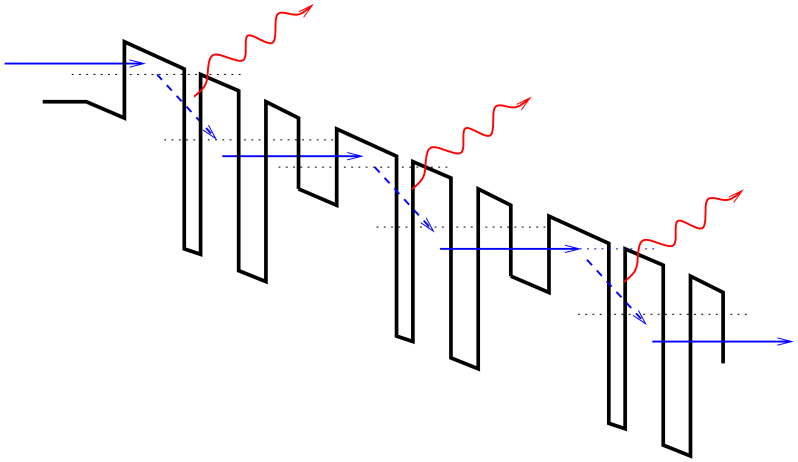
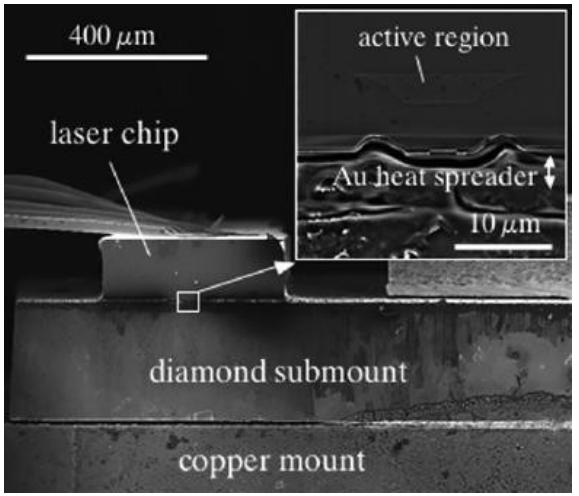
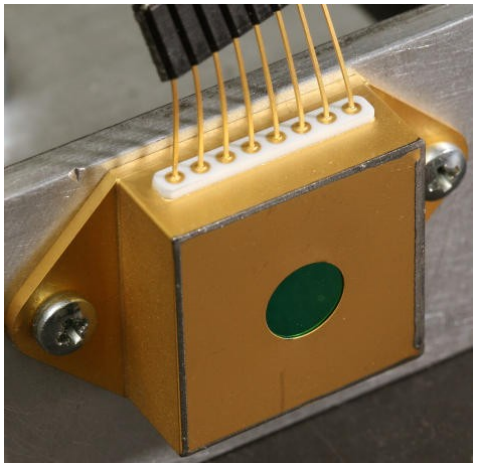
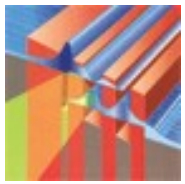
Photonic Sensors Workshop: Quantum Cascade Lasers









Quantum OptoElectronics group

Yargo Bonetti

ETH
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Swiss Federal Institute of Technology Zurich

2009-9-17

Topics

- What do we work on at QOE?
- QCL principles: physics and production
- Simulations of QCL structures
- MIR QCLs and applications
- FIR (THz) QCLs and applications
- FIR and MIR projects

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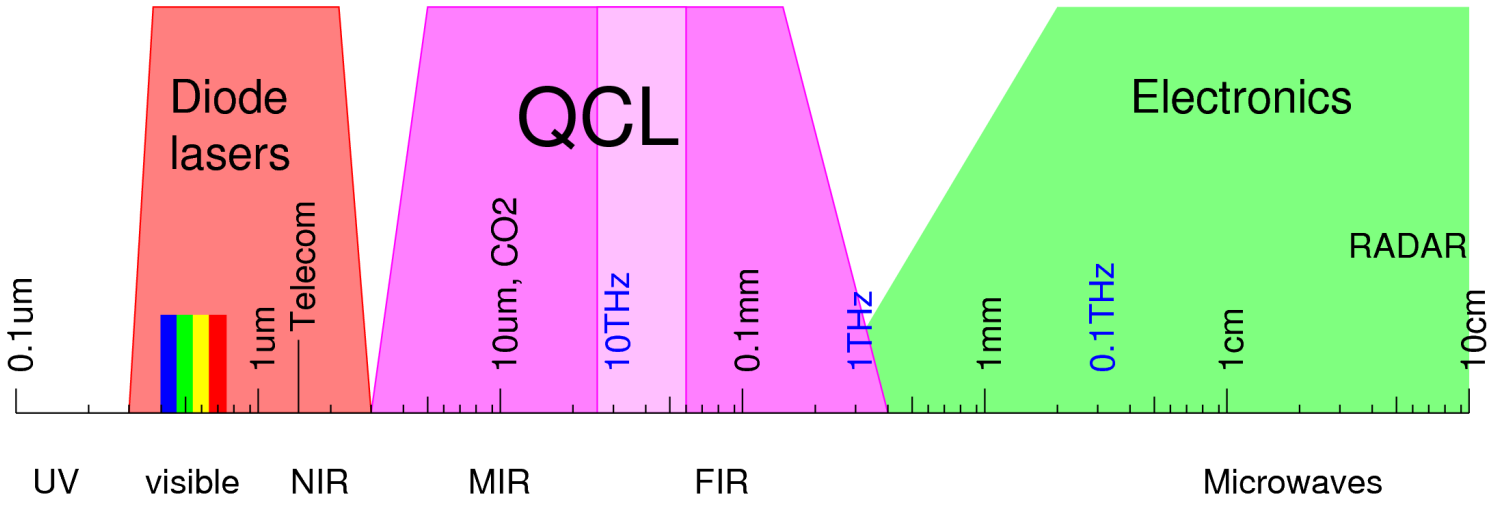

- MIR & FIR QCL
- QCL in External Cavity
- QCL in Magnetic Field
- Gain and Transport Modelling

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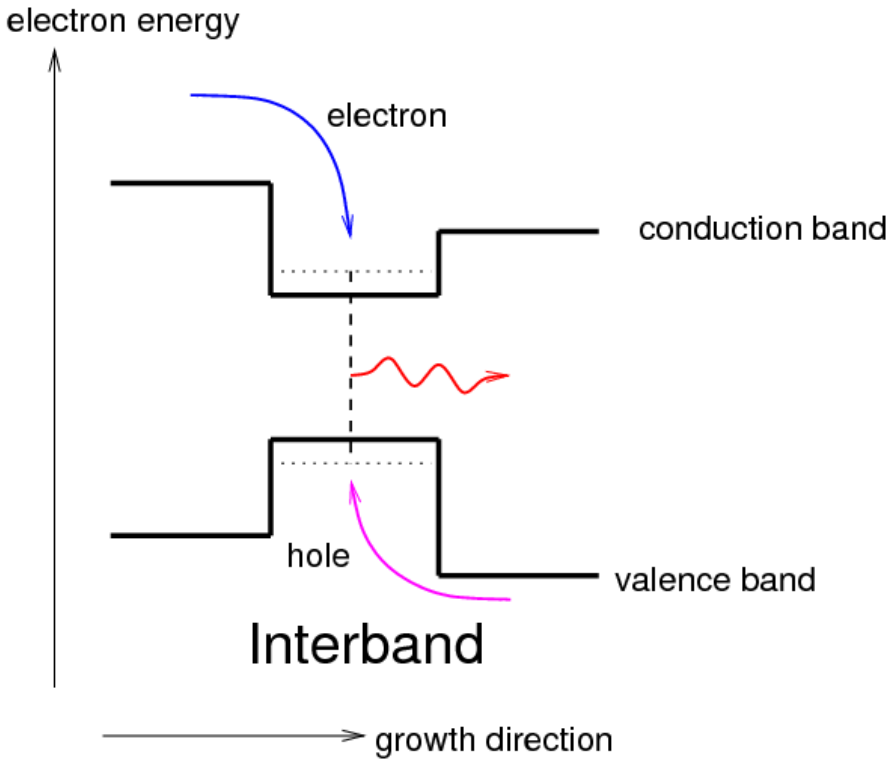
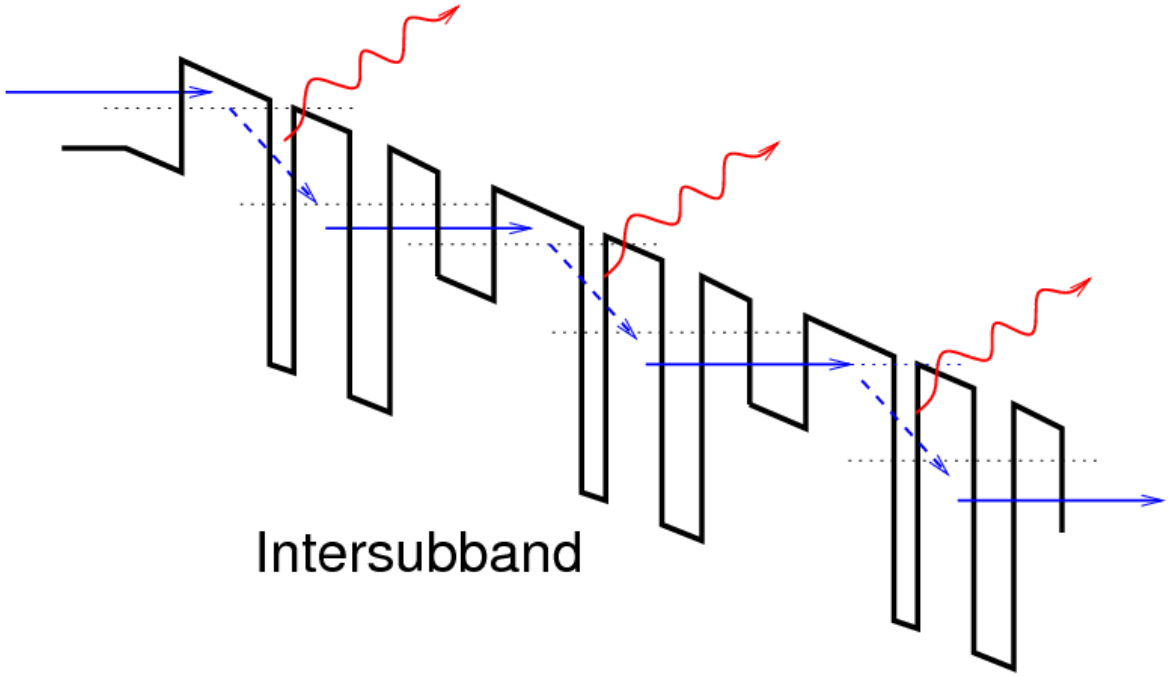
QC Laser Principle

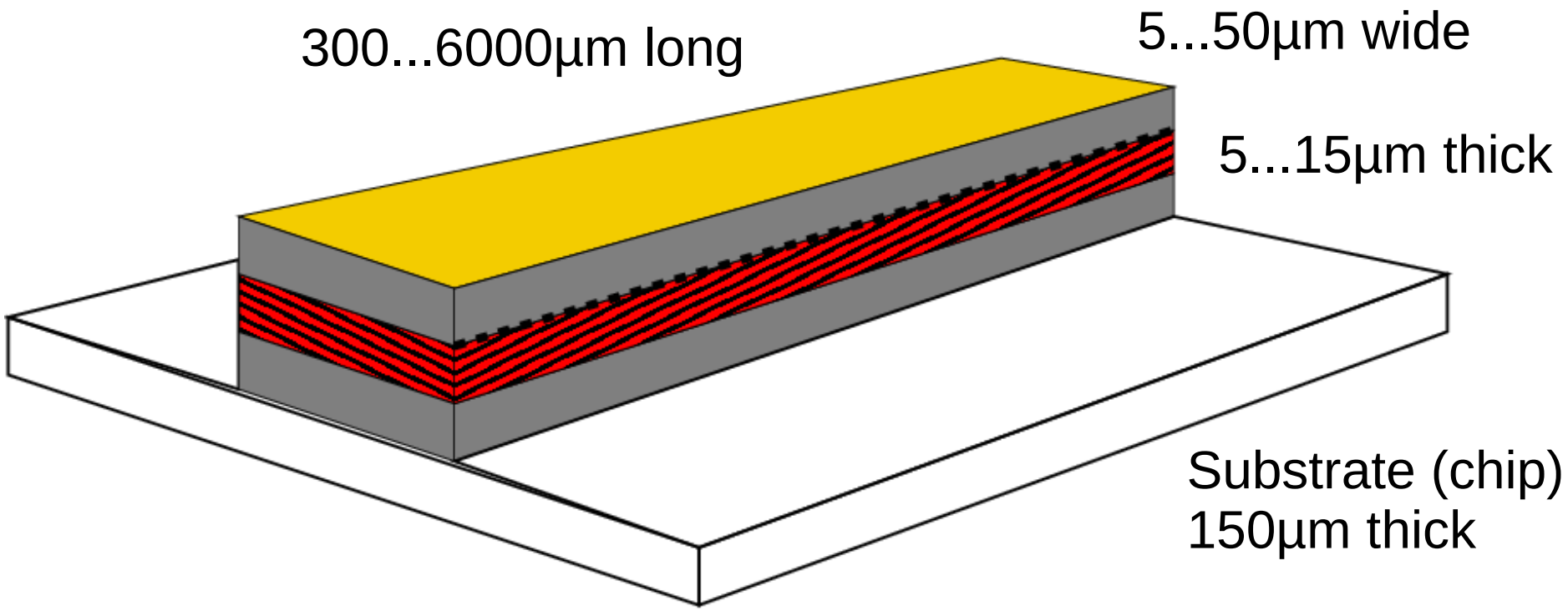




- Recombination of electrons and holes
- Photon energy defined by band-gap

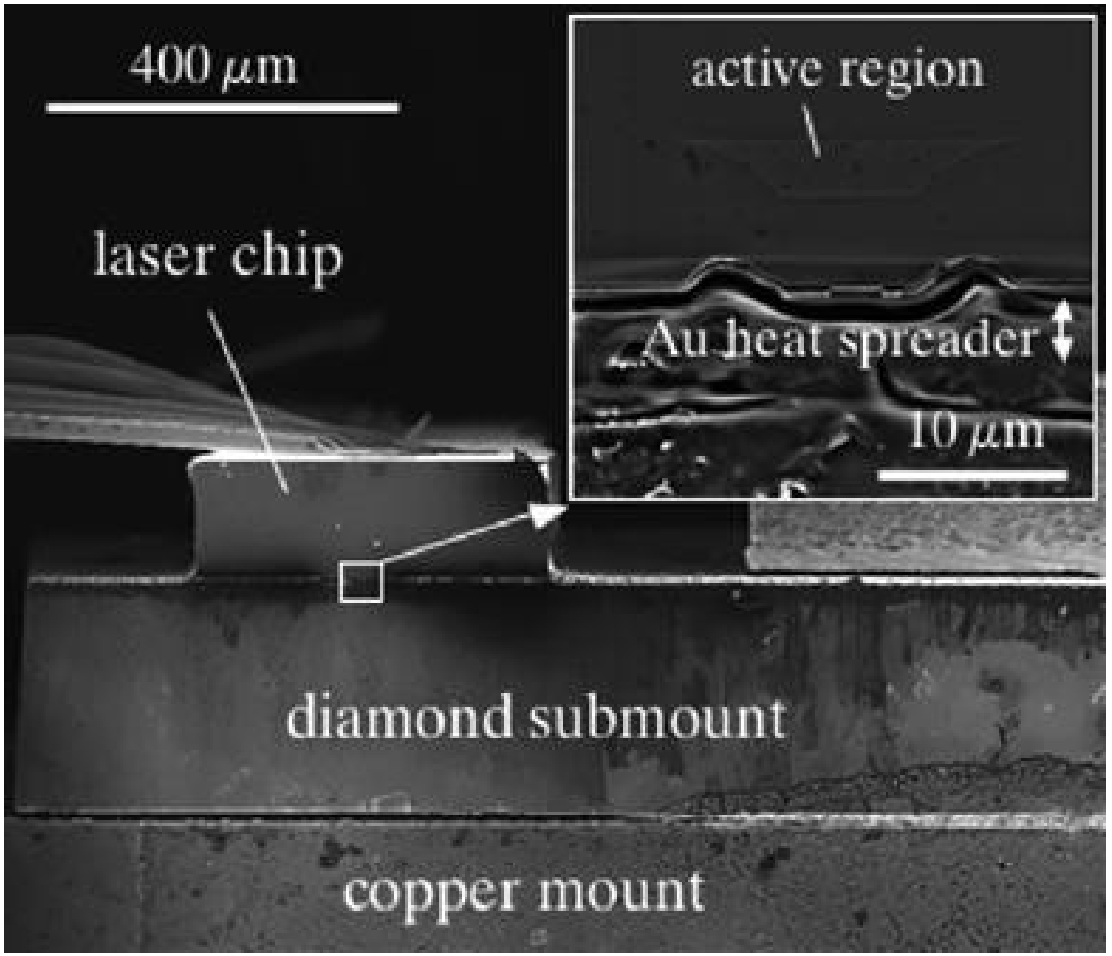
- De-excitation of electrons in cascade
- Photon energy defined by energy levels: band-structure engineering, wells&barriers

Processing of Laser Ridges, and Mounting



- MBE or MOVPE for waveguides and active zone
- Photolithography for DFB gratings and ridge
- Additional MOVPE regrowth for buried ridge
- Mounting (soldering) onto C/AlN/Cu, and wire-bonding

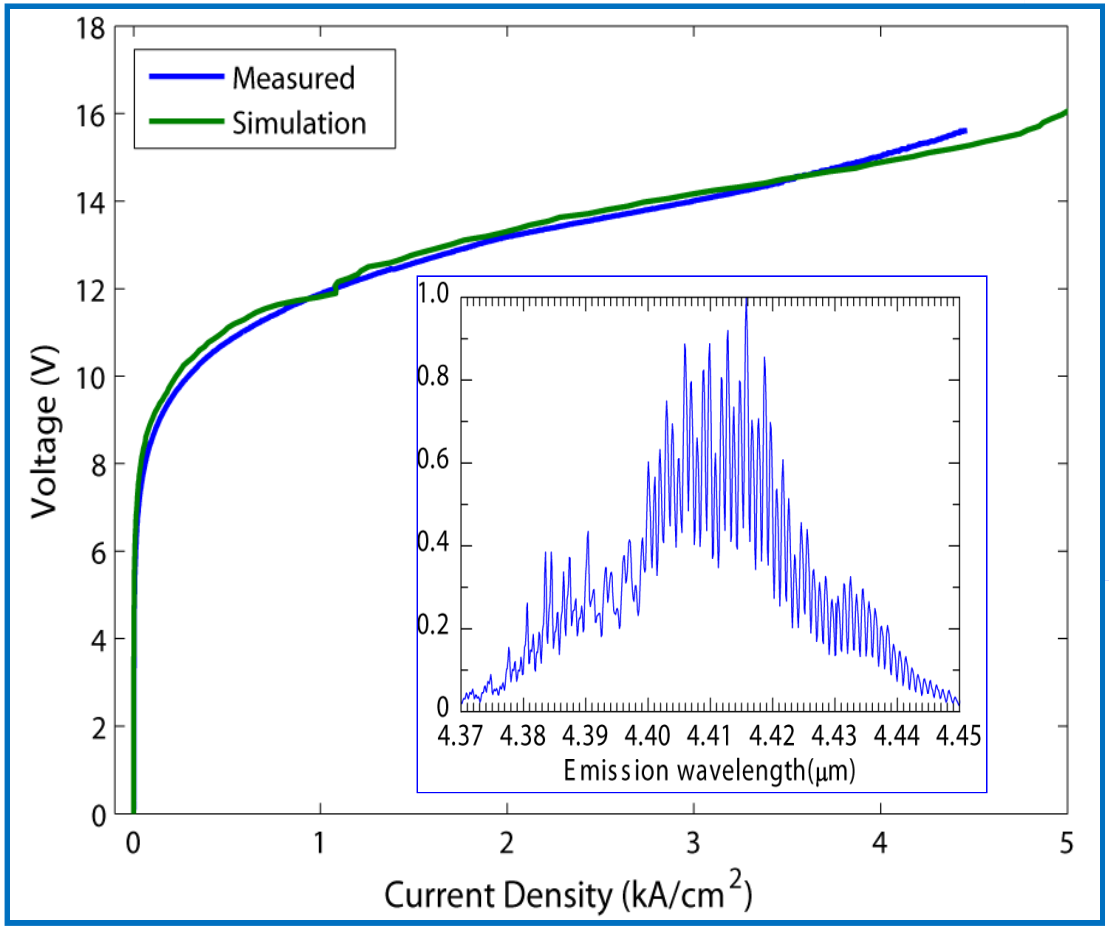
Example of mounted QCL

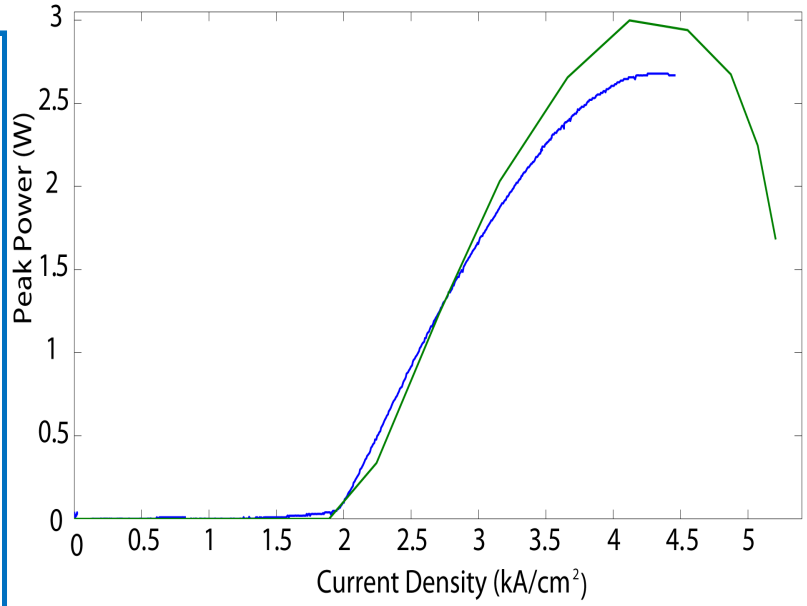


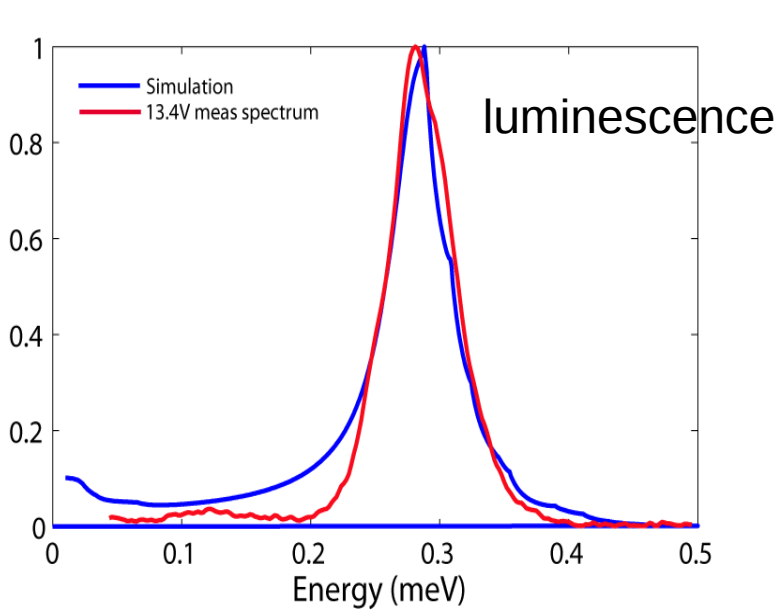
Buried active zone („buried het“) 8..9µm CW DFB QCL

A.Wittmann et al, IEEE J.Quant.Elec. 44,11,p1083 (2008)

Simulations of QCL structures







4.4μm CW QCL at room temperature

A.Bismuto, R.Terazzi

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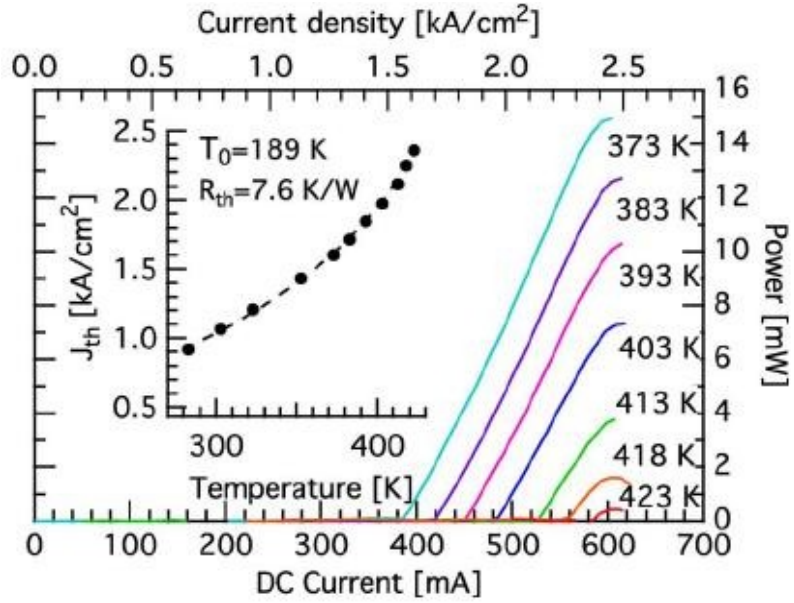
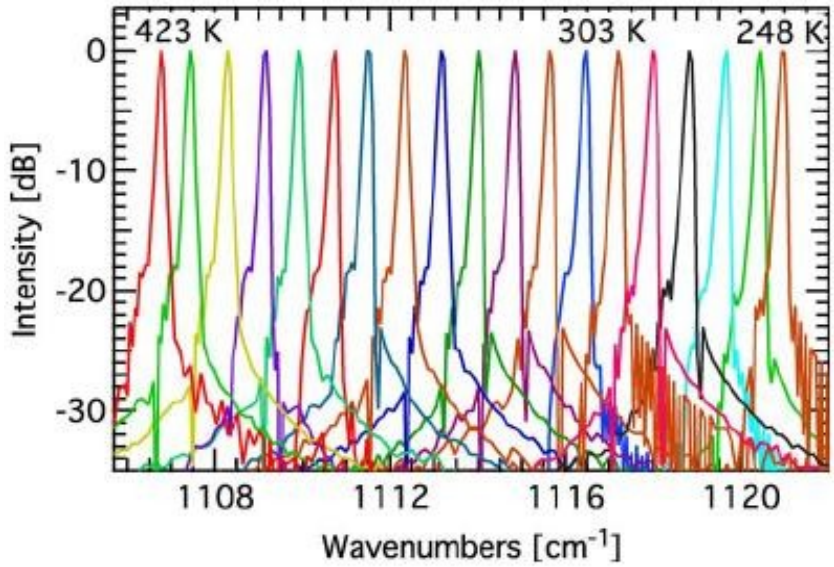
MIR: 9µm CW DFB 423K

- Low doping, strong DFB grating, thermal management through processing and mounting
- High T, 3..5W input, >10mW output

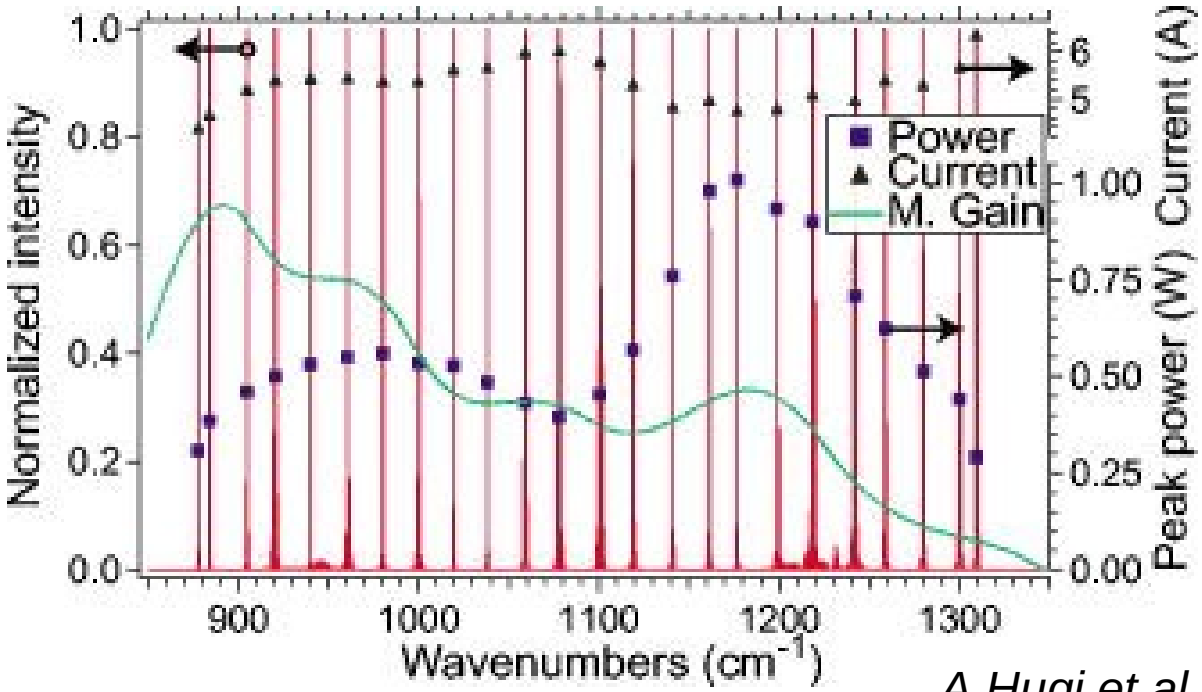




A.Wittmann et al, Phot.Technol.Lett. 21,12,p814 (2009)

MIR: 8...11µm pulsed EC

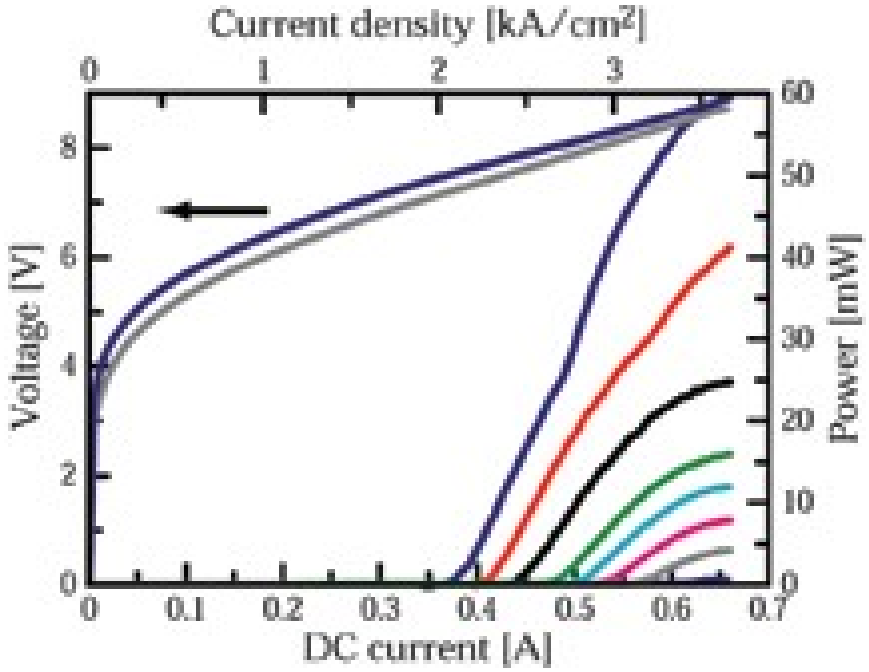
- Broad gain design (5 active zones)
- 432/cm spectral width in external cavity at 15°C

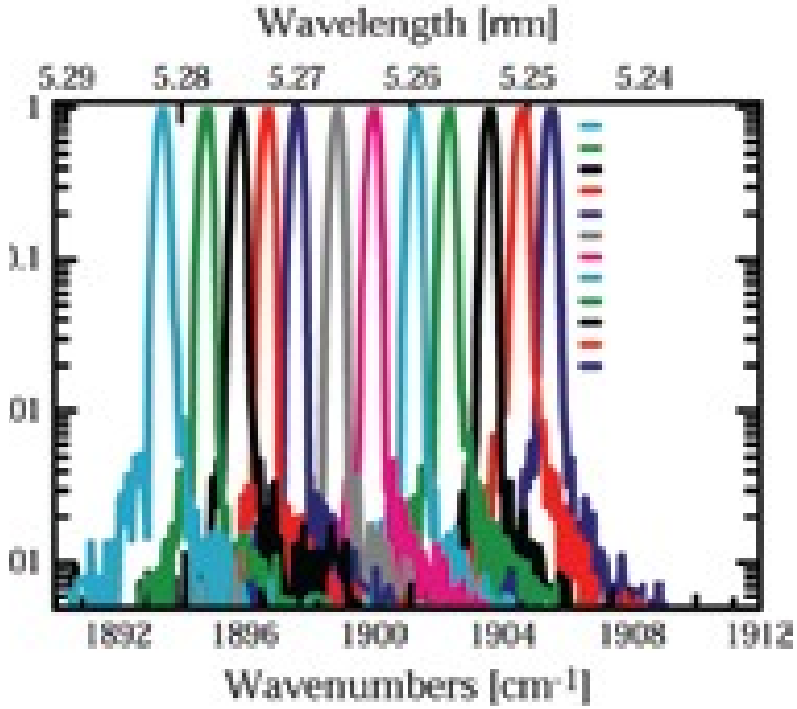


A.Hugi et al, APL 95,061103 (2009)

MIR: 5µm CW DFB

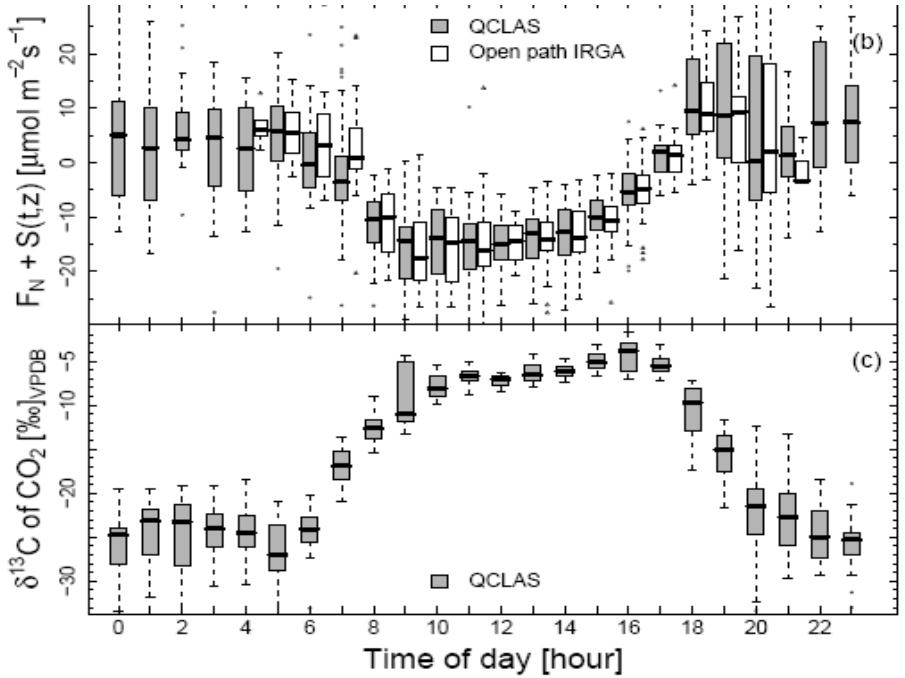
- 3..5W input, >50mW output
- Peltier cooled



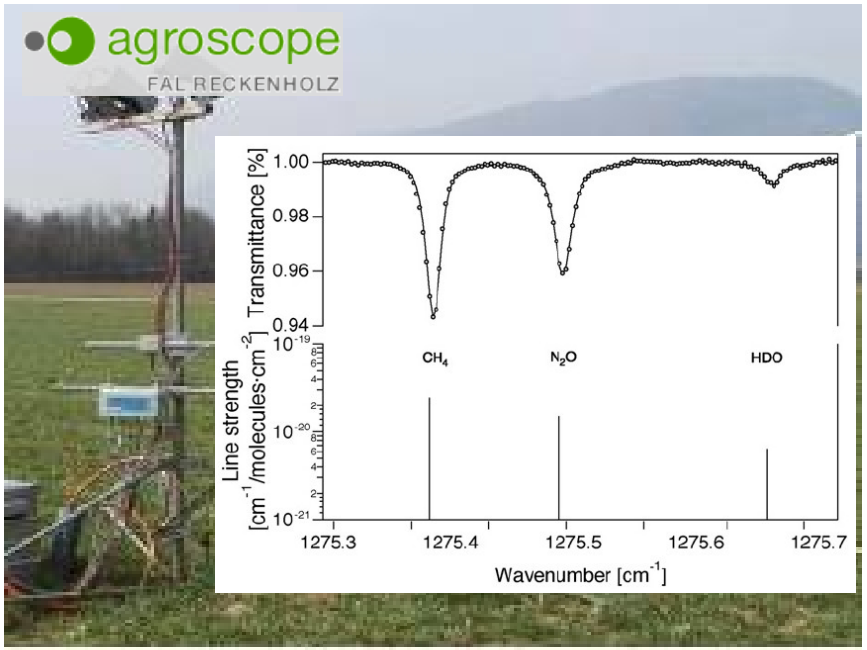


J.Faist, Opt.&Phot.News 17,32 (2006)

Application: Gas Spectroscopy



CO_2 isotopes & flux
Biogeosciences D (2009)



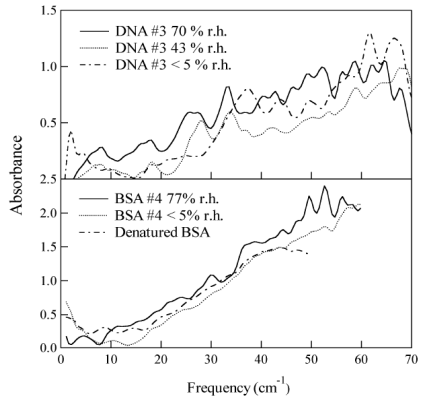
N_2O eddy covariance flux
Agric. Forest Meteorol. (2009)

QCLs are portable, low consumption, narrow-line, high power MIR sources

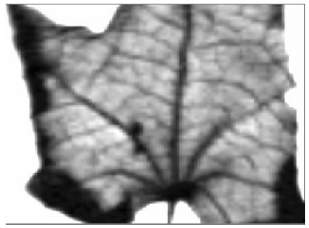
L.Emmenegger, EMPA

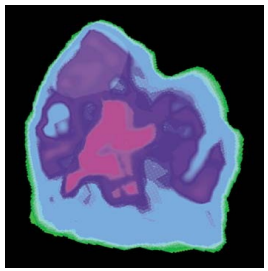
FIR: THz Applications

Spectroscopy

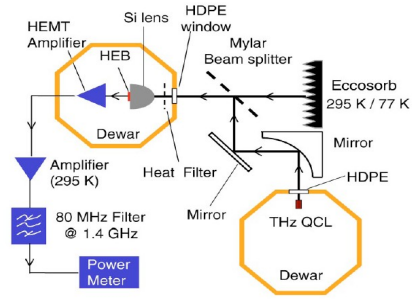


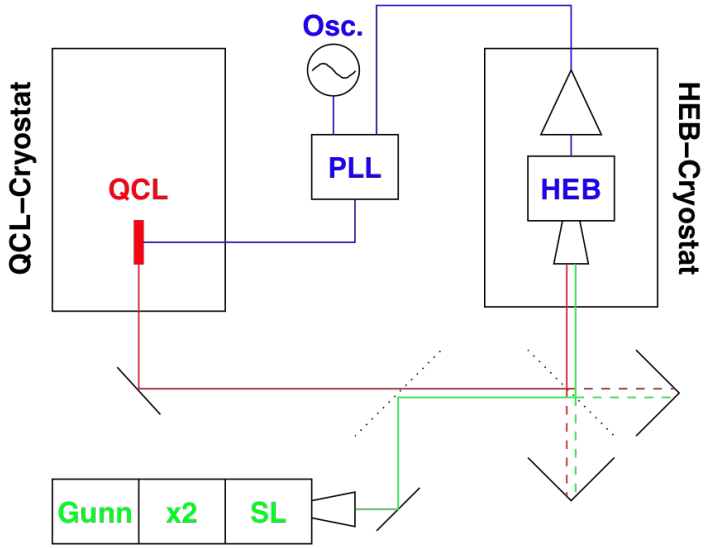
THz imaging





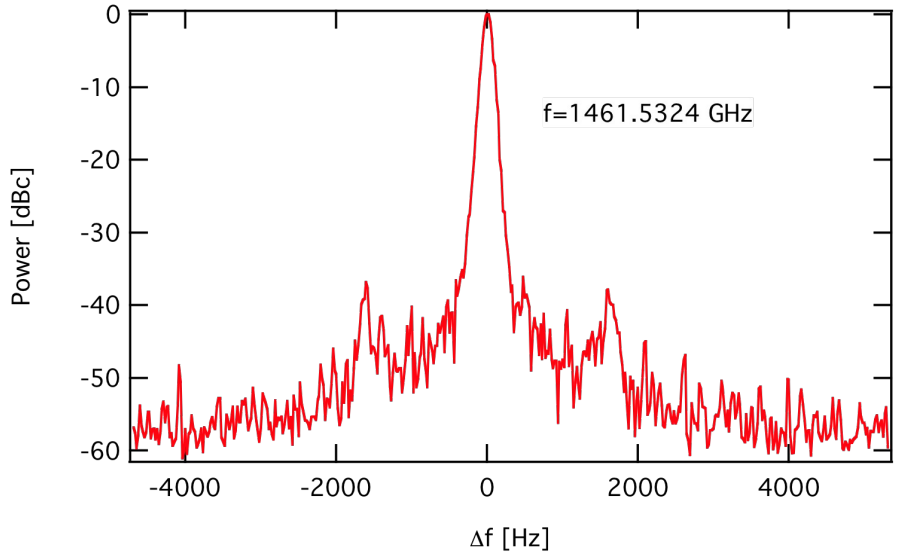
Astronomy





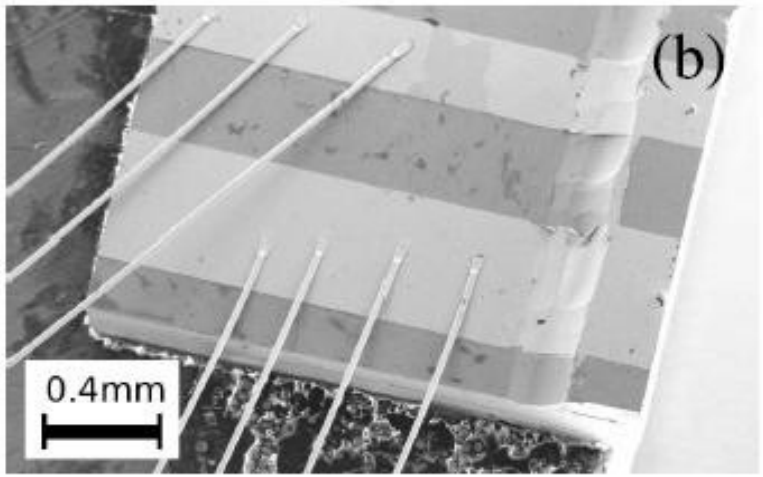
(a) Phase lock setup

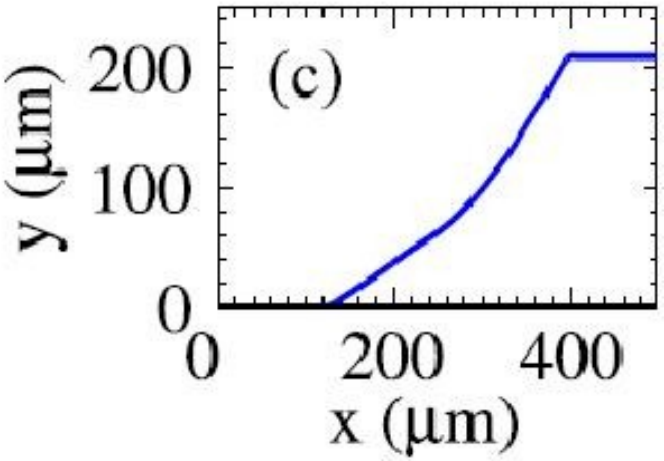
QCL locked against superlattice multiplier

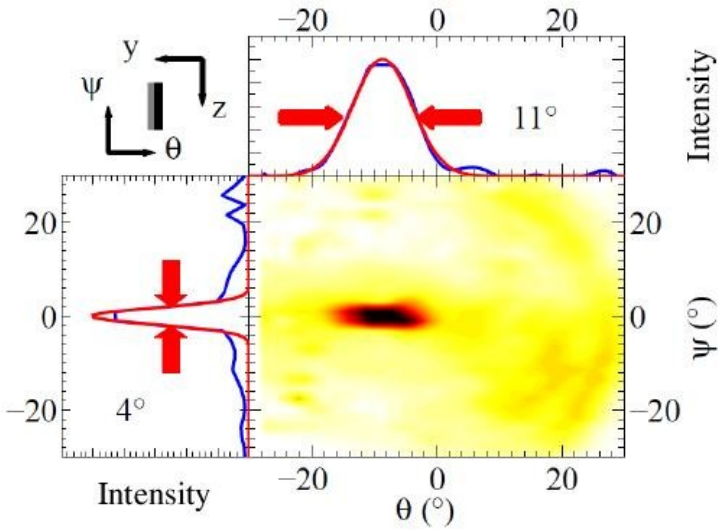


Chr.Walter

Improve THz QCL Farfield with Horn Antenna



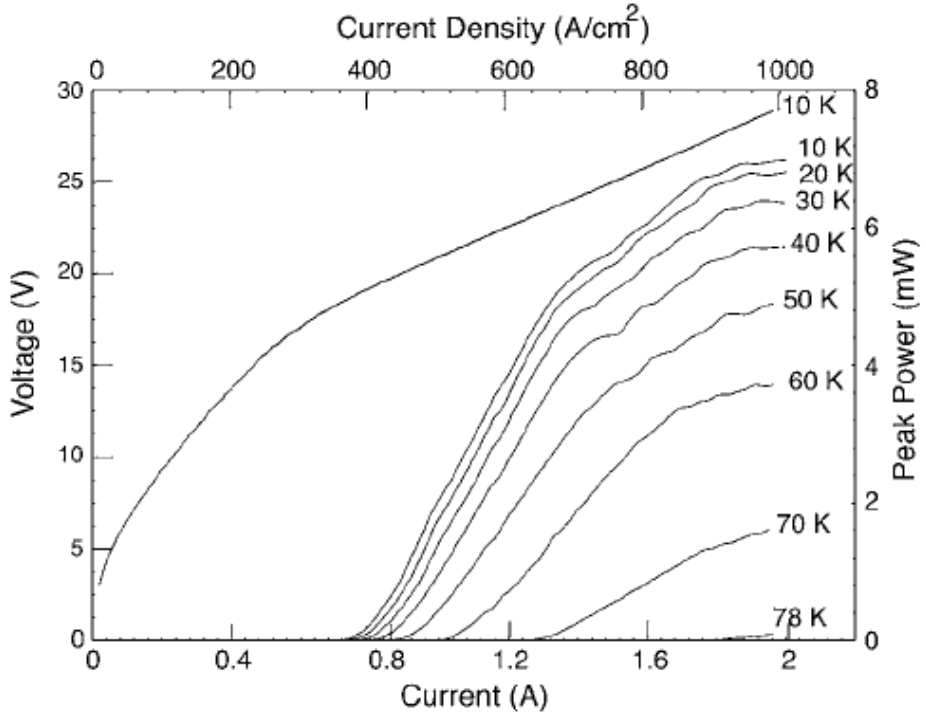


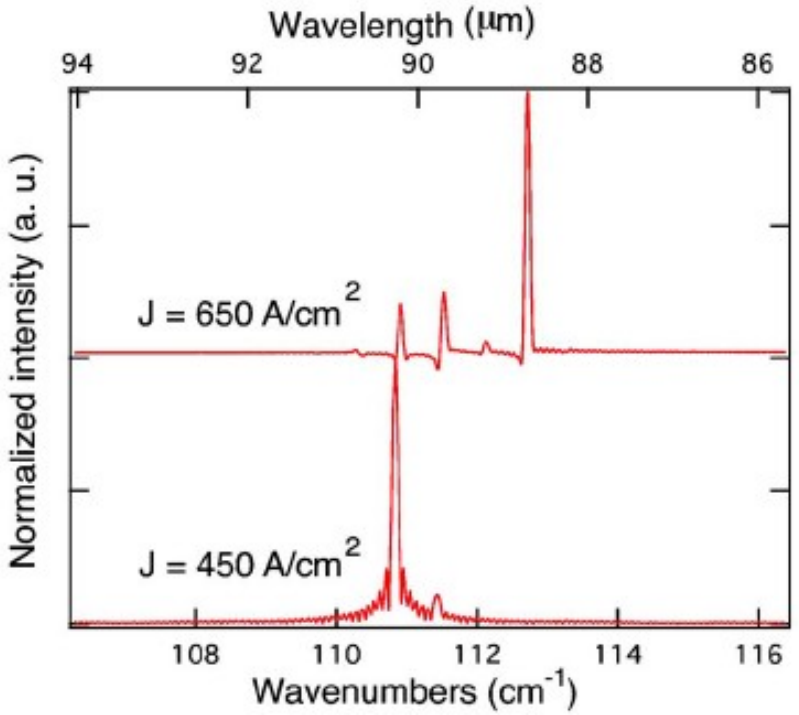


3.2THz double metal waveguide QCL with integrated horn antenna

J.Lloyd-Hughes

From MBE to MOVPE also with THz QCL



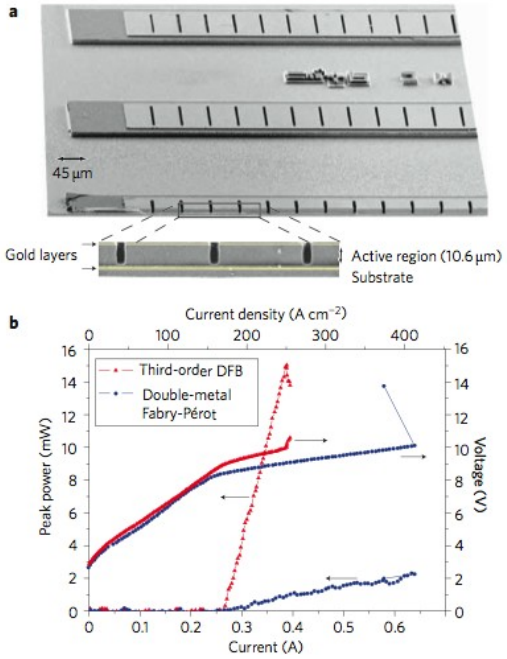


MOVPE faster than MBE,
advantageous for industrial production

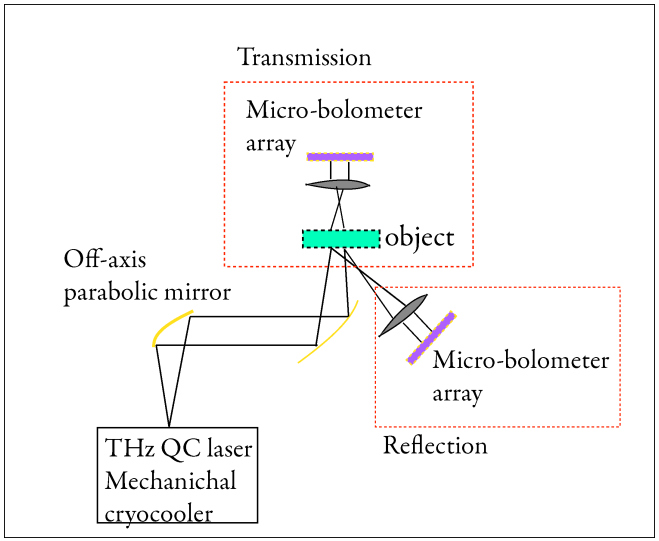
L.Sirigu et al, APL 92,181111 (2008)

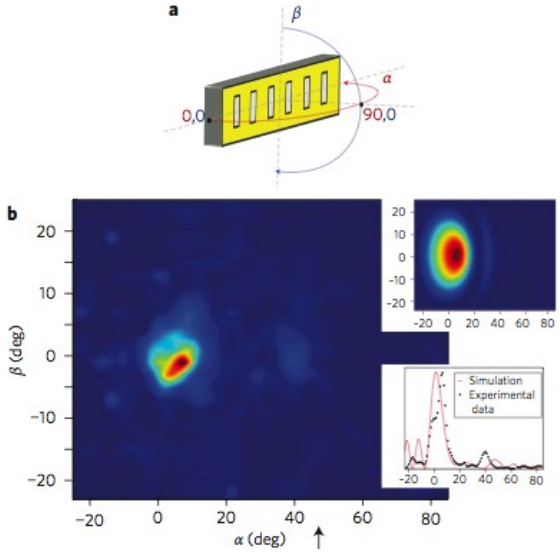
FIR project: THz imaging with QCLs

- THz radiation: non ionizing, high penetration depth (long wavelength, 100µm), fitting atmospheric windows with narrowband laser emission.
- High potential for non-invasive diagnostic and real-time, multi-color imaging.



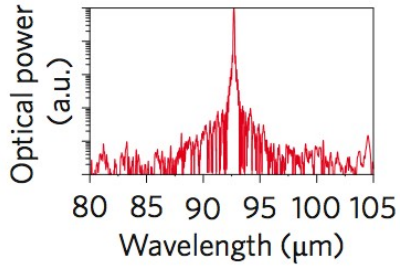
M. I Amanti et al., Nature Photonics, in press





SNF tech transfer project "TERASCOPE"

Exploiting newly realized, edge emitting narrow beam THz quantum cascade laser as source for an imaging system



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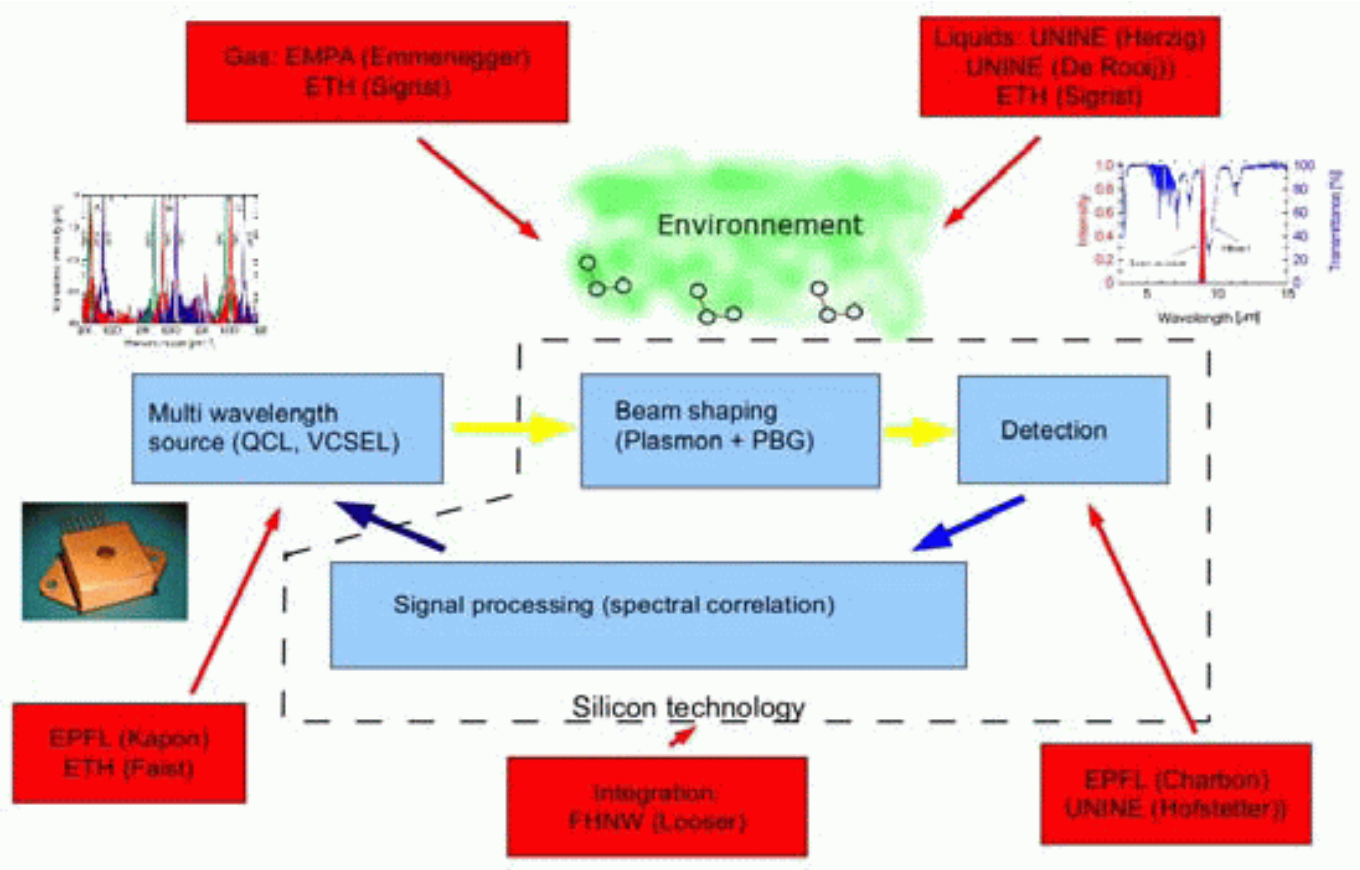
MIR project: Nano-Tera IRSENS



nano-tera.ch

SNF/Nano-Tera project (2009...2013)
Photonic sensor platform for gas and liquid sensing

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Swiss Federal Institute of Technology Zurich

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