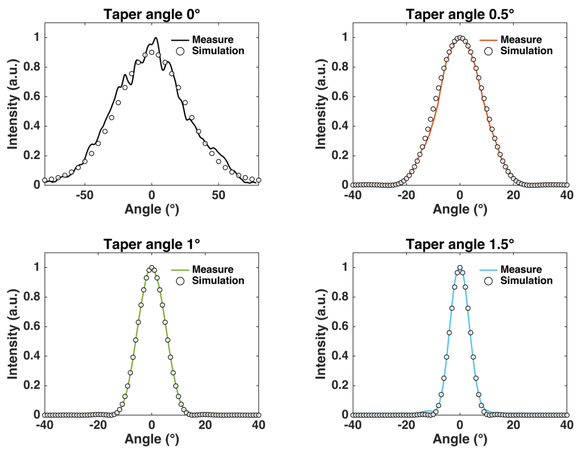


***Figure 6.** Angular intensity distribution for different taper angles.*

4. Conclusions & Outlooks

- Tapered LW-QCLs demonstrated an **improved power output**, together with a **reduced slow-axis divergence**
- DFB-Tapered QCLs emitted in single-longitudinal mode with a SMSR greater than 20 dB

Further development

- HR and AR coating for further improvement of the outcoupled optical power
- **Fine tuning** of the grating periodicity for spectroscopic applications

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