

Edge Emitting InP based Quantum Cascade Microlasers with deeply etched Bragg Mirrors



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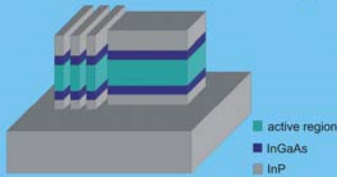


Objective

Single mode emission of lasers operating in the mid-infrared wavelength regime is desirable for a broad field of applications (e.g. gas-sensing)

Short cavity length leads to a large Fabry-Perot-modes spacing and hence to single mode emission

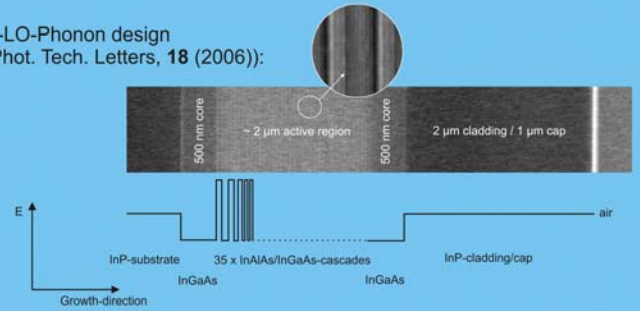
➔ Microlasers with deeply etched distributed Bragg reflectors



MBE-Growth

Structure is grown on lowly doped InP-substrate by a gas-source MBE-system
35 cascades of lattice matched InAlAs/InGaAs add up to a total layer thickness of 6.7 μm

Based on 2-LO-Phonon design (Liu et al., Phot. Tech. Letters, **18** (2006)):



Sample- / Device-Processing

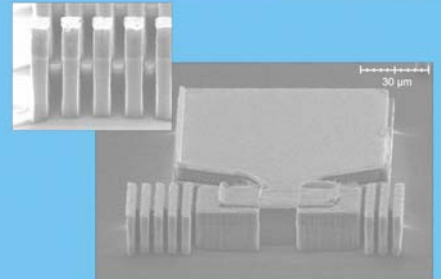
Bragg reflectors defined by e-beam lithography

One-step dry etching process by inductively coupled plasma etching provides smooth edges and perpendicular sidewalls without damaging Al-containing layers

Minimum etching depth of 7 μm required \rightarrow dry etching with Cl_2/Ar -mixture

Etching parameters: Cl_2/Ar -mixture ratio 1:3, chamber pressure 0.003 mbar, temperature = 100°C, time = 10 min, HF/ICP-powers 175/350 W

Cleaved devices are soldered epi-side up on copper heatsinks

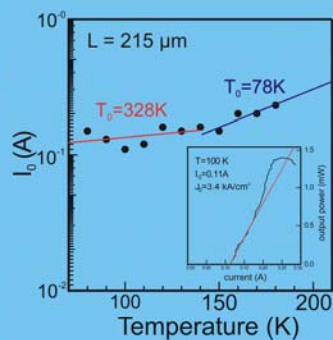
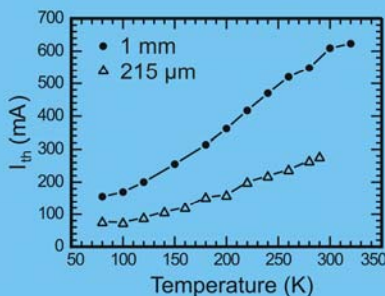


J. Semmel et al., APL, **91**, 071104 (2007)

Basic Characterization

Light output characteristics of a 215 μm long cavity with Bragg reflectors at both ends (HR: 5; AR: 3) show good temperature stability up to 150 K

$I_{th} = 110 \text{ mA} @ 100 \text{ K}$



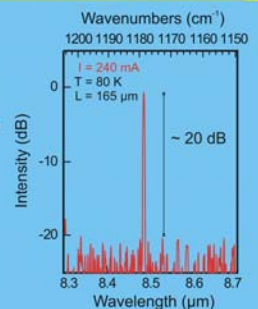
Comparison of threshold current of two identically processed devices with different cavity lengths yield a mirror reflectivity of ~ 0.7

Spectral Characteristics

Devices are measured in pulsed operation (pulse width: 100 ns / repetition rate: 9 kHz)

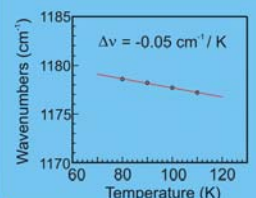
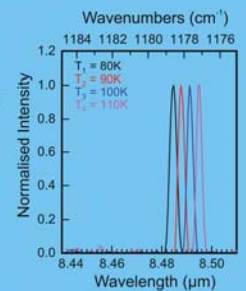
High resolution emission spectra of a 165 μm long device show SMSR of about 20 dB

Single mode emission can be ascribed to larger Fabry-Perot-modes spacing because of shorter cavity length



Wavelength shifts with increasing heat sink temperature with a ratio of $\Delta\nu = -0.05 \text{ cm}^{-1} / \text{K}$

Comparable temperature dependent shift of wavelength can be observed for DFB lasers with surface grating



Acknowledgement

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Summary

In conclusion, quantum cascade microlasers with deeply etched one-dimensional photonic crystals (Bragg reflectors) based on InP have been fabricated. In order to achieve the required high aspect ratio and etching depth of at least 7 μm a one-step dry etching process has been developed. The devices show single mode emission with a SMSR of $\sim 20 \text{ dB}$ due to a larger Fabry-Perot-modes spacing with decreasing cavity lengths.