II-VI

MATERIALS THAT MATTER®

Swissphotonics Workshop 2019
Thermal Management in Photonics Packaging

Actively Cooled Diode Laser Bars

Requirements and Assembly Technology

II-VI Laser Enterprise

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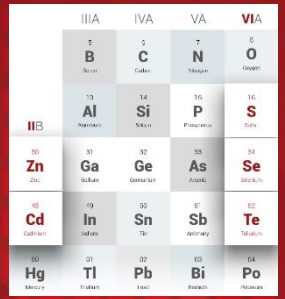

Materials for CO_2 laser optics: CdTe, ZnSe & ZnS

II-VI LASER ENTERPRISE

A Global Leader In Semiconductor Lasers

- **Rich heritage of innovation for over 30 years**
- **State-of-the-art semiconductor laser technology and manufacturing infrastructure**
- **280 employees**

Global Presence

- **Capacity Expansion through Epiworks and Anadigics**
- **Backend Manufacturing at Laser Enterprise Philippines, Photonics Shenzhen, and Fabrinet**

Laser Diode Portfolio

- **High Power Laser Diodes**
- **High Volume Components - VCSELs**
- **980nm Single-mode Pump Lasers**

Outline

MATERIALS THAT MATTER®

Performance of Diode Laser Bars

Thermal Management

- Micro Channel Heat Sink

Reliability

Perspective

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Overview II-VI's Product Generations

Median of multi-year production

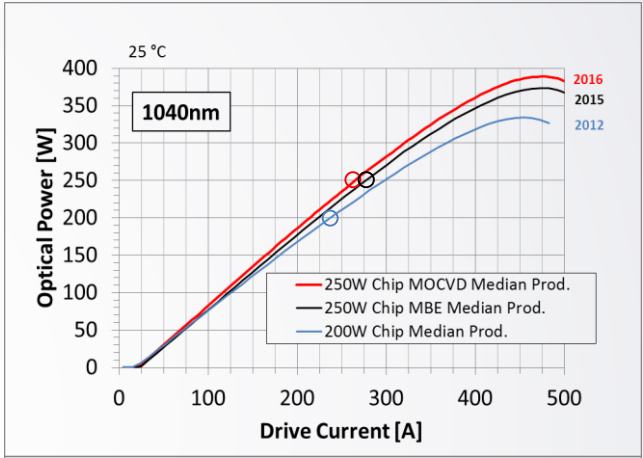
250W product

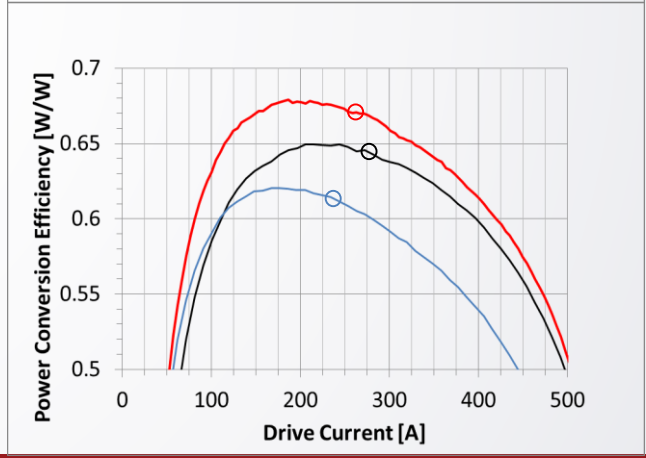
- 47 Emitters
- Operation current 255-265A
- PCE@250W >65% for 920 to 1080 nm
- PCE peak 67-68%
- Rollover 380W @ 475A

Thermal density
⇒ 380 W/cm²

MOCVD technology:

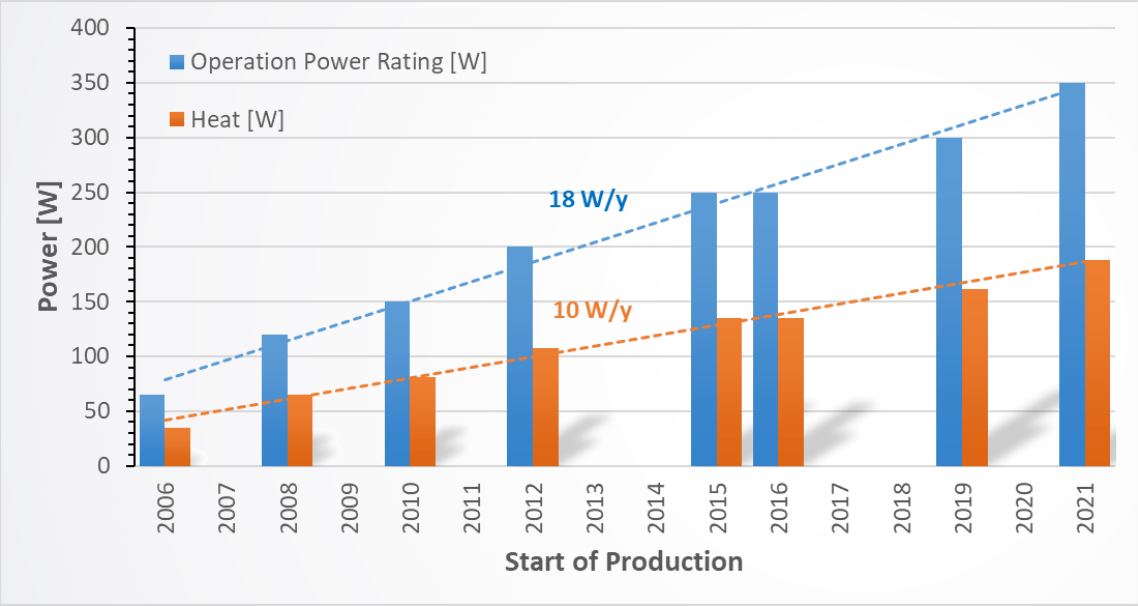
- improved control on epitaxy design
- 3% improved conversion efficiency





Evolution of Output Power Rating

- **Power ratings of II-VI high power bar product line**



Chip and packaged bar optimized for

- **Output power**
- **Conversion efficiency**
- **(Slow Axis) divergence**
- **Endurance**
- **Emitter line flatness**
- **Build height**

- **Wavelength range 920nm to 1080nm**

Efficient thermal management needed

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Thermal Management

- **reducing heat production => increase conversion efficiency**
  - chip design
  - electrical resistance
  - epitaxial growth quality

- **efficient heat removal**
  - conductive cooling (passive)
  - active cooling e.g. micro-channel heat sink

Micro-Channel Heat Sink

Heat exchanger using fluidal flow through microchannels (typically < 1 mm)

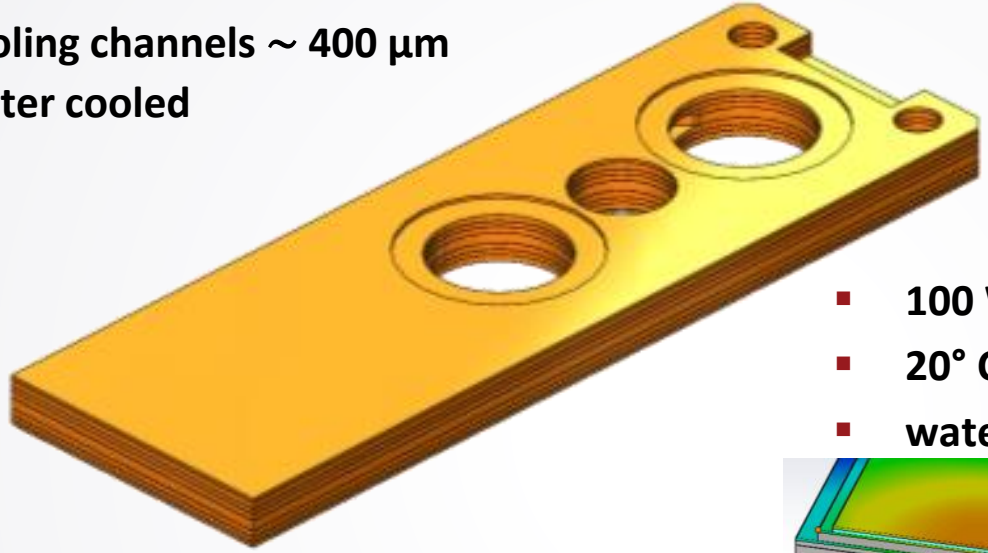
Requirements for cooling of a high power Diode Laser Bar

- **reliability: several 10k hours**
- **low mechanical stress on chip**
- **manufacturable**
- **low cost**
- **small footprint and build height**
- **high cooling capacity**
  - contact area
  - cooling distance (chip to microchannels) and material
  - cooling agent:
    - thermal capacity
    - viscosity
    - velocity

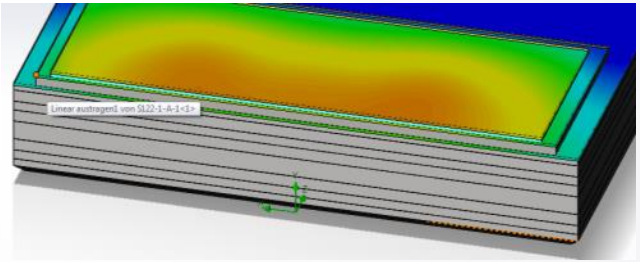
Micro-Channel Cooler Package

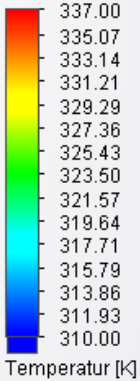
“Labrador” Micro-Channel Cooler

- cooling channels ~ 400 µm
- water cooled



- 100 W heat
- 20° C water temperature
- water flow 0.3 l/min





- ✓ fully AuSn soldered
- ✓ CTE matched pedestal
- ✓ copper: low cost & manufacturable
- ✓ stackable, build height = 3 mm
- ✓ low smile (emitter line warpage) ~ 0.7 µm
- ✓ thermal resistance ~ 0.3 K/W

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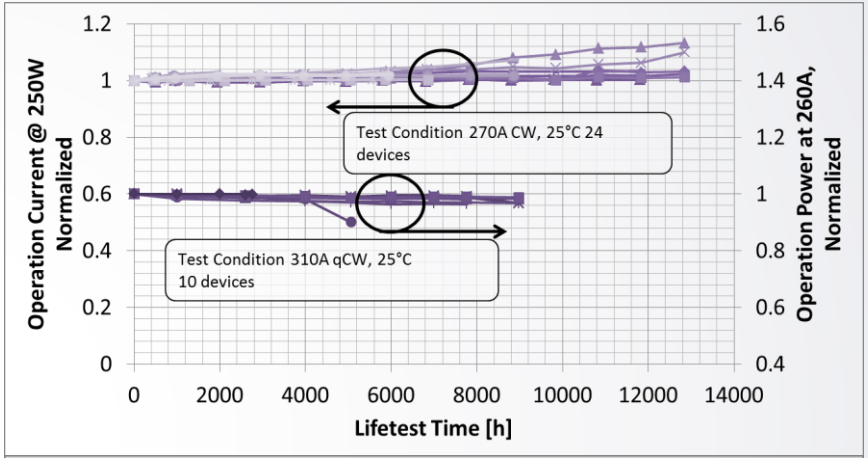
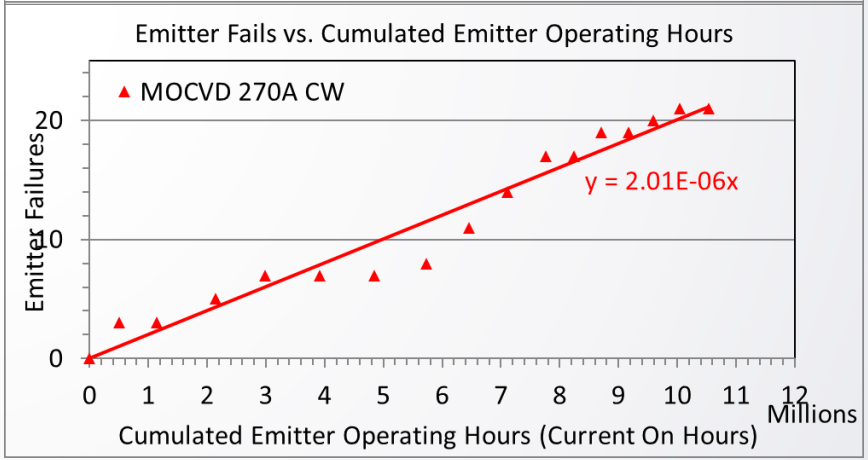
Reliability of 250W Product

Industrial reliability requirements - typically:

- **20’000 h CW or 35’000 h 50% DC pulsed**
- **End-of-life: 5-10% operation current increase**



- **Constant emitter failure rate 0.2% in 1000 h (2 kFIT)**
- **4% average degradation in 20’000 h**
- **MTTF @ EOL 10%: 50’000 h**



Reliability of Micro Channel Cooler

reliability strongly dependent on

- erosion
- electrochemical corrosion

flow rate

O, CO_2 concentration

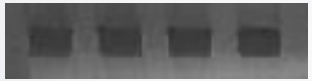
pH

conductivity

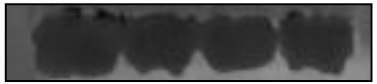
insufficient water quality

controlled water quality

0 h



11’000 h



14’500 h

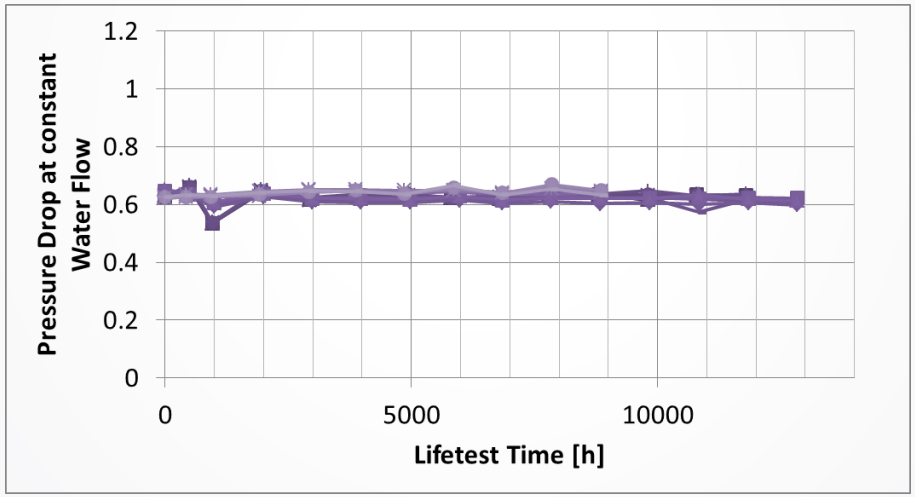
Pressure drop ↘ 50%!

Pressure drop constant!

Micro Channel Cooler Lifetime

Long term stability of the Micro Channel Cooler

- **Results from above lifetest**
- **Cooling performance stable in 13’000 h test - NO power degradation**
- **Pressure drop at constant flow stable in 13’000 h test**



➢ **Package suitable for long term operation**

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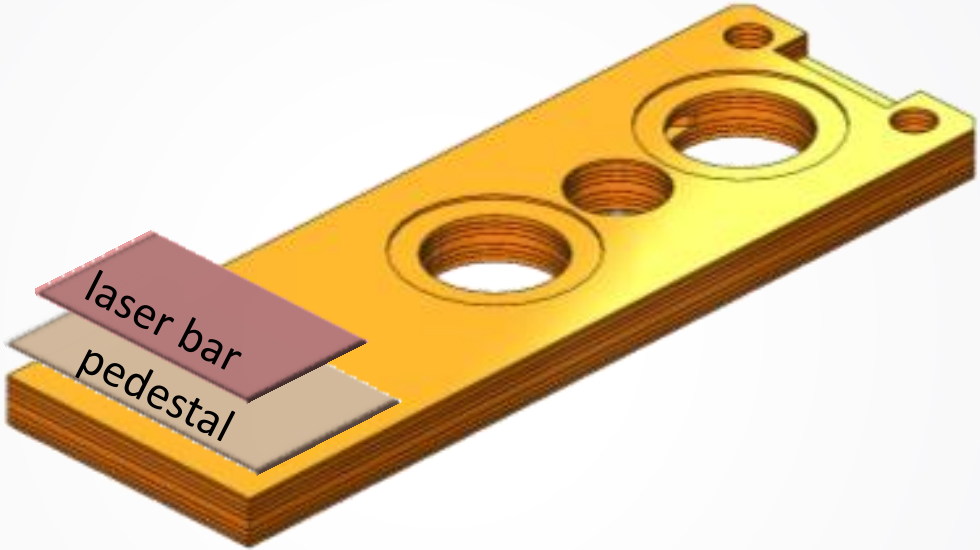
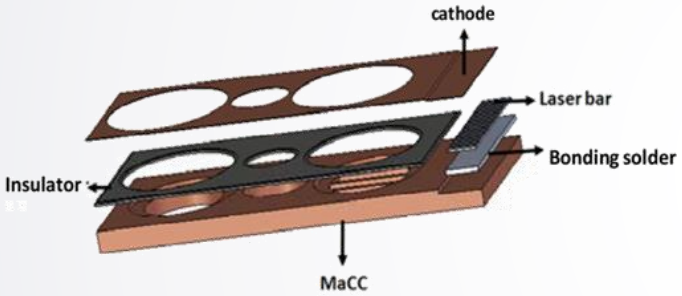
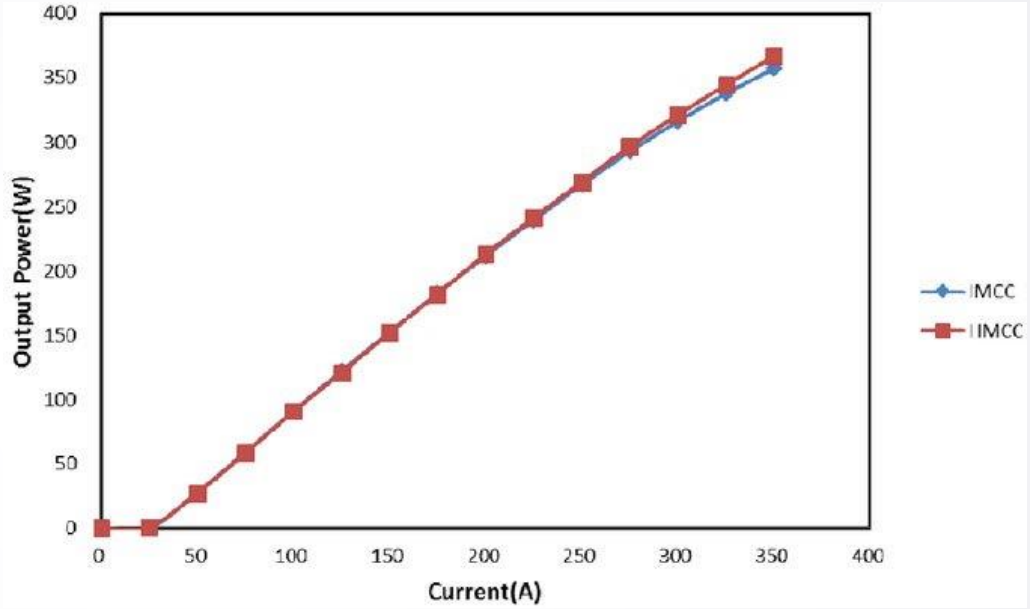
Perspective: stay cool!



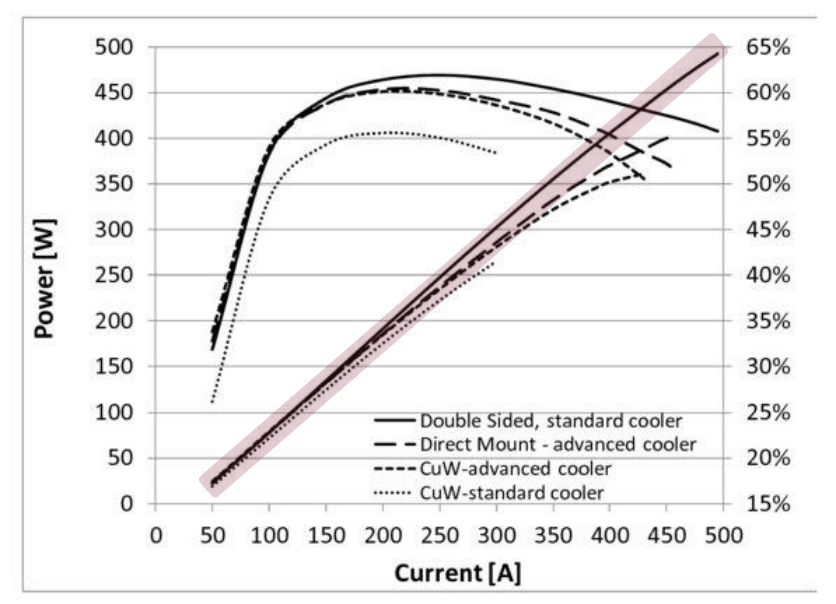
Direct Bonding





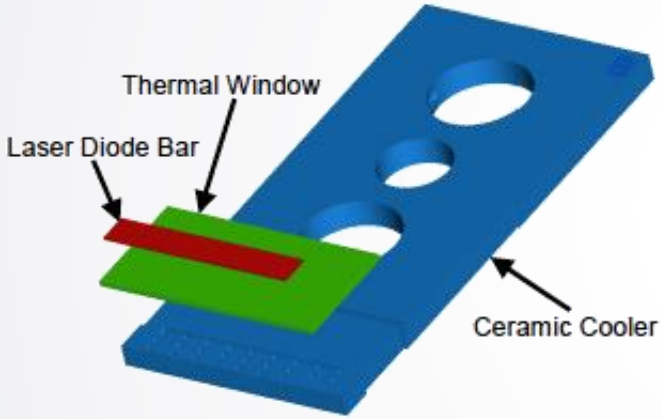
Boxue Wang et al., “High power vertical stacked and horizontal arrayed diode laser bar development based on insulation micro-channel cooling (IMCC) and hard solder bonding technology”, Proc. SPIE 10513, 2018

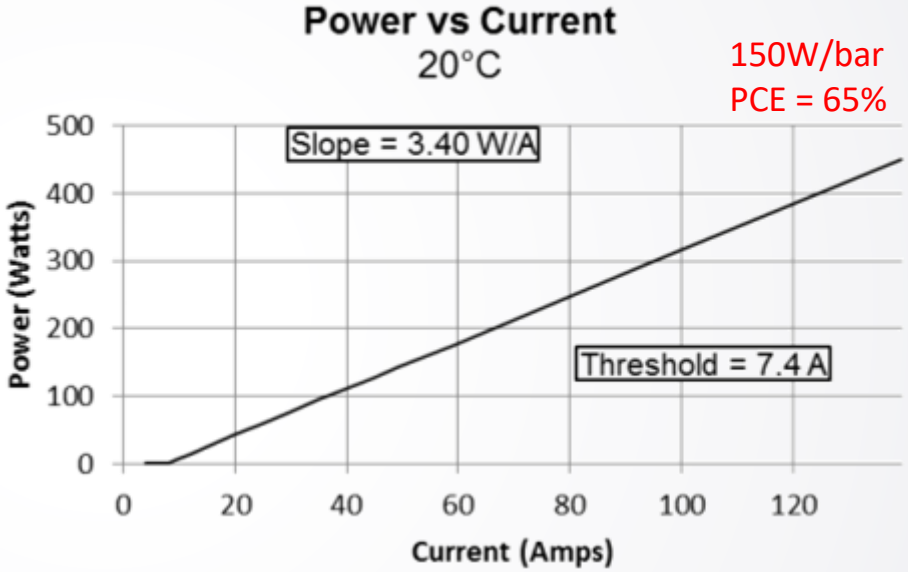
Double side cooling



Stefan Heinemann et al., “Advanced chip designs and novel cooling techniques for brightness scaling of industrial, high power diode laser bars ”, Proc. SPIE 10514, 2018

Ceramic cooler





Plot of P-I curve for a 3-bar array

Jeremy Junghans, et al. "Custom ceramic microchannel-cooled array for high-power fibercoupled application", Proc. SPIE 10514, 2018

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