QCL: MIR light sources

A. Muller, CEO Alpes Lasers SA

S. Blaser, R. Terazzi, R. Maulini, A. Bismuto, T. Gresch,
I. Sergachev, Y. Bideaux

ALPES LASERS

Summary

Alpes

QCL principles

Properties

- General
- External cavity tuning
- Single mode tuning
  - Long pulses
  - Enhanced long pulses tuning

Conclusion

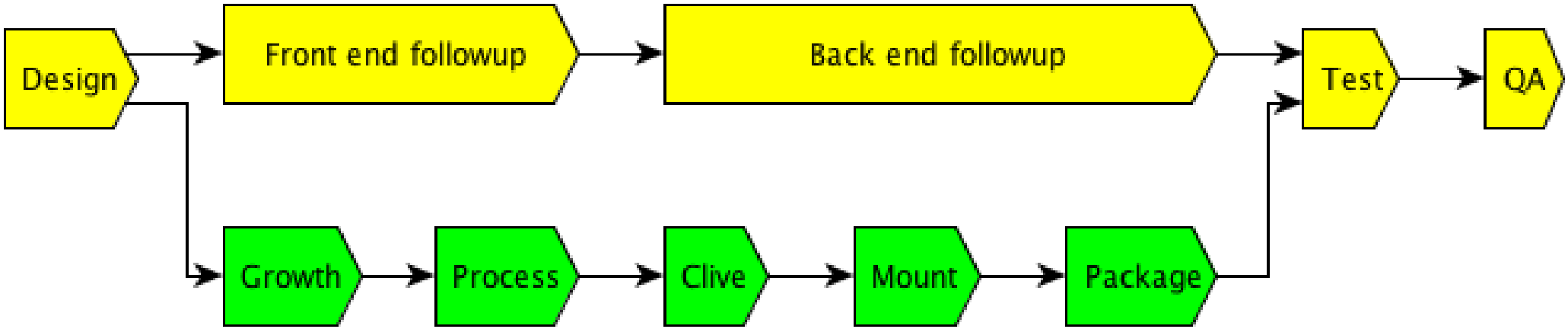
ALPES LASERS

Company Profile

Design and production of QCLs

- Incorporated in 1998 in Neuchâtel
- High level scientific team (22 people)
- Total of 250+ years experiences in QCL design and manufacture
- Strong intellectual property protection (12 major patents in QCLs)
- Market leader of QCLs

Fabrication fabless model



ALPES LASERS

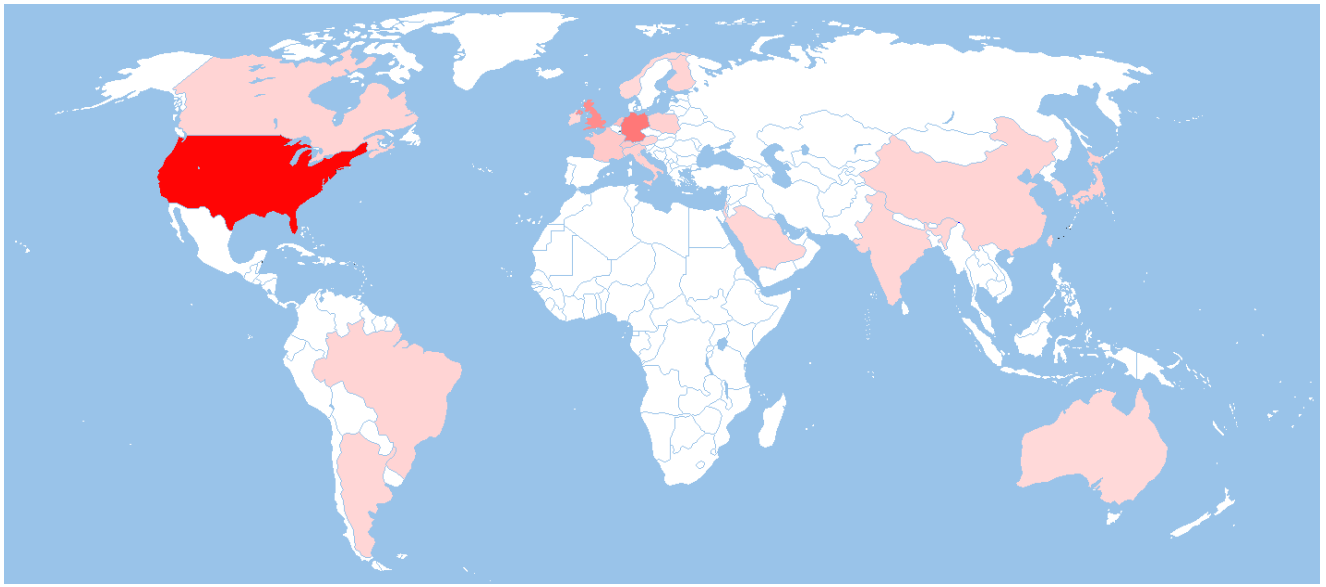
Market Leader of QCLs

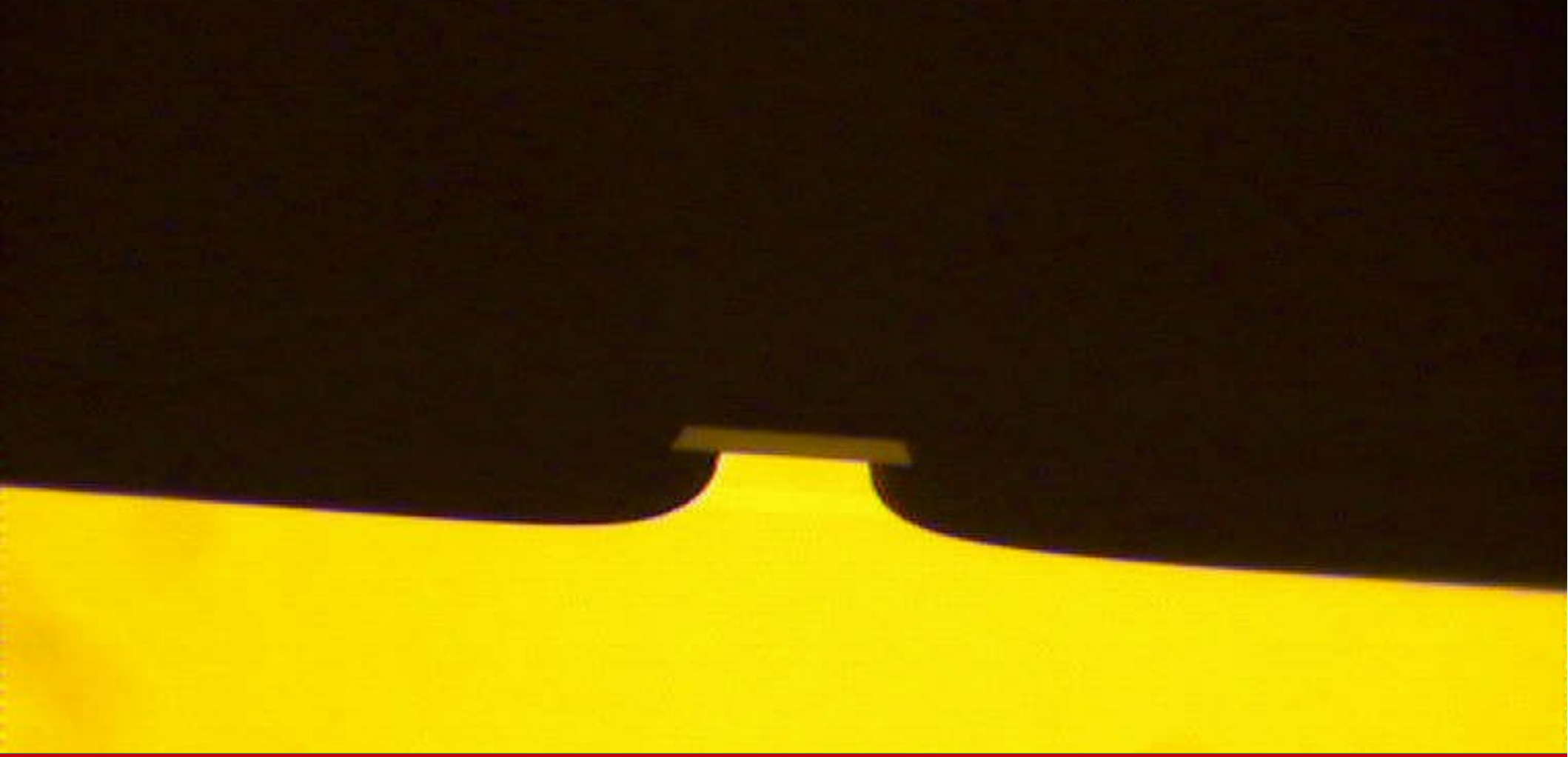
Major universities and R&D Centres

Industry, Spatial centres

Worldwide covering, distributors in
EU, US, JP, CN

2'400 QCLs sold all over the world over 15 years of existence.

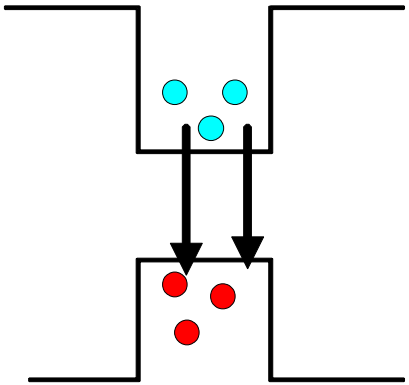




QCLs : principles

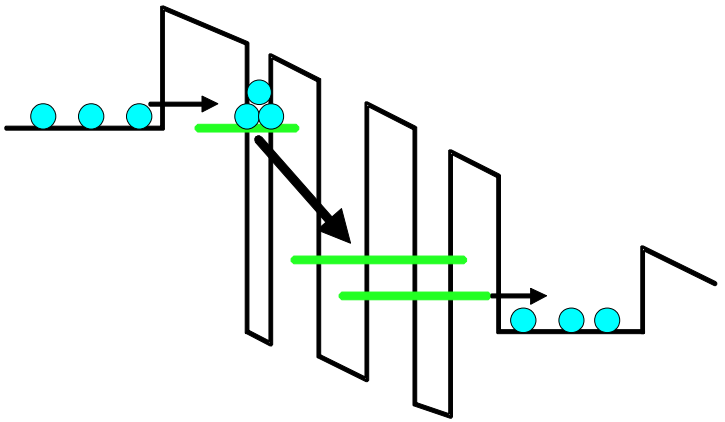
Difference with unipolar lasers

Standard



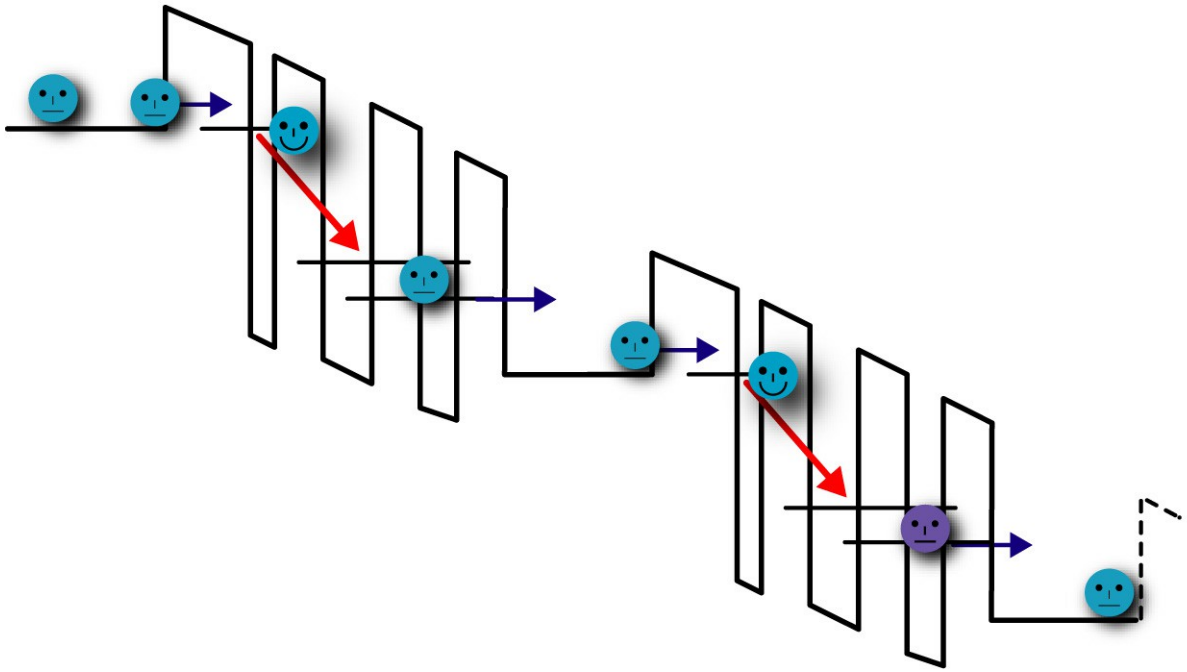
Wavelength is function of the material

Quantum Cascade



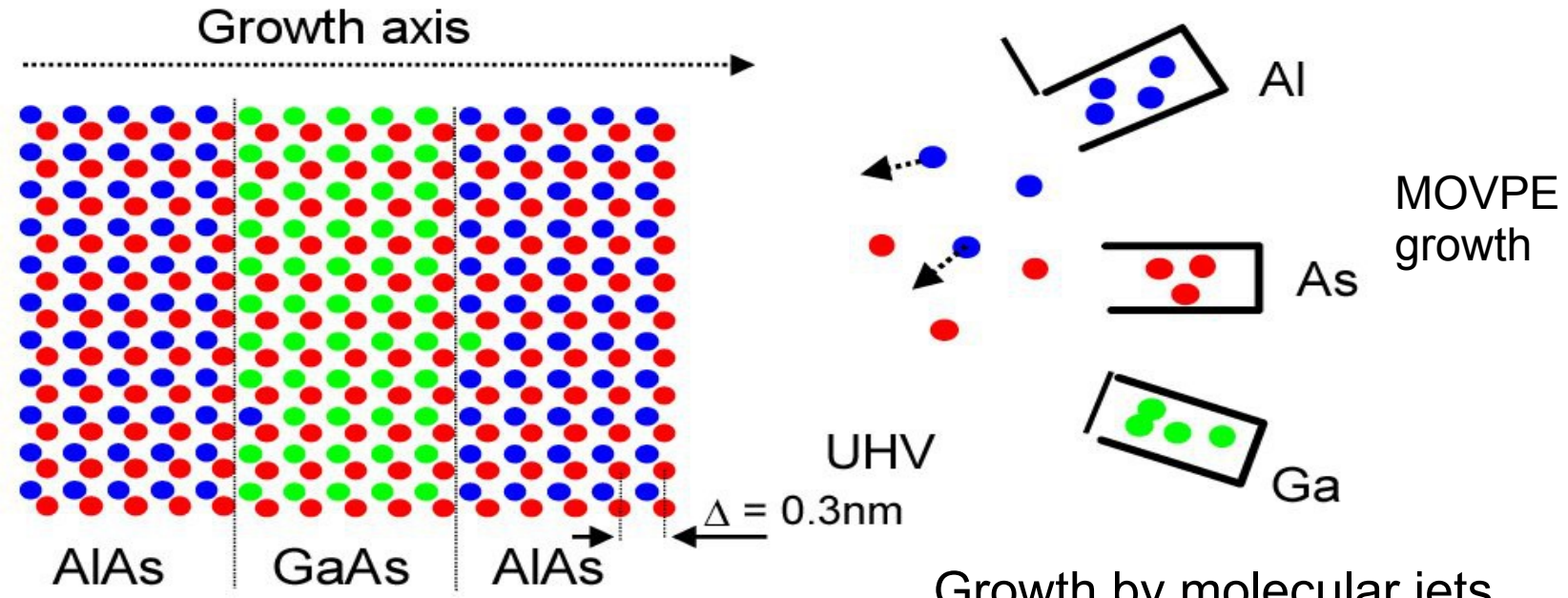
Wavelength is function of the geometry

Why cascade?

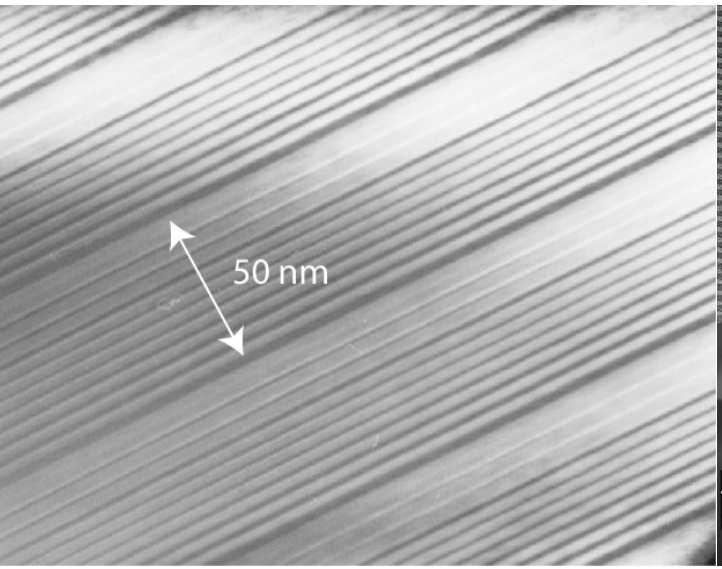


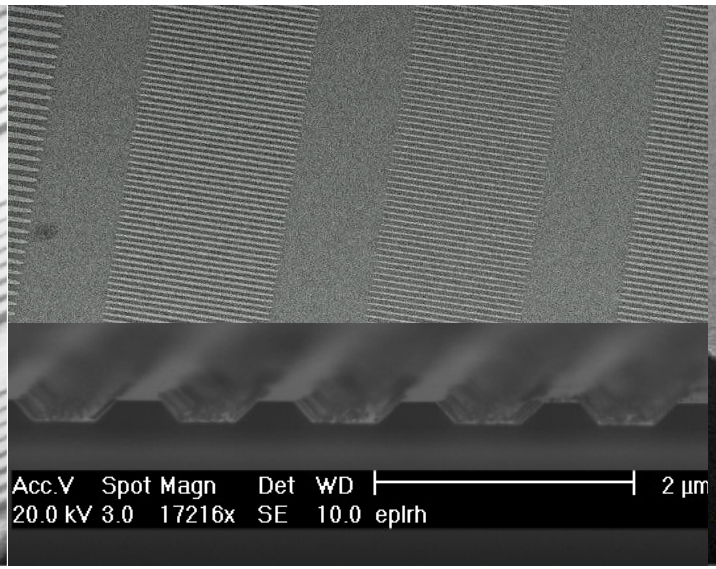
N repetitions of a period
1 electron may generate N photons

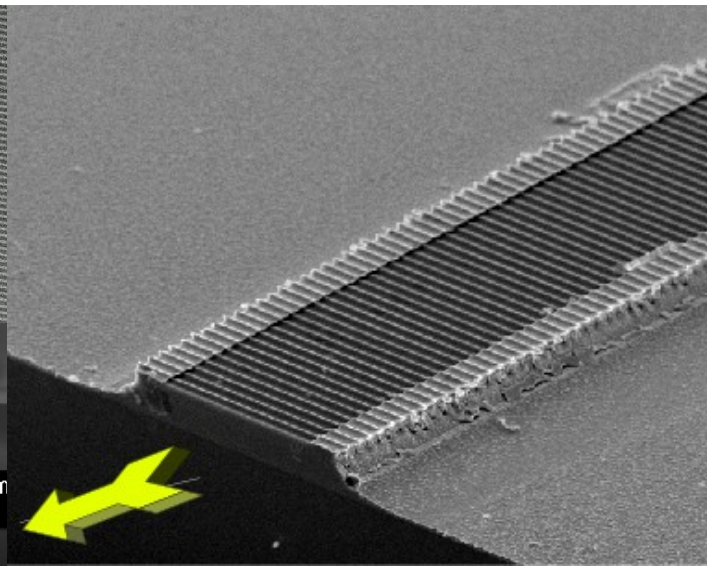
Fabrication



Growth by molecular jets

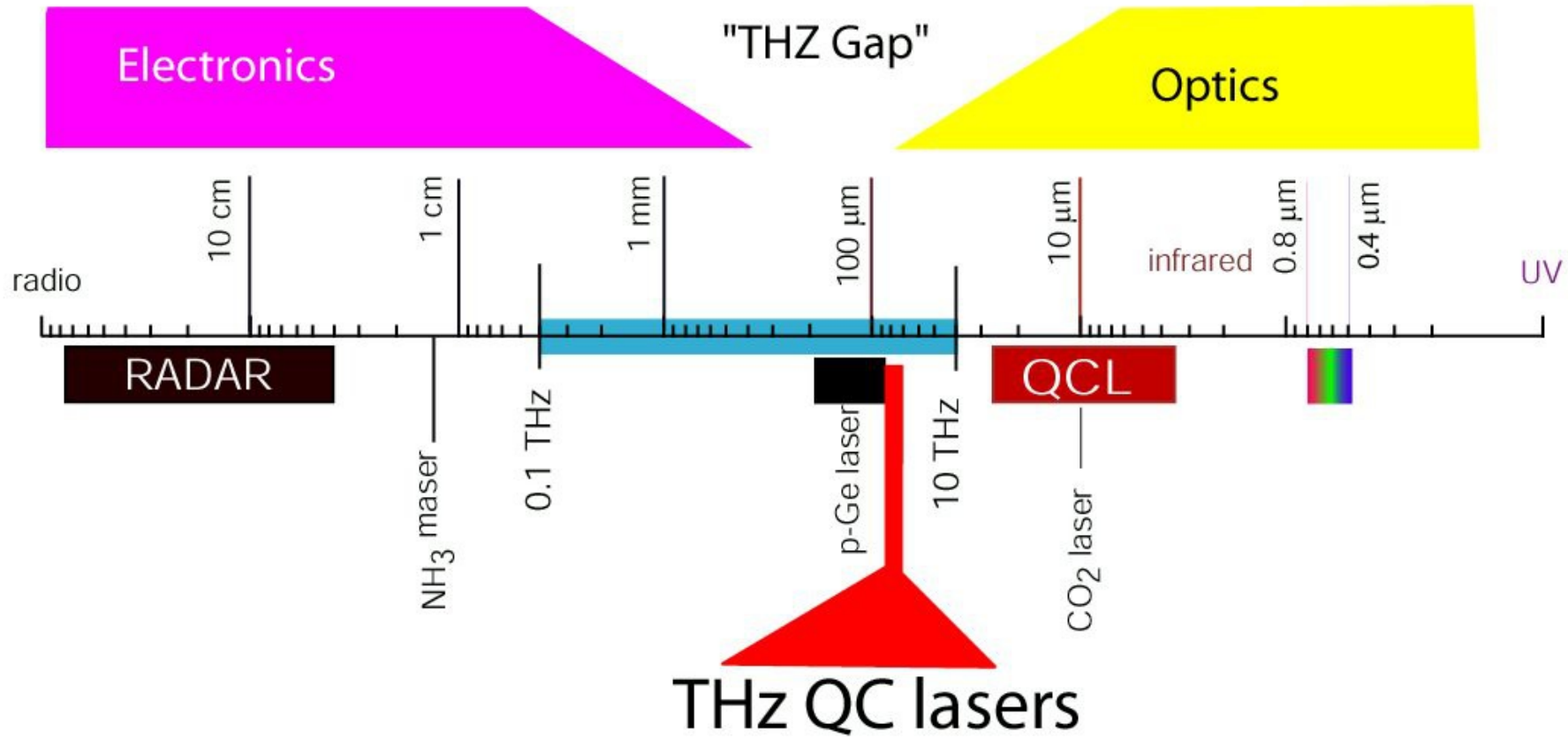


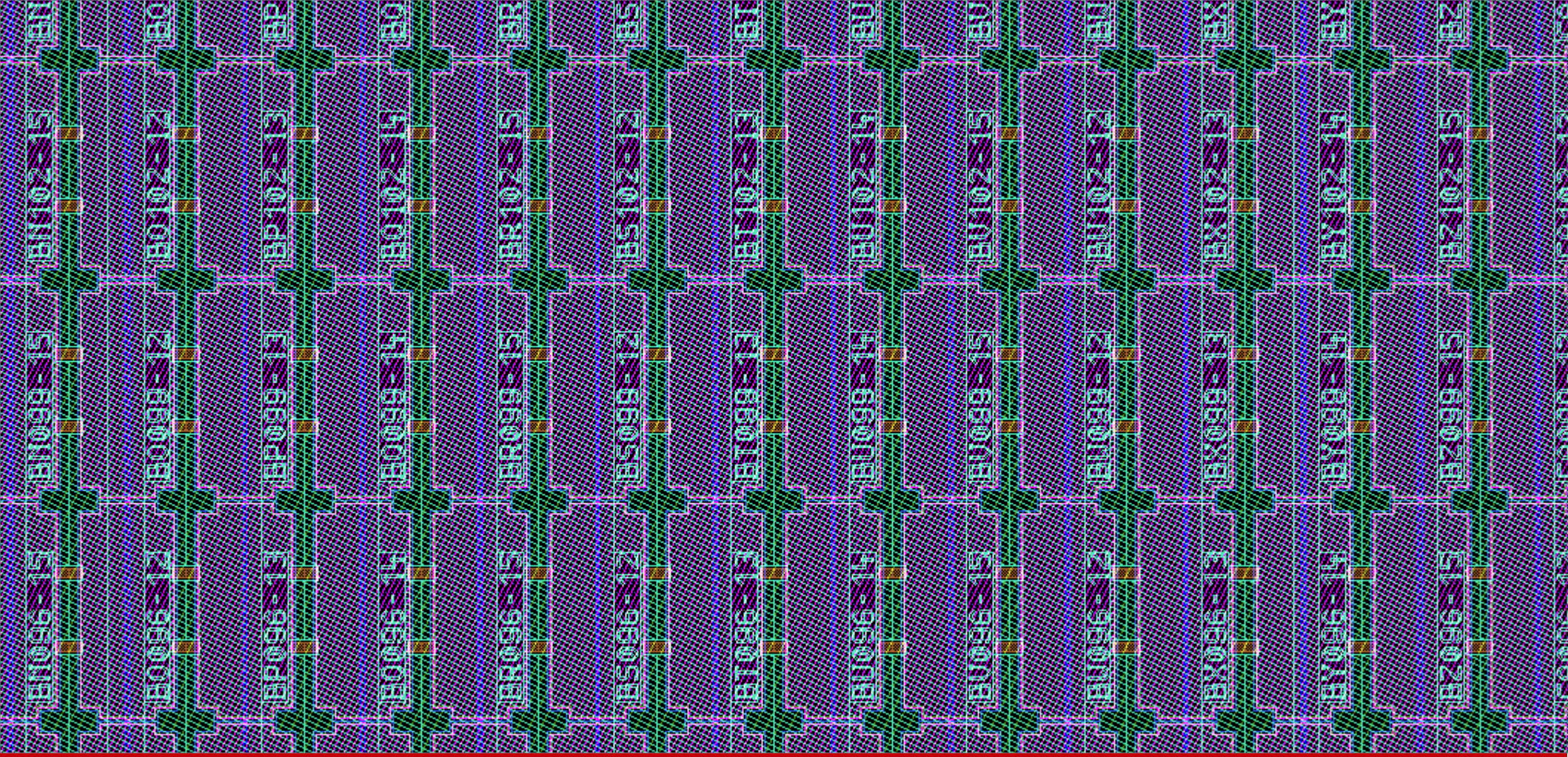




QCL: a mid- and far- IR light source

An effective and efficient mid-infrared light source covering the mid-infrared (4 to 20 µm) and terahertz waves (1 to 6 THz)





Properties

ALPES LASERS

properties

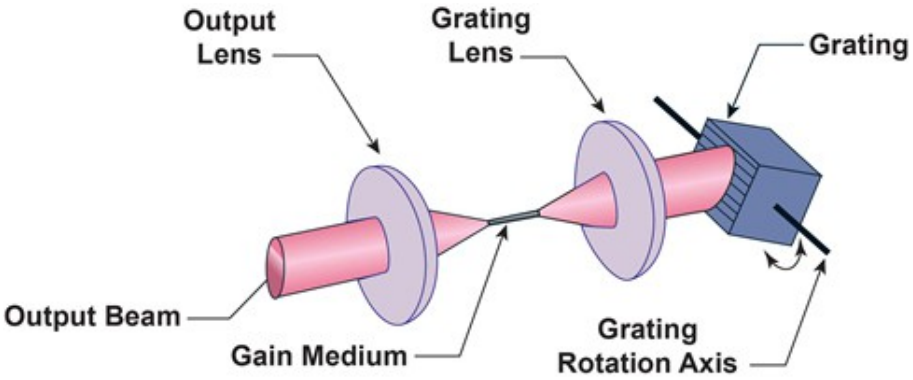
Single mode devices

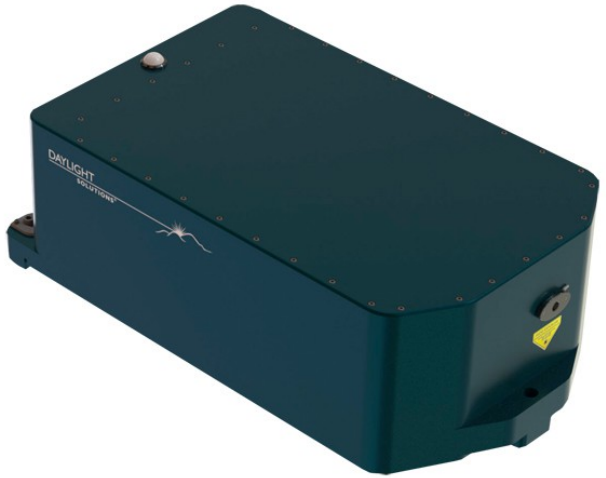
- RT operation P & CW, I_{th}:30-500mA
- 1-10mW typ., up to 100's mW
- CW linewidth ~5MHz min <6Hz

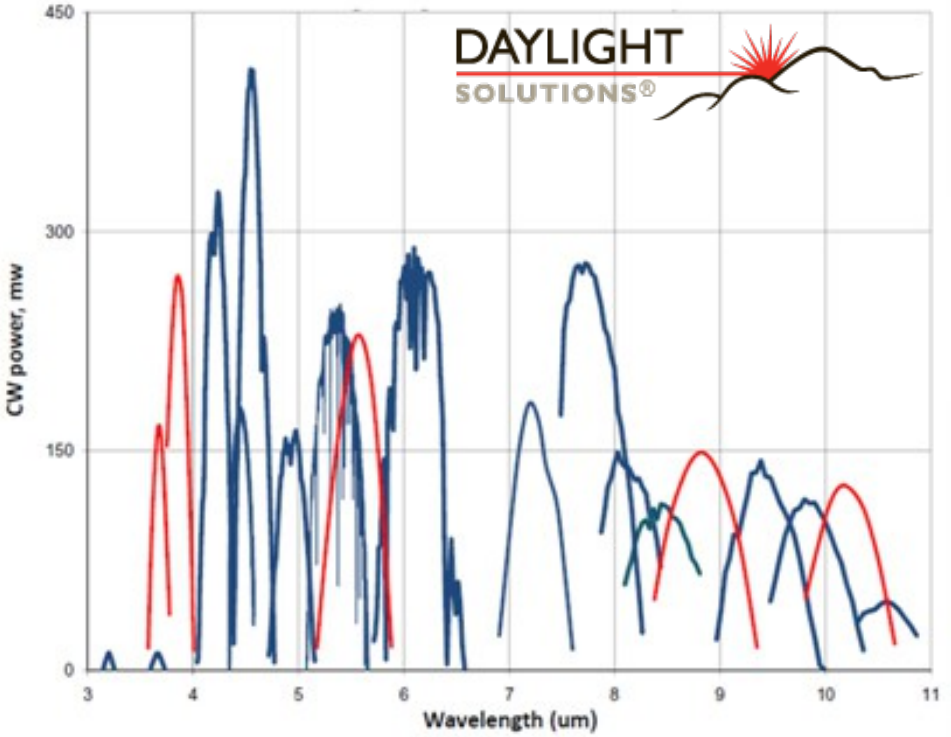
Multi mode devices

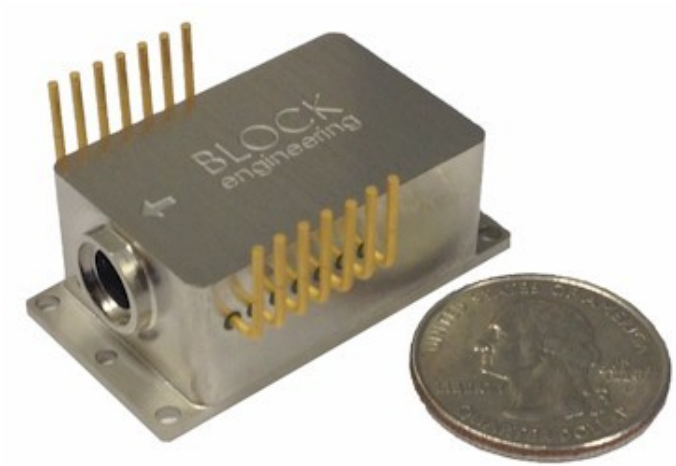
- Pulsed line-width up to 450 cm^{-1}
- CW line-width up to 300 cm^{-1}

External cavity tuning





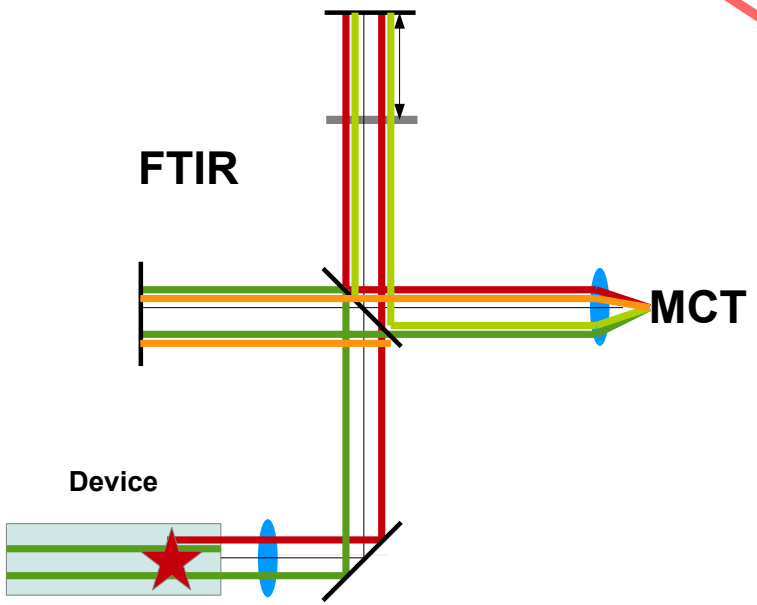


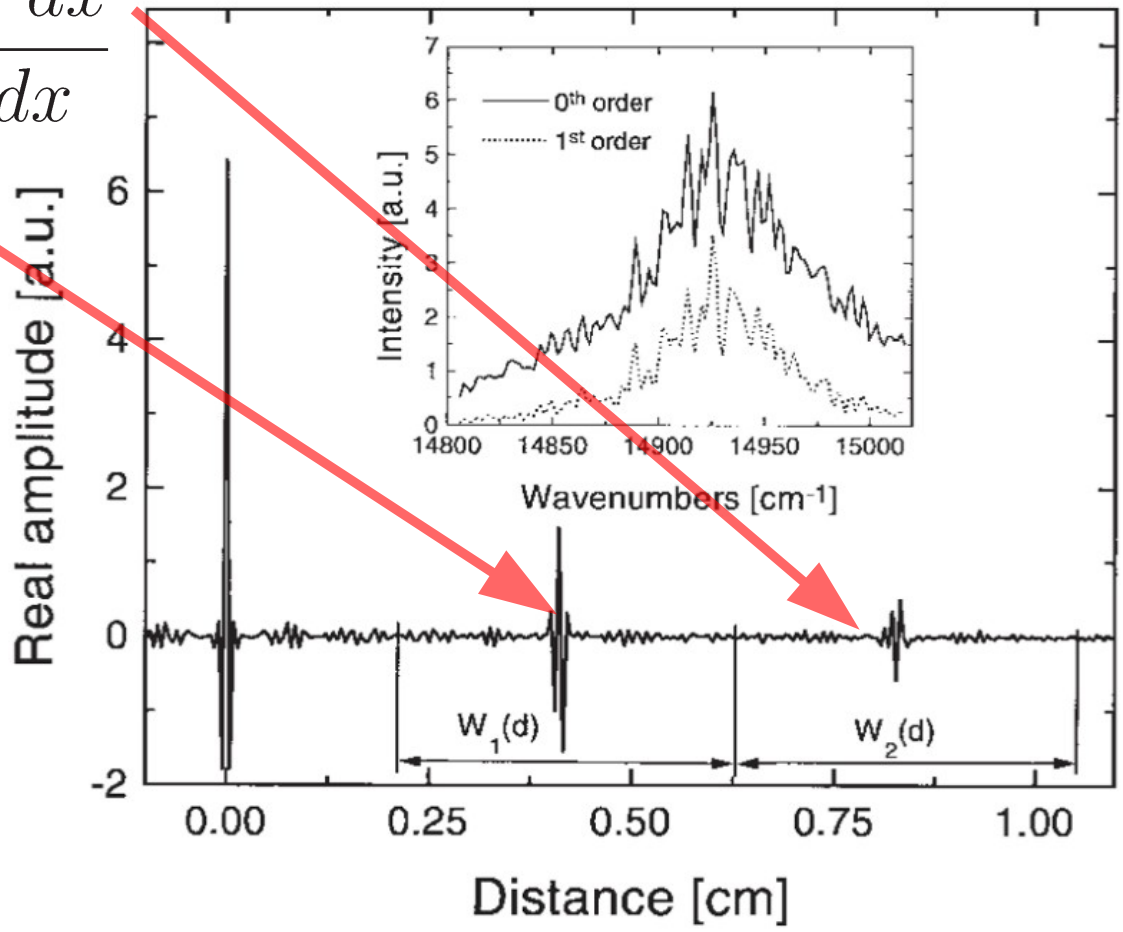


Gain measurements by Fourier transform analysis

Subthreshold gain measurements

$$b(\beta) = \frac{\int_{-\infty}^{\infty} W_{m+1}(x)\, e^{i2\pi\beta x} dx}{\int_{-\infty}^{\infty} W_m(x)\, e^{i2\pi\beta x} dx}$$



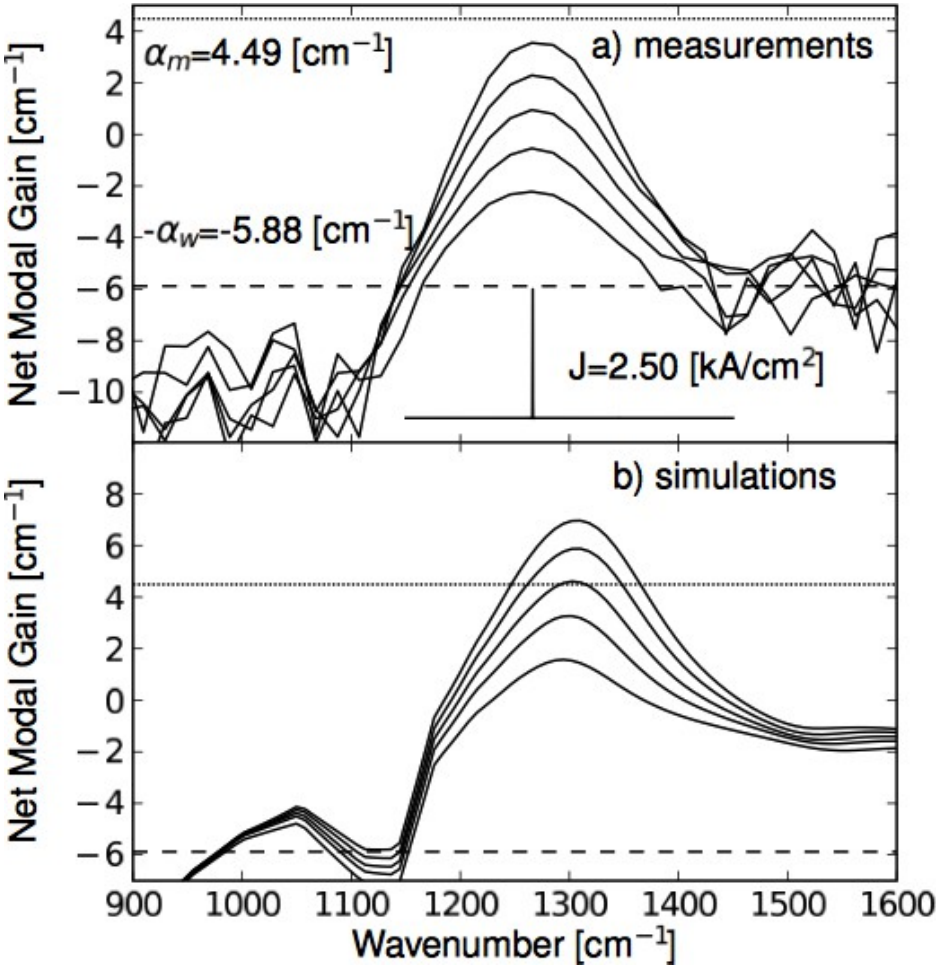


Hofstetter et al. Photonics Technology Letters, (199

ALPES LASERS

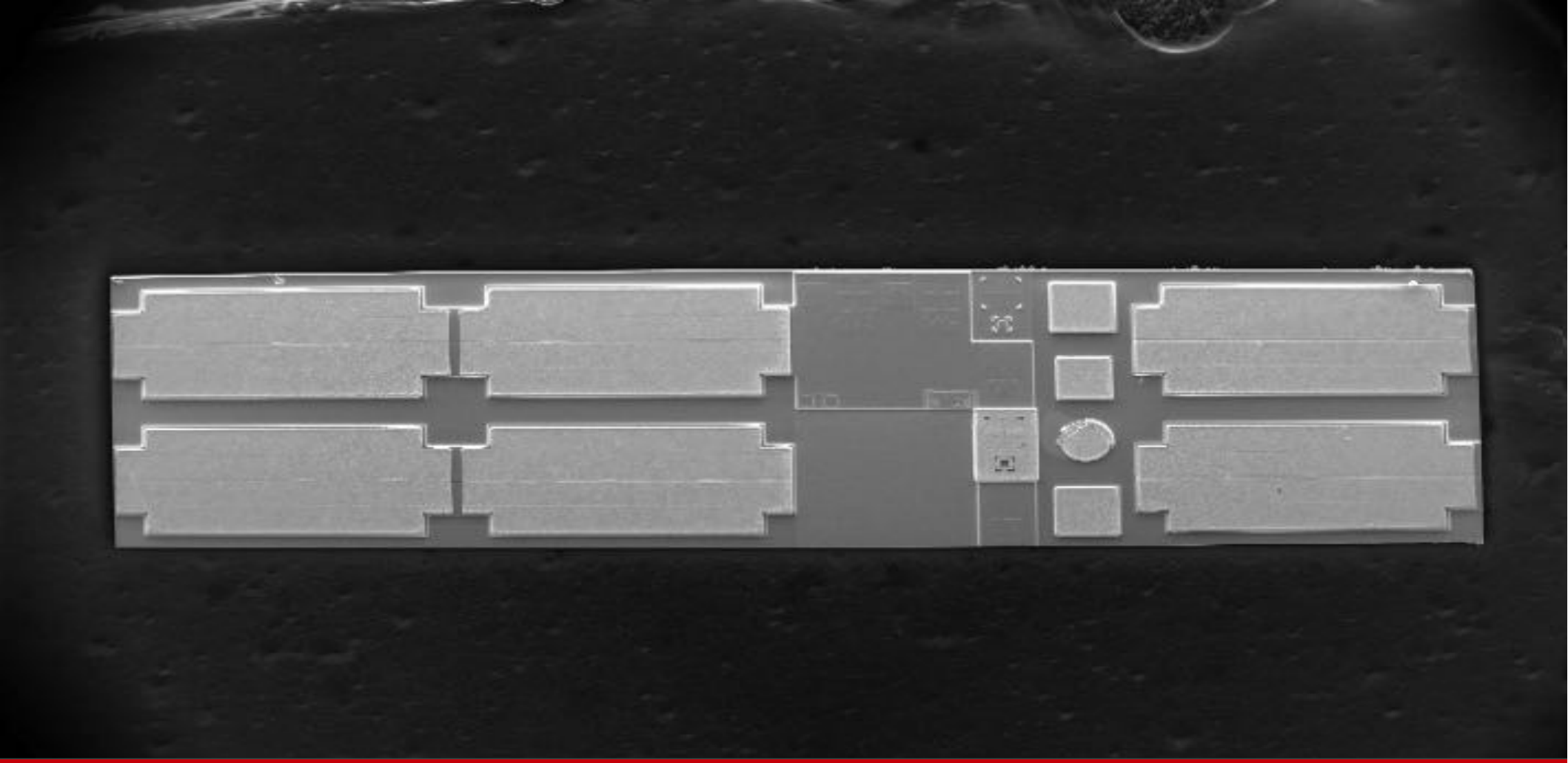
7.8 μm two-phonons single stack

Measurements and simulations for increasing current densities: 0.9, 1.1, 1.3, 1.5, 1.7 kA/cm2



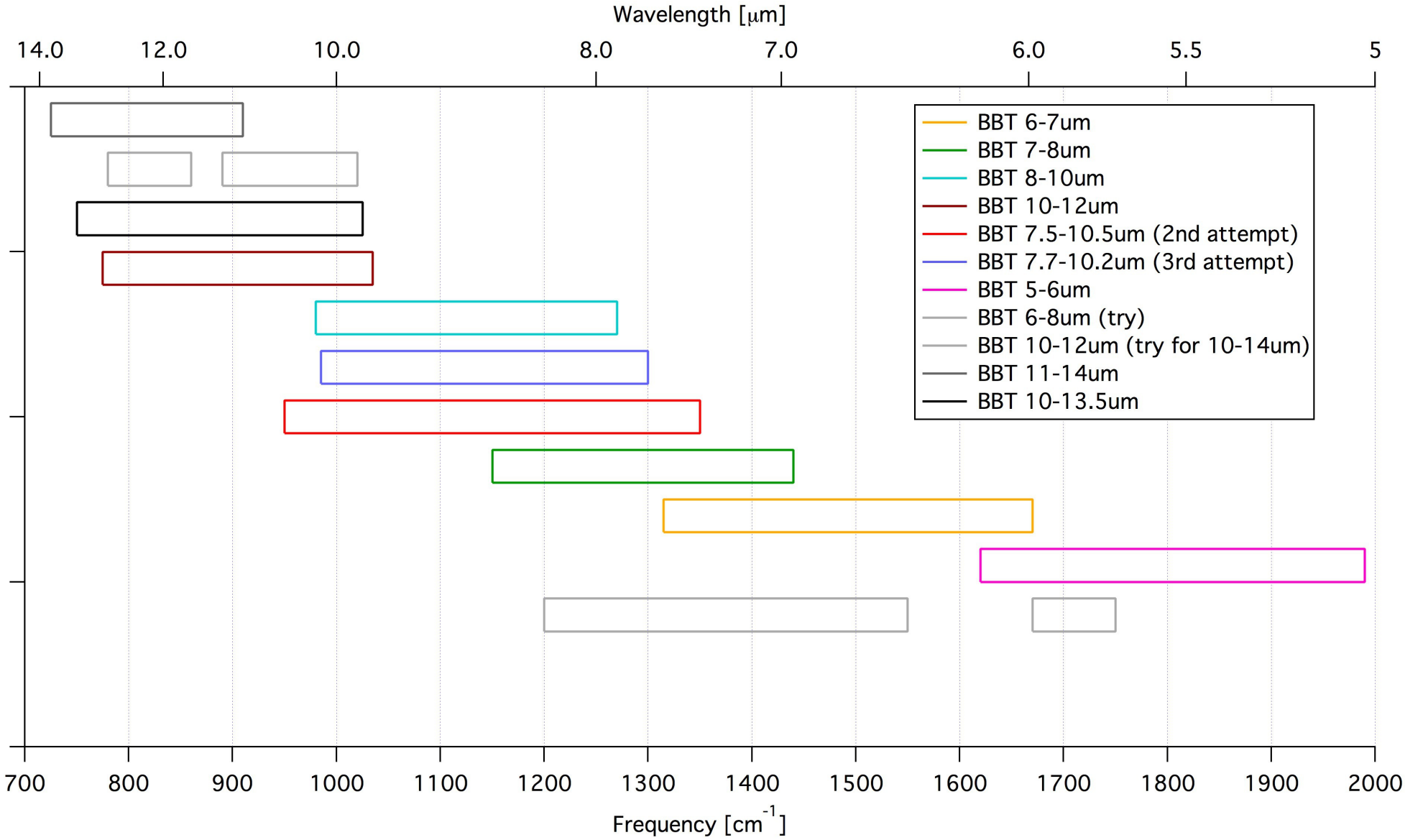
- Simulation based on density-matrix formalism
- Excellent agreement for gain dynamic range
- Global offset 4.4 cm-1 process related losses
- Cladding absorption predicted

R. Terazi, Y. Bidaux



Application to broad gain devices

Broad gain device offer



Application to broad gain devices

ALPES LASERS

HOME | PRODUCTS | TECHNOLOGY | LITERATURE | CONTACT | HELP CENTER

- Lasers devices
  - List of DFB lasers in stock
  - Broad Gain Device
  - Fabry-Pérot Lasers
  - Discovery Lasers
  - Packaging Options
- Accessories and Kits
- Services

Broadgain Lasers

These lasers are Fabry-Pérot lasers designed for maximum width of the gain profile. They can be used as broad spectrum illuminators for spectroscopy or imaging. Combined with an anti-reflection coating, they are suitable for use in an external cavity to obtain a tunable laser with wide tuning range. Their wide and flat gain spectrum can also be suitable to develop frequency combs.

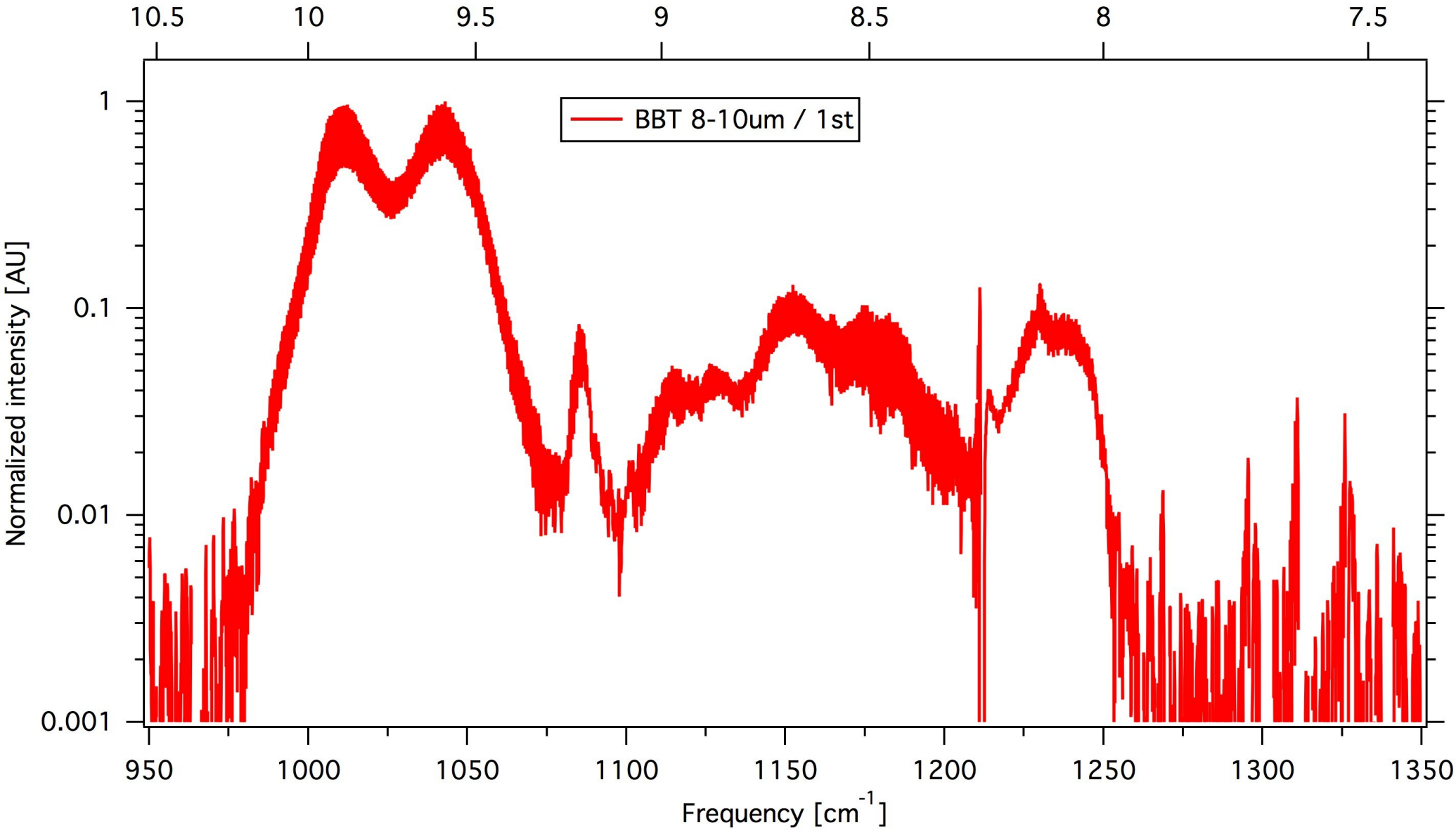
Broadgain Lasers are available in well-defined bands defined below. Test data is available on delivery for the uncoated devices; for AR coated testing is done prior to coating.

Type	FP min	FP max	PEC-min	PEC-max	CWEC-min	CWEC-max
BG-10-12	780	1030	787	1042	-	-
BG-7.5-10.5	990	1280	960	1330	-	-
BG-8-10	995	1260	976	1283	1020	1235
BG-7-8	1190	1425	1096	1473	1150	1420
BG-6-7	1345	1660	1325	1680	1370	1635

- FP min and max: Limits of the multimode emission.
- PEC min and max: Observed limits of single mode pulsed emission in an external cavity.
- CWEC min and max: Observed limits of continuous emission in an external cavity.

ALPES LASERS

Redesigned flat gain multi-stack QCL
1st version

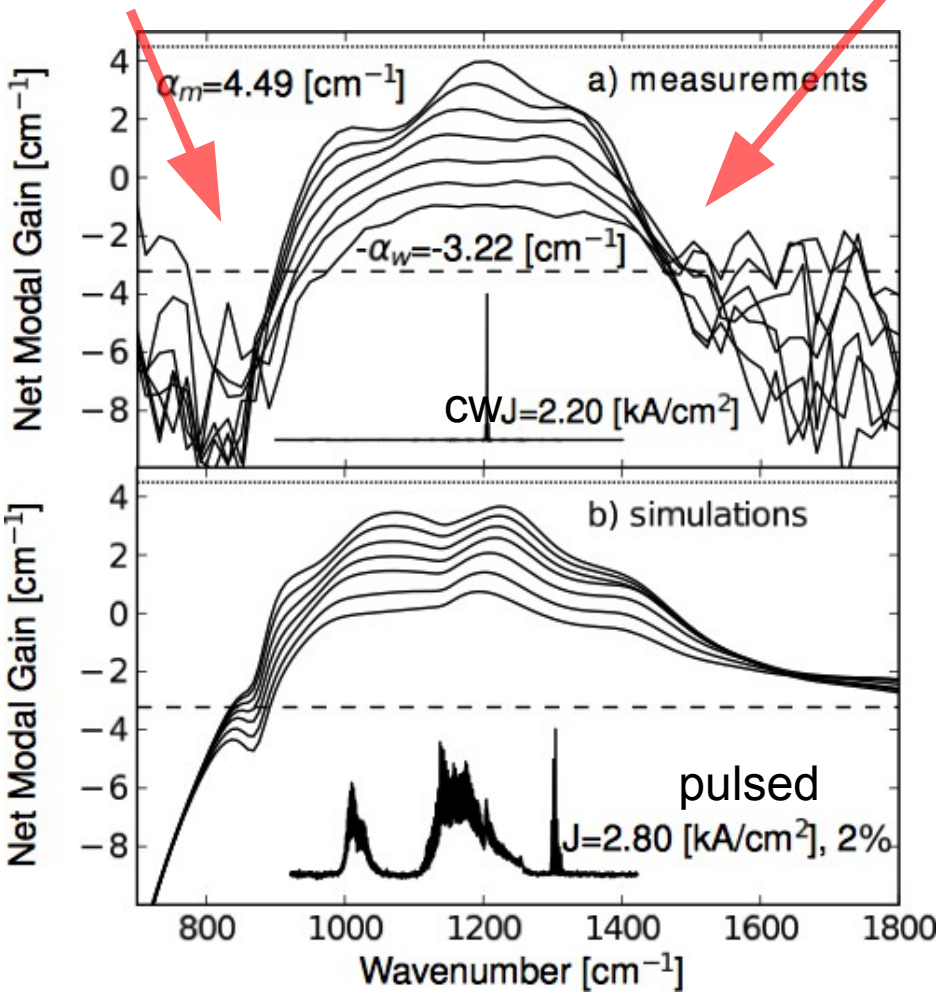


7.5-10.5 μm multi-stack

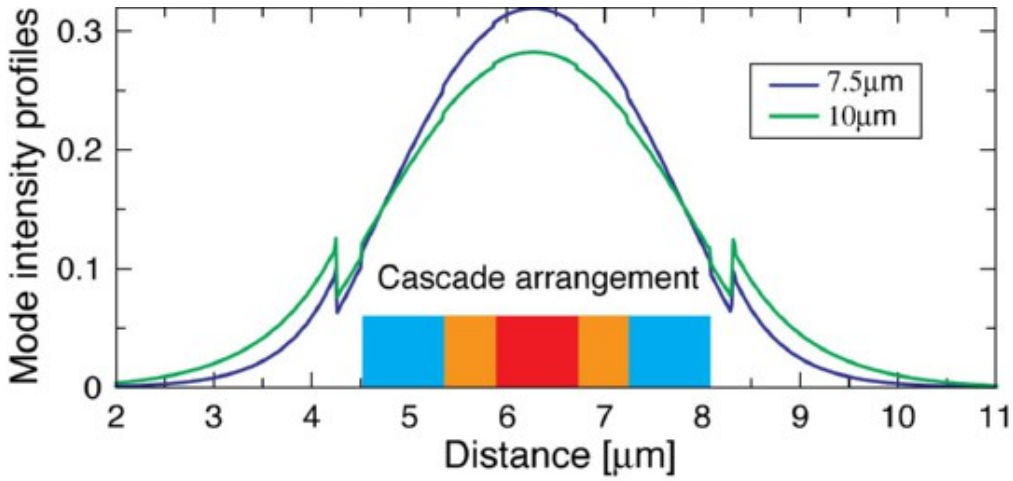
Measurements and simulations for increasing current densities: 0.8, 1.0, 1.2, 1.4, 1.6, 1.8, 2.0 kA/cm2

Cladding absorbtion

Sidewall roughness

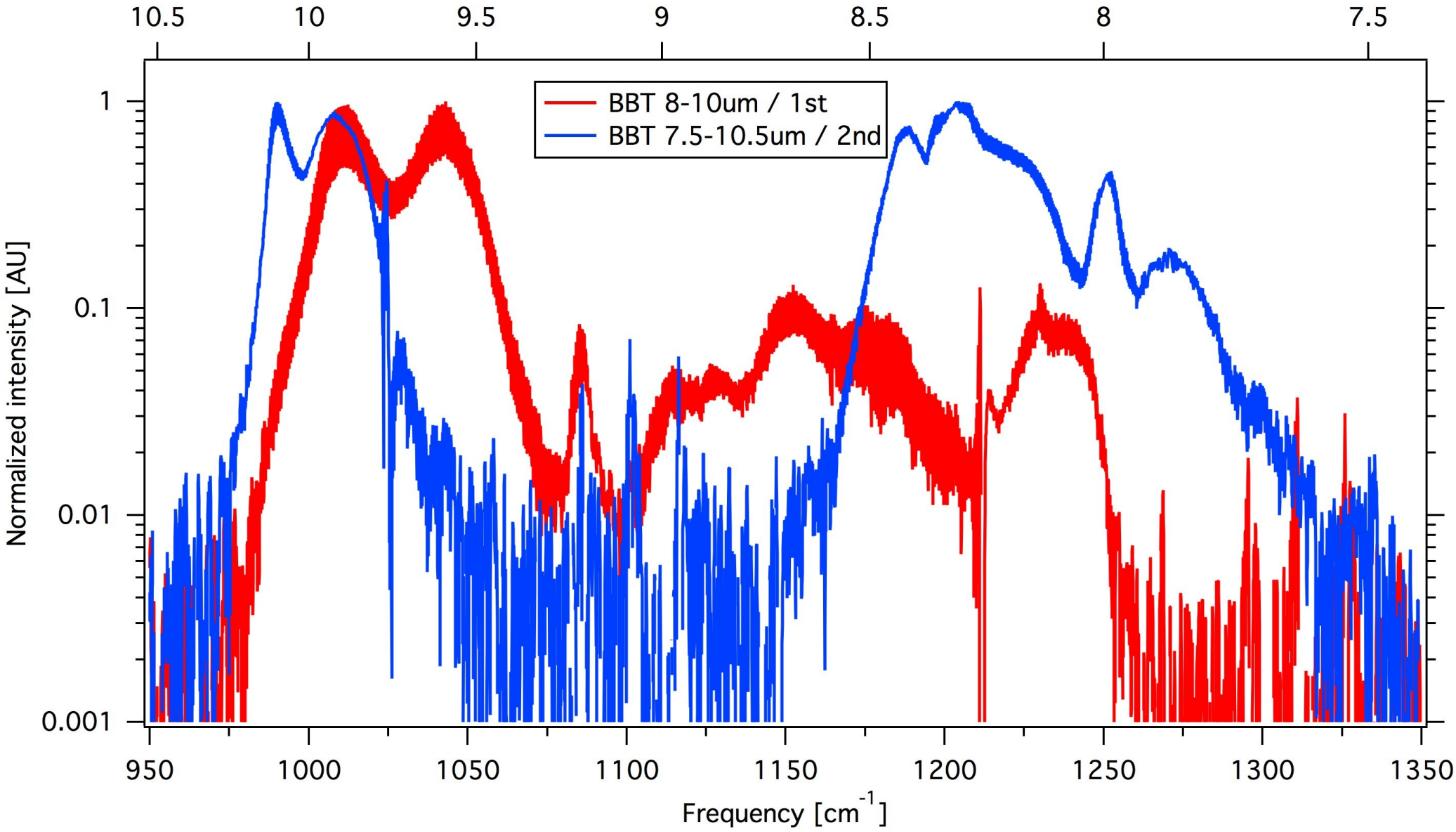


- Agreement : gain dynamic range, absolute losses, gain bandwidth, peak gain
- Small gain modulation due to growth unknowns



ALPES LASERS

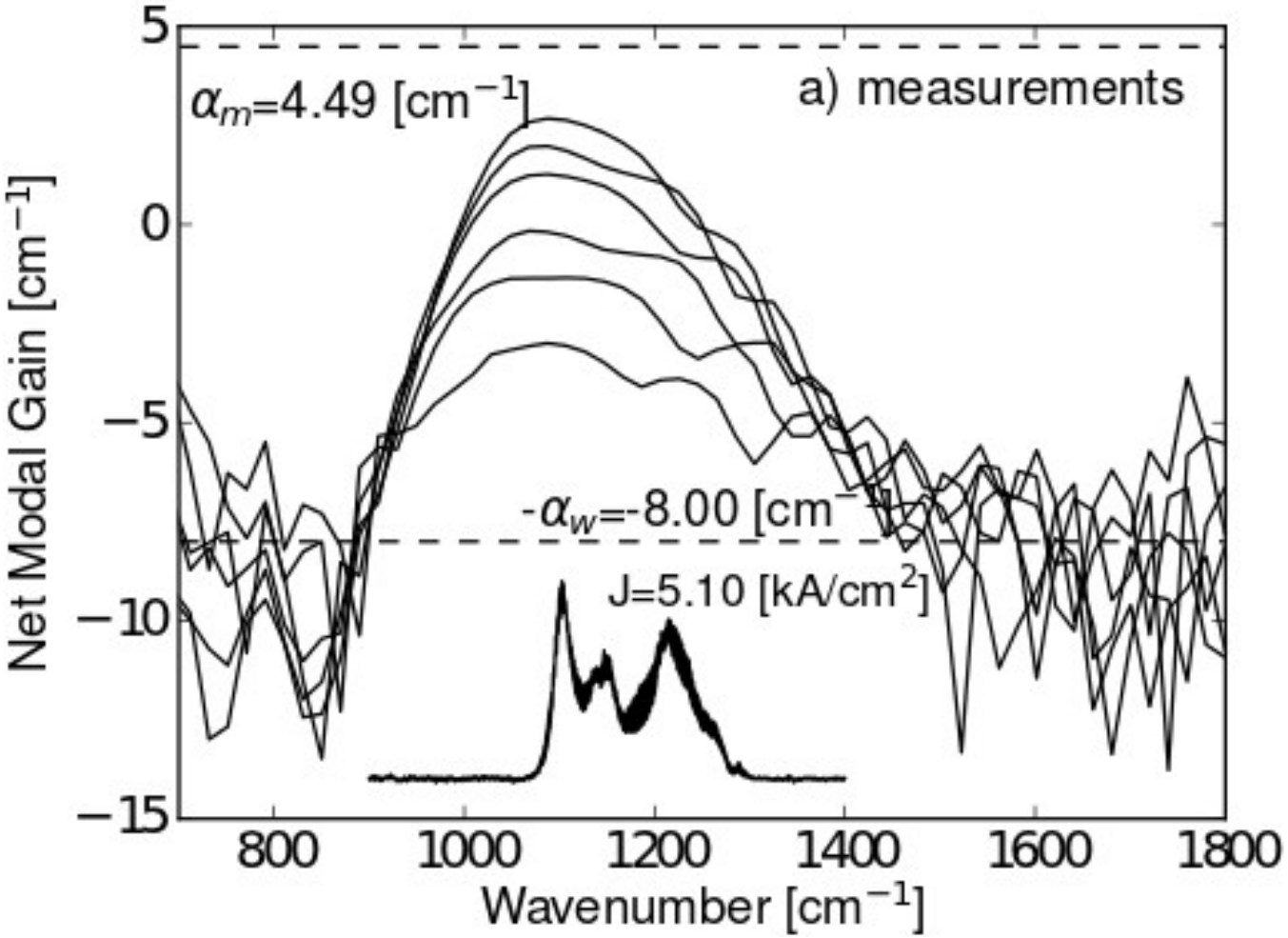
Redesigned flat gain multi-stack QCL 2nd version



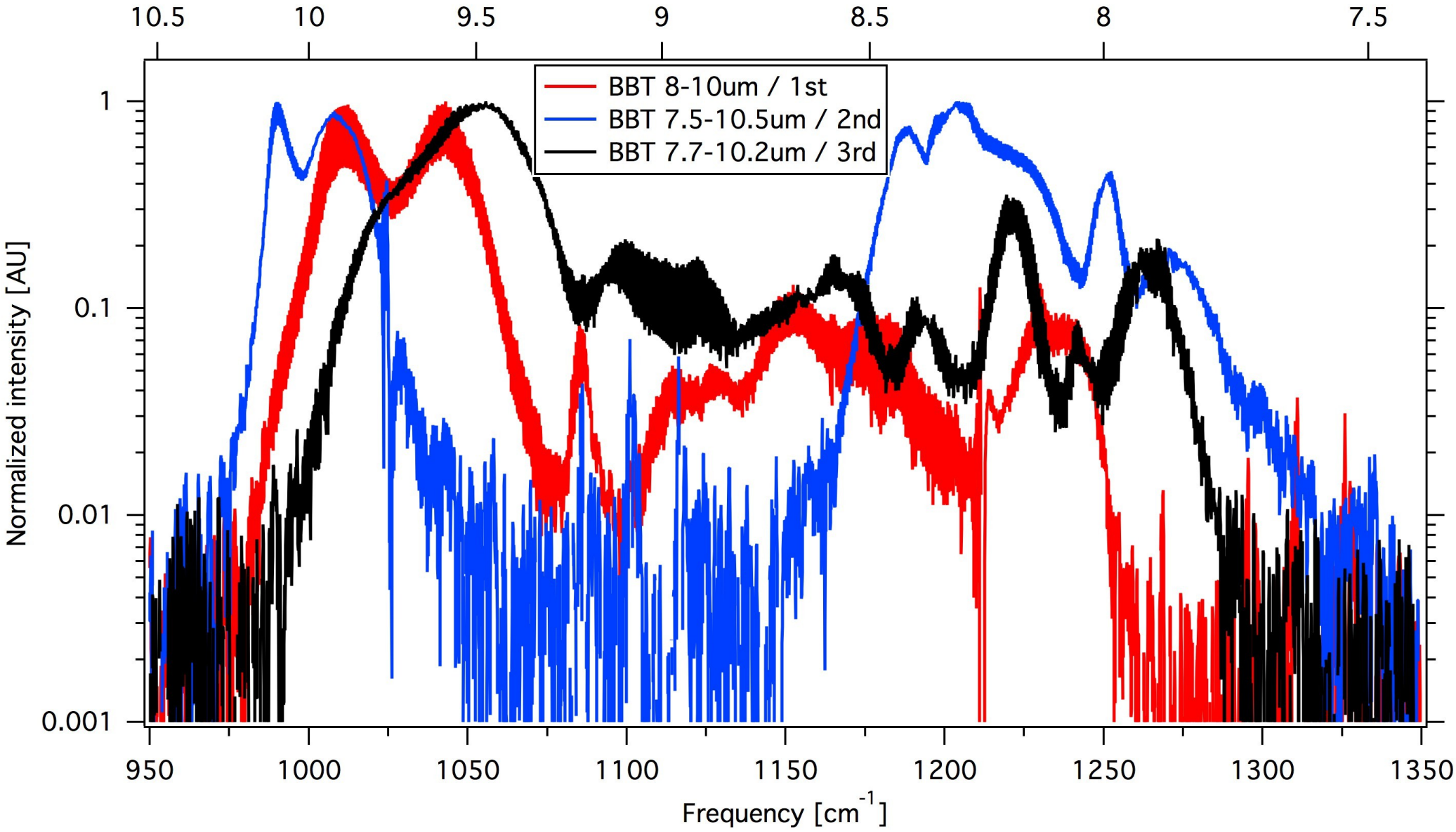
ALPES LASERS

Redesigned flat gain multi-stack QCL

Measurements and simulations for increasing current densities: 1.25, 1.75, 2.25, 2.75, 3.25, 3.75 kA/cm².

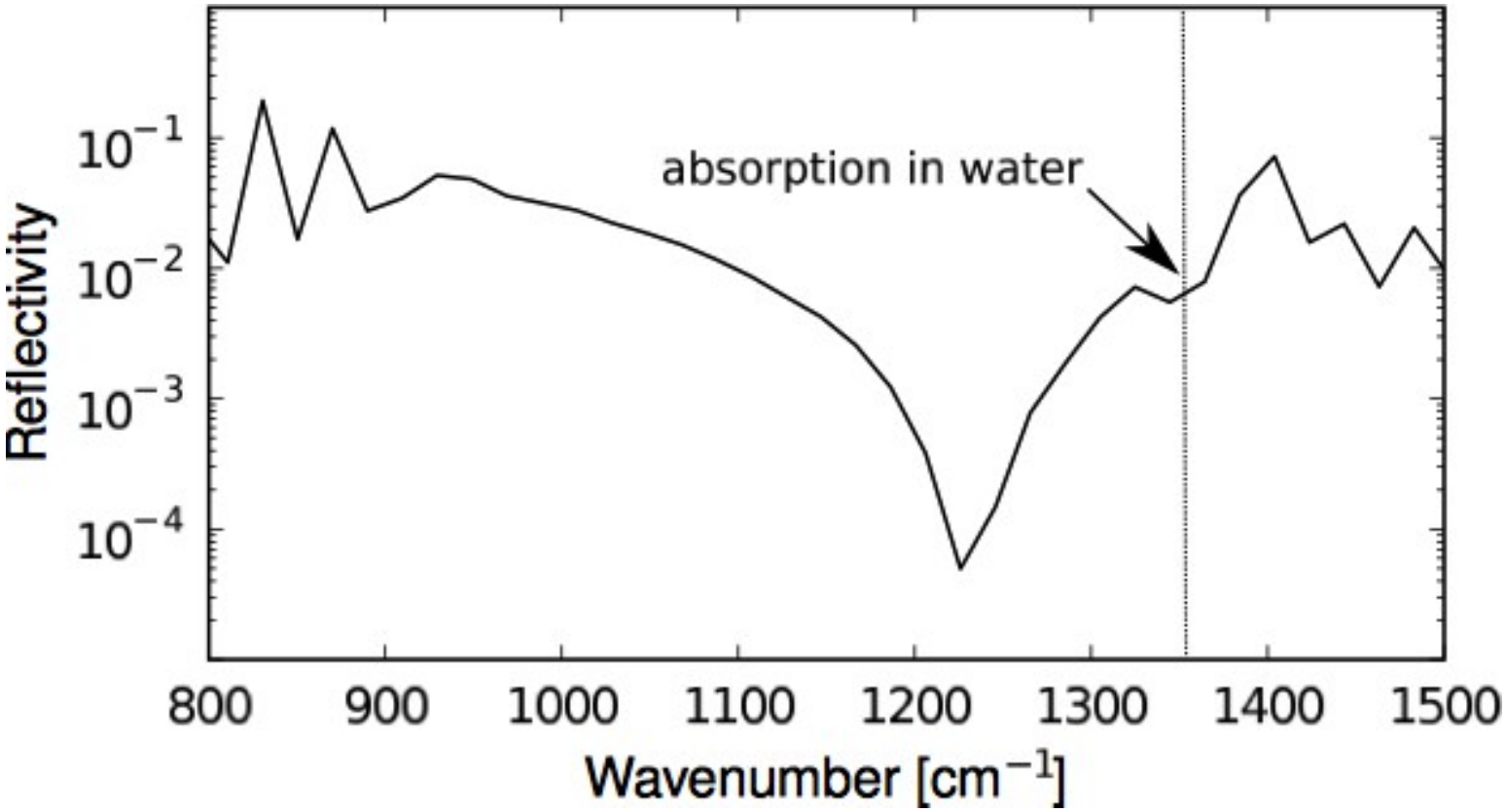


Redesigned flat gain multi-stack QCL
3rd version

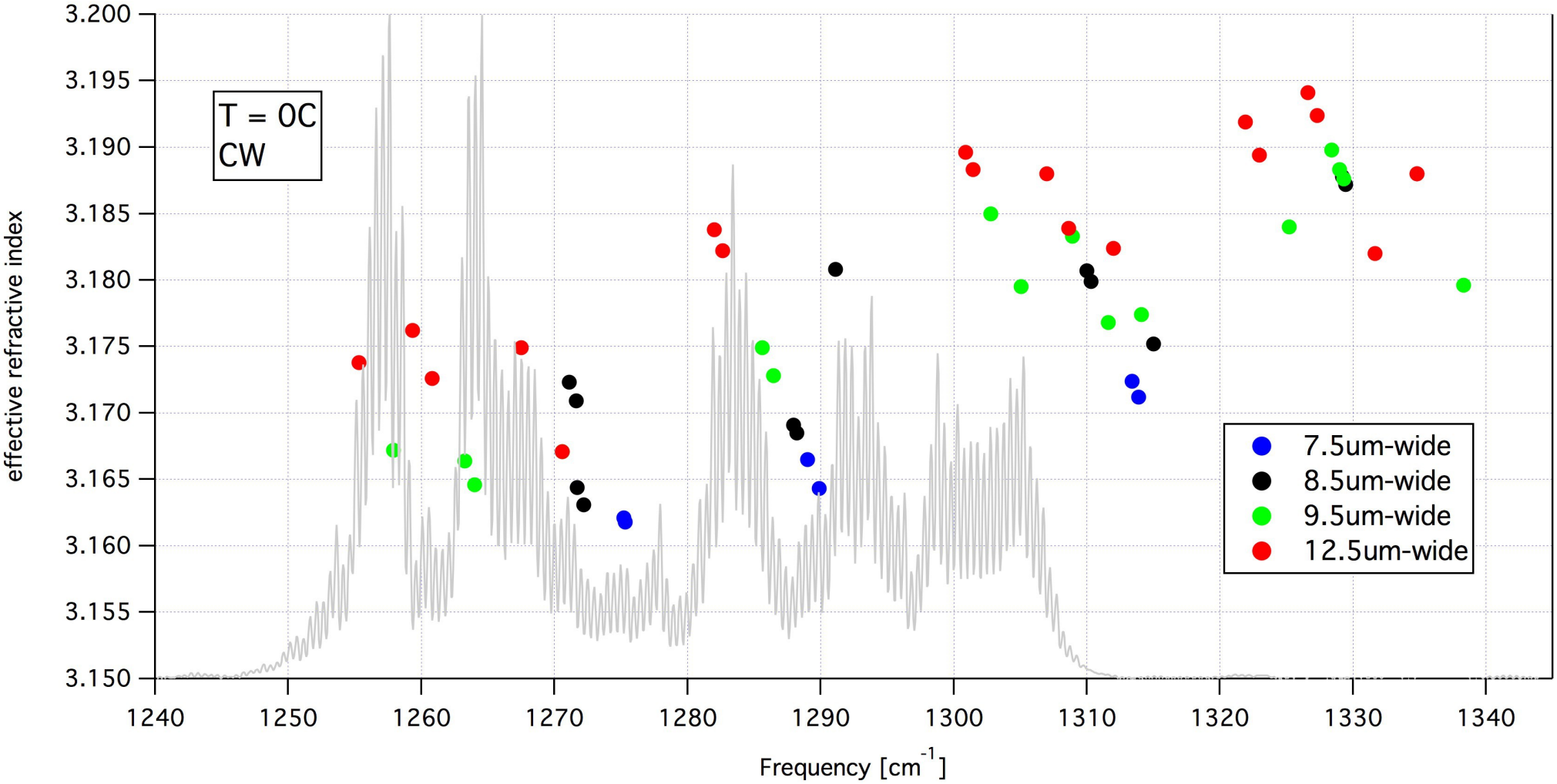


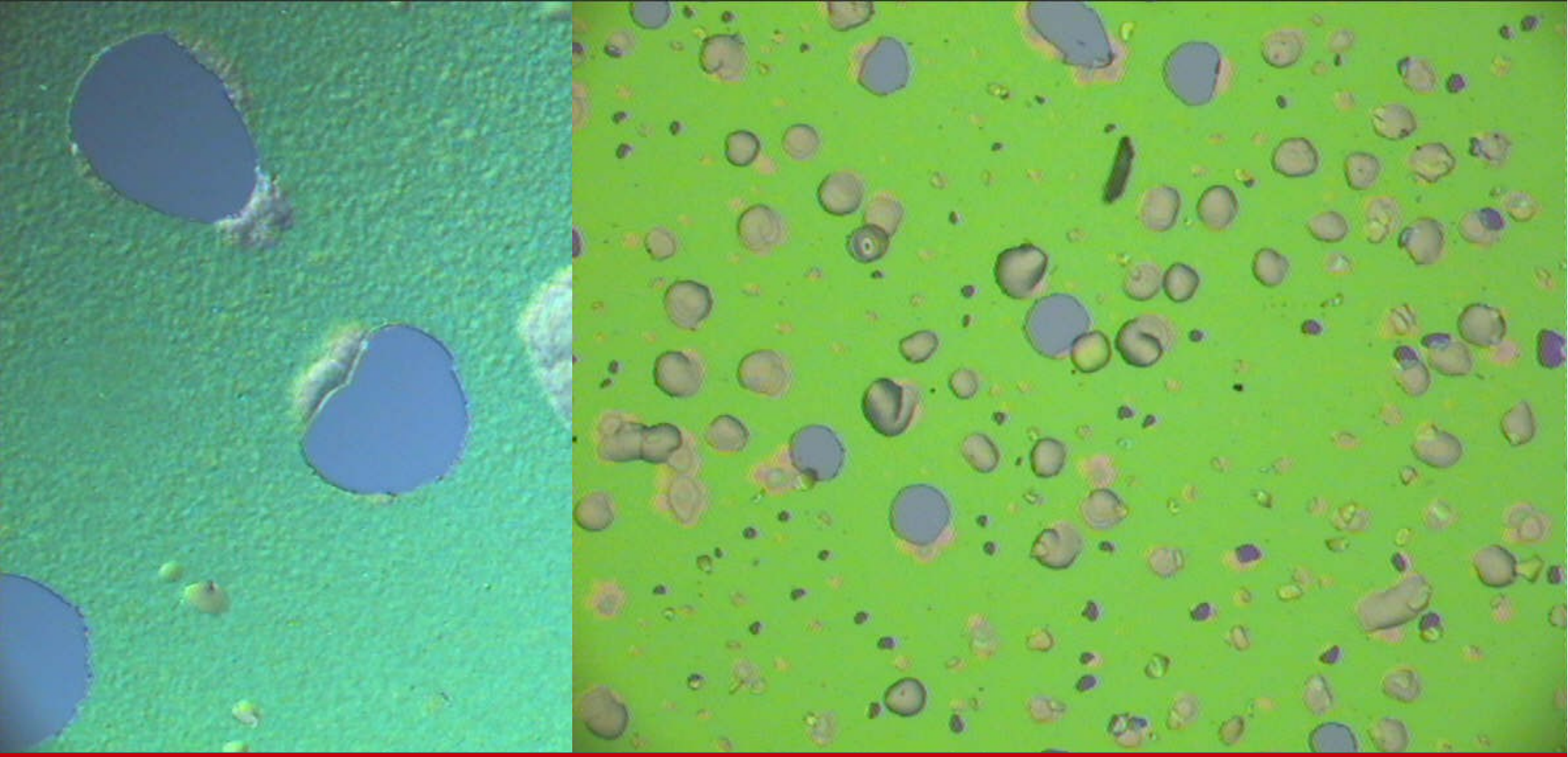
Study of broadband coating

- A minimum of reflectivity of $4*10^{-5}$ at 1250 cm^{-1} has been measured.



Application to wide multiple DFB material





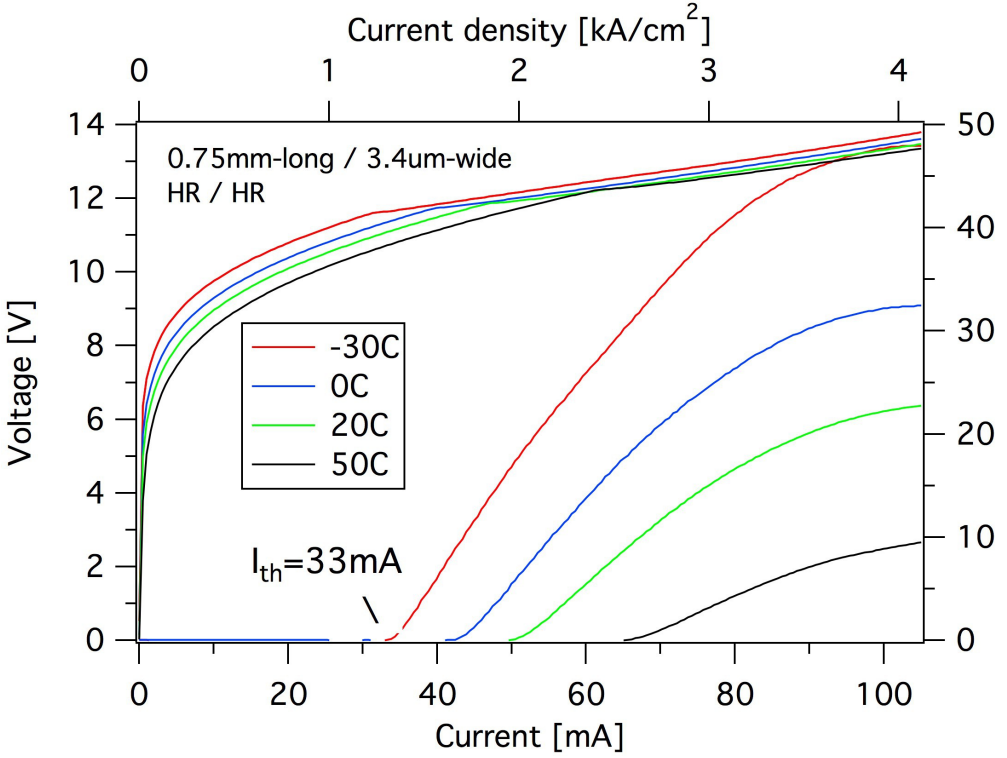
Single mode tuning

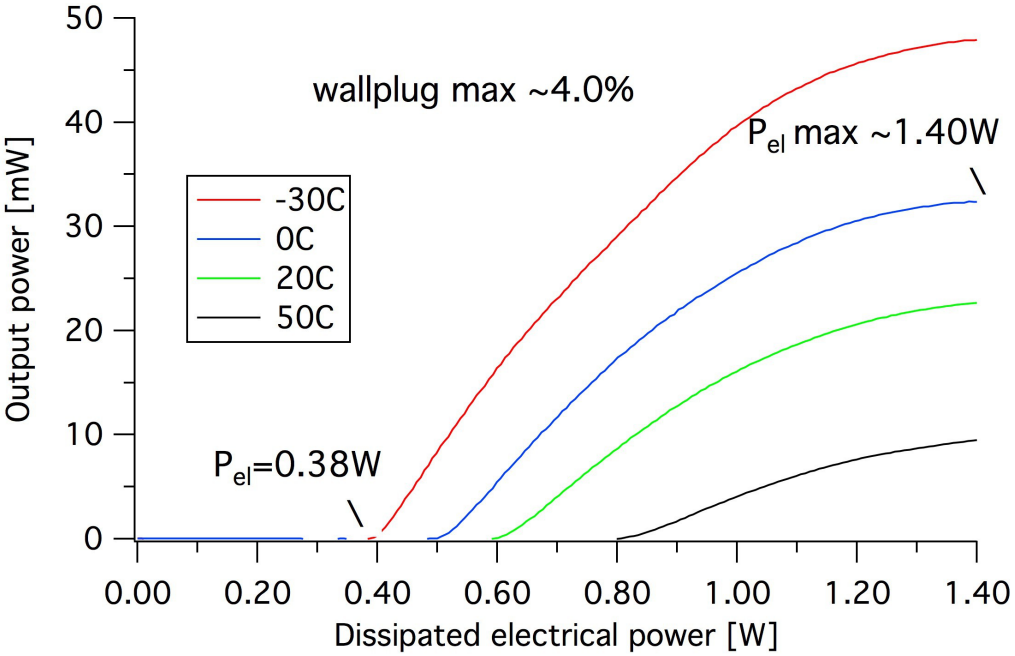
Low-dissipation DFB devices 4.52 μm

Optical Power : 48 mW

Wallplug efficiency max : 4 %

P_{el} max : 1.4 W

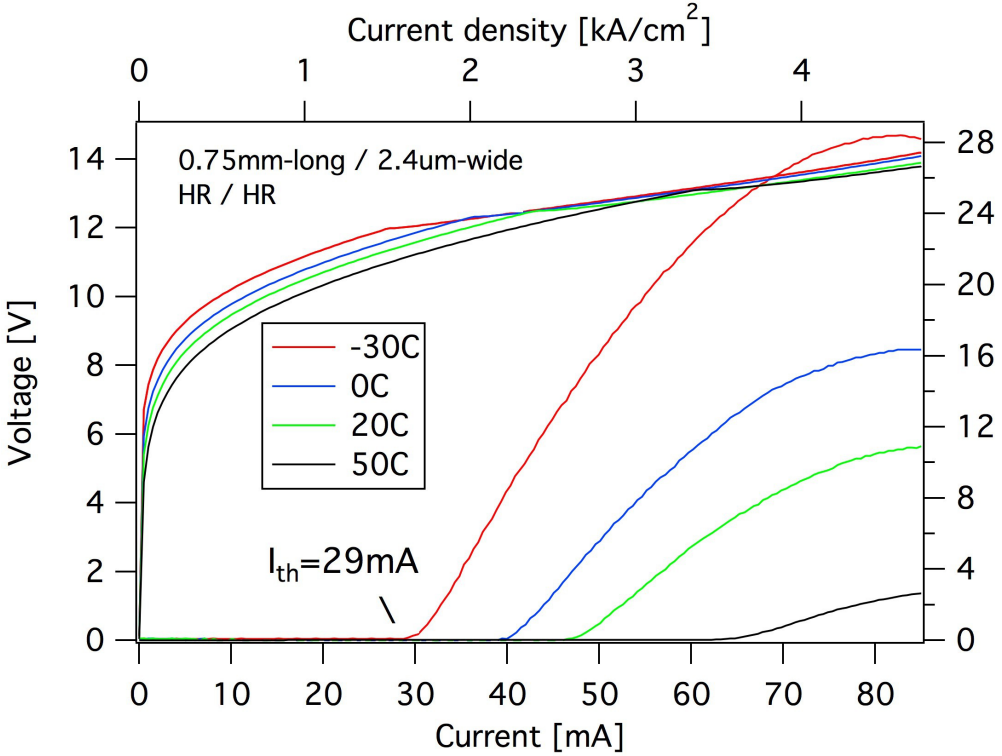


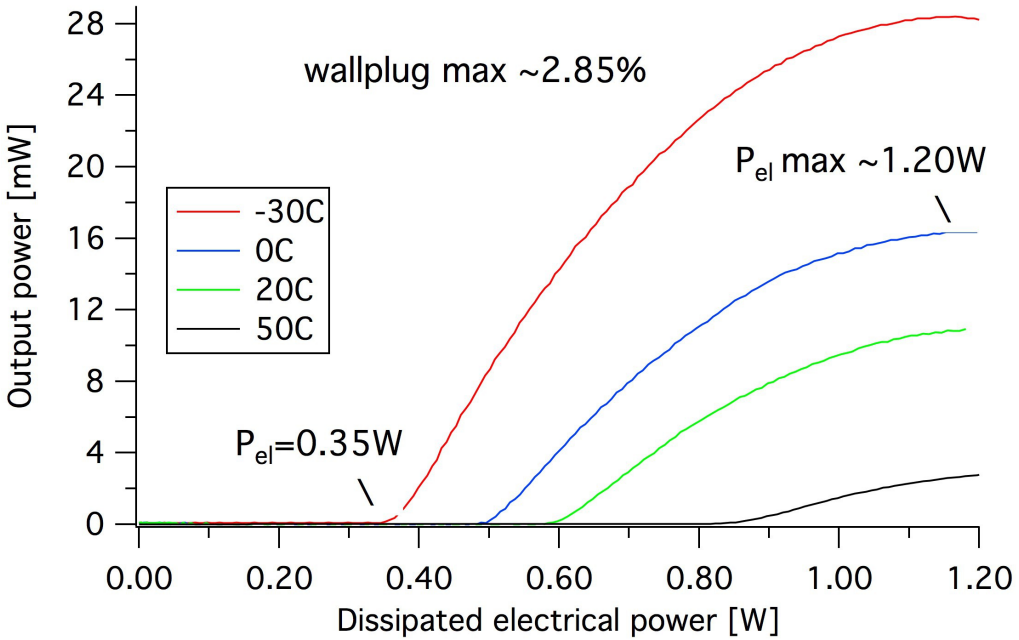


Low-dissipation DFB devices 4.50 μm

Threshold current : 29 mA

P_{el} max : 1.2 W

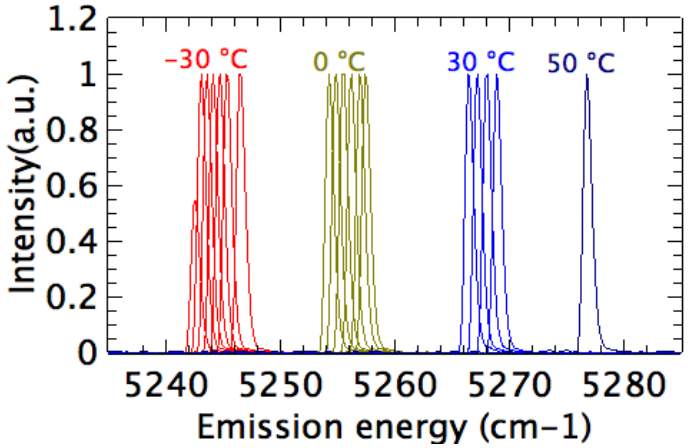


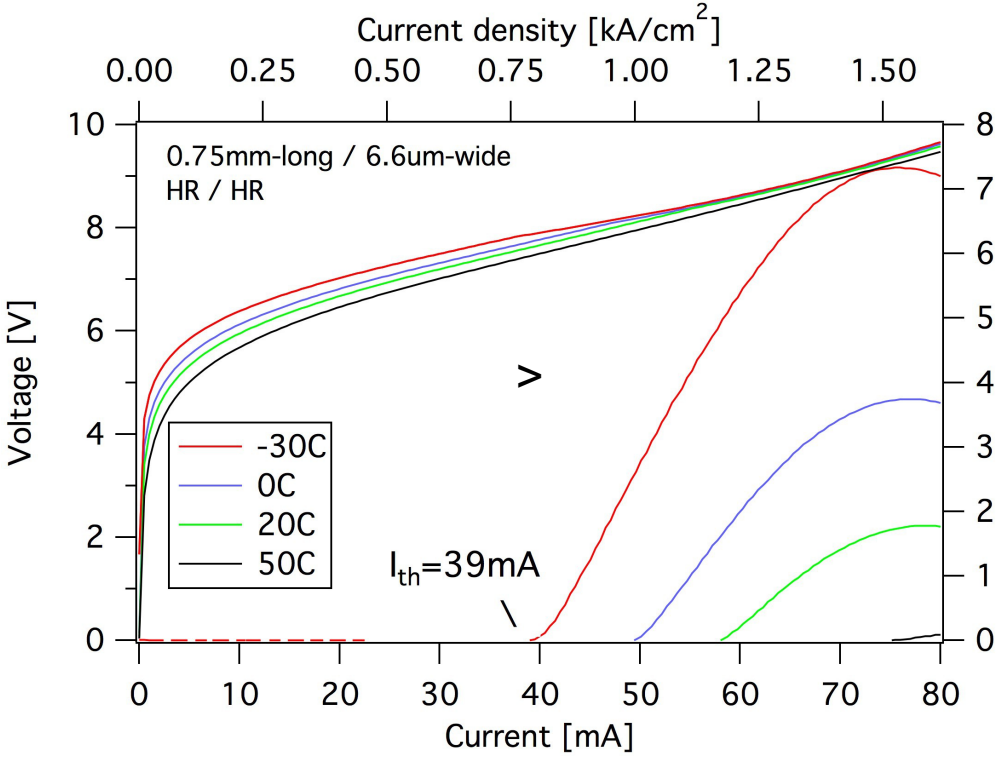


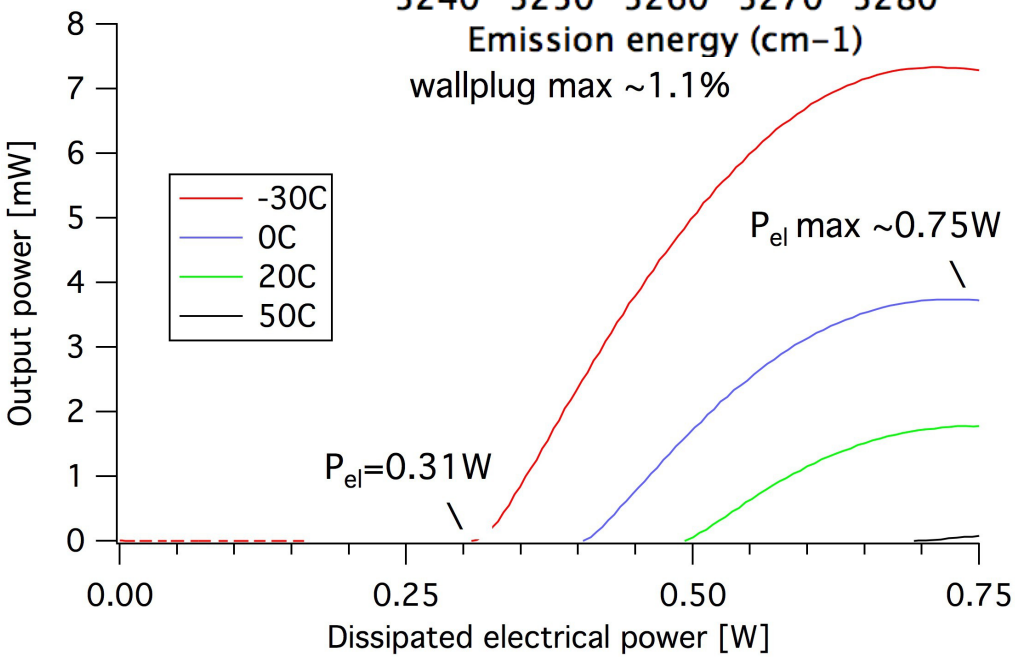
Low-dissipation devices 5.26 μm

Threshold power : 0.31 W

P_{el} max < 0.75 W





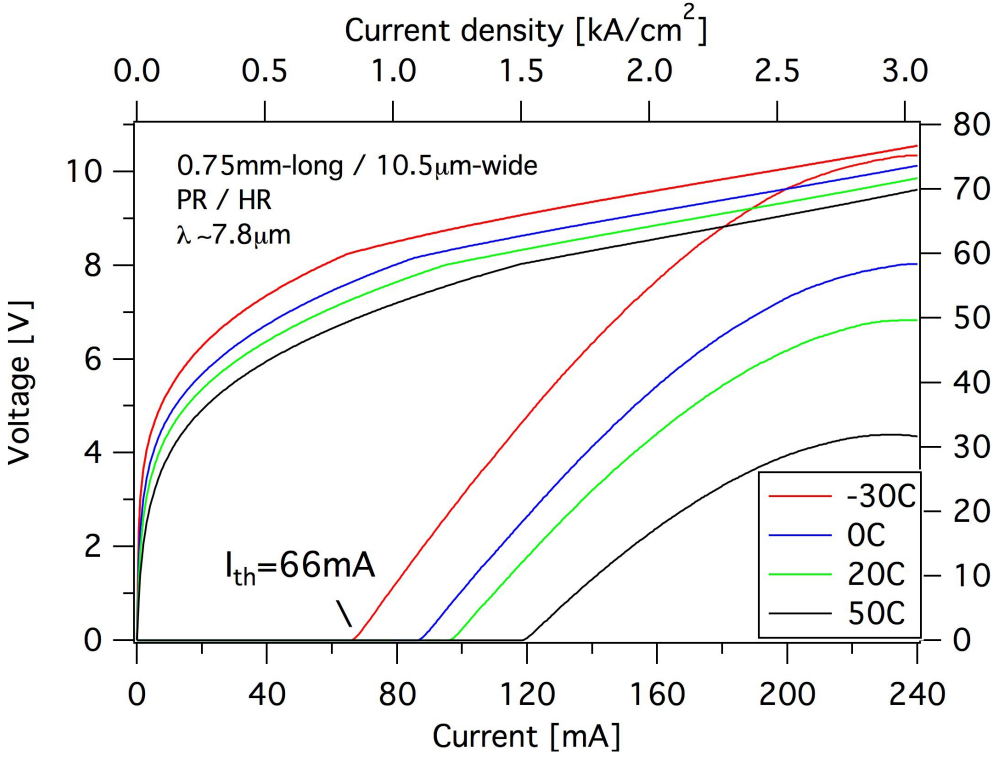


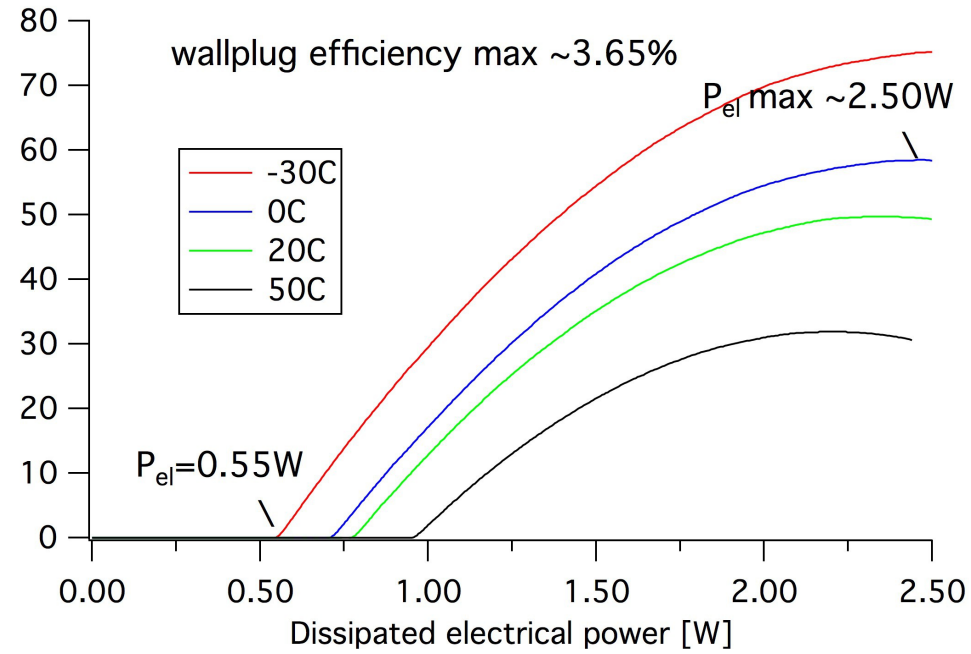
Low-dissipation DFB devices at 7.8 μm

Threshold current : 66 mA

Threshold power : 0.55 W

P_{max} > 70 mW / >3 dynamical range



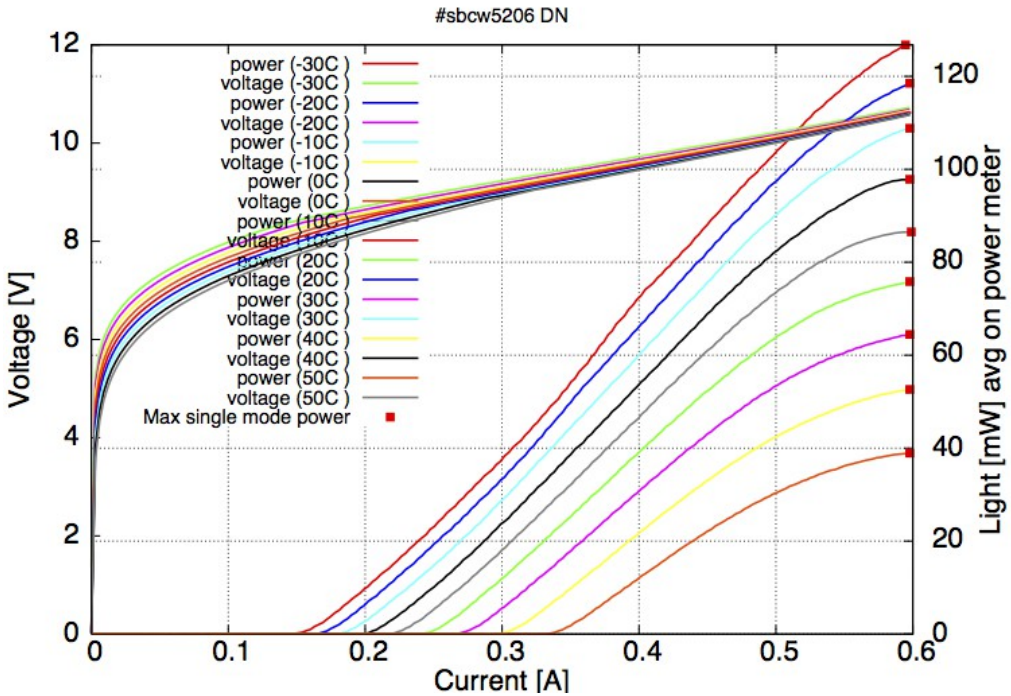


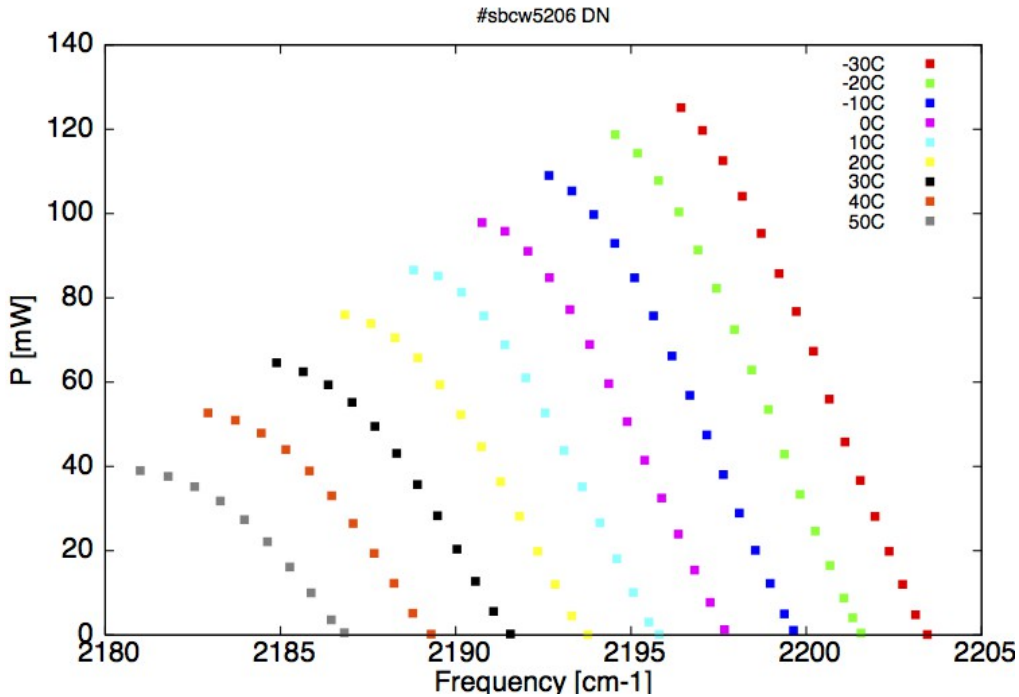
High power DFB devices 4.56 μm

~80 mW @RT / 40 mW @50C

P_{el} max < 6.4W

Single mode



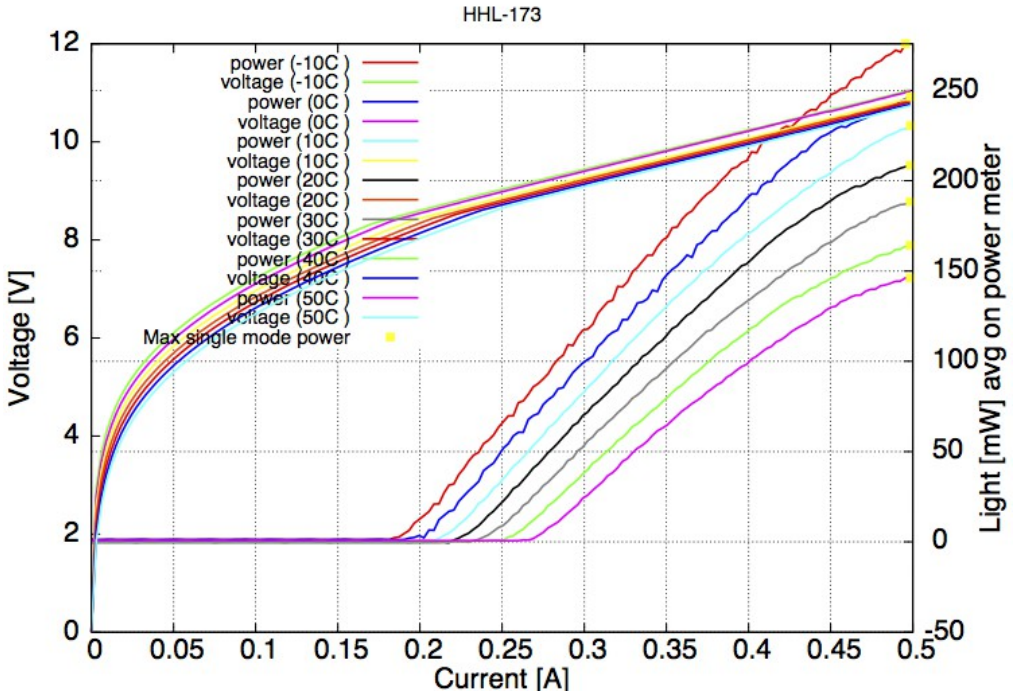


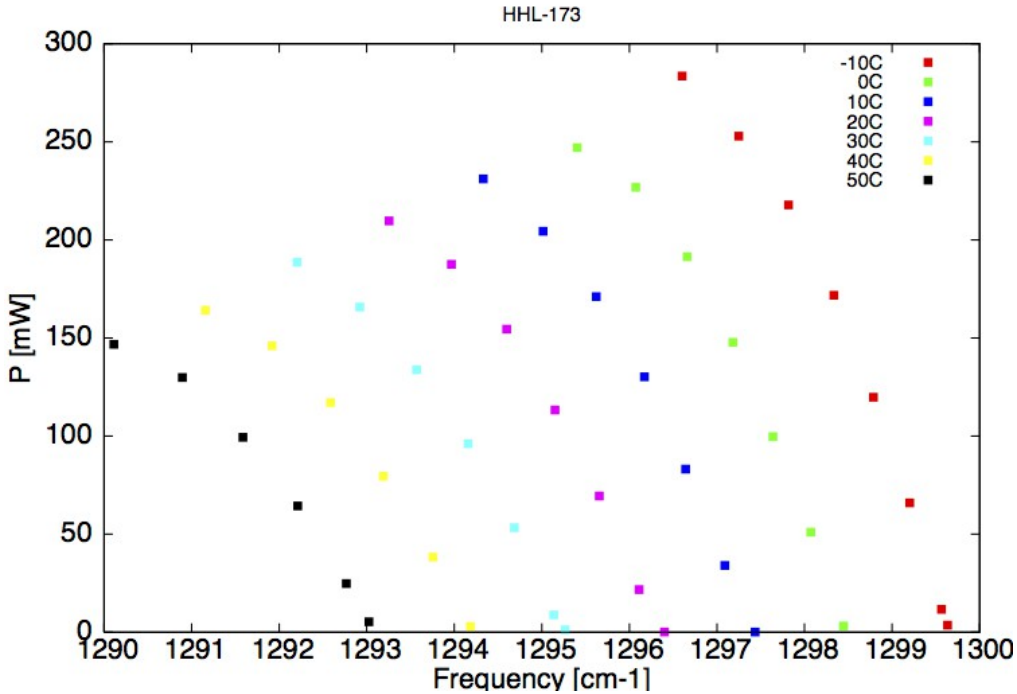
High power DFB devices 7.72 μm

~200 mW @RT / 140 mW @50C

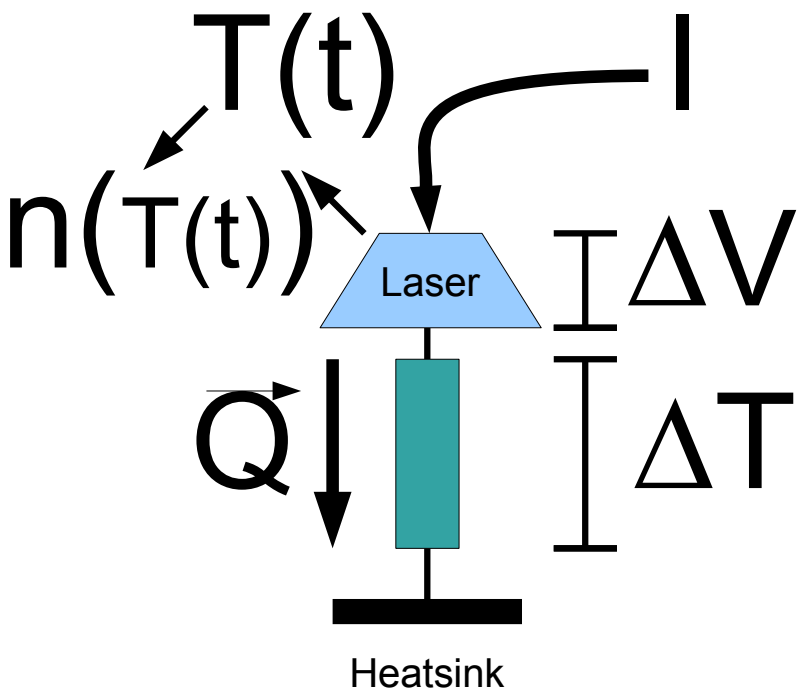
P_{el} max < 5.5W

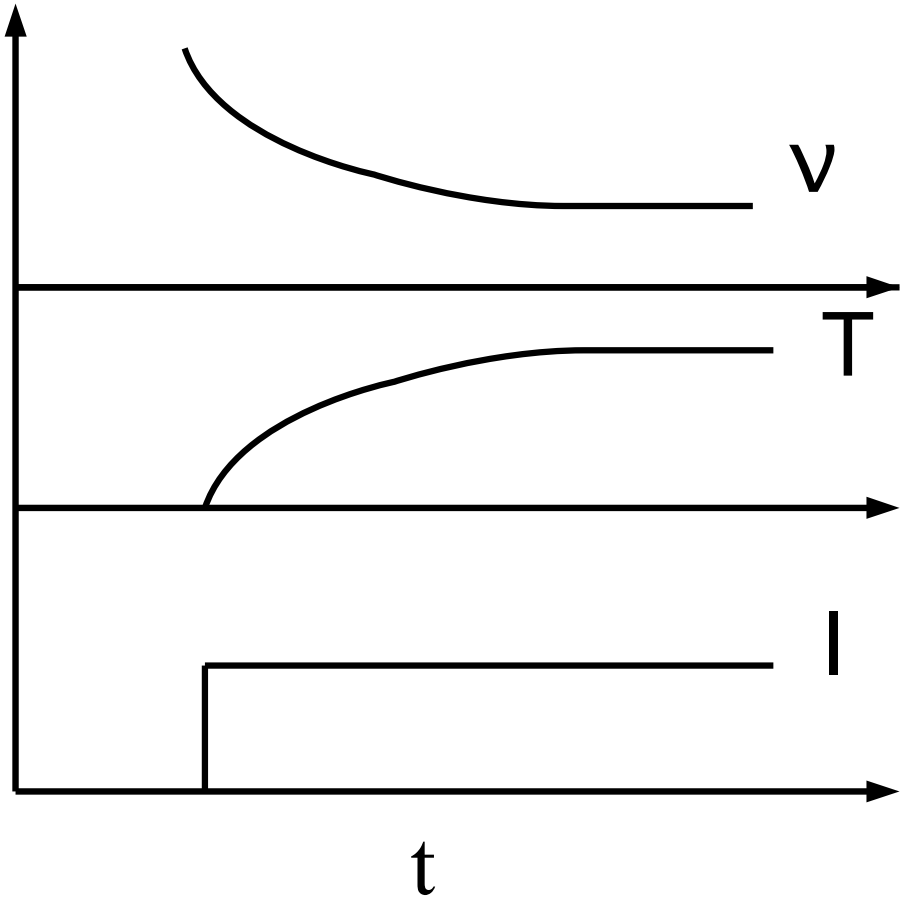
Single mode





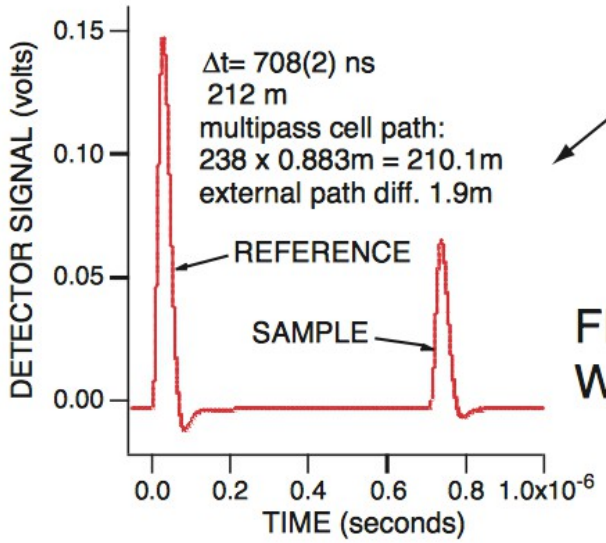
QCL Thermal Tuning

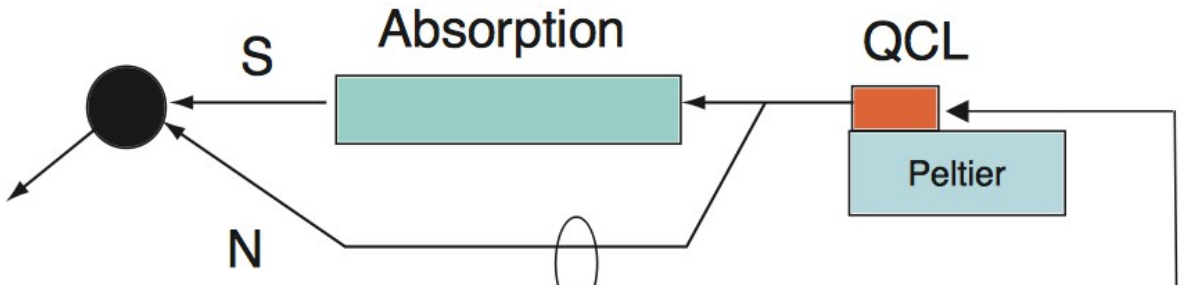




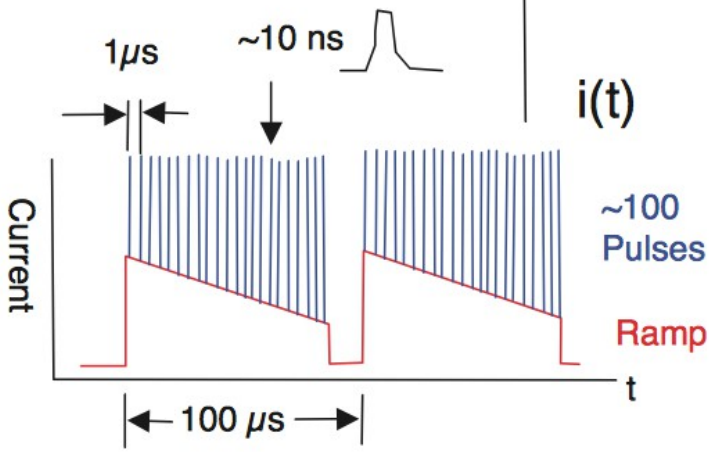
~0.2 K/ns -14 ppm/ns at turn on

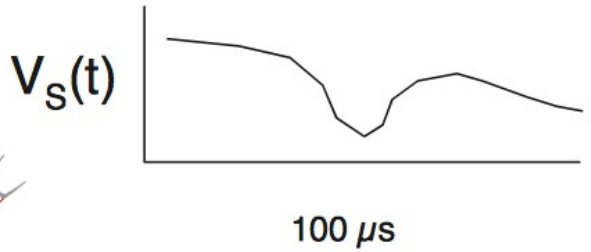
Inter-pulse modulation



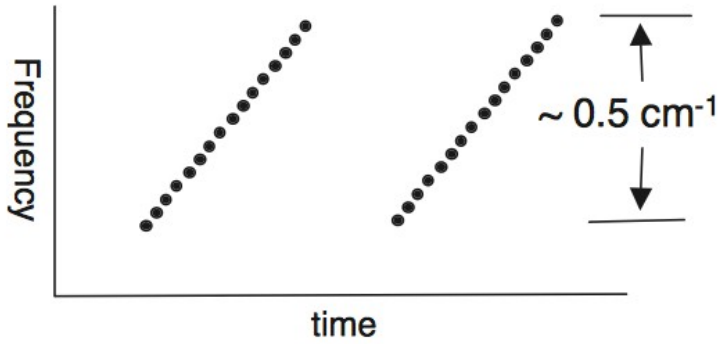


FRINGE SUPPRESSION
WITH TIME GATING



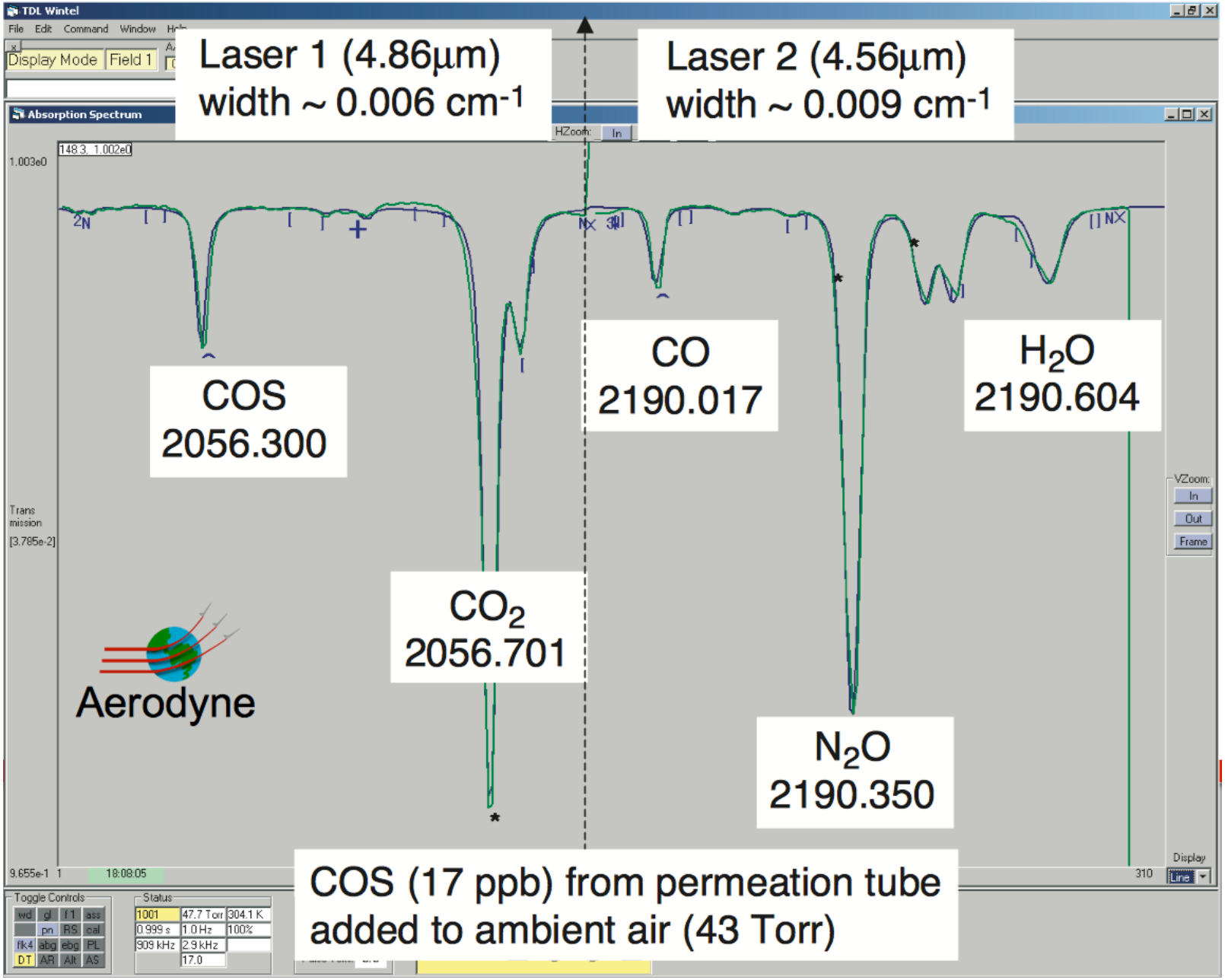


Average
Divide
Fit spectra
Calc. Conc.
Adj. Peltier



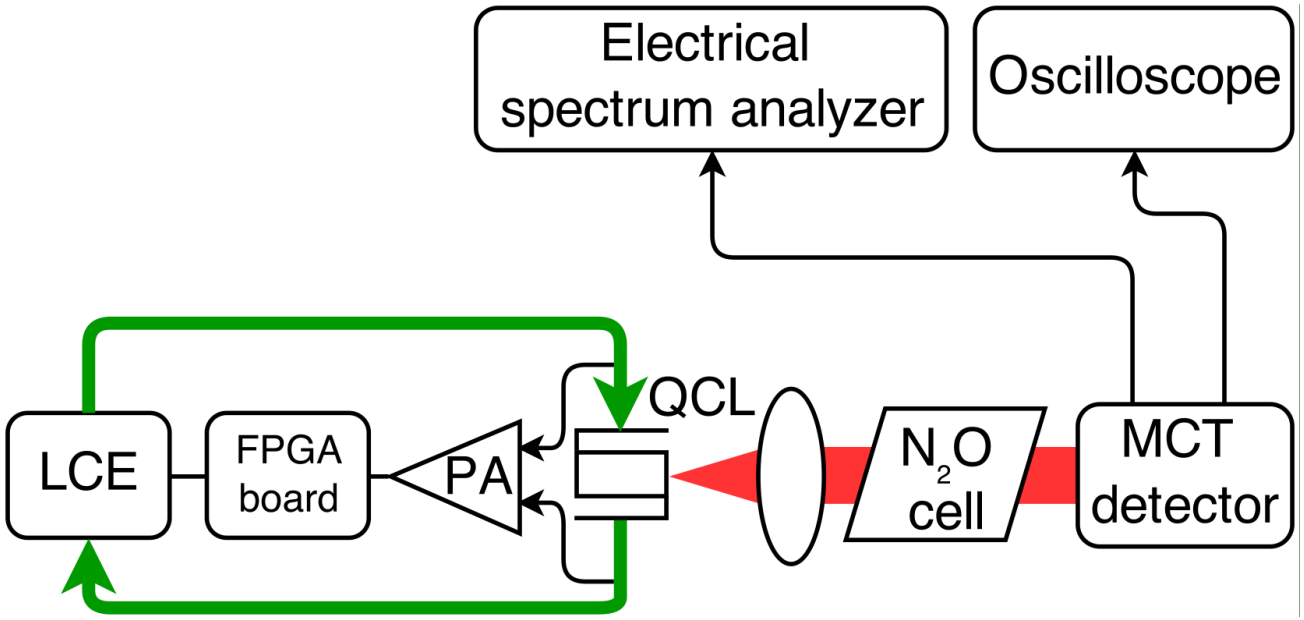
Aerodyne

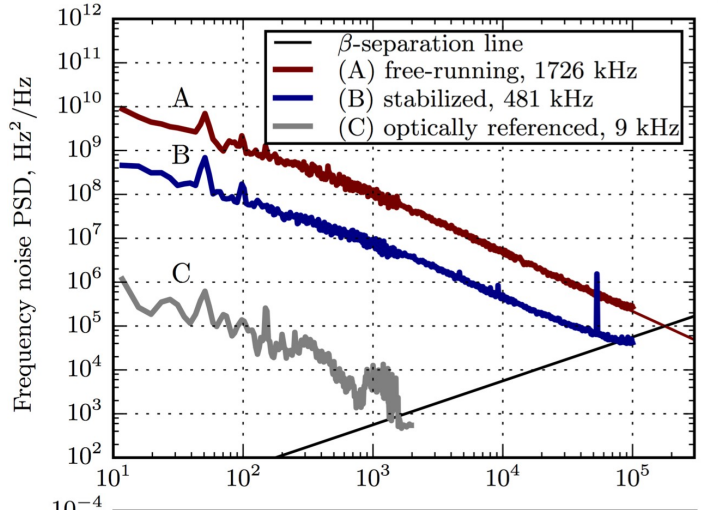
Inter-pulse modulation

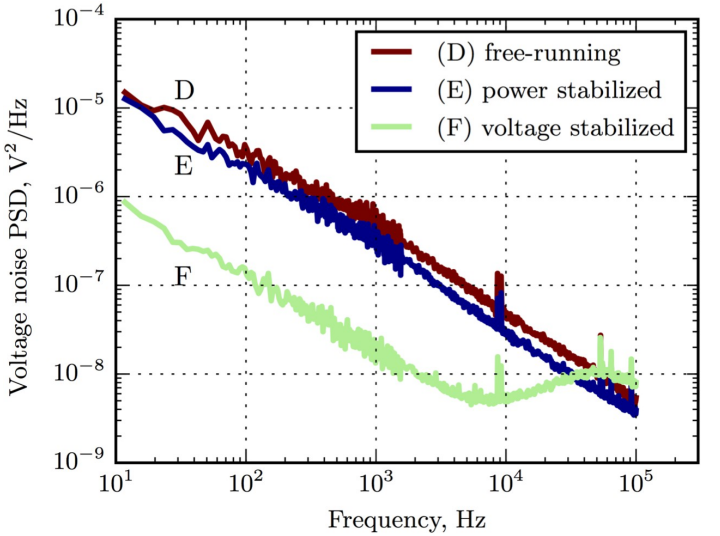


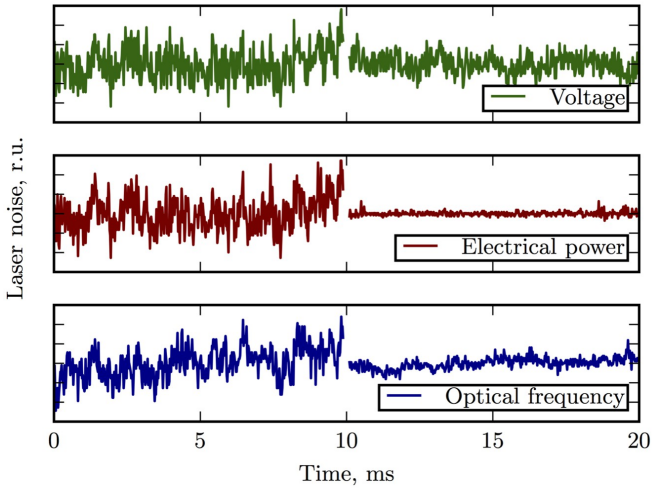
Aerodyne

CW Line-width









November 15, 2014 / Vol. 39, No. 22 / OPTICS LETTERS 6411

All-electrical frequency noise reduction and linewidth narrowing in quantum cascade lasers

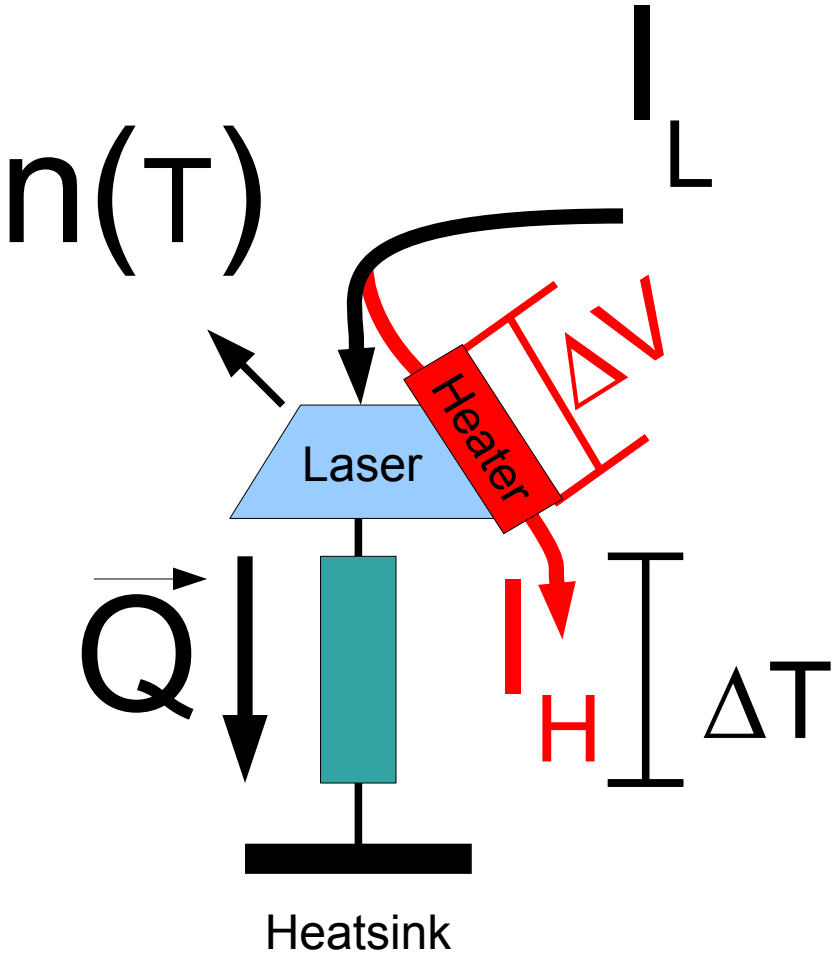
Ilia Sergachev,[1,*] Richard Maulini,[1] Alfredo Bismuto,[1] Stéphane Blaser,[1] Tobias Gresch,[1] Yves Bidaux,[1] Antoine Müller,[1] Stéphane Schilt,[2] and Thomas Südmeyer[2]

[1]*Alpes Lasers SA, 1-3 Max.-de-Meuron, CH-2001 Neuchâtel, Switzerland*

[2]*Laboratoire Temps-Fréquence, Institut de Physique, Université de Neuchâtel, CH-2000 Neuchâtel, Switzerland*

**Corresponding author: ilia.sergachev@alpeslasers.ch*

QCL Enhanced Thermal Tuning



Electrical heater

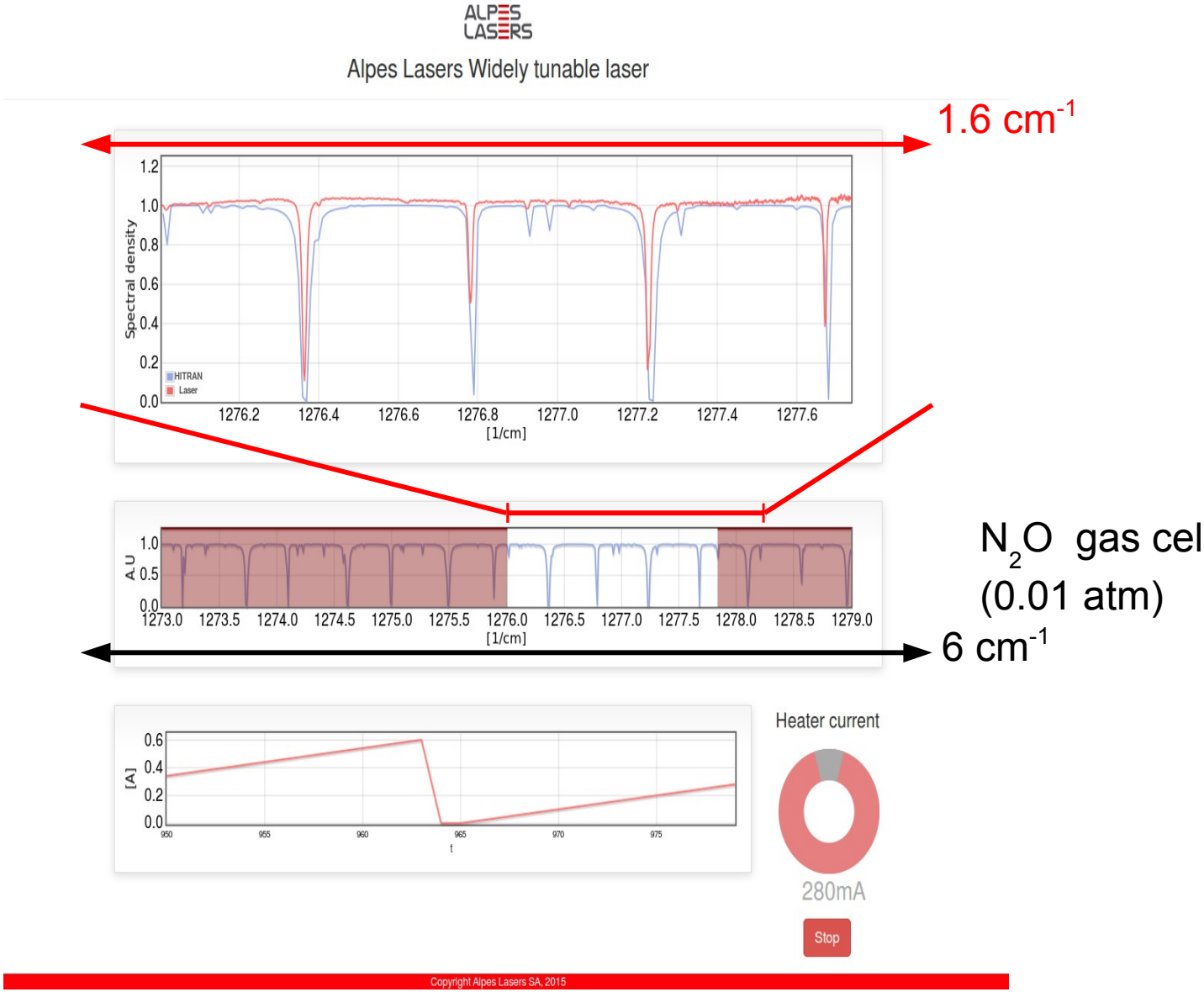
- Fast
- Precise

Independent

- ν & $P_{opt.}$ tuning

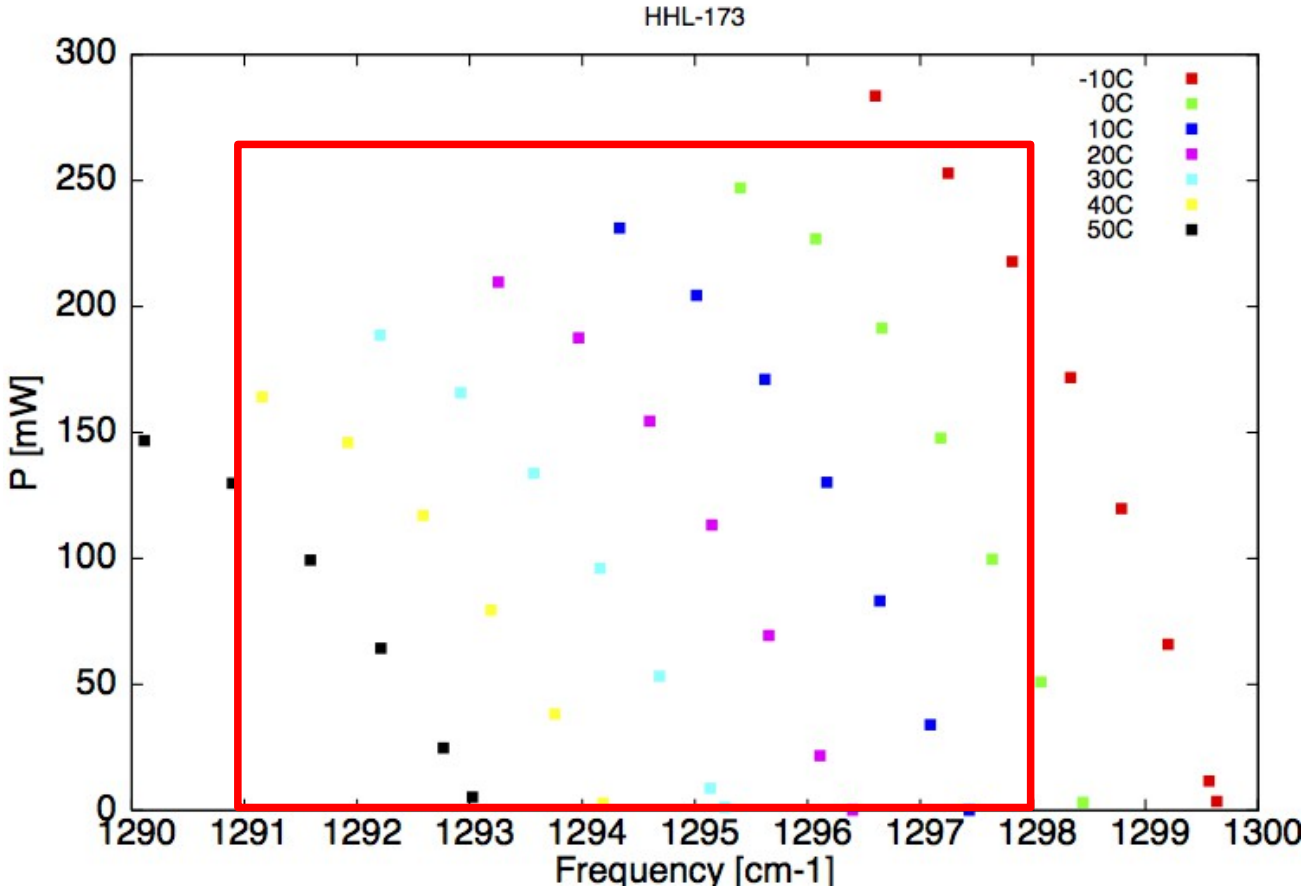
Enhanced electrical tuning

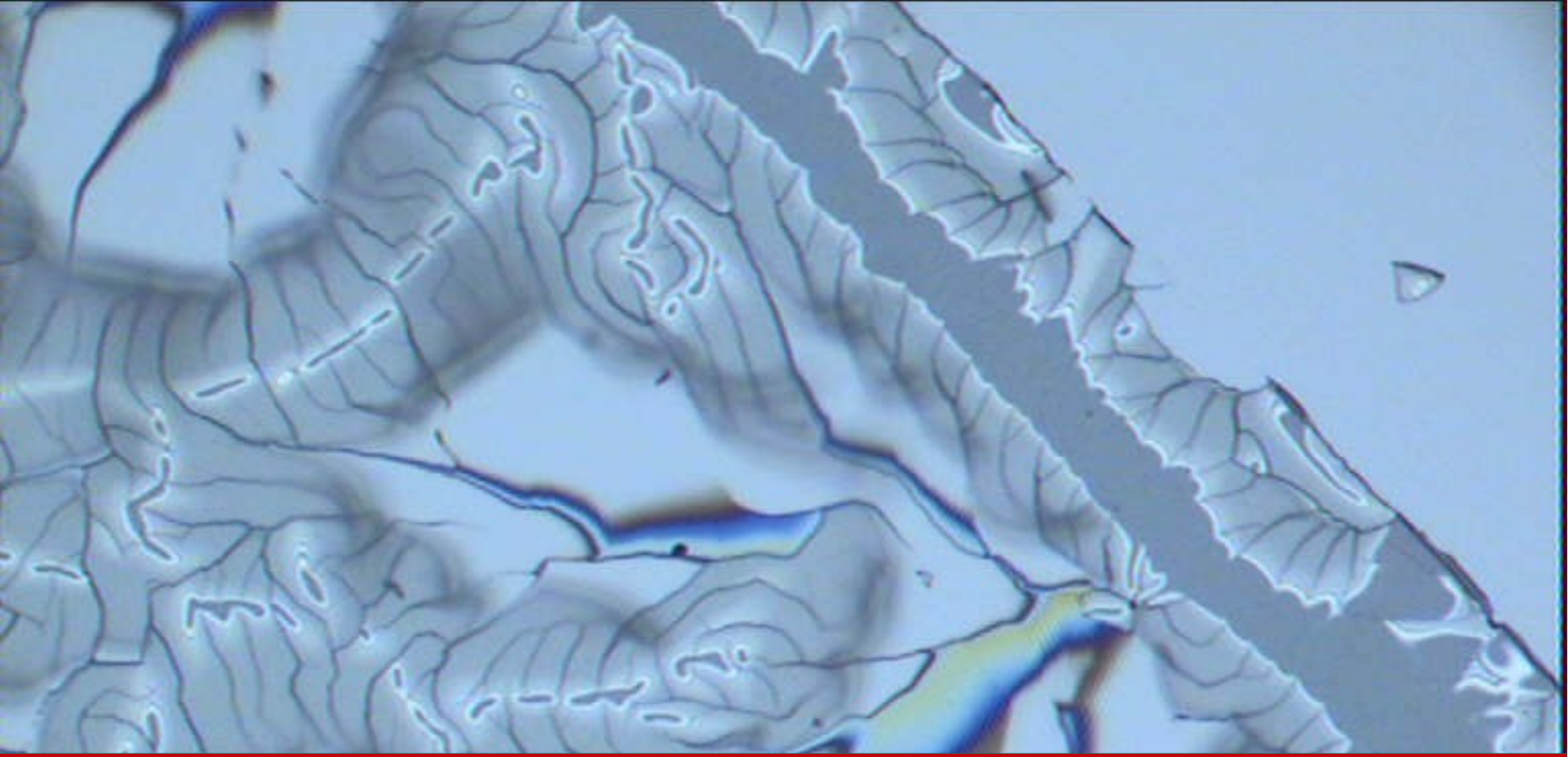
Soon available



Up to 10 cm-1 electrical tuning using integrated microheater...

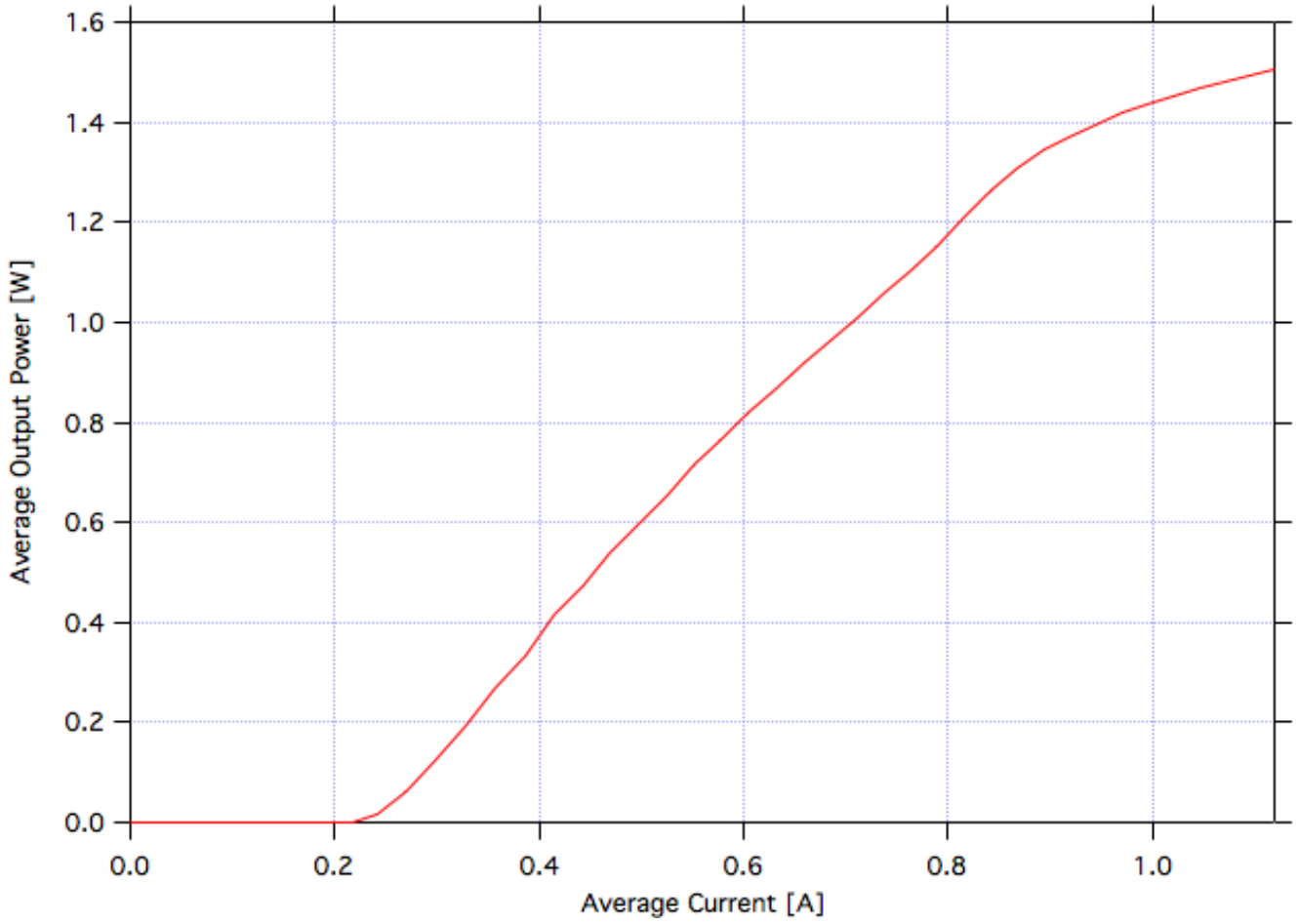
Comparison with T, I tuning





Power

High Power Quantum Cascade Lasers

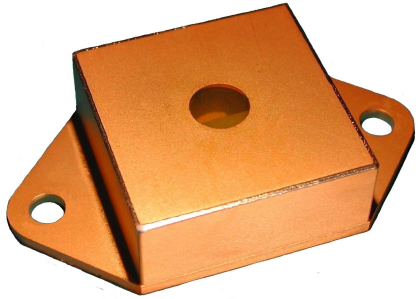


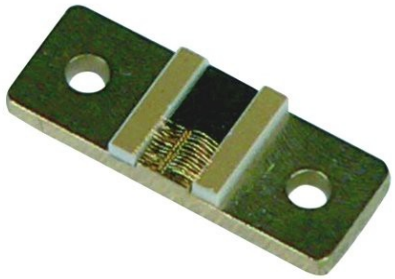
1.5 W output power at 4.9 μm in HHL package

R. Maulini

ALPES LASERS

Conclusion





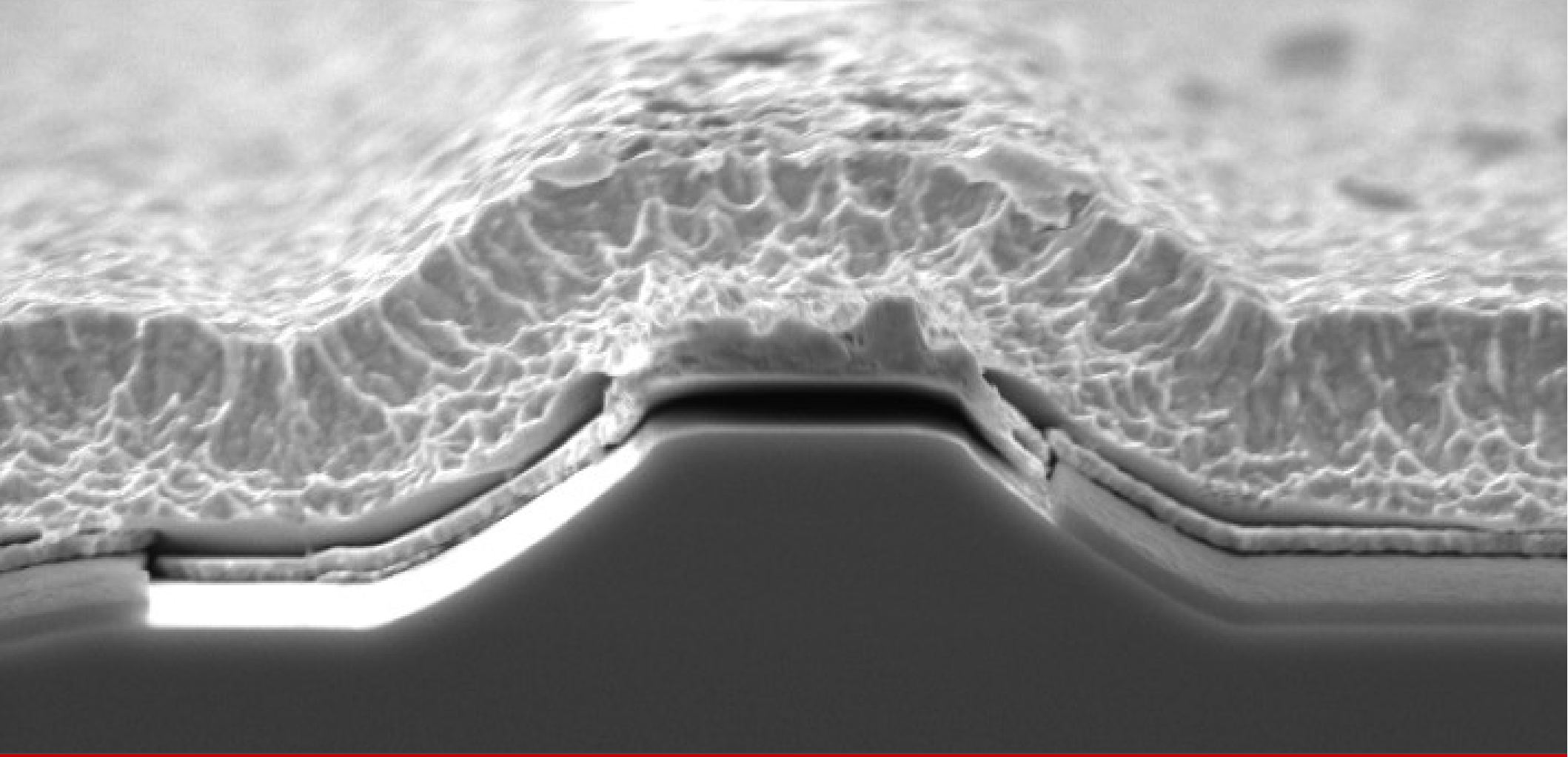
Availability

- CW: 4–12 μm, P: 3.3–23 μm

Line-width

- Narrow <5MHz, <100kHz actively
- Broad up to CW: 300 cm^{-1}, P: 450 cm^{-1}

Electrical tune-ability up to 7 cm^{-1}



www.alpeslasers.ch
info@alpeslasers.ch