High performance, low dissipation QCL across the mid-IR range

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Outline

- Alpes Lasers overview
- Single mode sources
  - DFB sources below 1W between 4.5-9.3µm
  - High power DFB
- High power FP devices
- Conclusion and next steps

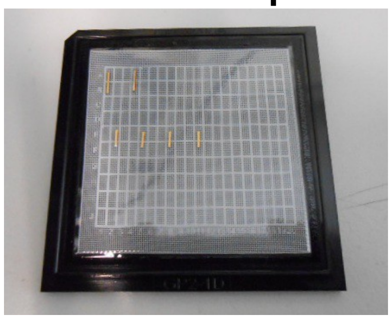
Our company

Alpes Lasers

- founded in 1998
- 19 employees (11PhD, 5 eng.)
- >200 Person*Year
- fabless component manufacturer
- 2400+ sold lasers
- 550+ packaged lasers
- several patents on QCL principles

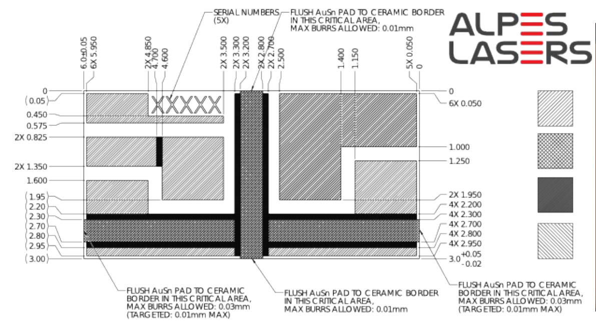
QC lasers and electronics

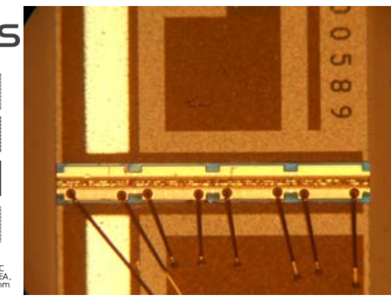
- Bare chips



- NS

- AlN submount (3x6mm)





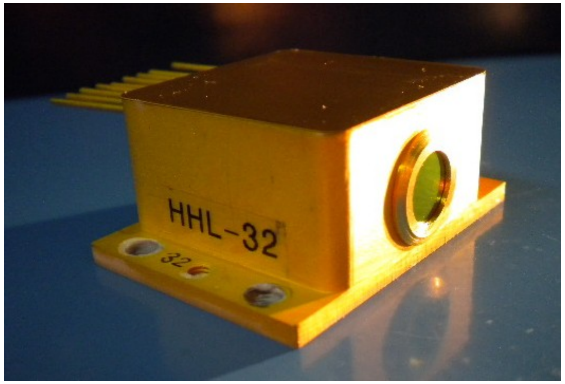
- TC3

- Driver kits (starter kits)

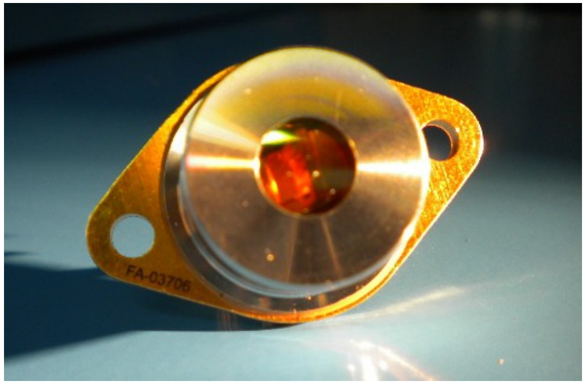
QCL subsystems

- TO3-L

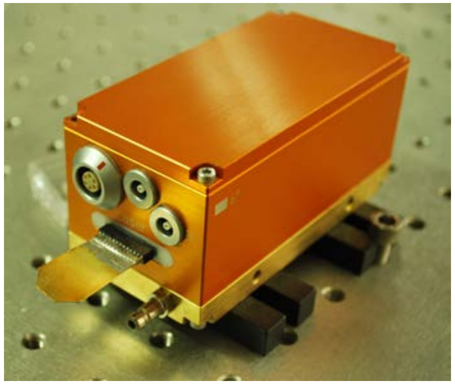
- HHL-L



- TO3-W



- LLH



- lower consumption packages being validated (TO5, etc.)

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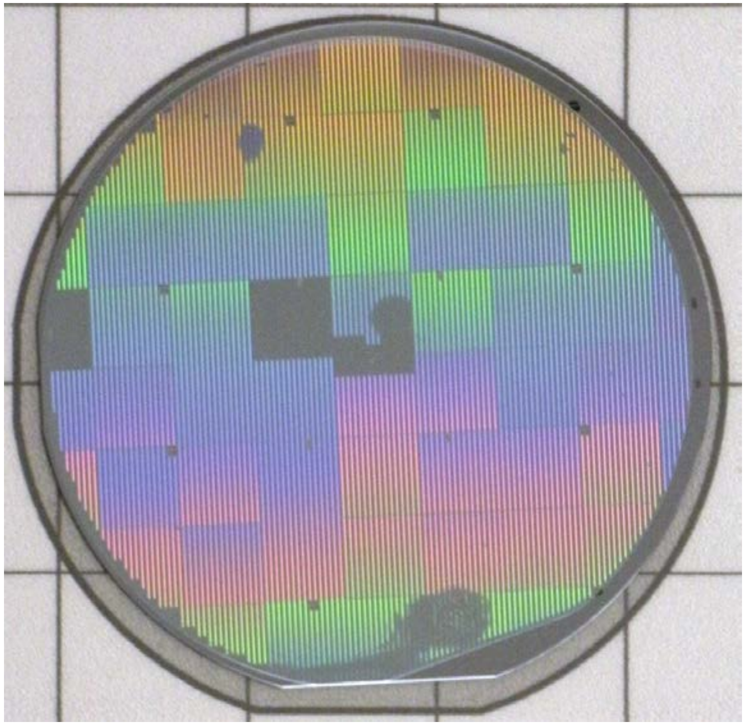
DFB technology

		C7 1.9655 0.8%	D7 1.9145 1.6%	E7 1.8085 2.0%	F7 1.9255 1.6%	G7 1.8765 0.8%		
	B6 1.836 1.2%	C6 1.948 2.0%	D6 1.8645 2.0%	E6 1.8765 2.0%	F6 1.7765 2.0%	G6 1.8695 2.0%	H6 1.933 1.2%	
A5 1.887 0.4%	B5 1.741 2.0%	C5 1.7375 2.0%	D5 1.741 2.0%	E5 1.8835 2.0%	F5 1.734 2.0%	G5 1.746 2.0%	H5 1.887 2.0%	I5 1.7765 0.4%
A4 (LOCK) 00.00000 1.0%	B4 1.8395 2.0%	C4 1.8835 2.0%	D4 (LOCK) 00.00000 2.0%	E4 1.848 1.5%	F4 1.9555 2.0%	G4 1.8765 2.0%	H4 1.873 2.0%	I4 1.7375 1.0%
A3 1.831 1.0%	B3 1.789 2.0%	C3 1.873 2.0%	D3 1.88 2.0%	E3 1.7375 1.5%	F3 1.7565 2.0%	G3 1.887 2.0%	H3 1.799 2.0%	I3 1.843 1.0%
A2 1.746 0.5%	B2 1.9045 2.0%	C2 1.843 2.0%	D2 1.892 2.0%	E2 1.751 2.0%	F2 1.836 2.0%	G2 1.8395 2.0%	H2 1.7615 2.0%	I2 1.9655 0.5%
	B1 1.8695 1.4%	C1 1.9405 2.0%	D1 1.897 2.0%	E1 1.8185 2.0%	F1 1.88 2.0%	G1 1.8595 2.0%	H1 1.826 1.4%	
		C0 1.8545 1.1%	D0 1.724 1.9%	E0 1.729 2.0%	F0 1.7665 1.9%	G0 1.734 1.1%		

Proprietary gratings design tool

UV technology



DFB grating during fabrication

- gratings written by standard lithography from 4-12 µm
- many different wavelengths can be fabricated at once
- efficient device mounting
- full 2''-wafer process
- polyvalent production process

Single mode sources

A killer application is still missing... why ?

- Laser sources :
  - Low efficiency compared to diode lasers
  - High electrical dissipation (W_{el}>>1W)
  - Nb of lasers per wafers still low (long lasers & small wafers)
  - Fabrication is still expensive
- Photonics :
  - Difficult to do photonic integration
  - Optical elements expensive
  - Detectors less sensitive and more expensive

Thermal budget in QCLs

- Most of QCLs have 5-15 W of electrical dissipation
- Up to 100 W are needed to control the temperature
- Optical power levels of few mW sufficient for many applications

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Research goal:

- Low dissipation devices
- Short chips
- Still enough optical power for spectroscopy

Advantages of short devices

- Low dissipation (more easy CW bar testing)
- More devices per wafer

Number of defects

$$P = \sum_k \lambda^k \frac{e^{-\lambda}}{k!}$$

Probability of major defect in the laser wg

Advantages of short devices

- Low dissipation (more easy CW bar testing)
- More devices per wafer

- Probability of defects (λ) follows a Poissonian law

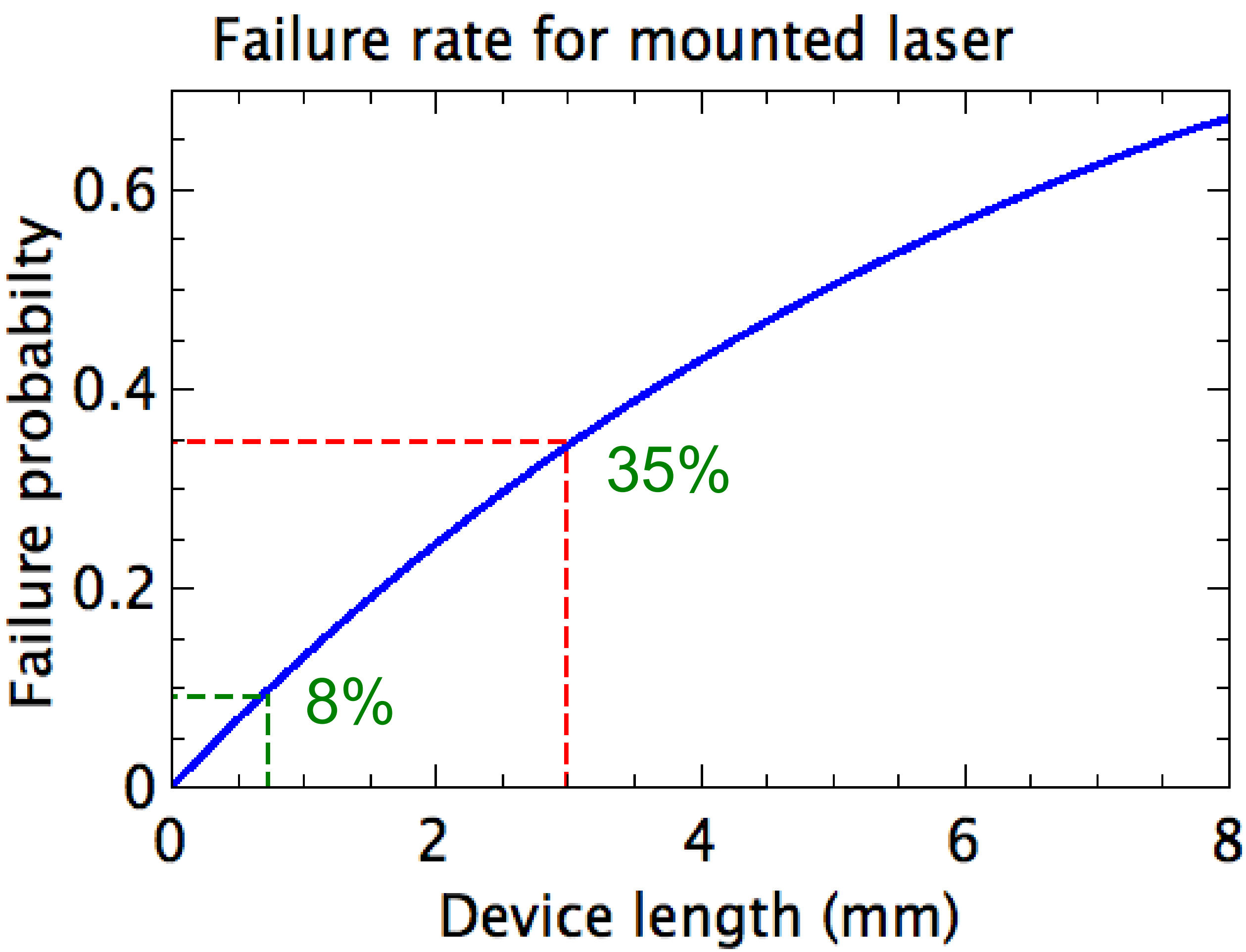
- Failure rate sensibly reduced with shorter lasers

Number of defects

$$P = \sum_k \lambda^k \frac{e^{-\lambda}}{k!}$$

Probability of major defect in the laser wg

Advantages of short devices



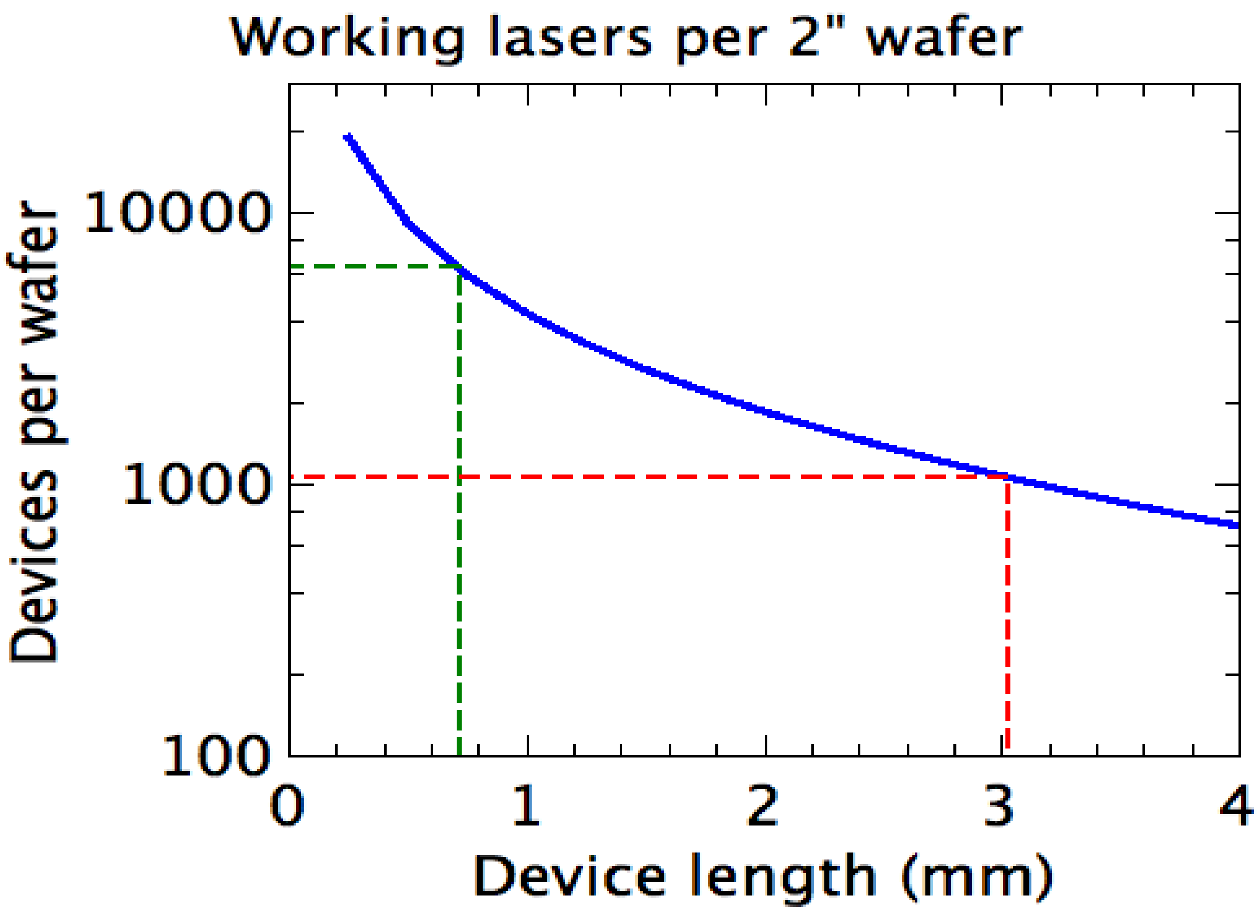
Number of defects

$$P = \sum_k \lambda^k \frac{e^{-\lambda}}{k!}$$

Probability of major defect in the laser wg

• Defect density estimated on the AL-Stock data (preliminary)

Advantages of short devices



Number of defects

$$P = \sum_k \lambda^k \frac{e^{-\lambda}}{k!}$$

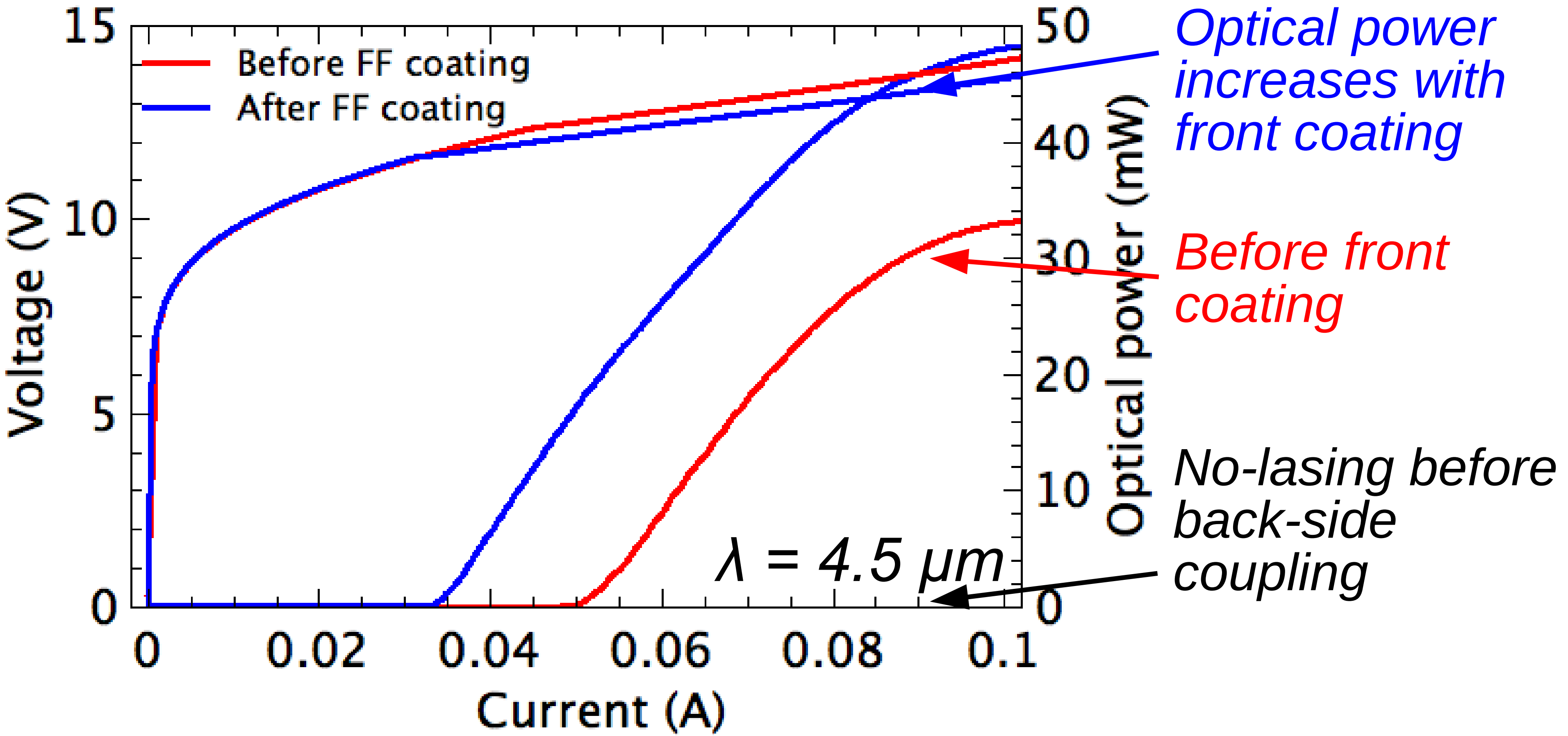
Probability of major defect in the laser wg

- Doublefold impact on the number of chips/wafer

Optimizing reflectivity for short devices

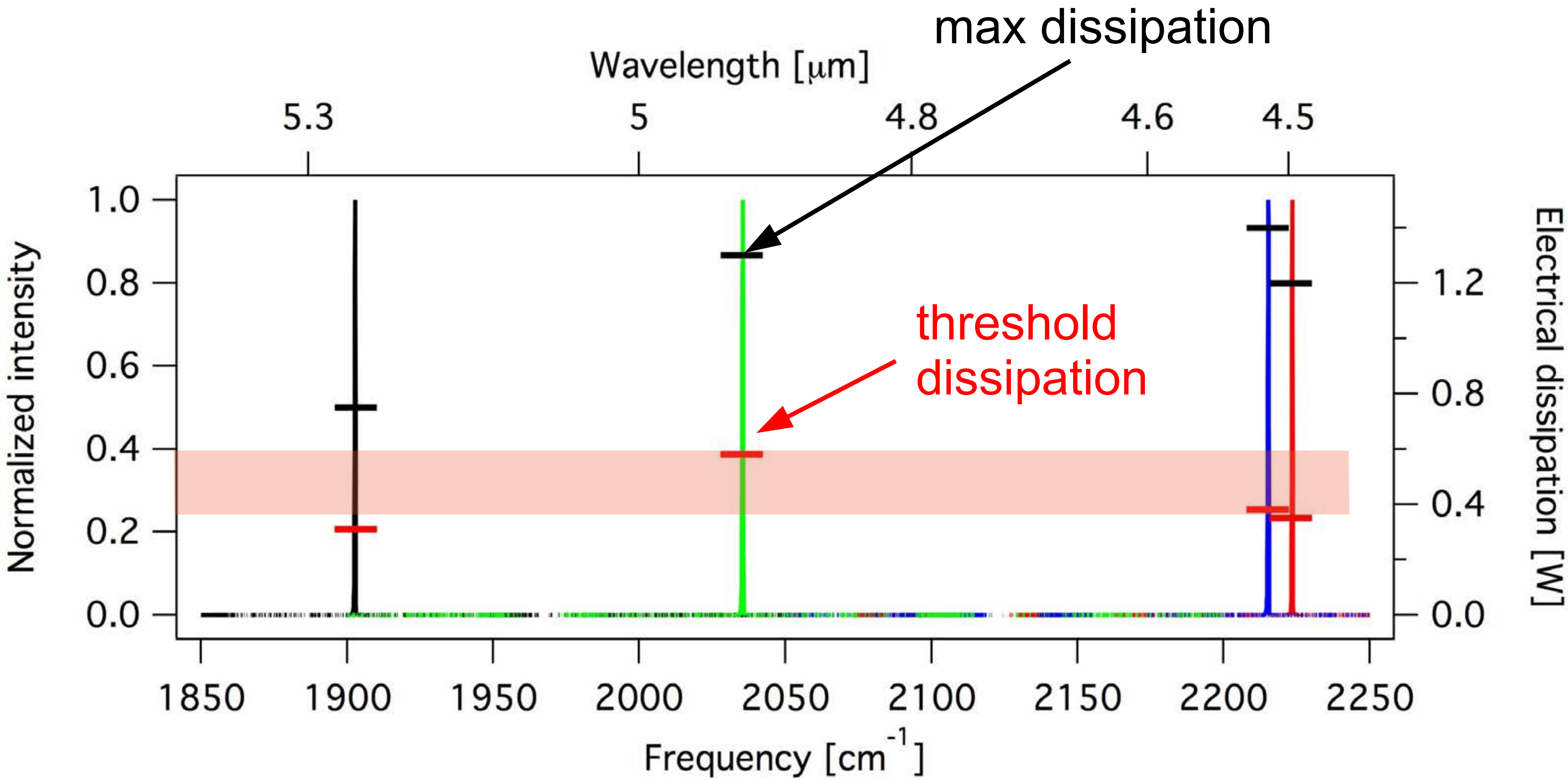
- Starting range 4.5μm and 5.5μm
- Optimize the grating coupling to obtain both low consumption DFBs and high power DFBs on the **same wafer**
- 750μm-long devices, 3-4μm-wide
- Back-facet HR coating
- Front-facet partial HR coating

Effect of front-facet coating



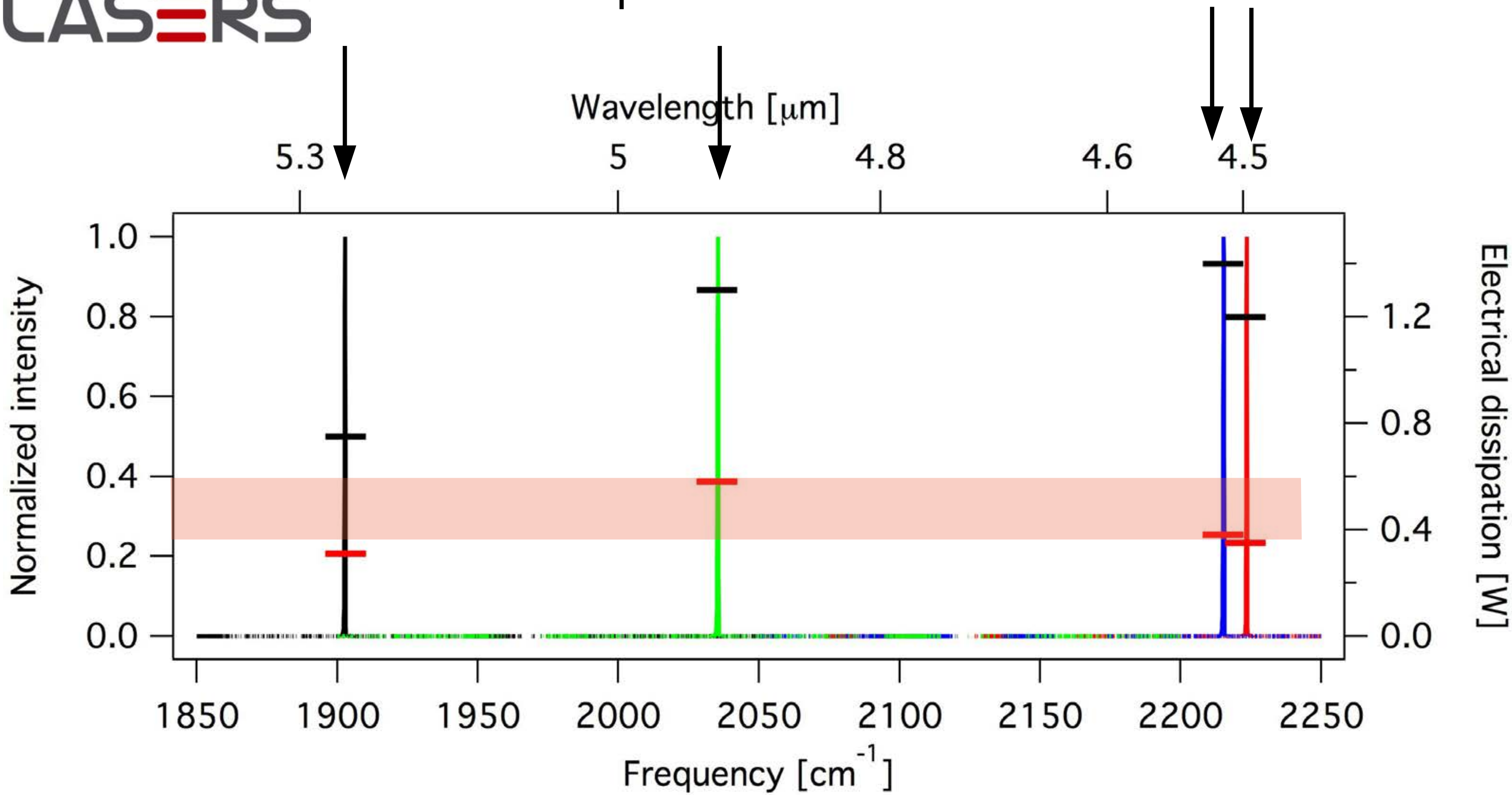
750 µm long devices
3 µm wide ridge

Low consumption devices



- dissipation at threshold as low as 0.3W
- max consumption < 1.4W between 4.5μm and 5.3μm

Low consumption devices



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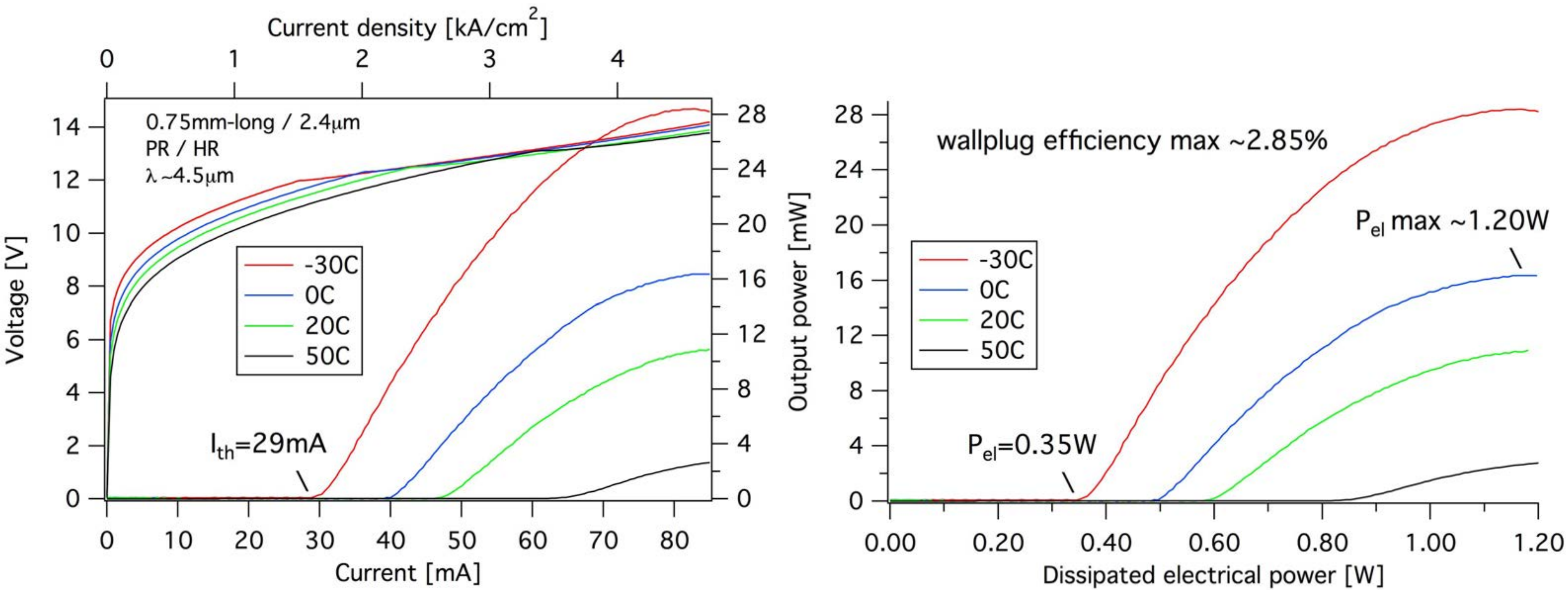
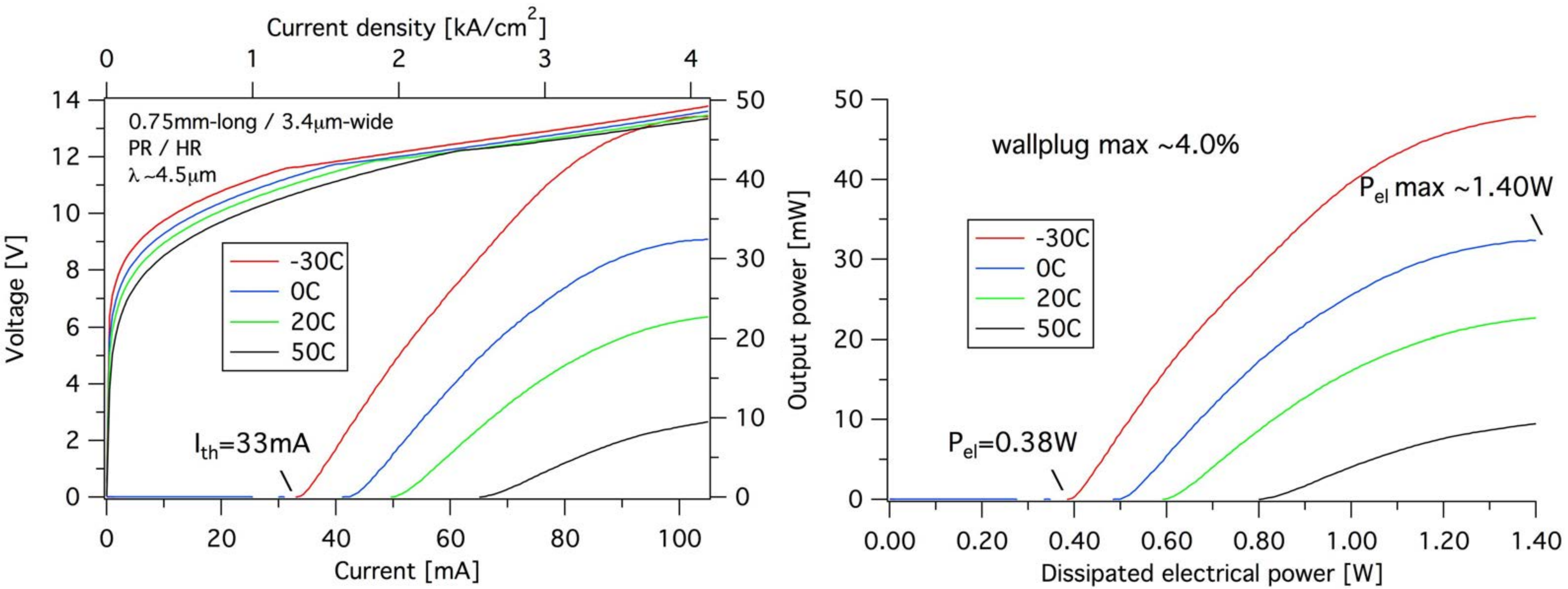
- max consumption < 1.4W between 4.5µm and 5.3µm

Low-dissipation DFB devices at 4.50µm



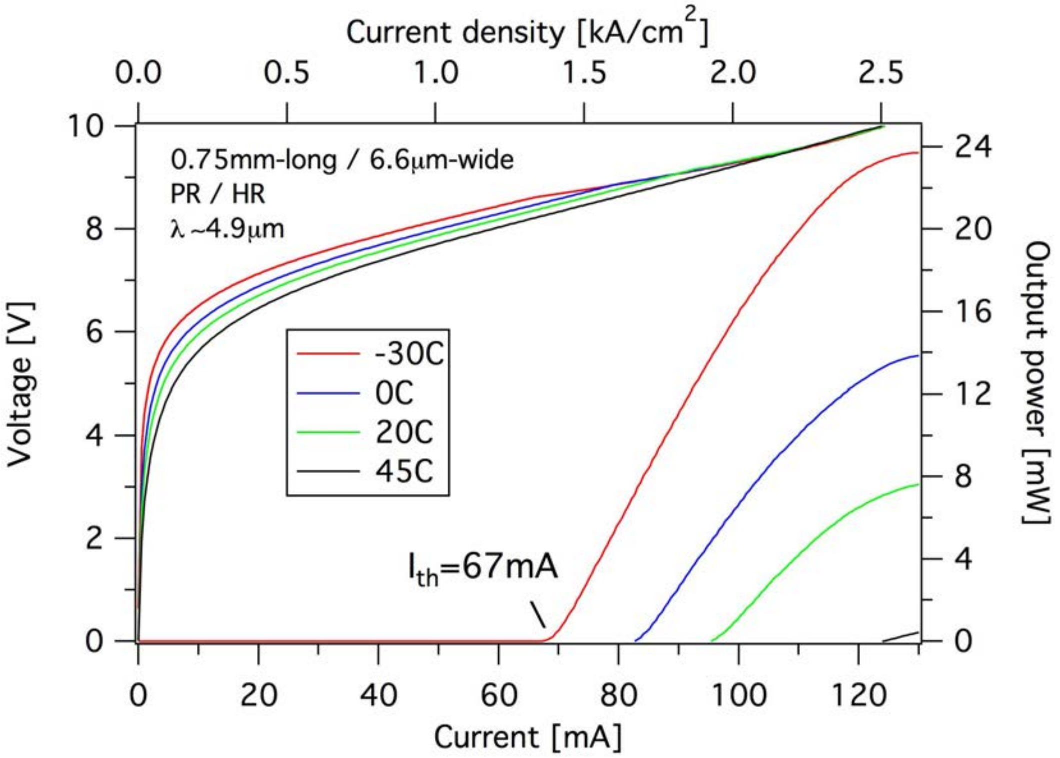
- very low threshold current : 29mA
- P_{el} max ~1.2W
- single-mode

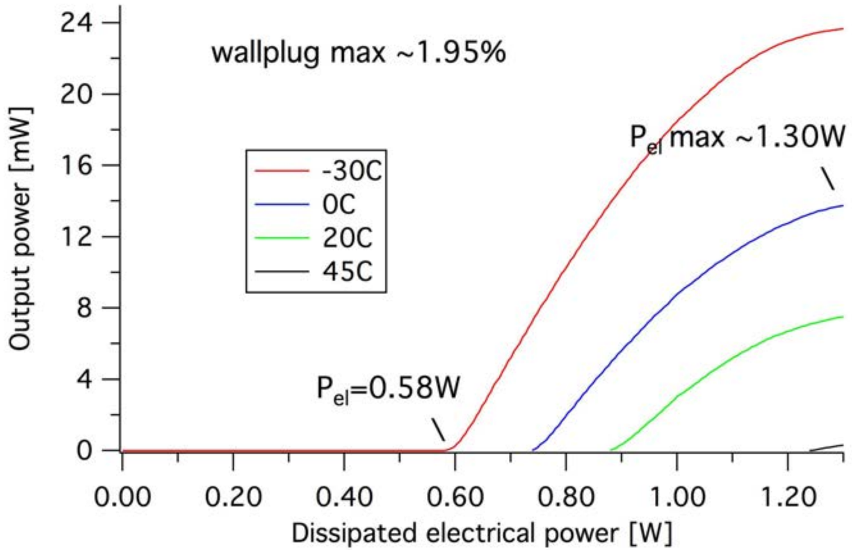
Low-dissipation DFB devices at 4.51μm

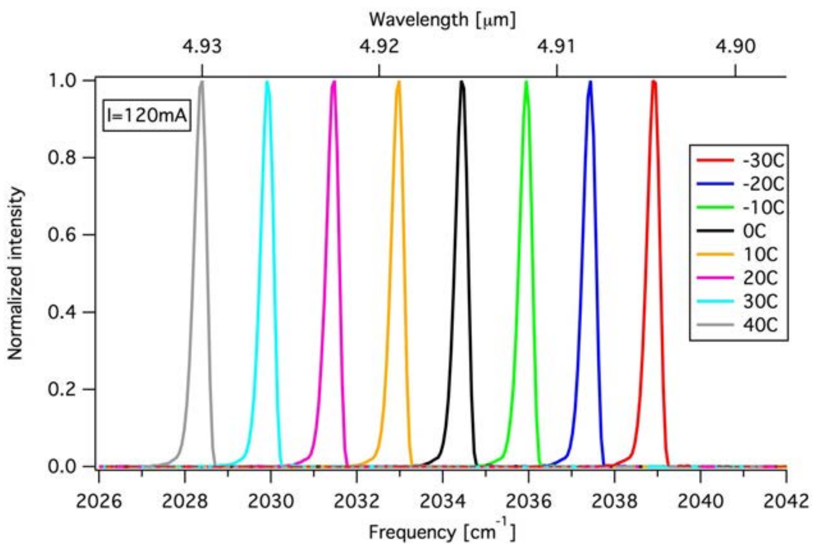


- opt power up to 48mW / wallplug up to 4%
- P_{el} max ~1.4W
- single-mode

Low-dissipation DFB devices at 4.90μm

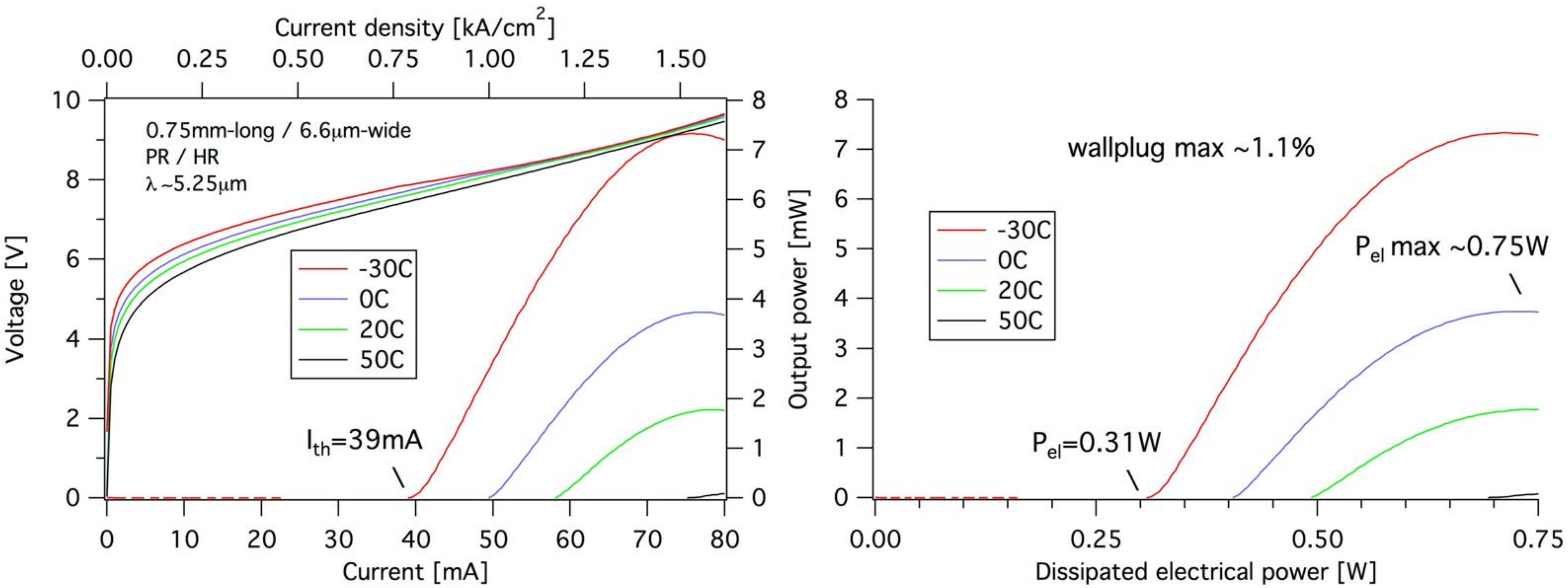






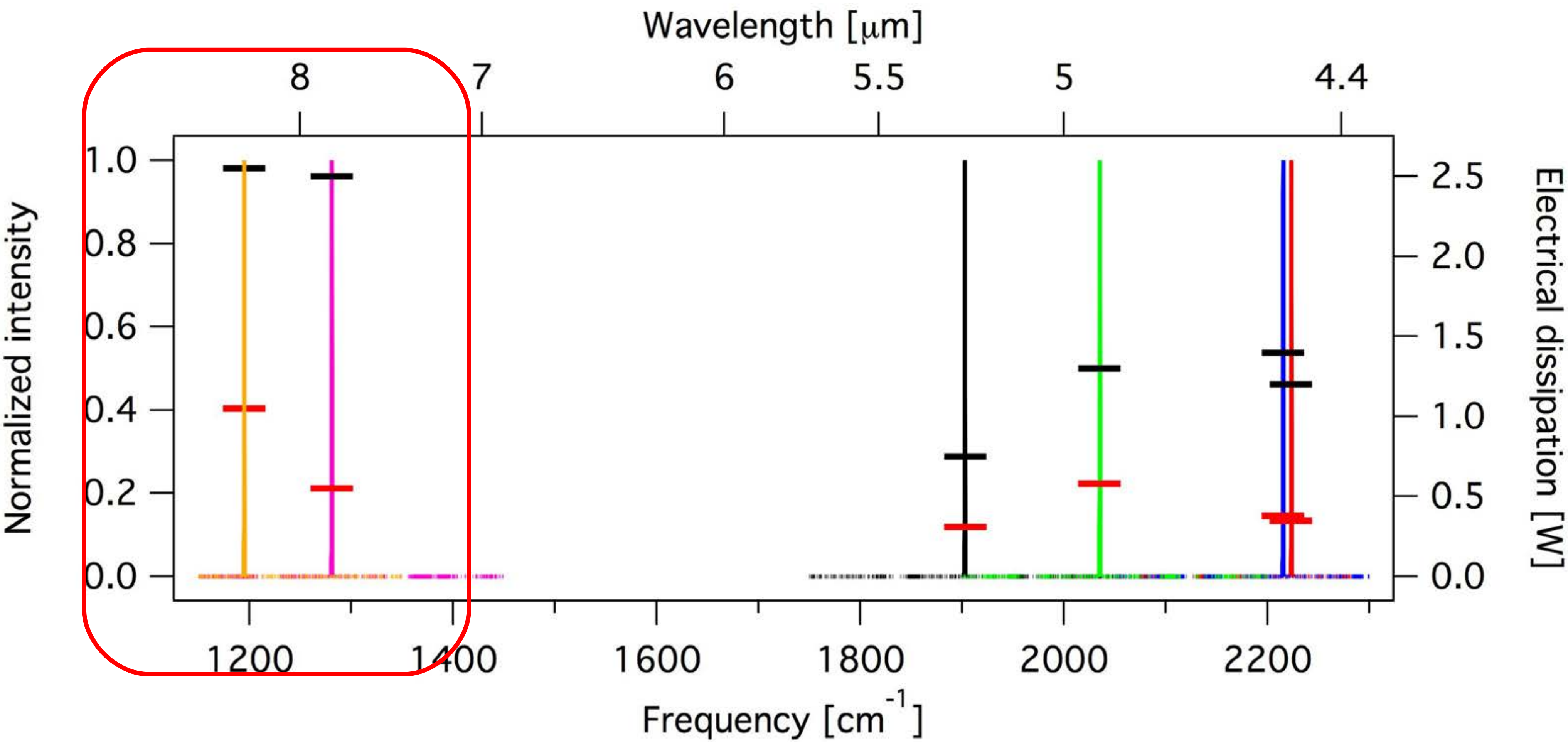
- broader ridges
- low threshold current : 67mA
- P_{el} max ~1.3W

Low-dissipation DFB devices at 5.25μm



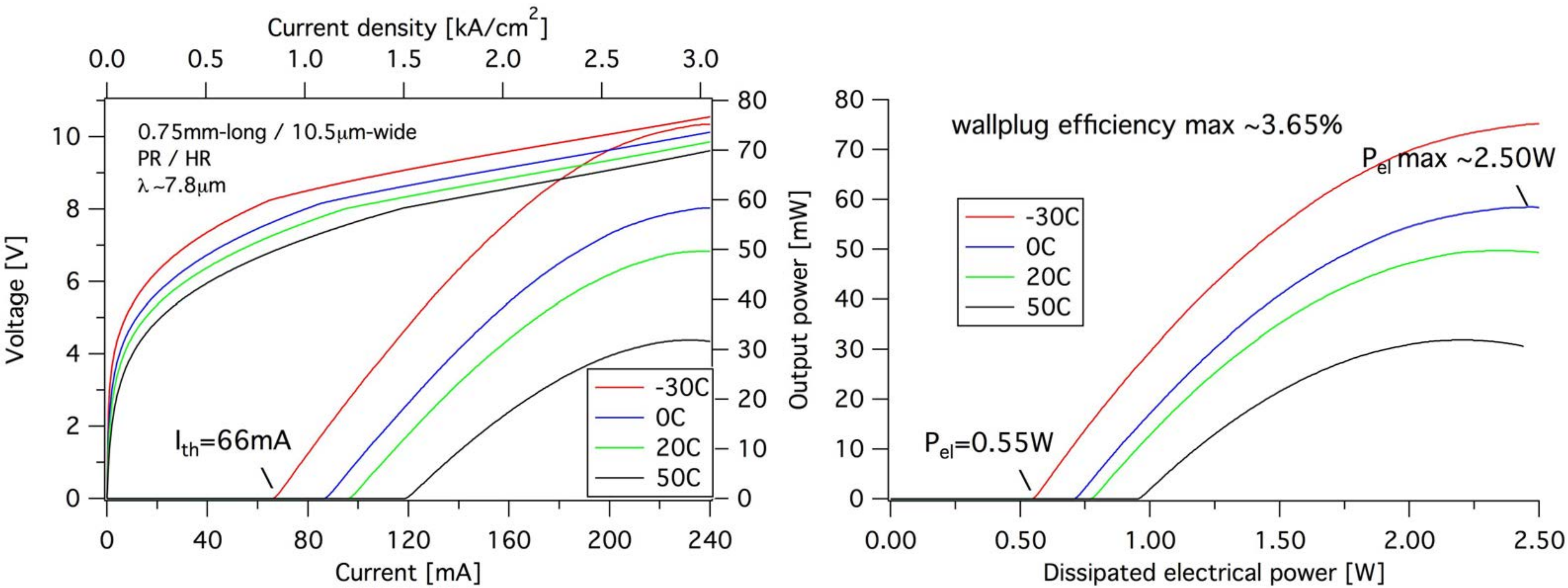
- electrical dissipation as low as 0.31W
- P_{el} max ~ 0.7W
- gain starving (too low doped layer)
- single-mode

Low consumption devices
2nd atmospheric window



- max consumption < 2.6W between 4.5μm and 8.4μm

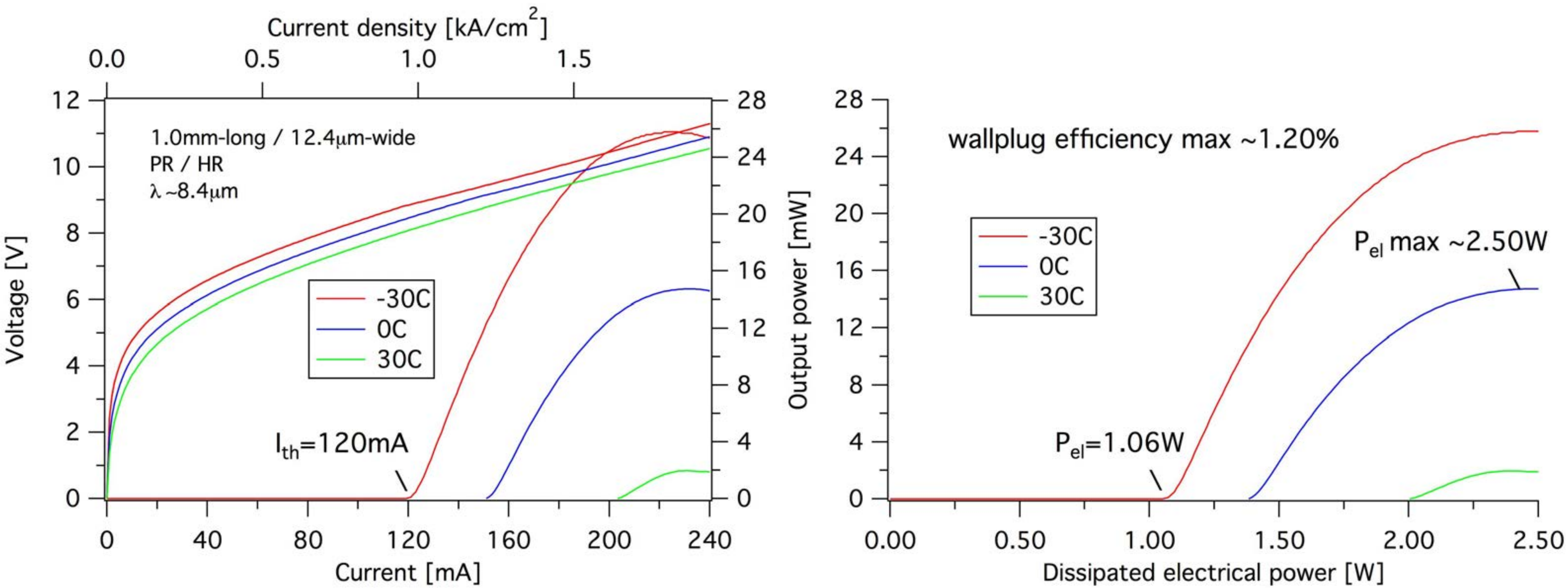
Low-dissipation DFB devices at 7.8μm



- very low threshold current : 66mA
- very low threshold power : 0.55W
- Pmax >70mW / huge dynamical range
- single-mode

PR coatings:
S. Riedi (ETHZ)

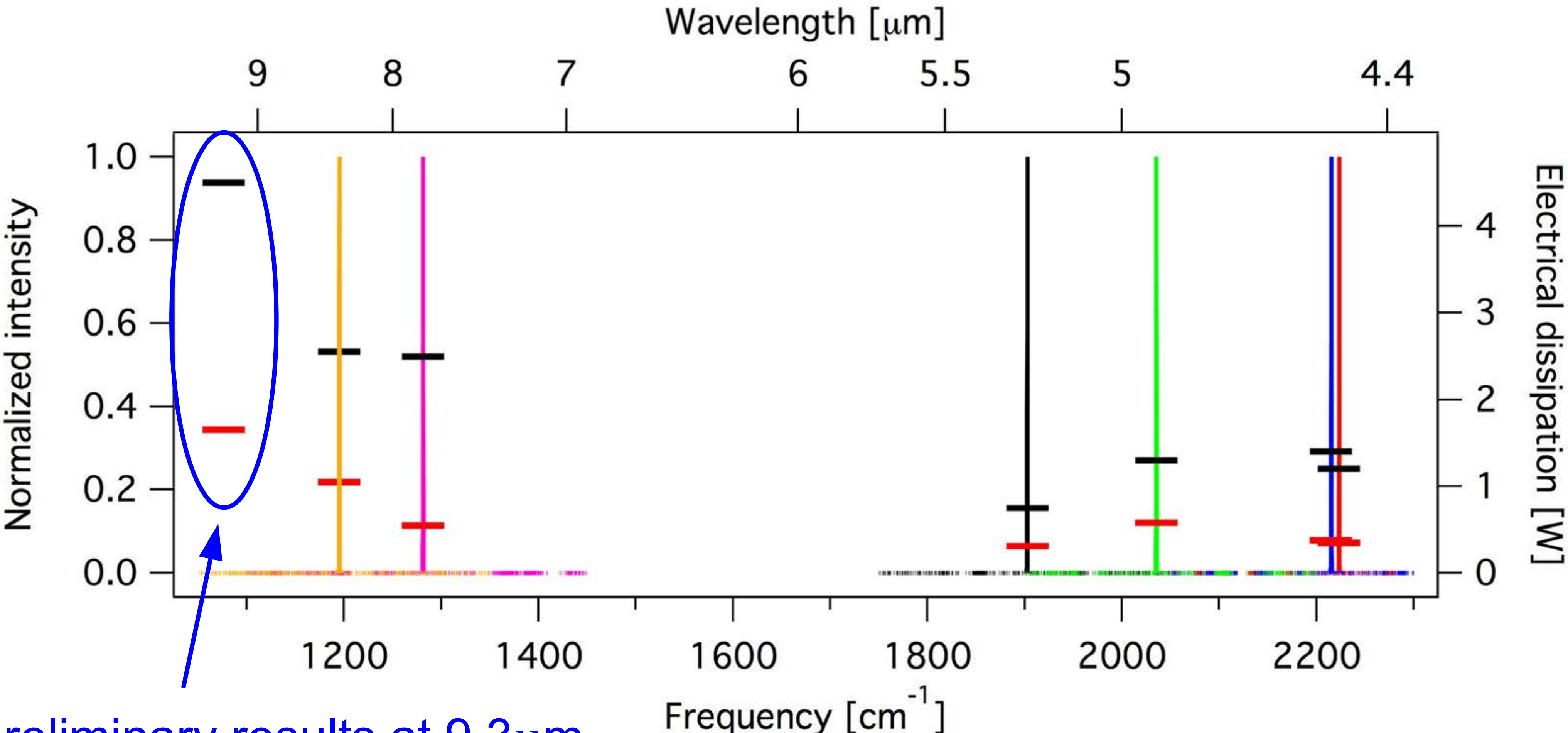
Low-dissipation DFB devices at 8.4μm



- did not lase while uncoated/HR !
- low threshold power : 1.06W
- single-mode
- as for 4.9µm case, design is too little doped

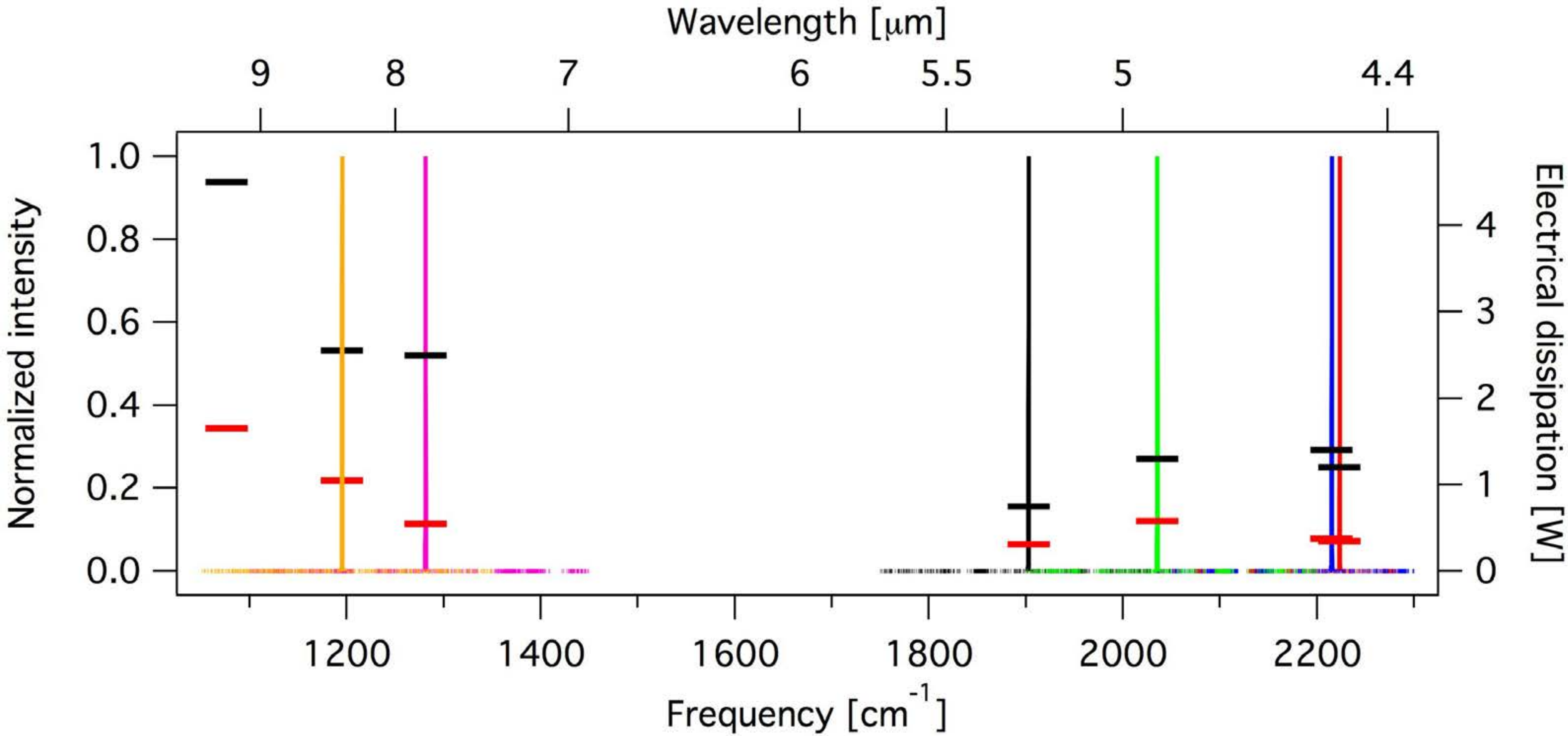
PR coatings:
S. Riedi (ETHZ)

Low consumption devices
2nd atmospheric window



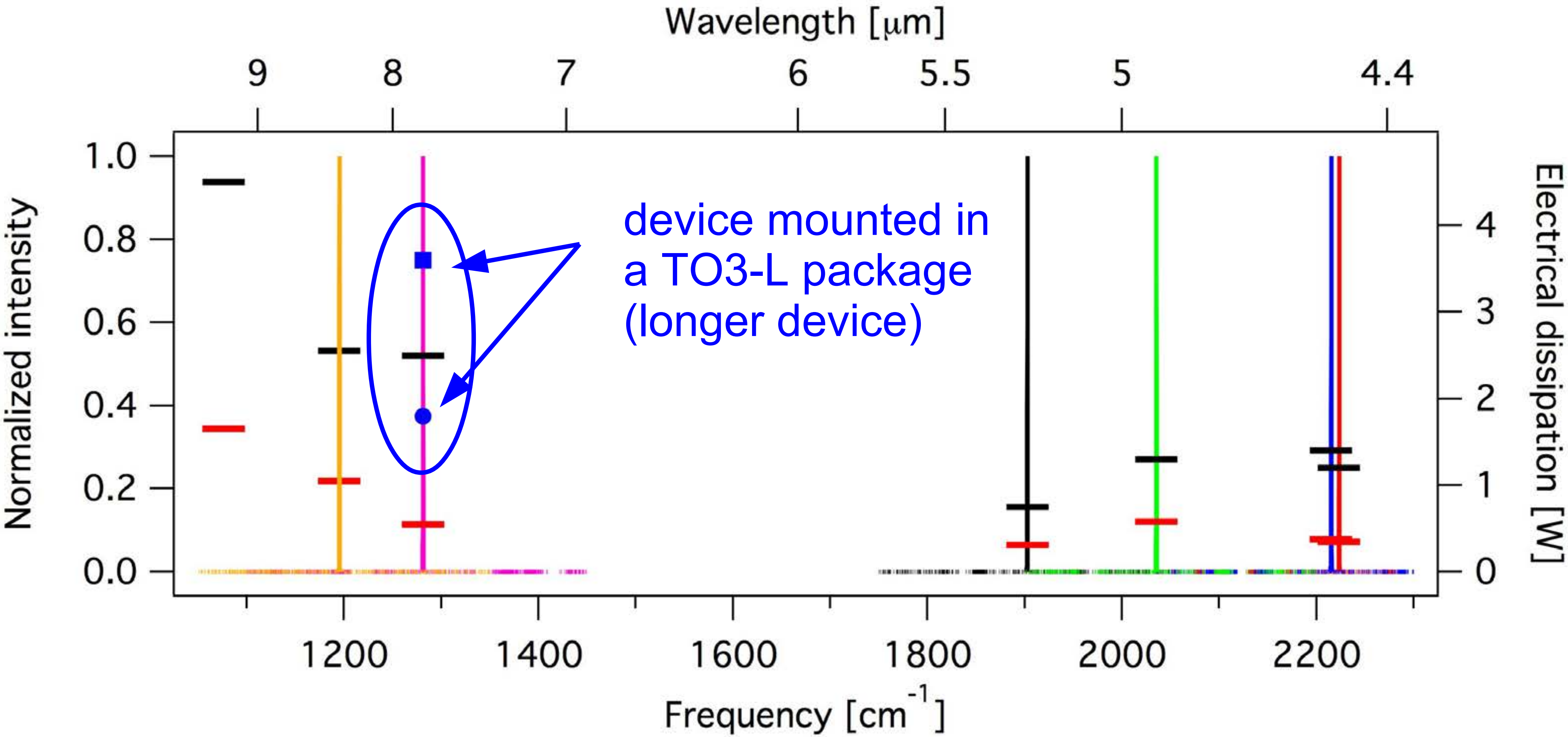
preliminary results at 9.3µm
(only HR on back facet)
FF coating not yet implemented

DFB devices at 7.8μm in TO3-L



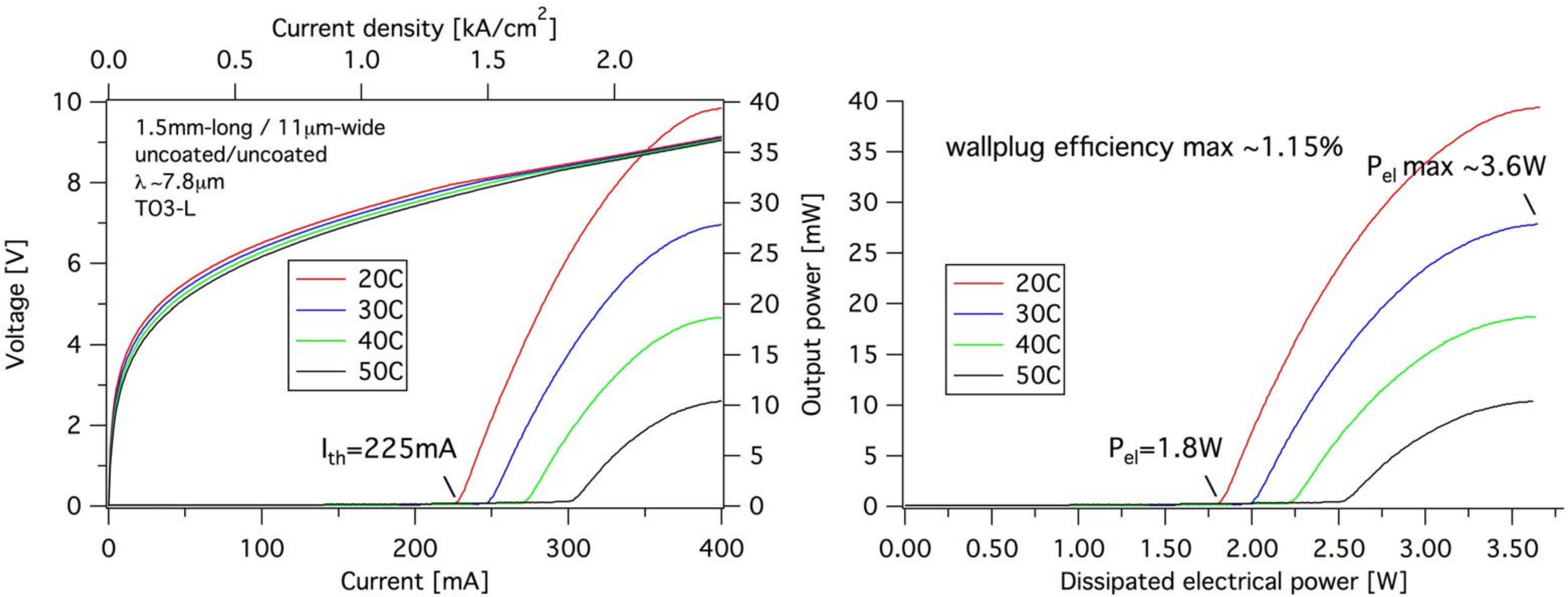
Can we package these devices in low-dissipation packages ?

DFB devices at 7.8μm in TO3-L



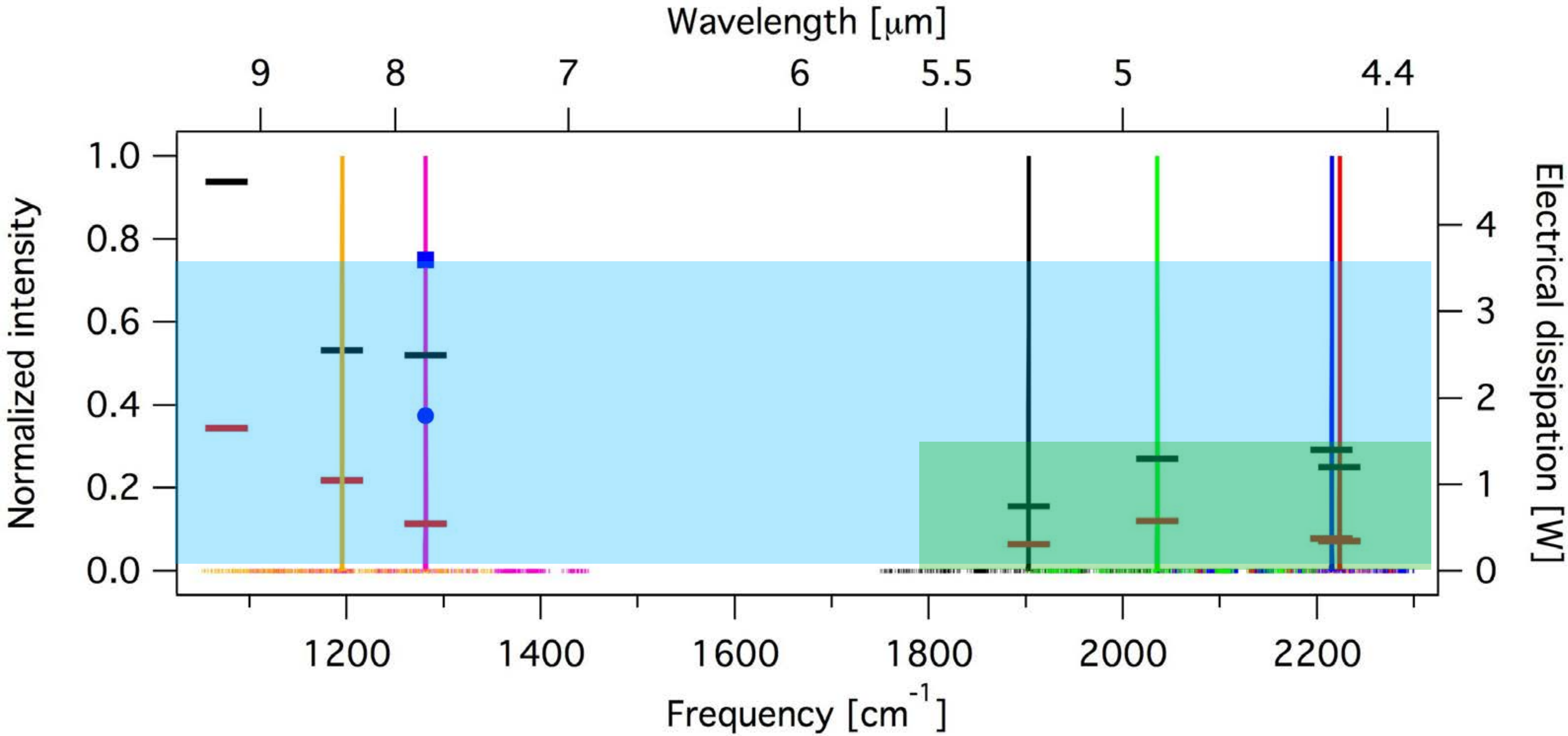
Can we package these devices in low-dissipation packages ?

DFB devices at 7.8μm in TO3-L



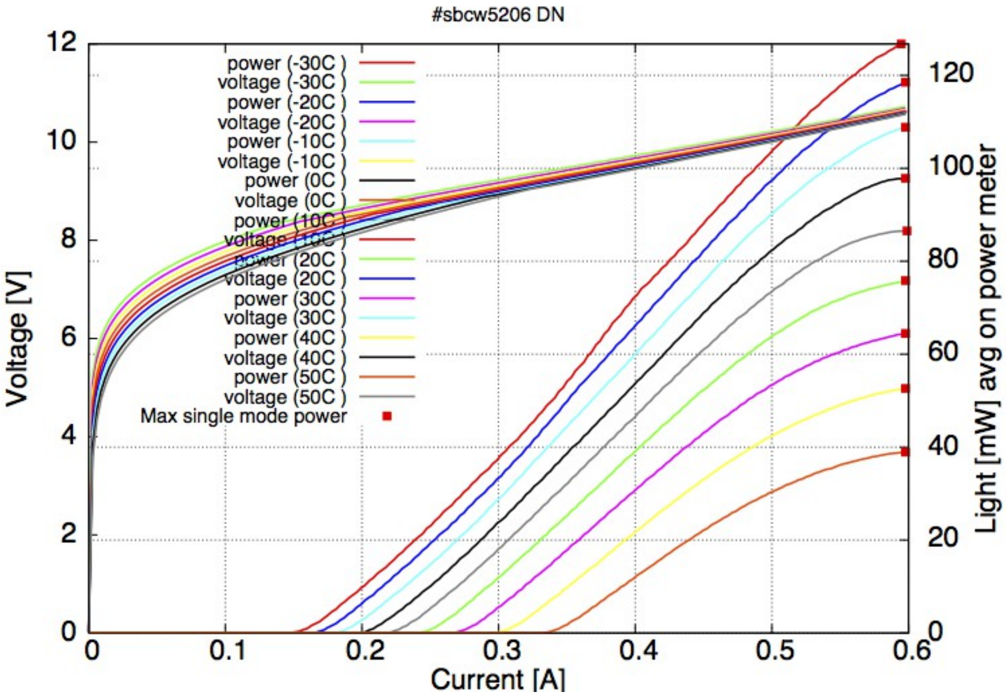
- longer / uncoated device !
- higher currents but CW operation in TO3-L
- max electrical power : up to 3.6W
- single-mode

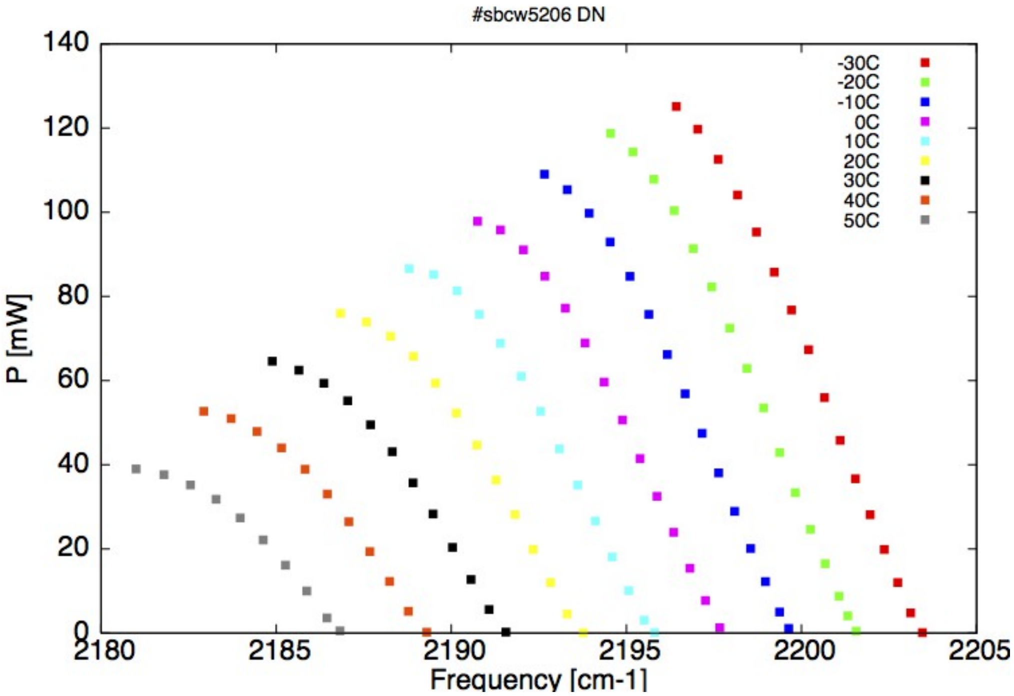
Low consumption devices



- blue : uncoated device in a TO3-L
- all range suitable for TO3 operation !!
- smaller packages for low wavelengths

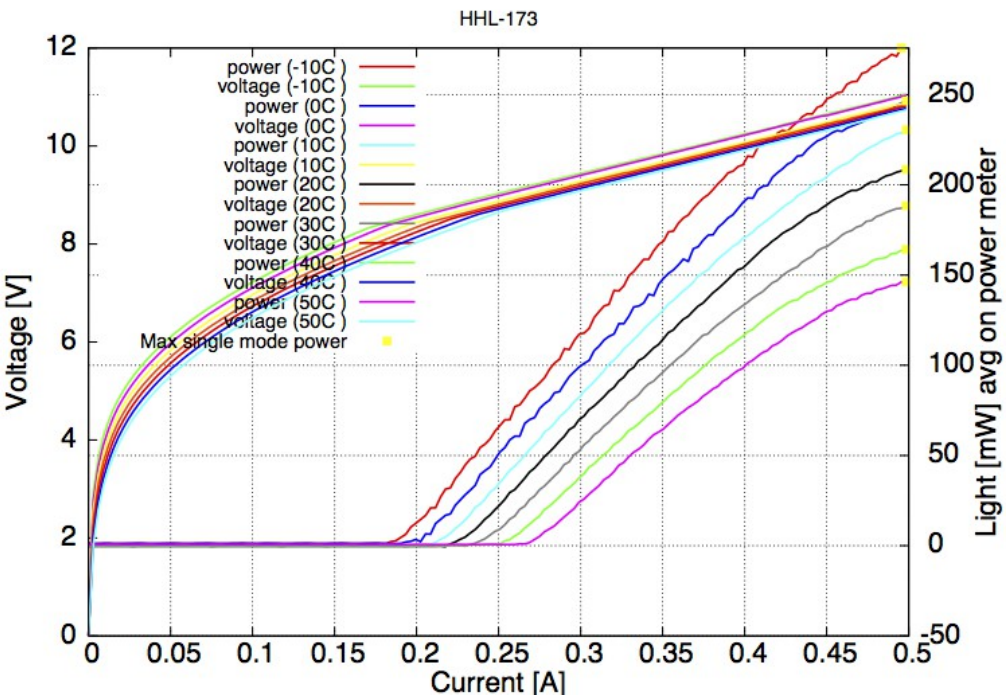
High power DFB devices at 4.56µm

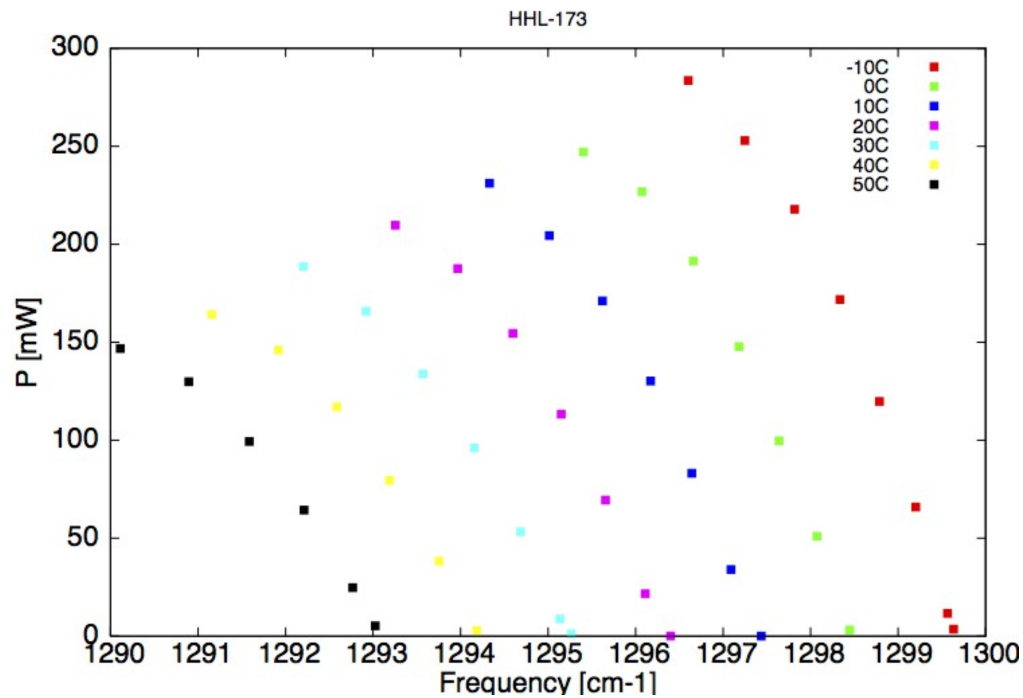




- ~ 80mW at RT / still > 40mW at 50C
- P_{el} max < 6.4W
- single-mode across the all range

High power DFB devices at 7.72µm



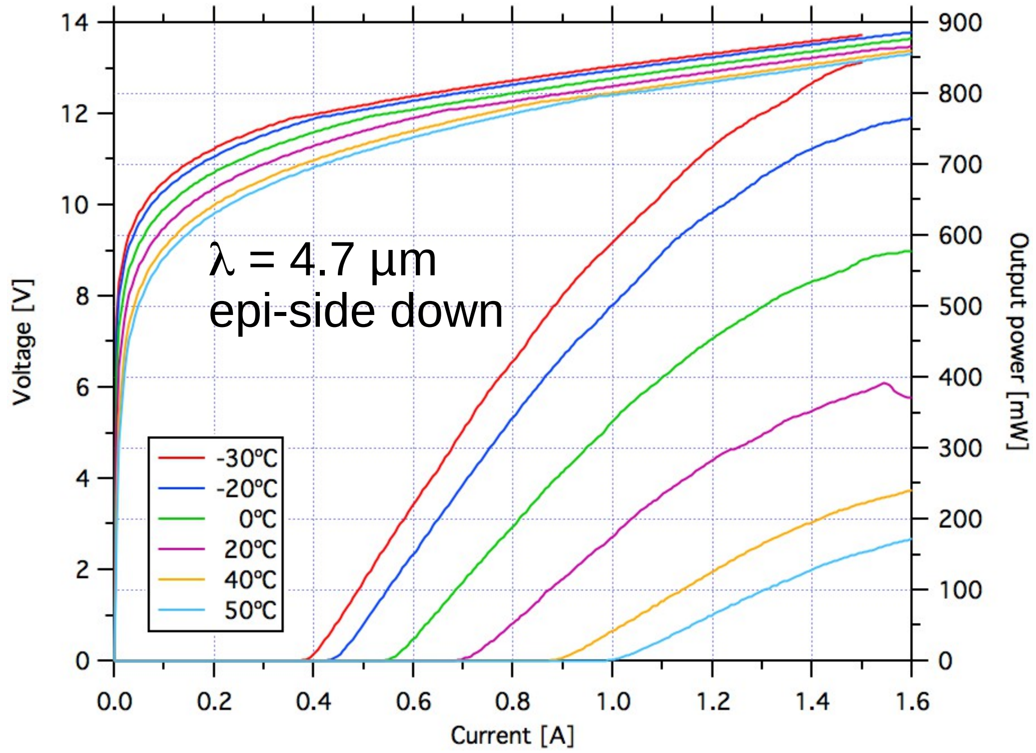


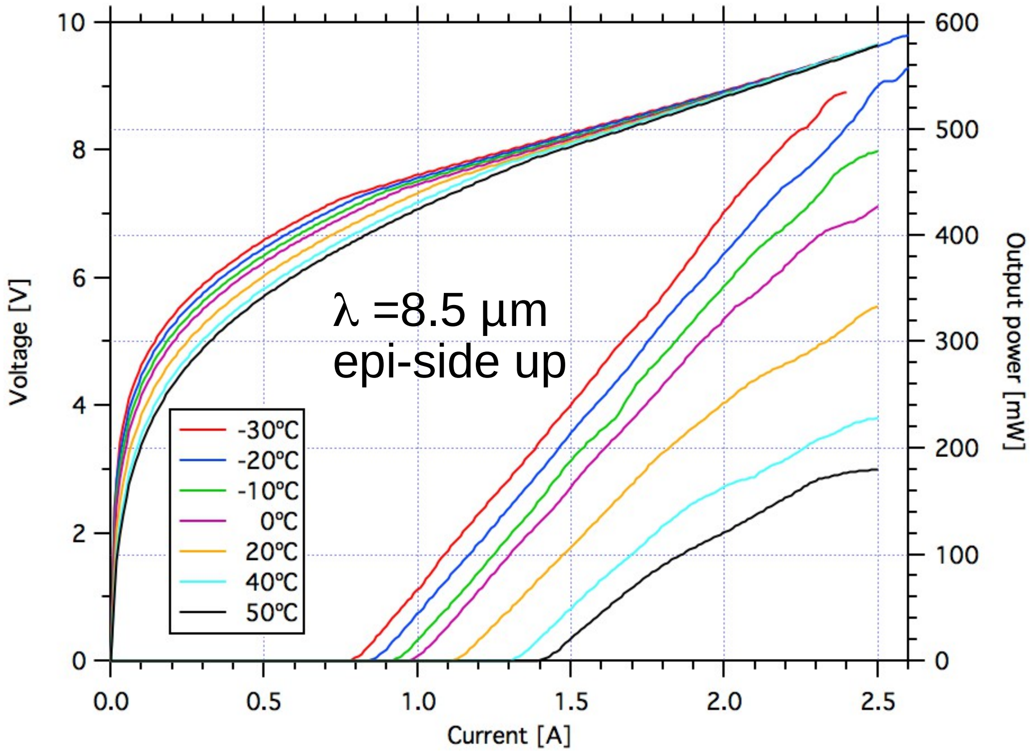
- ~ 200mW at RT / still >140mW at 50C
- P_{el} max < 5.5W
- single-mode across the all range

High-power FP devices

High power FP devices

- high power CW operation on TEC
- preliminary results, not yet optimized





- facet coatings : uncoated/HR (no partial AR)

Conclusion

- Low-dissipation DFB lasers between 4.5 and 9.3µm with T_{op} up to >50C
- High-power DFB using the same fabrication process (>140mW at 50C)
- Range of available lasers to be expanded
- Broadgain optimisation for CW operation
- High-power devices optimisation
- Genetic optimisation of the active region design to increase efficiency
- Cloud simulation capability

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Special thanks to:

- Dr. Alfredo Bismuto (R&D, process)
- Dr. Tobias Gresch (process masks)
- Dr. Richard Maulini (high power)
- Dr. Romain Terrazzi (design, simulations)
- Dr. Pierre-Yves Baroni (coatings)
- all Alpes Lasers team

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- Dr. Antoine Muller (CEO)
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