nano-tera.ch
swiss scientific initiative in health / security / environment systems

MIXSEL RTD 2009

FNSNF

Wafer fused VECSELs emitting in 1.3 μm and 1.5 μm range

Kamil Pierściński[1], Alexei Sirbu[1], Andrei Caliman[2], Alexandru Mereuta[2],
Vladimir Yakovlev[1], Grigore Suruceanu[2] and Eli Kapon[1,2]

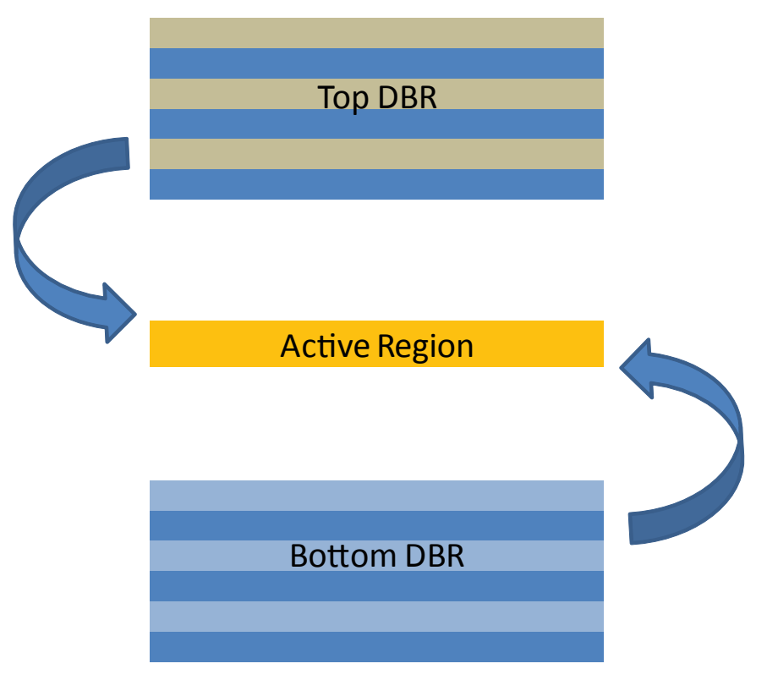
[1]Laboratory of Physics of Nanostructures, École Polytechnique Fédérale de Lausanne
[2]Beam Express SA, Lausanne

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE
Beam express

VECSELs combine many properties of traditional solid- state disk lasers and semiconductor gain material. They are particularly well suited for intracavity frequency conversion (high intracavity conversion efficiency >25% pump to SHG). Both optical and electrical pumping schemes are possible. Potential for broad gain bandwith, multi-Watt output and power scaling.

Wafer fusion

- Active region is sandwiched between a top low reflectivity n-type DBR (intermediate DBR) and an undoped bottom high reflectivity DBR. Both grown by MOVPE on GaAs substrates.
- DBRs are wafer fused onto n-type InP substrates before final fusion onto AR.

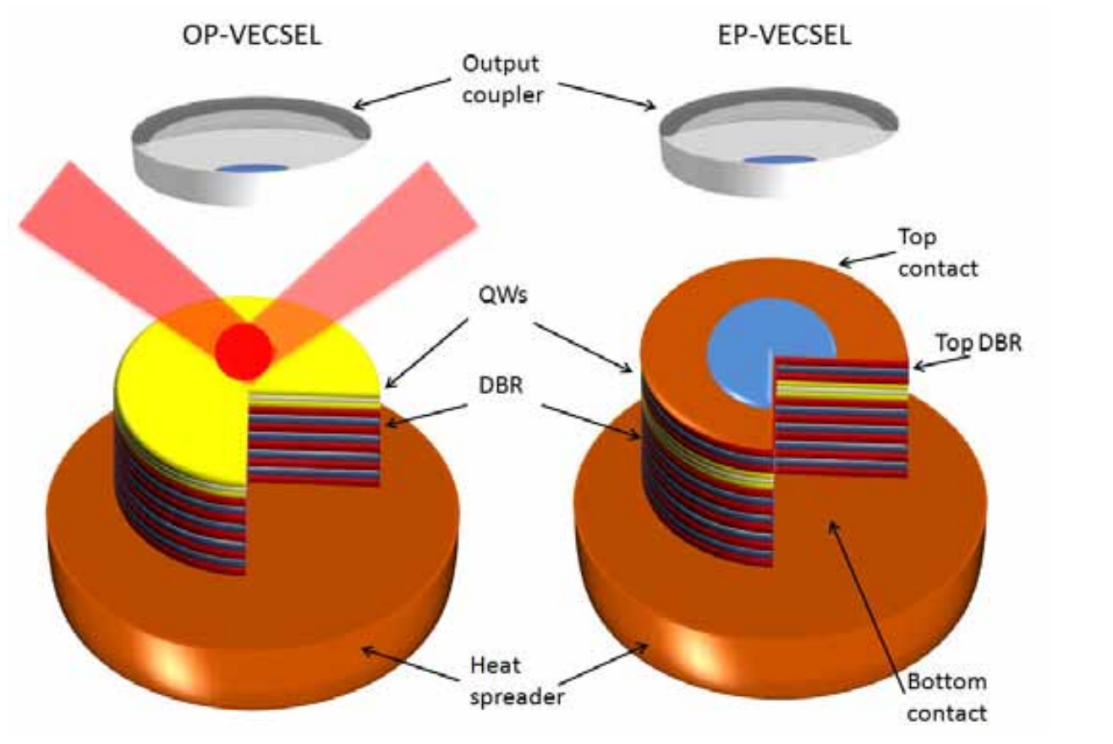


The wafer fusion approach allows the independent optimization of the gain medium and the distributed Bragg reflector (DBR) of the gain mirror in these devices, without compromising interface quality or manufacturability.

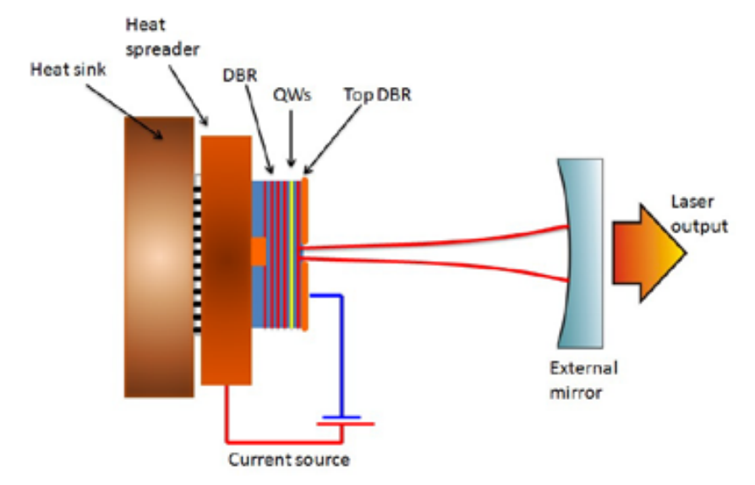
Optical and electrical pumping

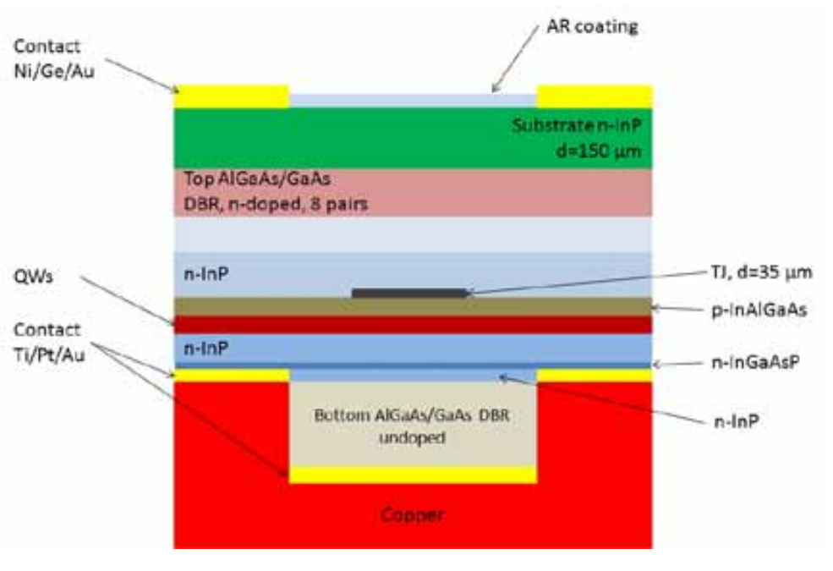
Optical pumping:
- less complicated design
- no doping
- multi-Watt output powers
- bulky pump laser assembly

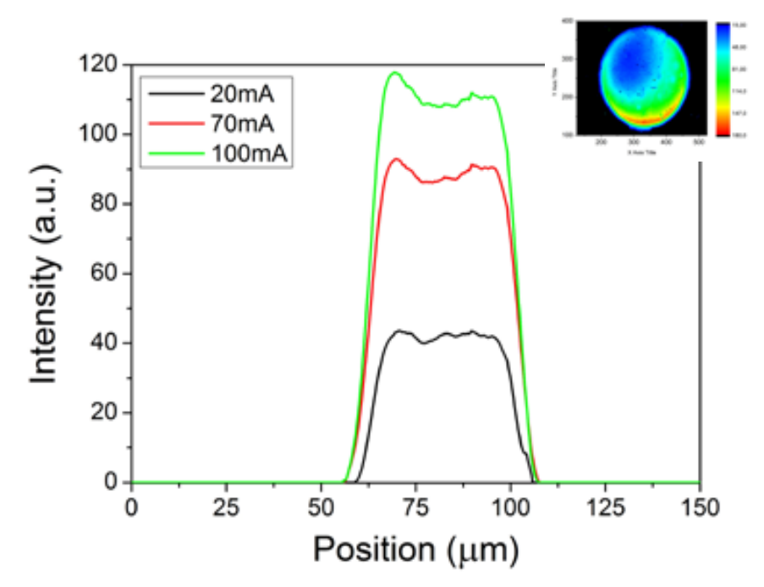
Electrical pumping:
- compact form factor
- low power consumption
- low noise



Electrically pumped VECSELs







A challenge: low electrical resistance and low optical losses
Optical losses compensated by enhancement of field in the quantum wells using an intermediate DBR.

Device design

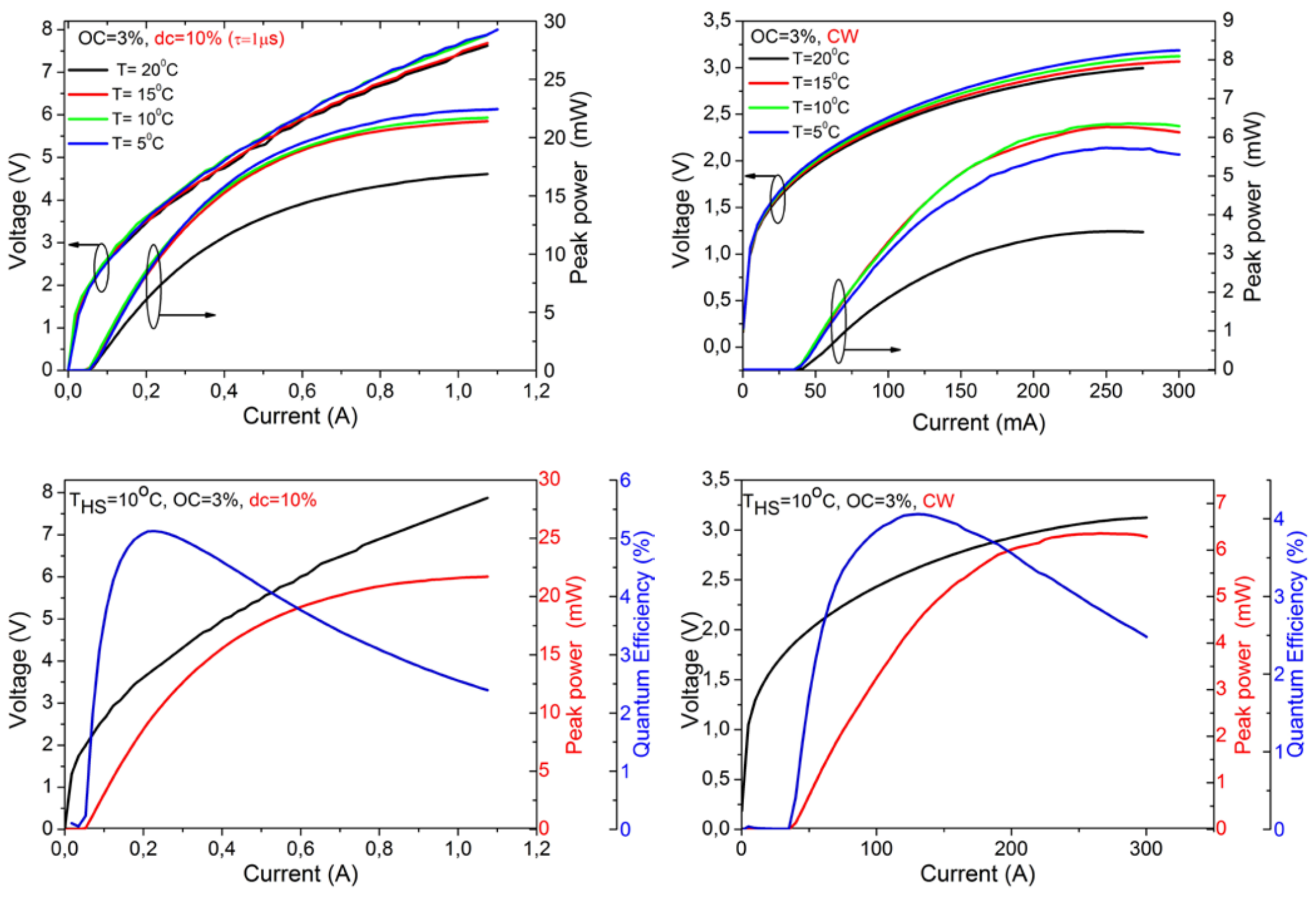
Wafer fused 1470 nm EP-VECSEL:

- n++/p++ InAlGaAs tunnel junction
- InP-based, 3.5 λ active region, one group of 6 undoped InAlGaAs strained QWs placed at antinode of electric field distribution, room-temperature PL centered at 1440 nm
- InAlGaAs p-n junction, a top n-InP-spacer, and a bottom n-InP current spreading layer
- top n-DBR, 8 pairs AlGaAs/GaAs
- bottom AlGaAs/GaAs undoped DBR

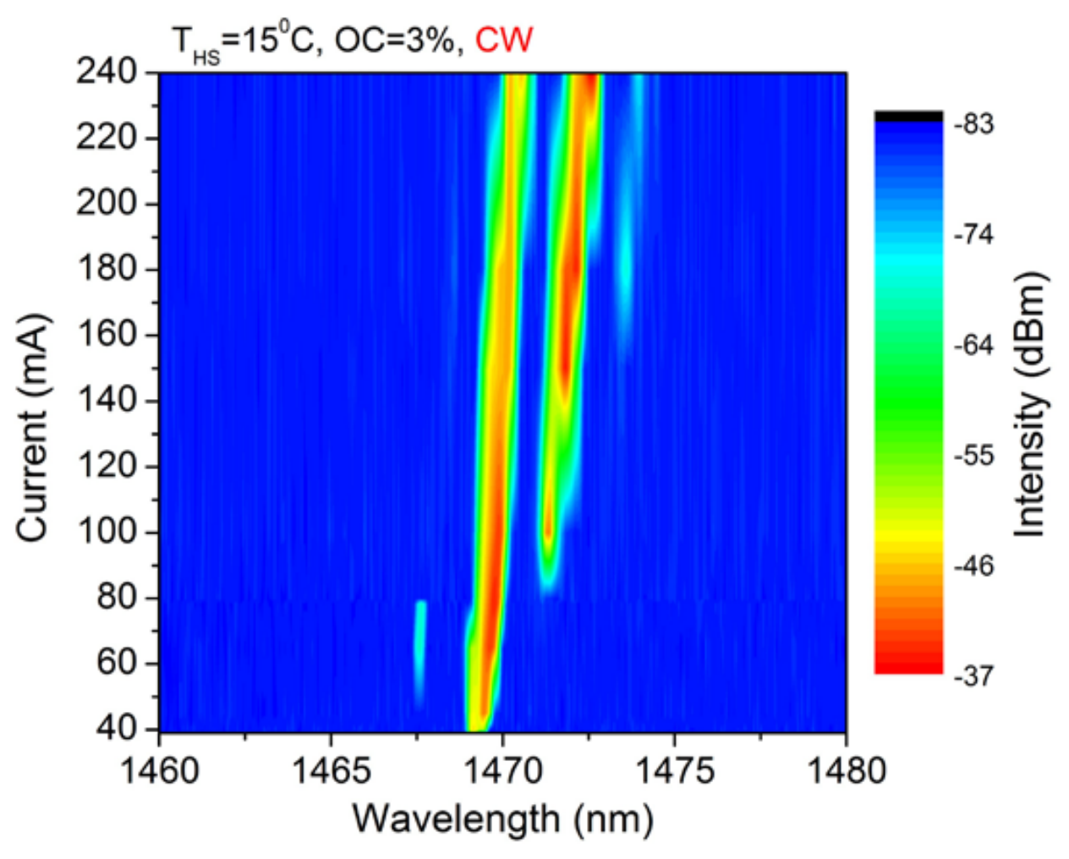
Current uniformity

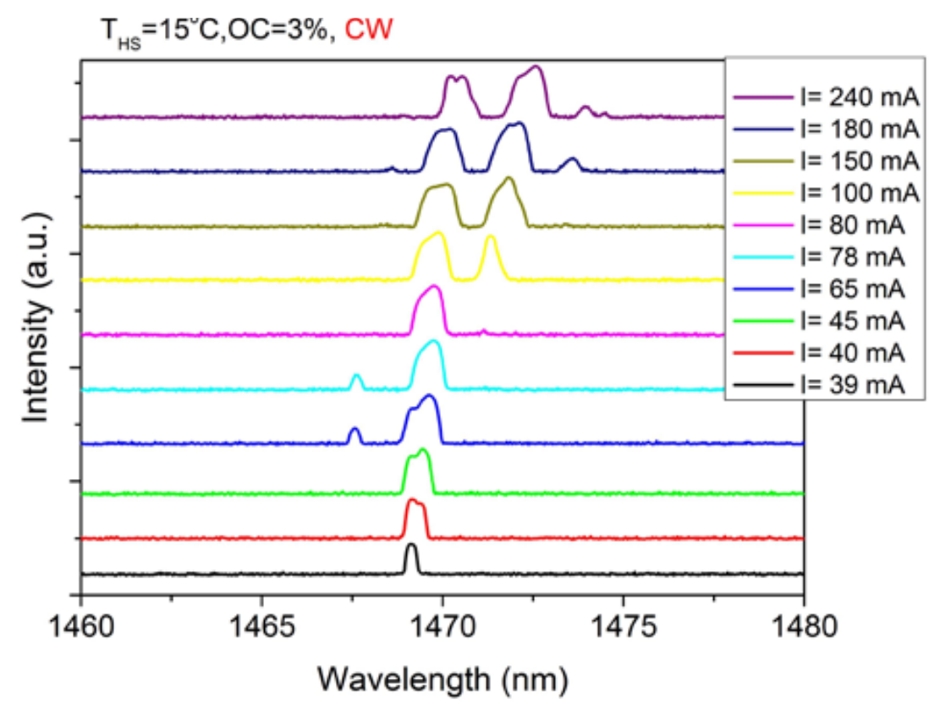
Better current spreading than n-GaAs substrate emitting devices due to high electron mobility in n-InP.
Efficient current spreading through 150μm-thick n-InP substrate is important for decreasing the current non-uniformity through the tunnel junction resulting from the window in the top electrical contact.

Pulsed and CW performance



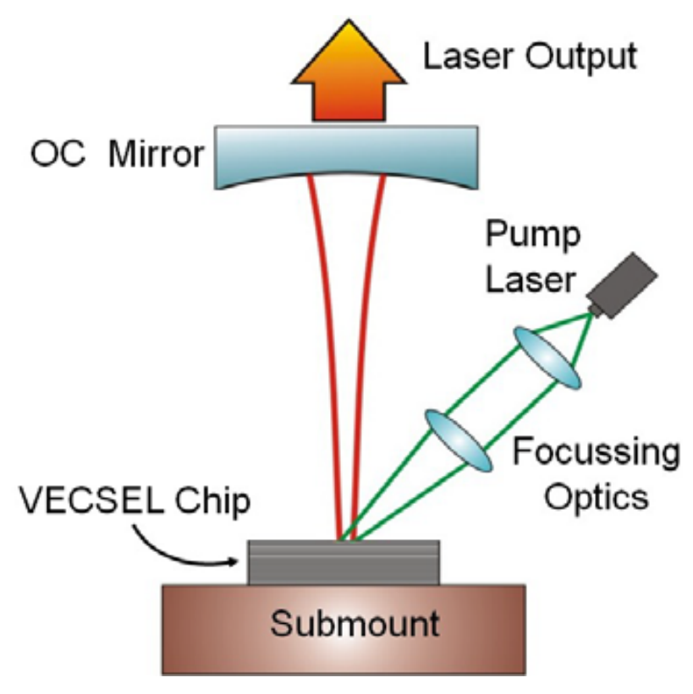
Max power in pulse mode 25mW, 2% duty cycle, RT
Max power in CW mode 6.5 mW @ 15C
Threshold current: 40 mA in CW, 60 mA in pulse mode

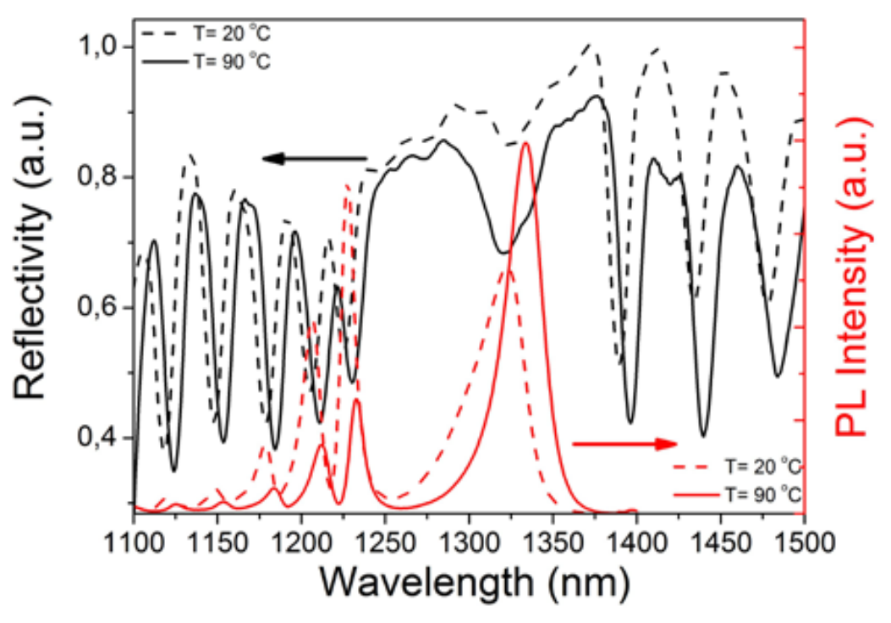




From wavelength tuning:
$\Delta\lambda$=1.4468 nm; ΔT=15.3 K
R_{TH}=16.1K/W

Optically pumped VECSELs





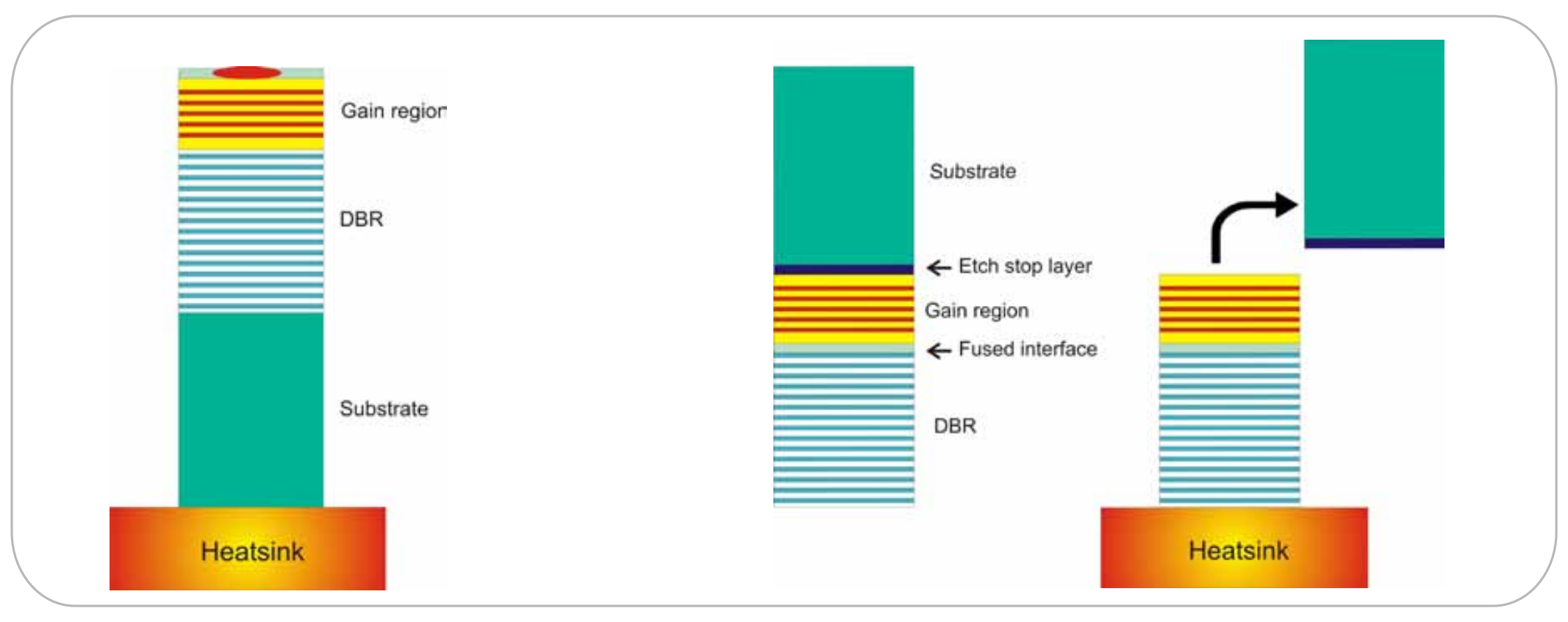
The major constraints on the performance: thermal, through:

- material gain and loss mechanisms (e.g. thermal excitation of carriers from QWs)
- DBR band and the micro-cavity resonance, as well as the QW, gain spectrum shift with temperature at different rate causing these key components to walk away from each other (detuning)

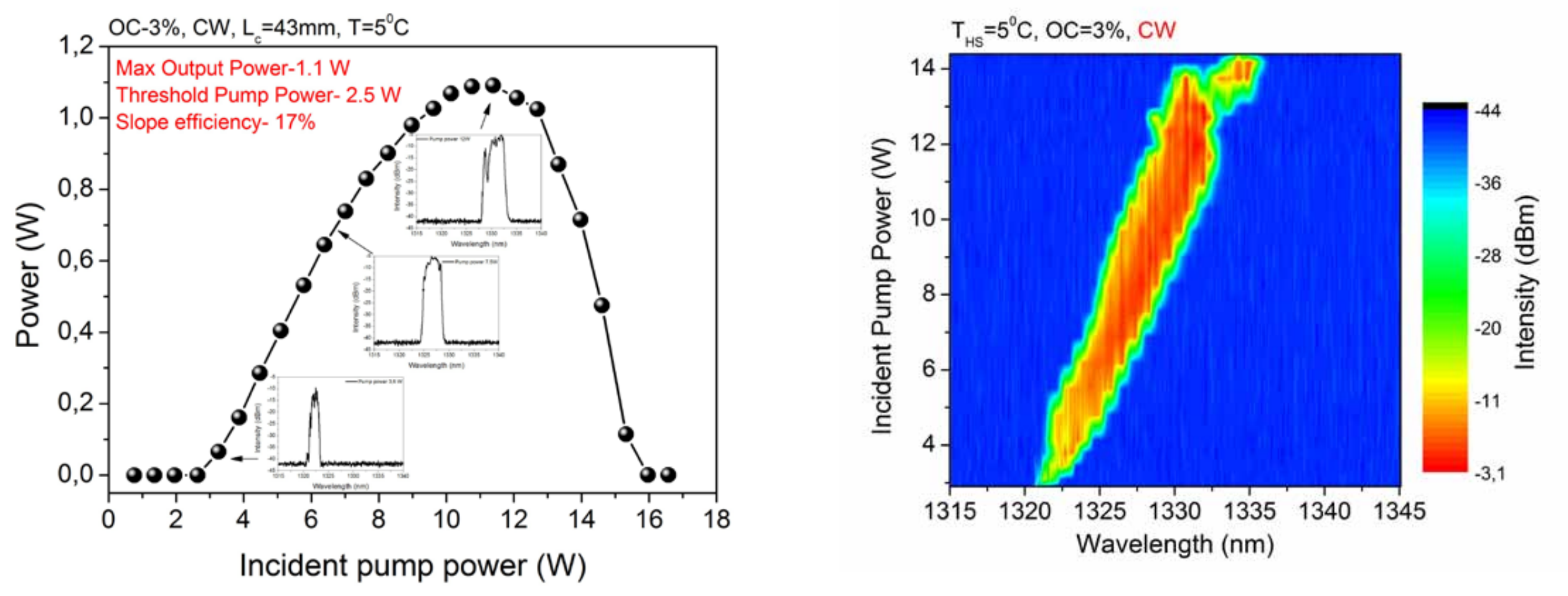
Flip-chip scheme

The challenge: thermal management
possible solutions:

- intracavity heatspreader (affects spectral characteristics)
- flip-chip device mounted to diamond heatspreader

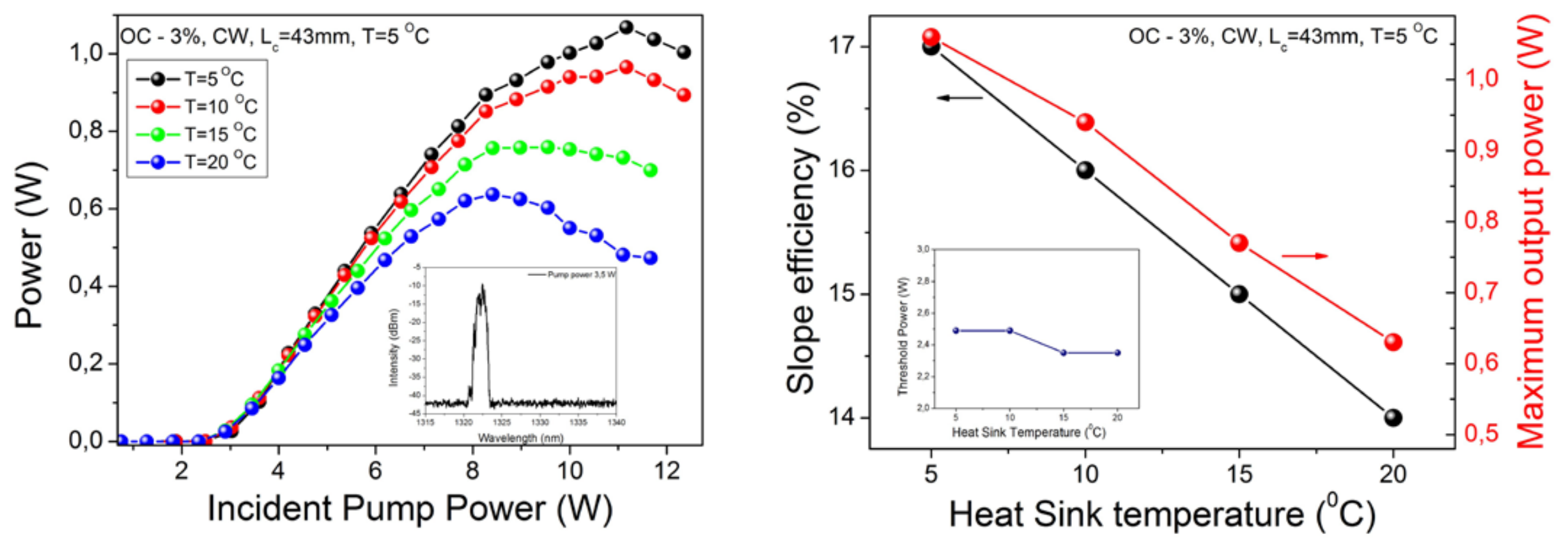


State of the art



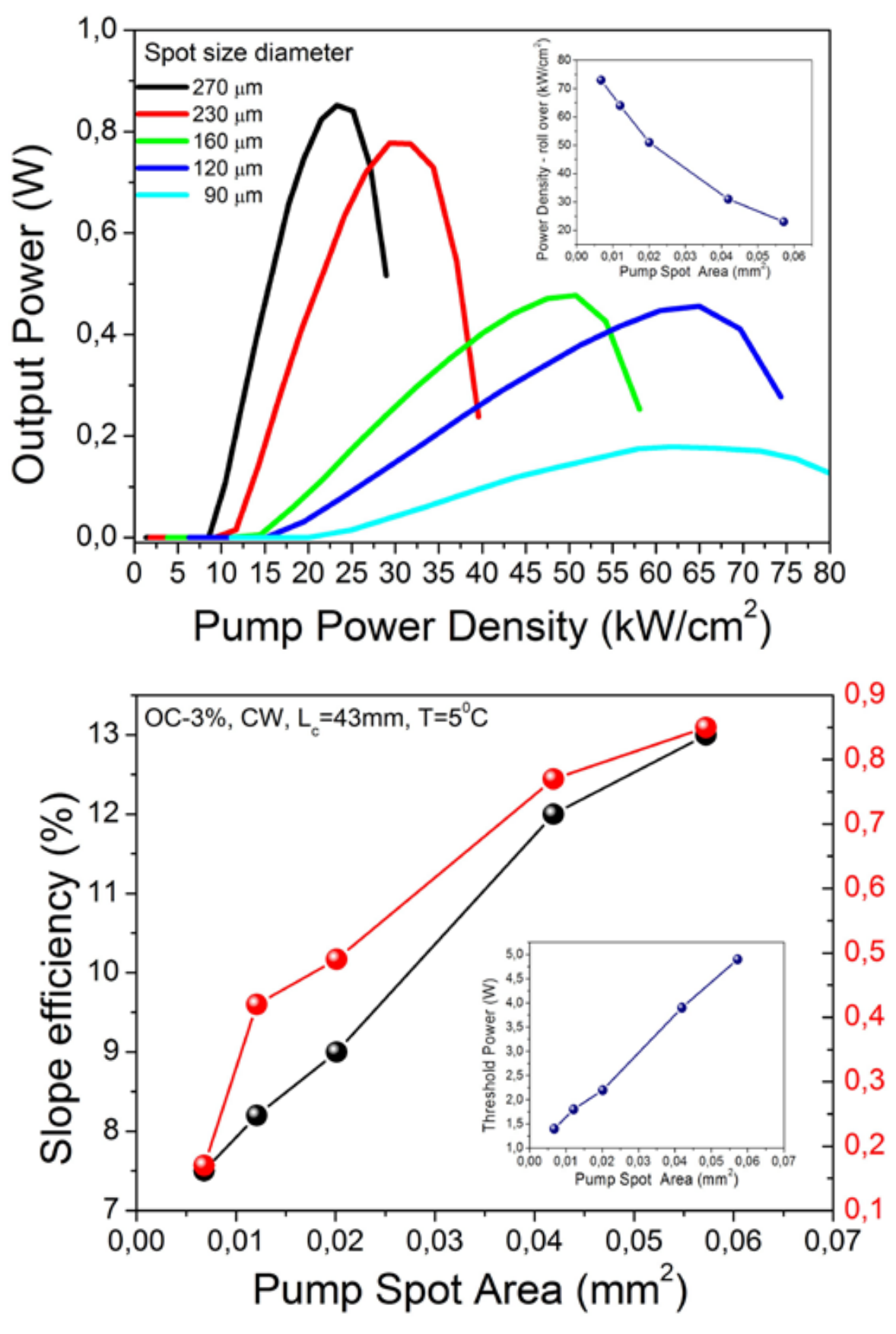
Max power in CW mode: 1.1 W @ 5C
with efficiency ~13%

Temperature influence on performance



Performance affected by heat removal. Max. submount operating temperature extrapolated as 42 °C.

Power scaling



High potential for power-scaling. Increasing the pump spot much higher output power can be extracted from the device.
More efficient heat extraction needed for power scaling: intracavity diamond heatspreader allows for direct removal of excess heat from AR.