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

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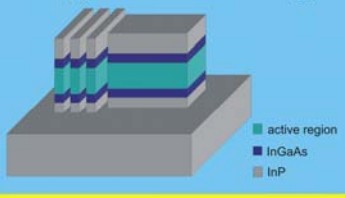
Objective

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

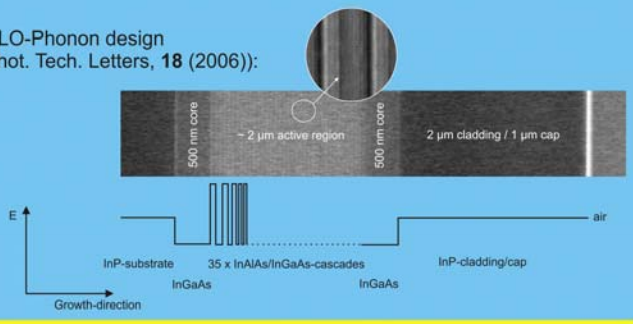


MBE-Growth

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

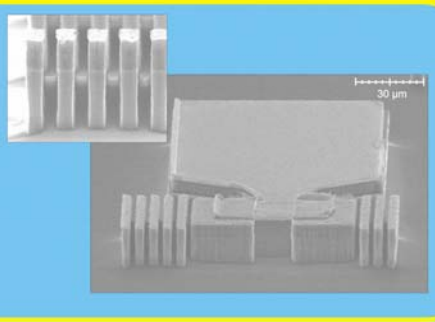
One-step dry etching process by inductively coupled plasma etching provides smooth edges and perpendicular sidewalls without damaging Al-containing layers

Minimum etching depth of 7 µm required → 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

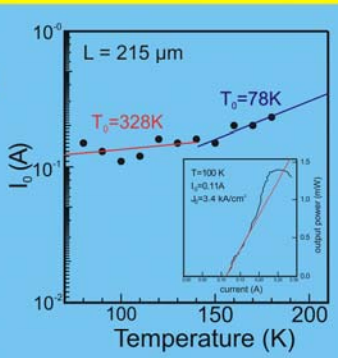
J. Semmel et al., APL, **91**, 071104 (2007)

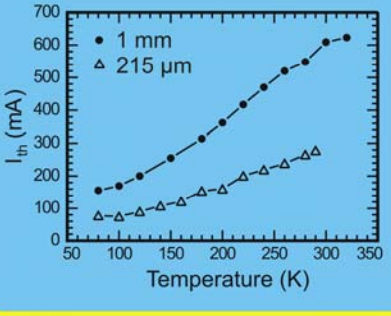


Basic Characterization

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 mA @ 100 K





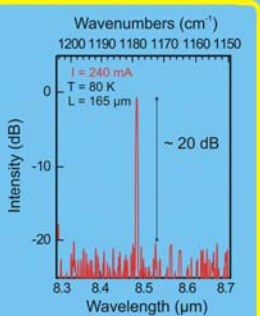
Comparison of threshold current of two identically processed devices with different cavity lenghts yield a mirror reflectivity of ~ 0.7

Spectral Characteristics

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

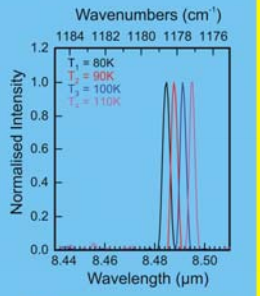
High resolution emission spectra of a 165 µm long device show SMSR of about 20 dB

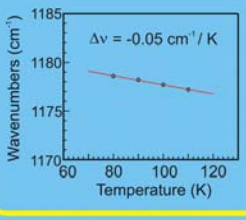
Single mode emission can be ascribed to larger Fabry-Perot-modes spacing because of shorter cavity length



Wavelength shifts with increasing heat sink temperature with a ratio of $\Delta\nu$ = -0.05 cm^{-1} / 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 ~ 20 dB due to a larger Fabry-Perot-modes spacing with decreasing cavity lengths.