High power, high wallplug efficiency room temperature continuous wave quantum cascade lasers

<u>R. Maulini</u>, A. Lyakh, A. Tsekoun, I. Dunayevskiy, R. Go, and C. Kumar N. Patel

Pranalytica, Inc., 1101 Colorado Ave., Santa Monica, CA 90401

C. Pflügl, L. Diehl, Q. J. Wang, and Federico Capasso

School of Engineering and Applied Sciences, Harvard University, Cambridge, MA 02138

X. J. Wang, J. Y. Fan, and T. Tanbun-Ek

Adtech Optics, Inc., 18007 Cortney Court, City of Industry, CA 91748

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Outline

- High-power QCL design
- Introduction
- Pranalytica's 4.6 µm high-power QCLs
- Pranalytica's high-power QCL packaging
- Reliability of high-power QCLs
- Widely tunable high power external cavity QCLs

Introduction

QCLs have mainly been used in point chemical sensors

High power QCLs in the first atmospheric window open up new applications:

- Infrared countermeasures (IRCM)
- Free space optical (FSO) telecommunications
- Remote sensing
- Ultra-sensitive trace gas detection using photoacoustic spectroscopy
- Non-linear frequency conversion (e.g. THz generation)

QCL Design

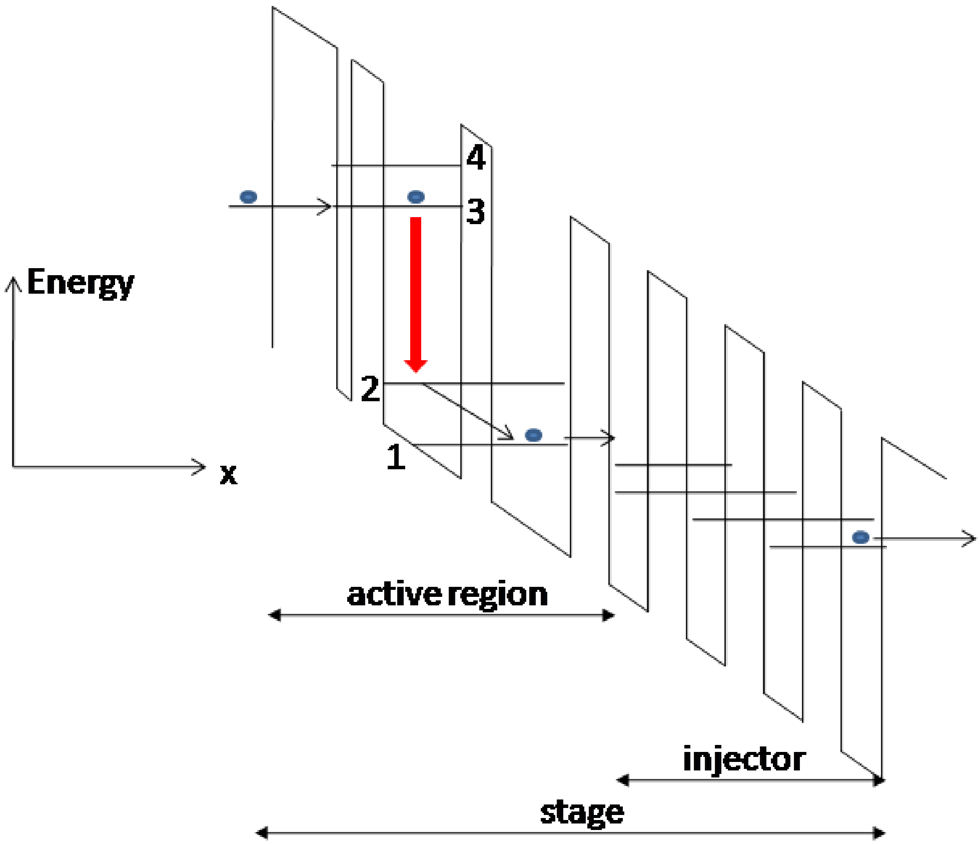
For CW/RT active region can heat up to 400K

- Higher threshold current
- Lower slope efficiency

Design optimization includes

A. Optimization of gain region for high-temperature operation
B. Optimization of heat dissipation

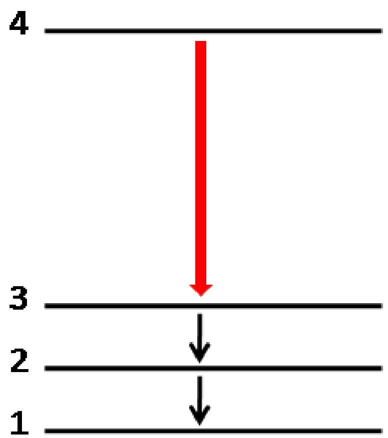
A. Gain Region Design



- Increased ΔE_{43}: improved injection efficiency to level 3
- Increased ΔE_{21}: reduced thermal population of level 2

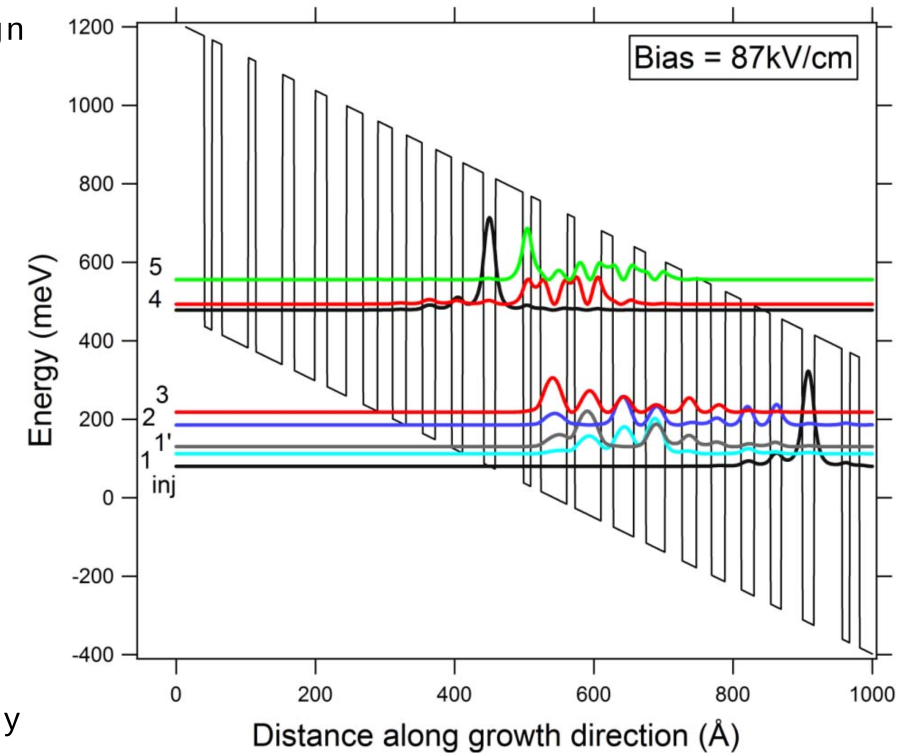
Pranalytica's 4.6 µm Gain Stage Design

Typical two-phonon design



$E_{32}=E_{21}$=LO phonon energy

Modified two-phonon design
(patent pending)

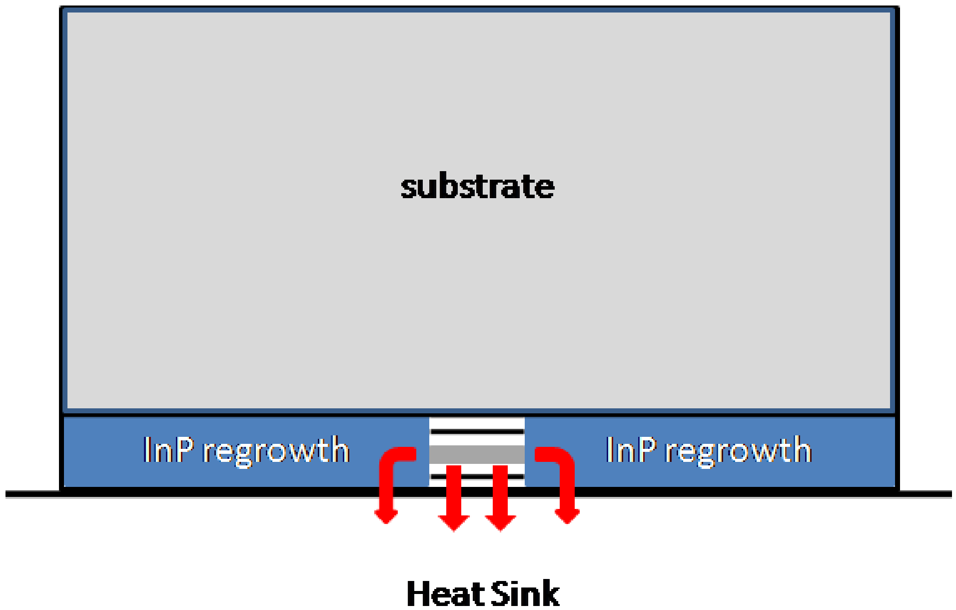


E_{32} = LO phonon energy
$E_{21} \cong E_{21'}$ > LO phonon energy

- E_{21}≠LO phonon energy => more flexibility for design optimization
- Increased E_{31} => reduced electron back scattering for lower laser level 3
- Increased E_{54} => increased injection efficiency for upper laser level 4

Design: Pranalytica (A. Lyakh)

B. Optimization of Heat Dissipation



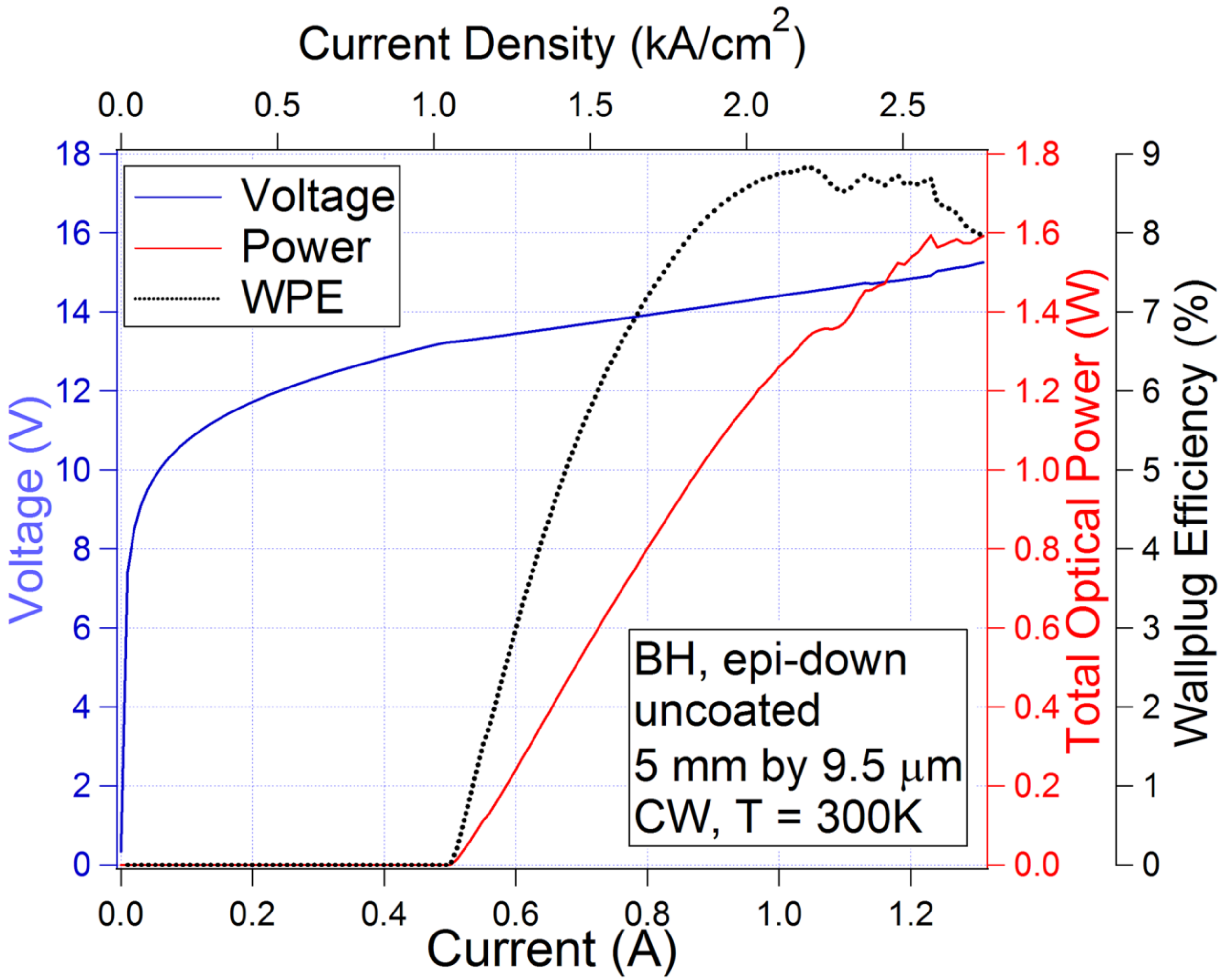
InP has higher thermal conductivity than active region:

- Exclusively InP waveguide
- BH with InP regrowth

Epi-down mounting

- AlN submount, AuSn solder

Pranalytica's 4.6 µm High-Power QCLs



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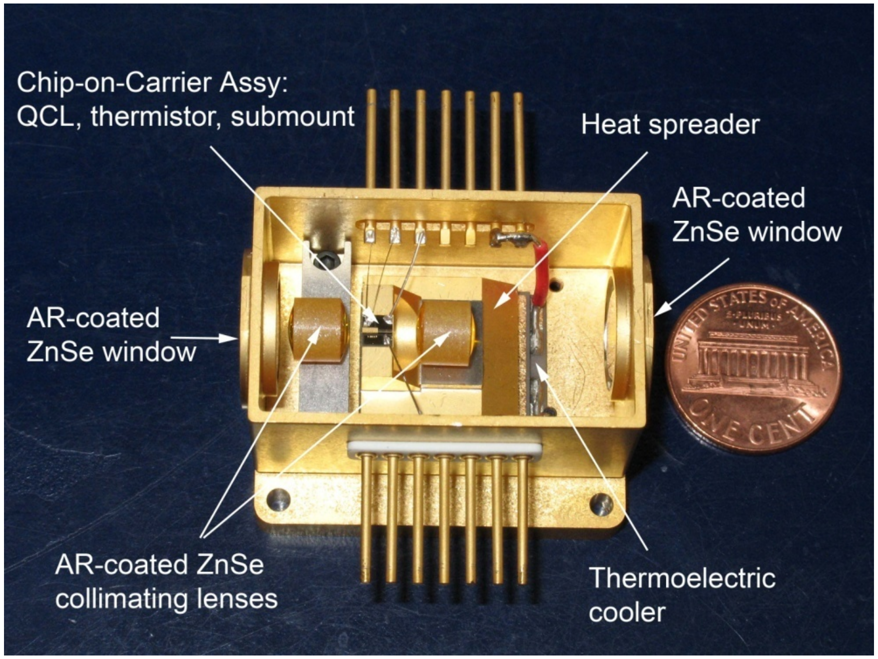
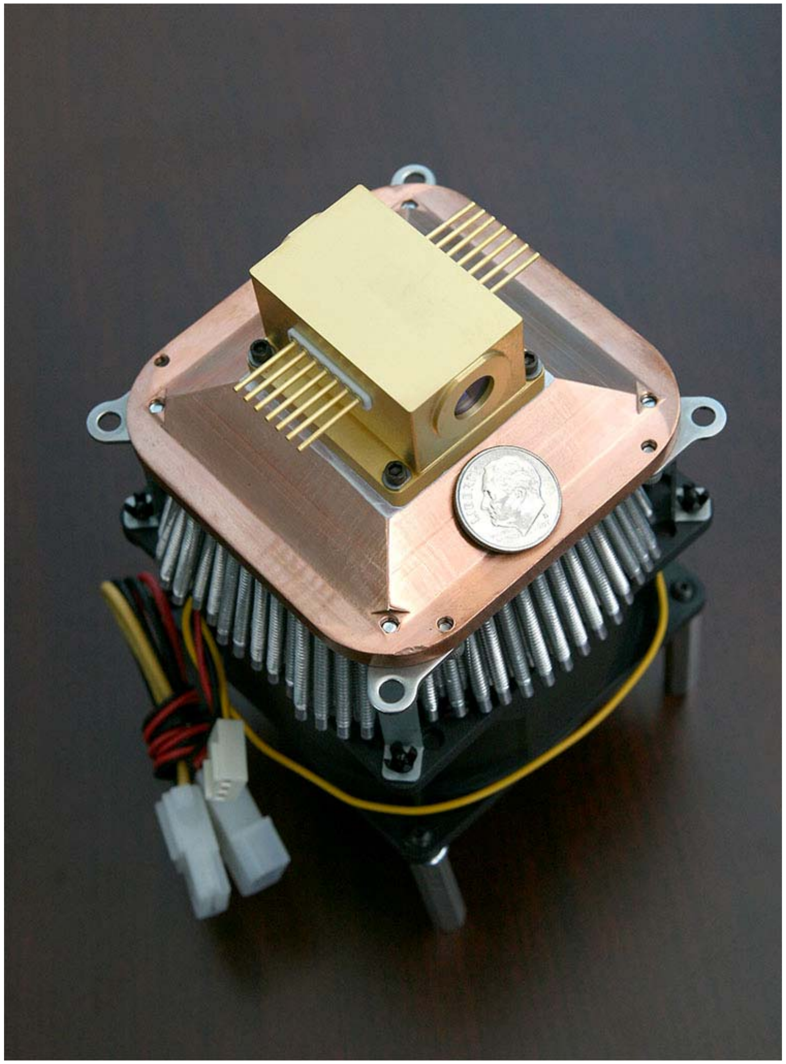
Integrated Package for QCLs

Requirements:

- Capable of dissipating heat of high power CW QCLs
- Capable of lowering device temperature with respect to case temperature (hermetically sealed)
- M-LWIR compatible optics
- High reliability
  - Fluxless assembly
  - No epoxies, glues, etc.
  - Well-characterized, long lifetime must be demonstrated at the package level

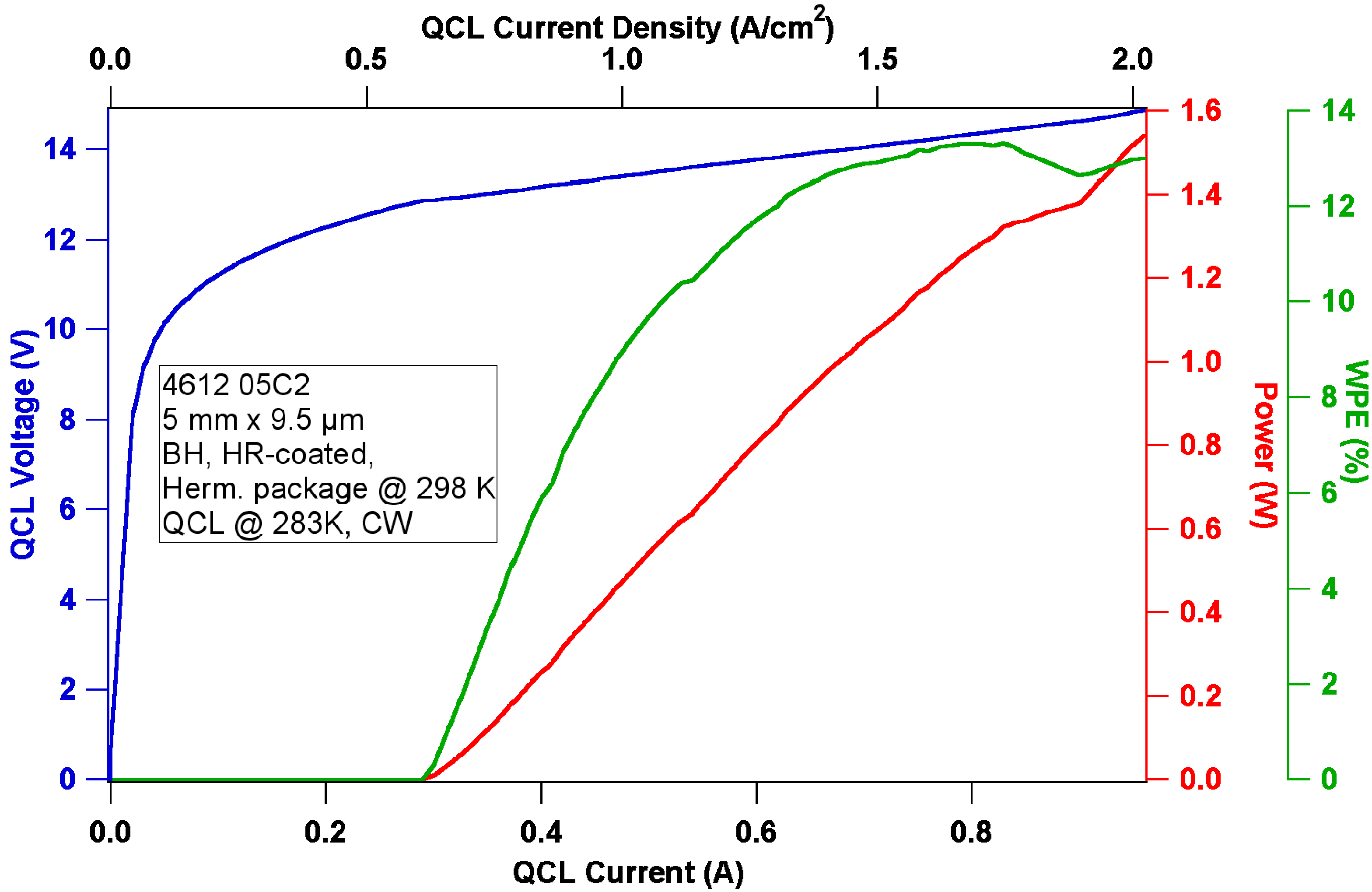
Fully Packaged CW/RT 4.6 μm High Power QCLs





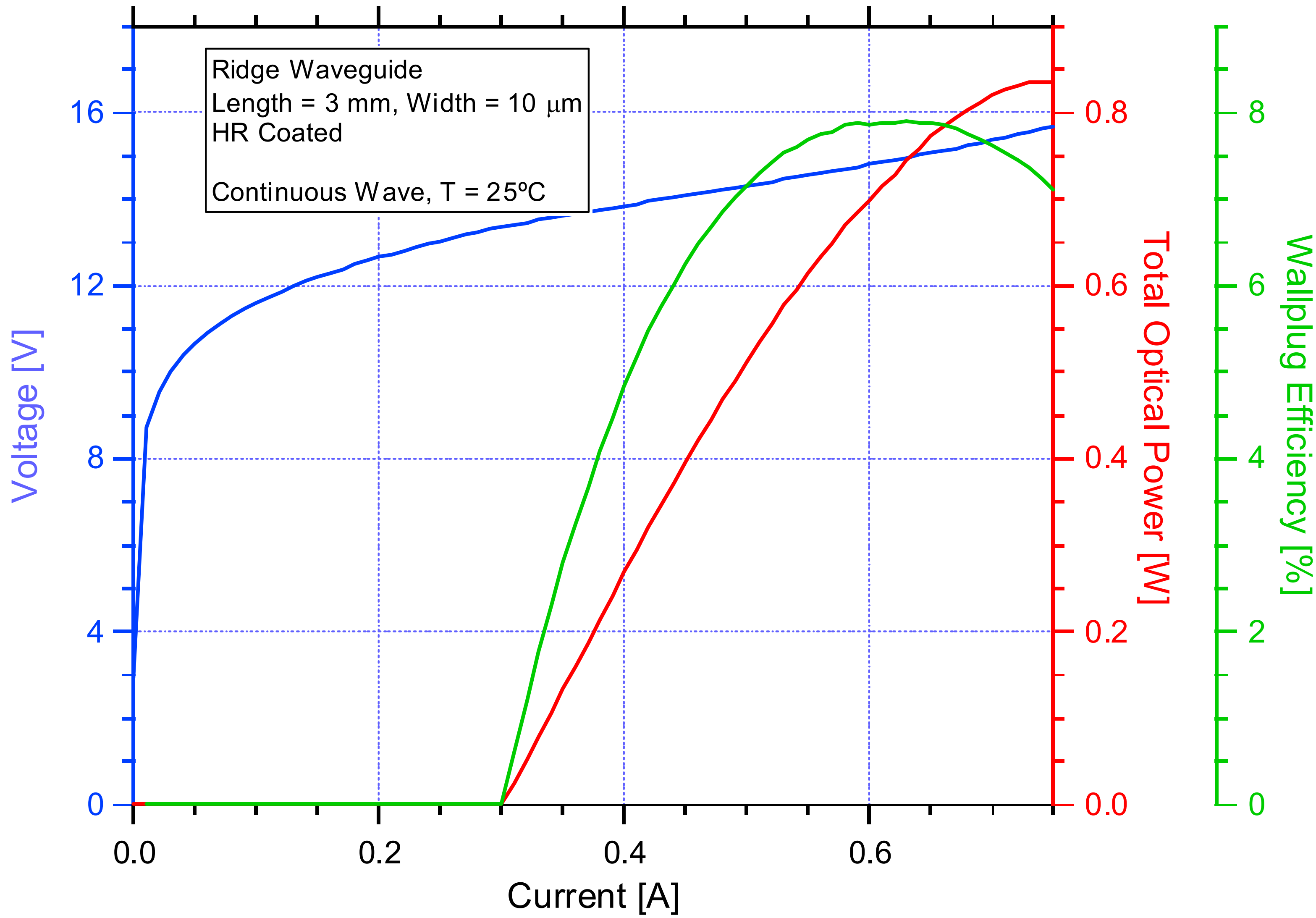
High Power CW/RT 4.6 μm Laser system

Hermetically Sealed QCL Package Results



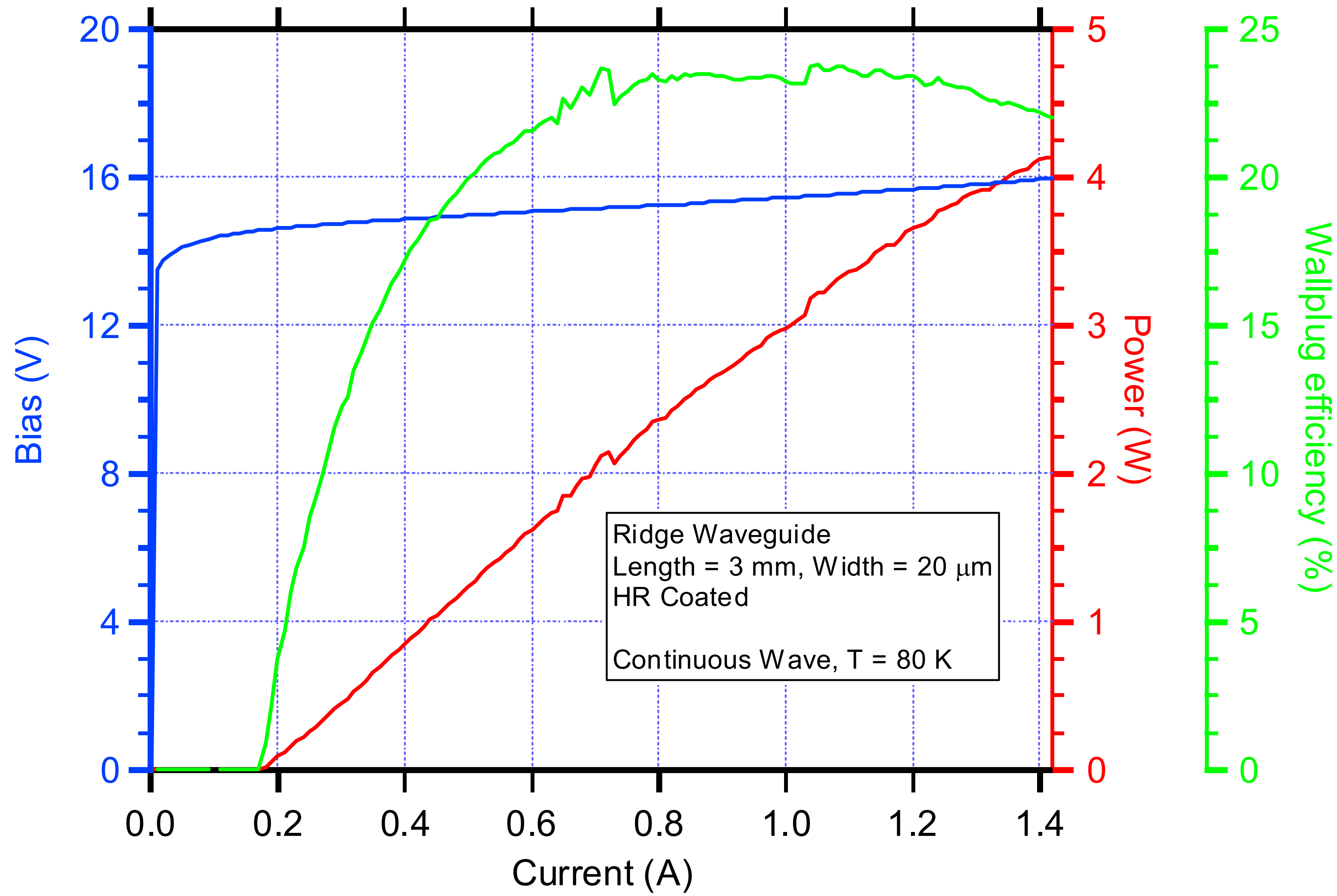
1.55 W (1 facet), 13.5 % efficiency

Is BH processing really necessary?



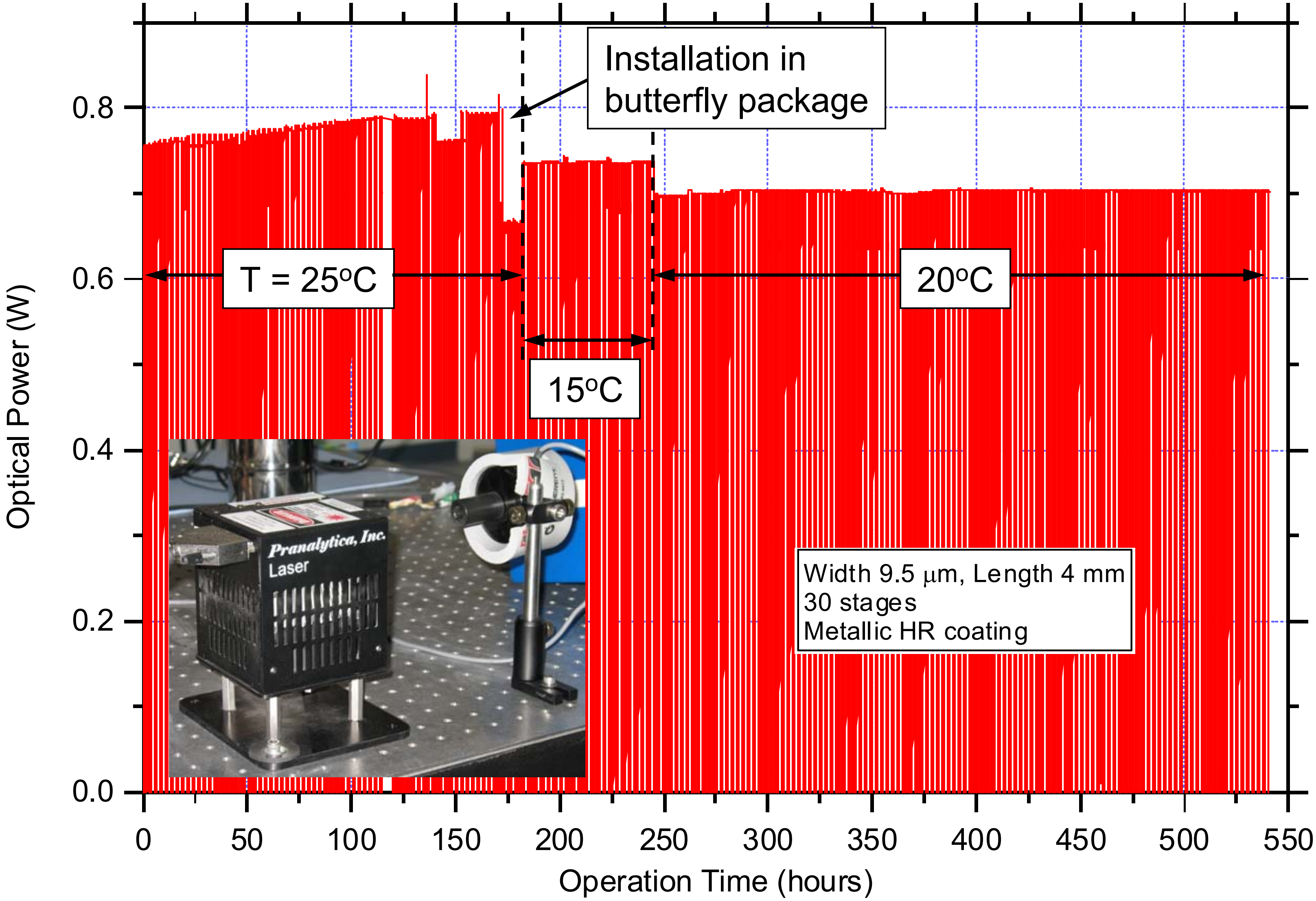
0.83 W (1 facet), ~8 % efficiency

Cryogenic temperature performance

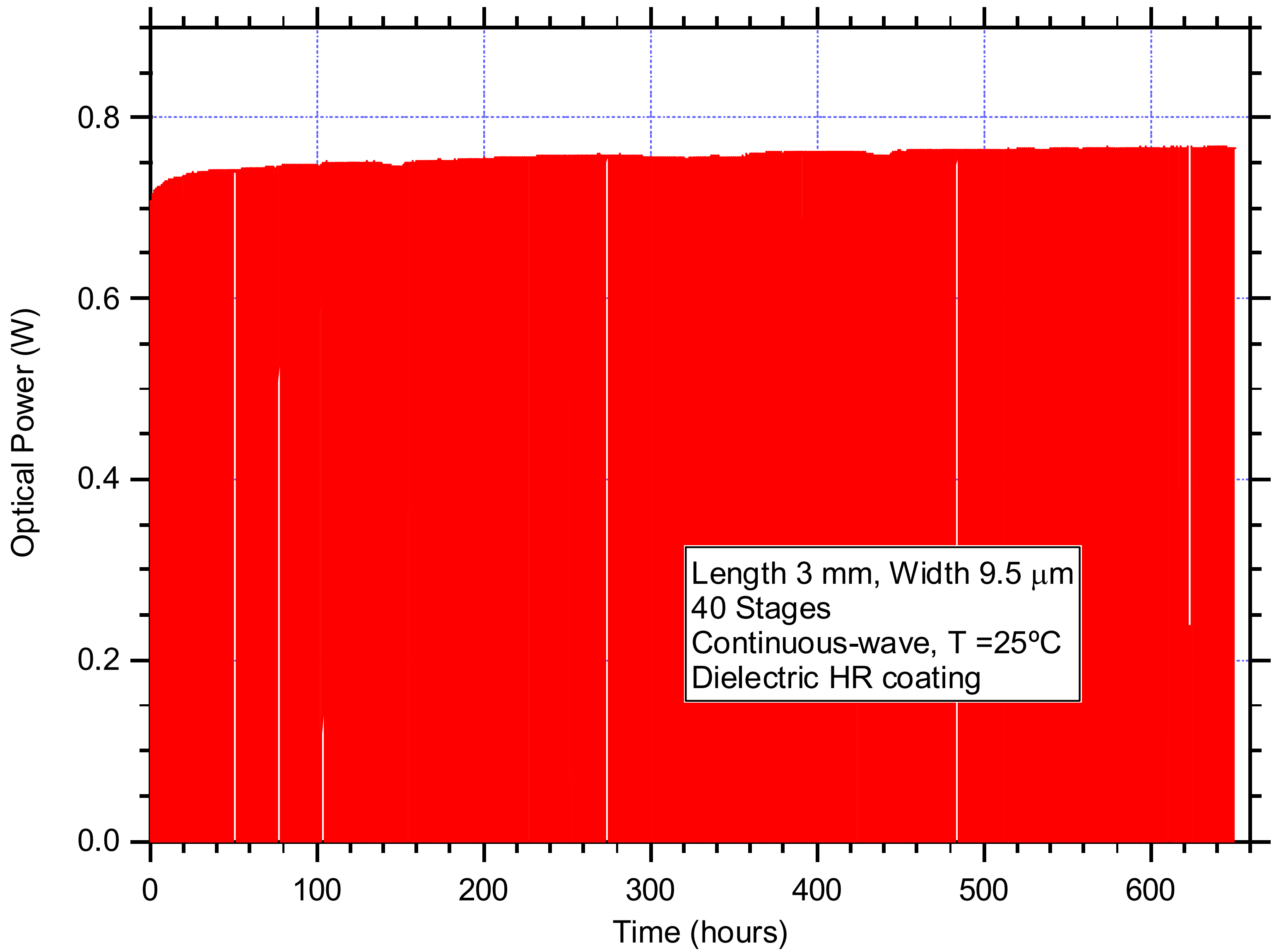


4.1 W, ~24 % efficiency

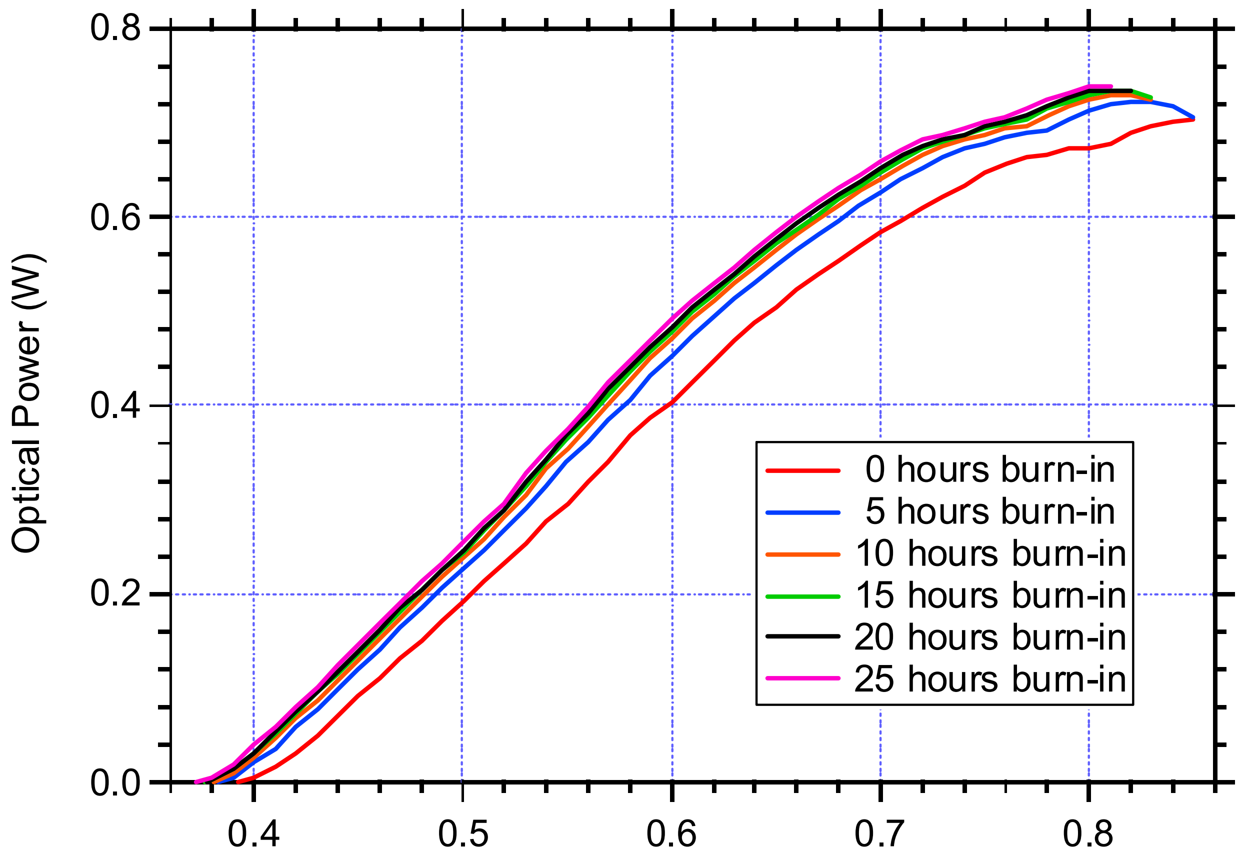
Reliability of high power QCL with metallic HR coating



Reliability of high power QCL with dielectric HR coating



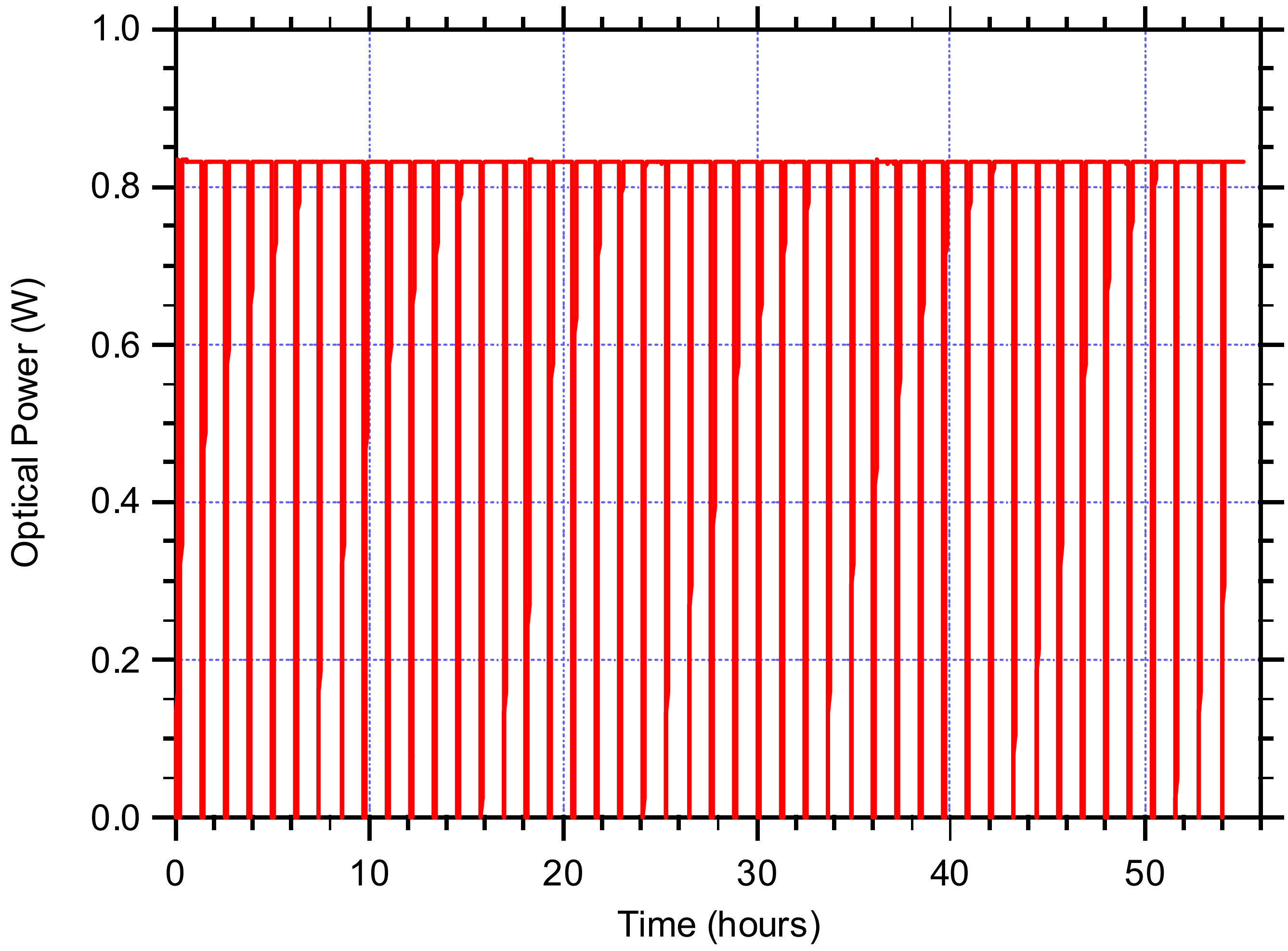
Burn-in effect: Buried-Heterostructure devices



Increase of maximum power
Decrease of threshold current & roll-over current

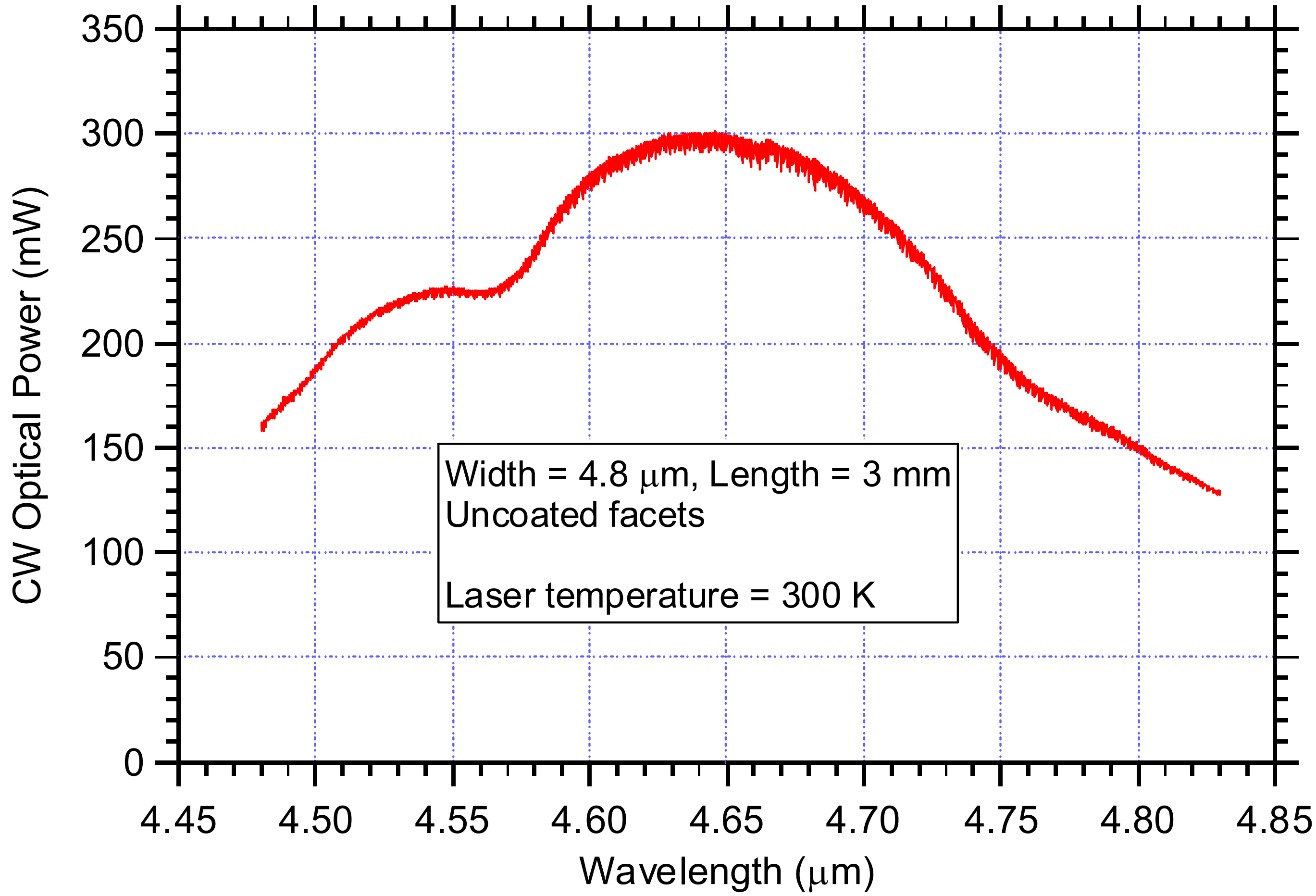
Attributed to a reduction of leakage current in lateral regrowth

Burn-in effect: Ridge waveguide devices



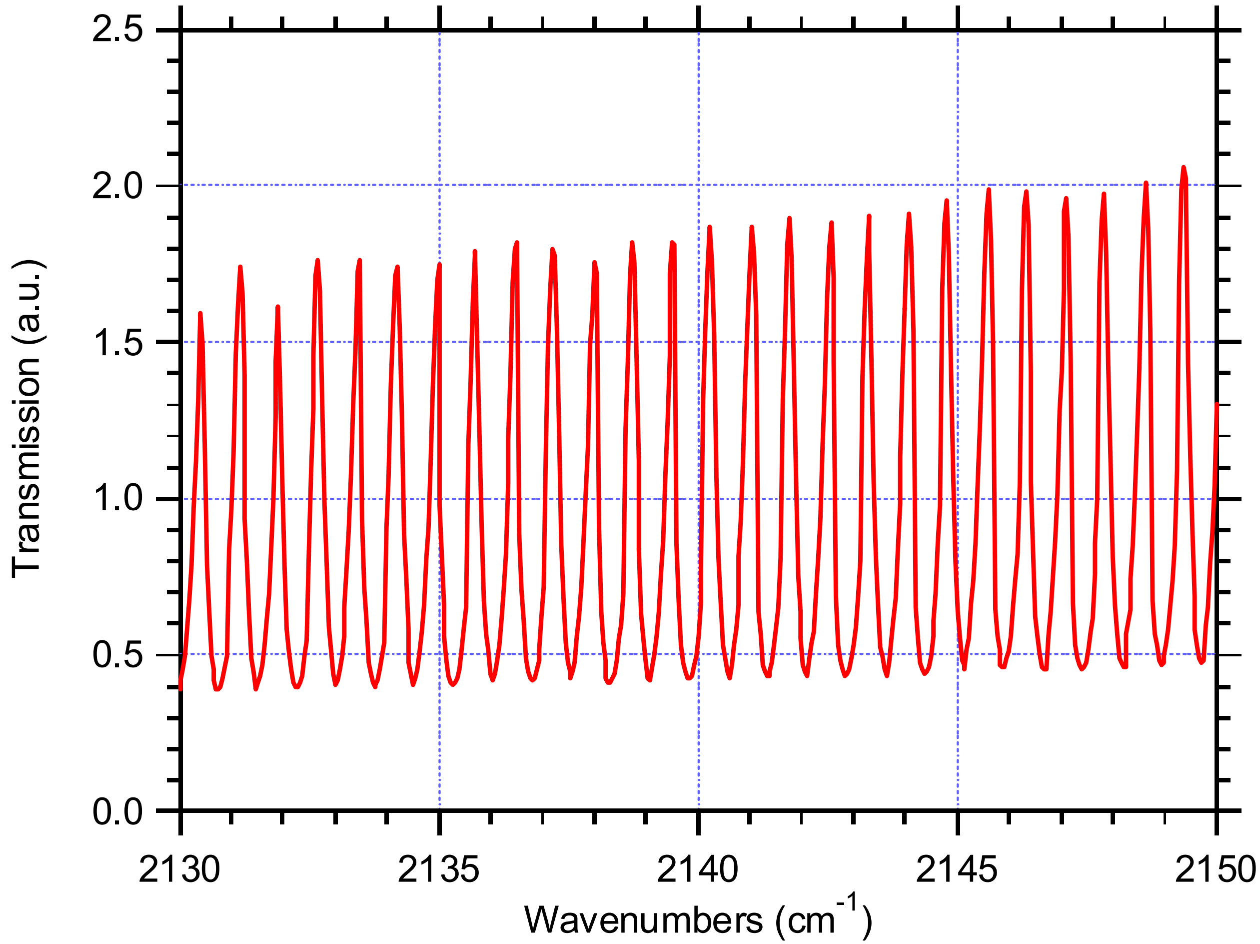
No burn-in effect observed

Widely tunable high power external cavity QCLs



Single-frequency tuning range = 163 cm^{-1}
Maximum wallplug efficiency = 5%

Tunable external cavity QCLs: Etalon scan



Free spectral range = 0.77 cm^{-1}
Scan resolution = 0.04 cm

Thank you

Questions?