InP Based Vertical Cavity Components

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InP-Based Vertical Cavity Components

- WDM VCSEL Arrays
  - Wafer-fused
  - Lattice-matched AsSb*
- VC-SOAs
  - Wafer-fused, optically pumped
  - Lattice-matched bipolar cascade (tunable)**
- VC Wavelength-Converting Photon Number Amplifier
  - Lattice-matched bipolar cascade (tunable)

* with DARPA-SPAWAR funding
** with DARPA-ARO-UCSD funding

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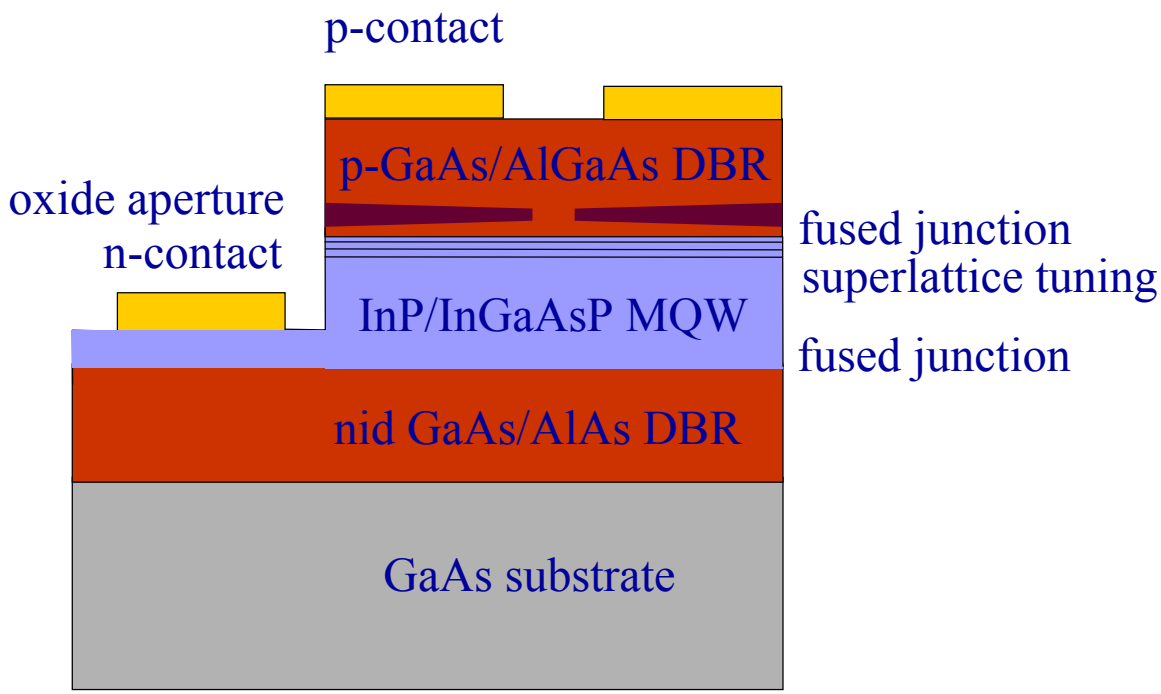
Wafer-Fused WDM VCSEL Arrays



25.5 period carbon doped GaAs/$Al_{0.9}Ga_{0.1}As$ p-DBR

6 quantum well strained active region

31 period undoped bottom DBR

Fused junctions placed at null in optical field

Device pitch is 250 µm for coupling using standard components

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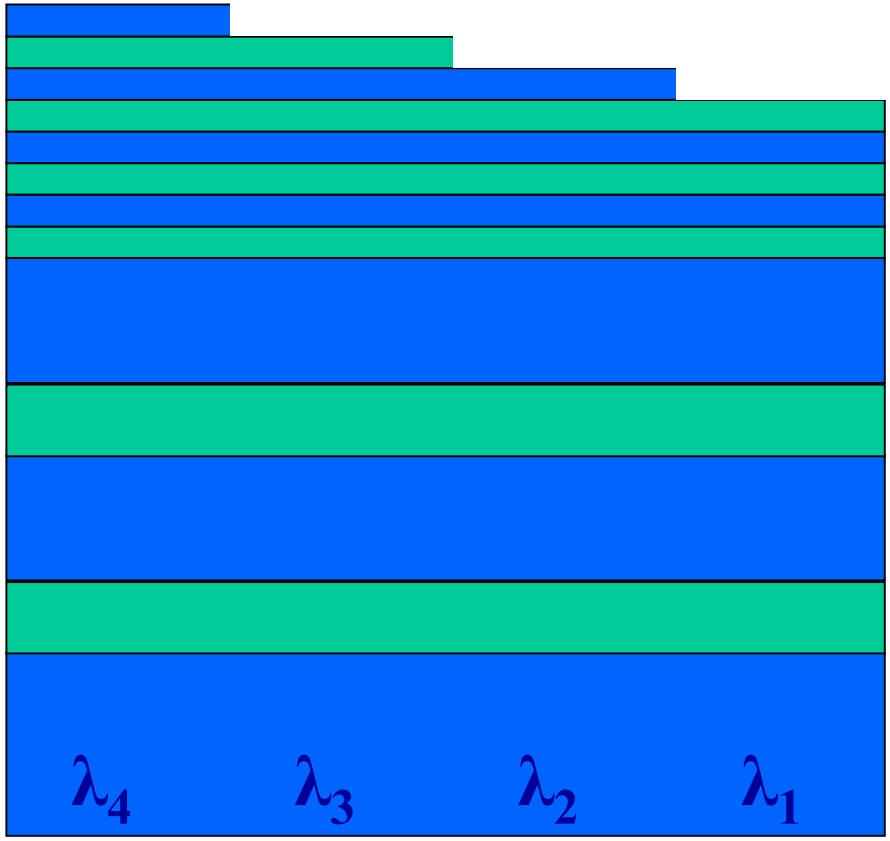
Superlattice for Cavity Tuning



4 period 75Å InP/75Å 1.3Q superlattice

p-InP cladding

InGaAsP MQW

n-InP cladding

InGaAsP etch stop

InP substrate

75 Å etch reduces cavity wavelength by approximately 5 nm. Device pitch is 250 µm for coupling using standard components.

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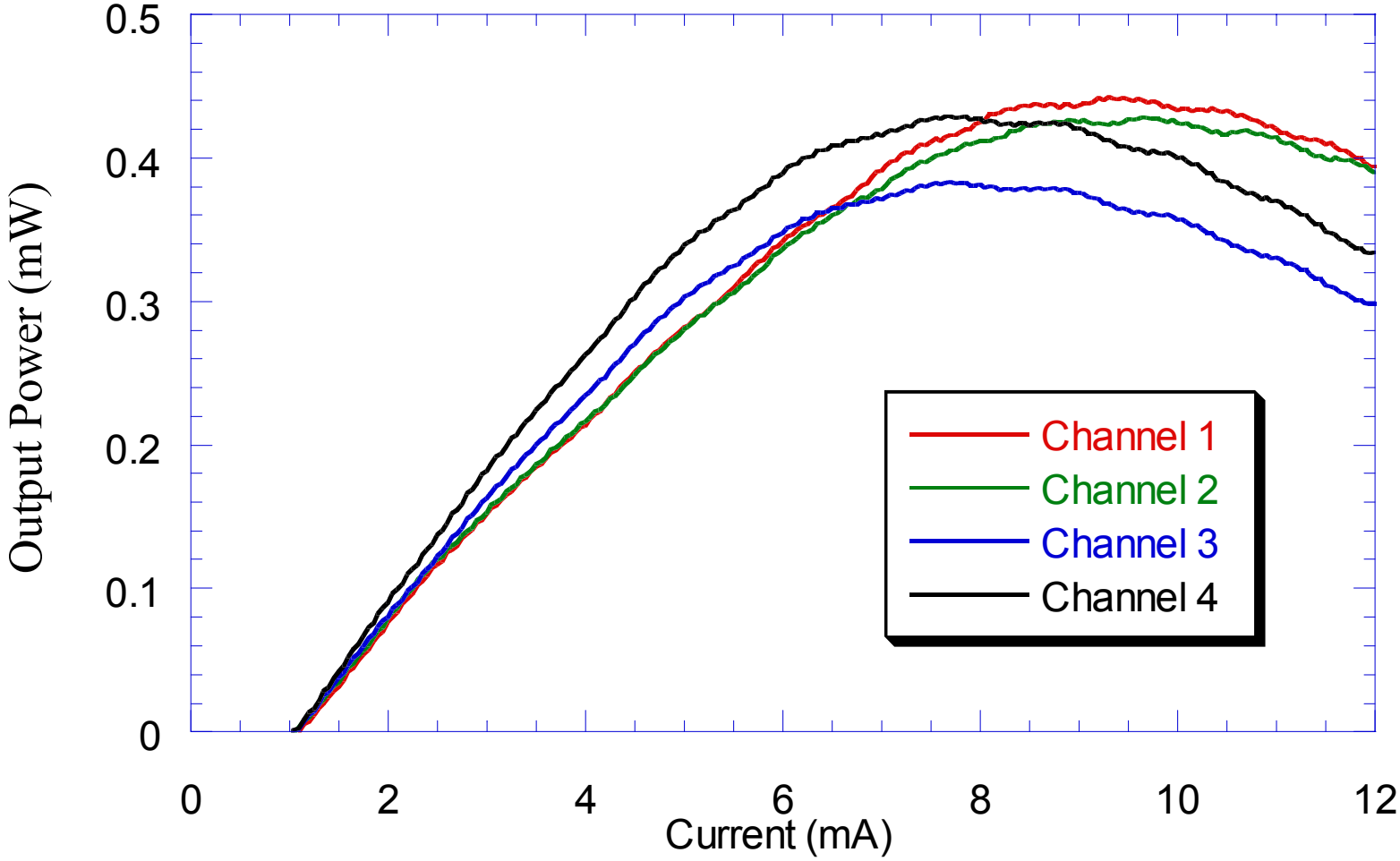
Wafer- Fused WDM Array Channel Powers



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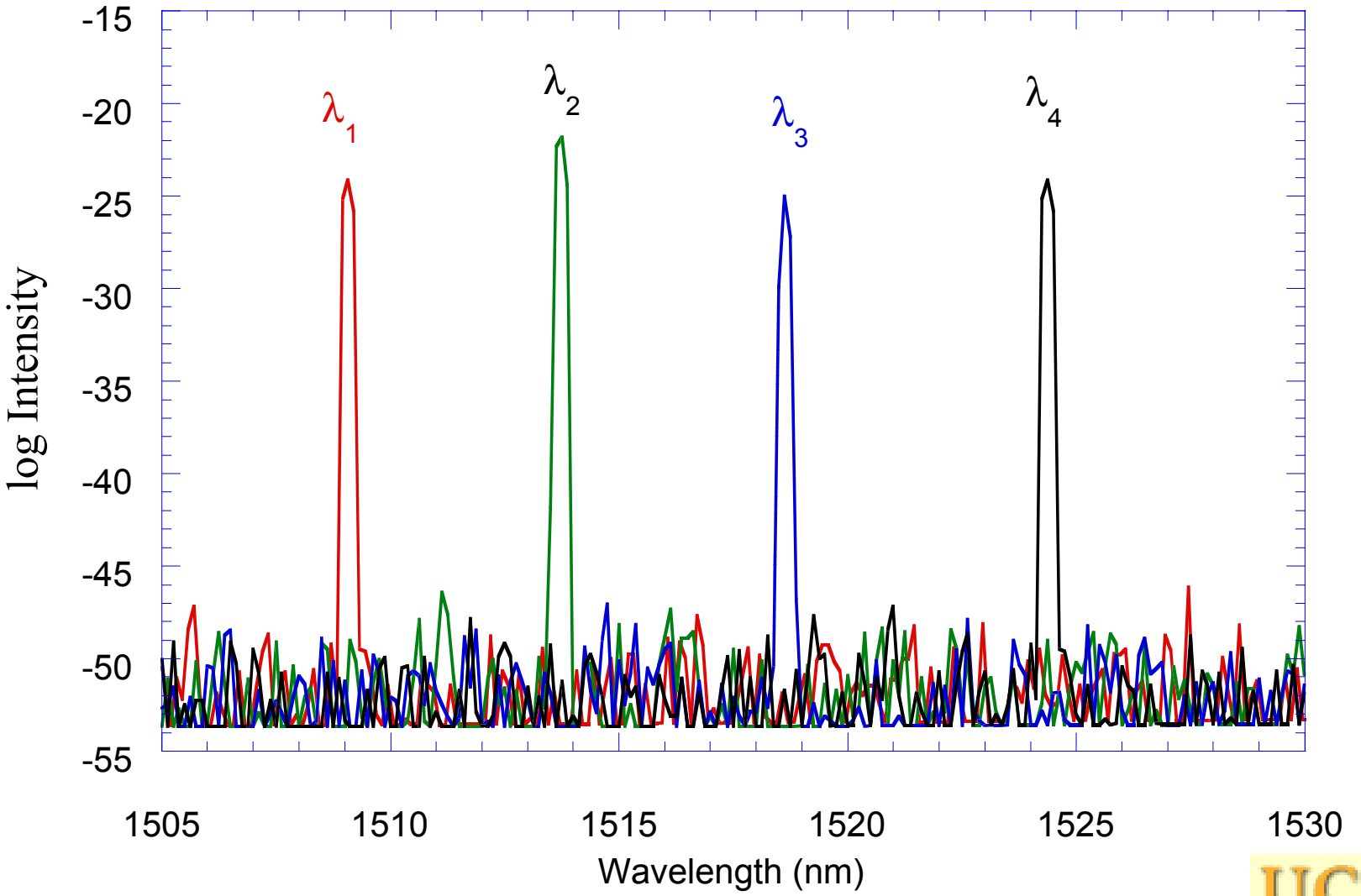
WDM Array Spectra



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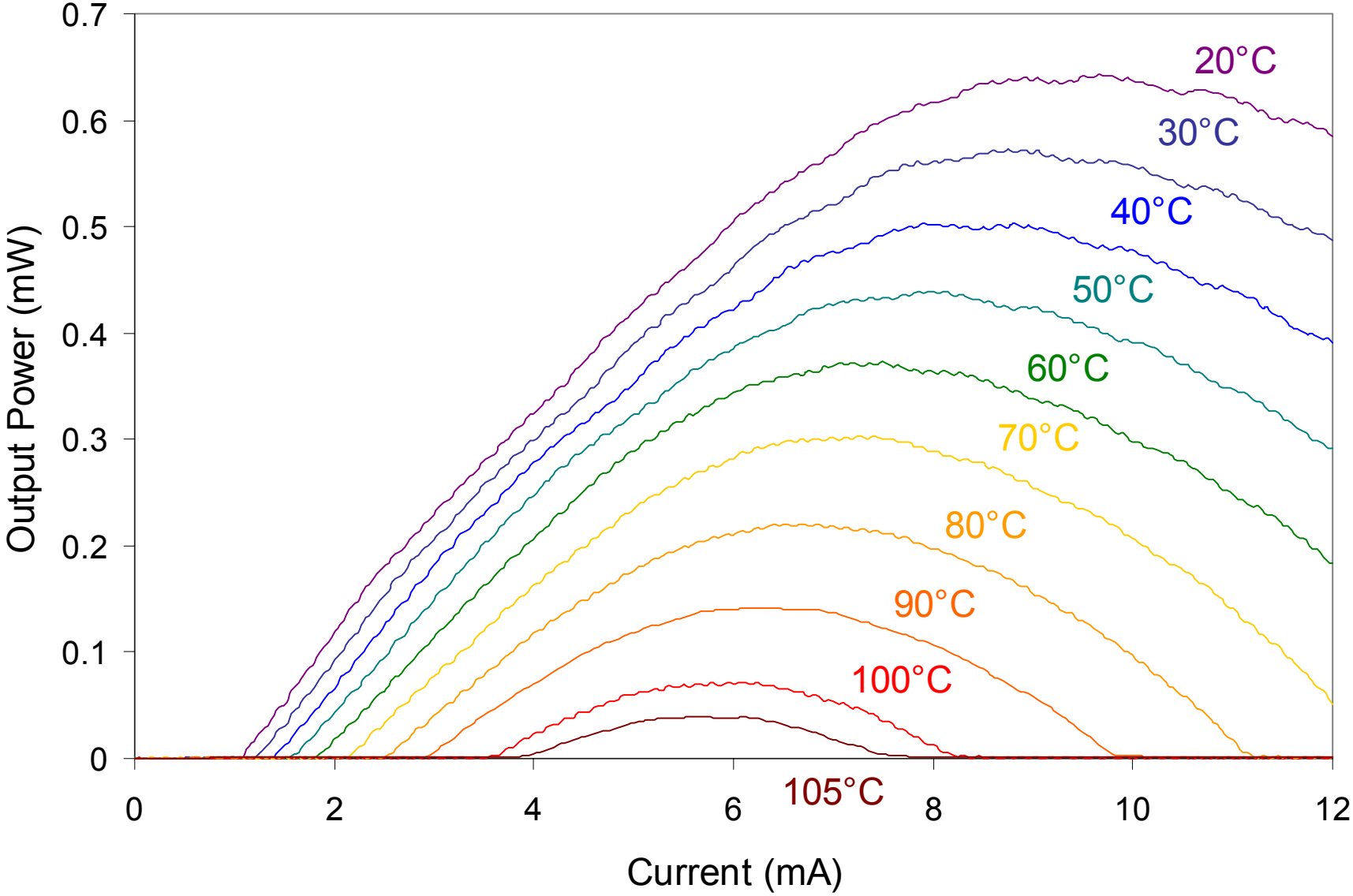
Wafer Fused WDM Array



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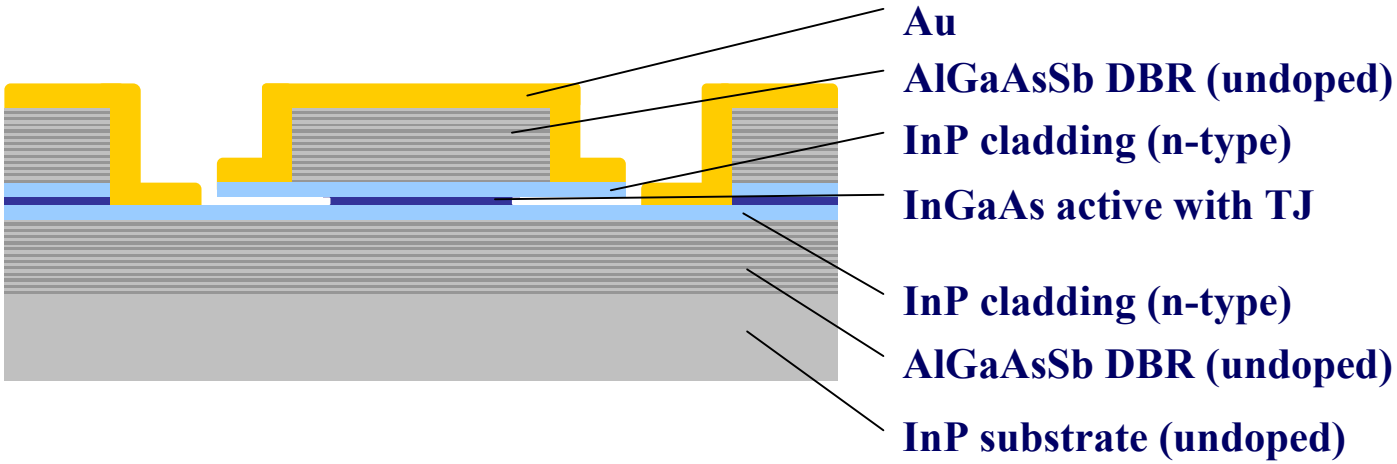
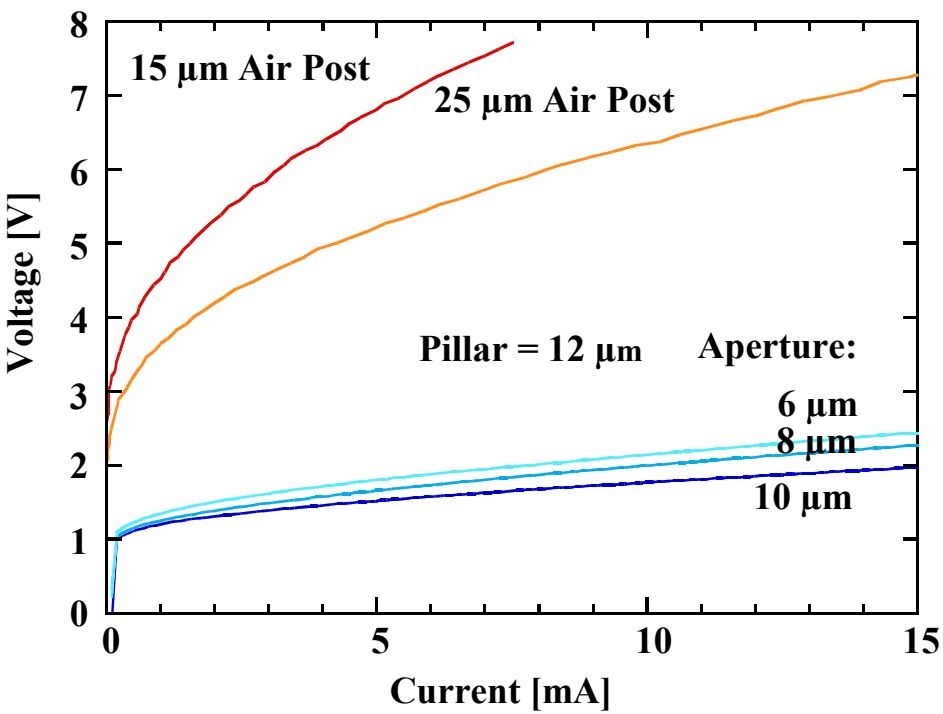
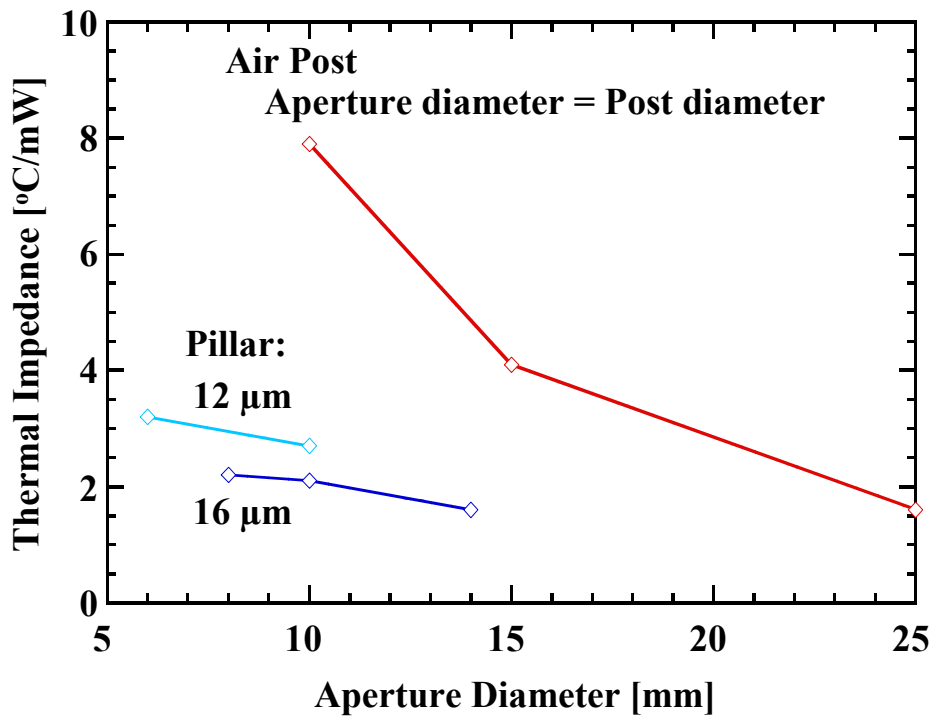
Lattice-Matched VCSELS for WDM Arrays*







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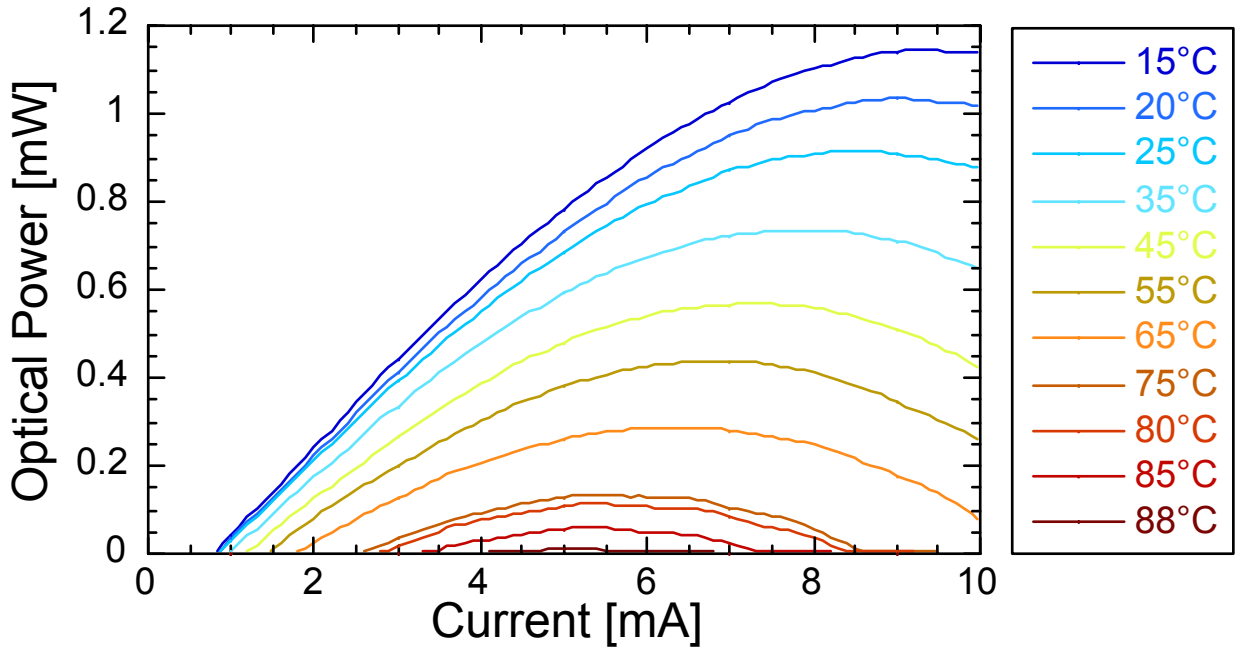
High Temperature CW Operation

8µm Diameter VCSEL



Maximum output power:

>1.0mW at 20°C

>0.1mW at 80°C

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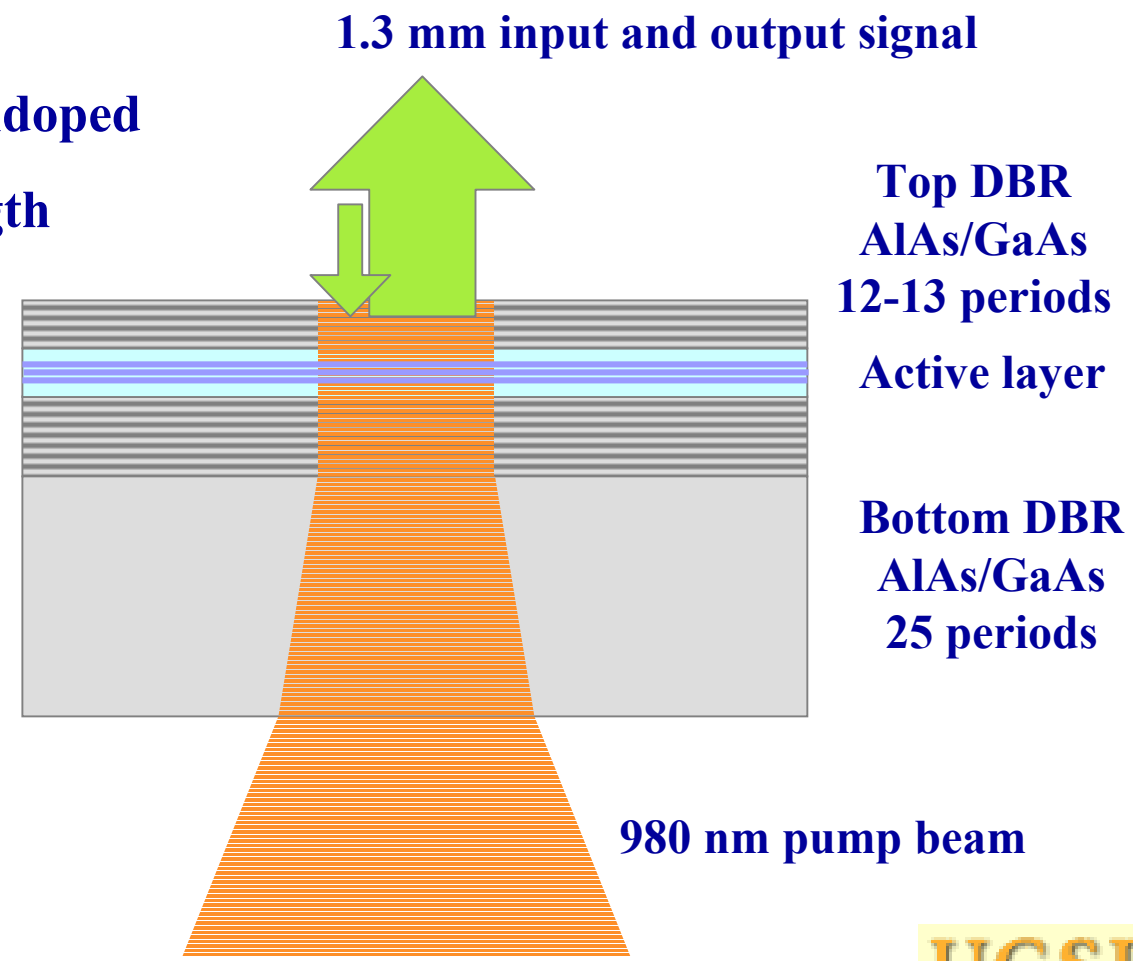
Wafer-Fused 1.3 µm VCSOA

- Stacked MQW InAsP/InGaAsP active region (3 x 7 wells)
- Optical pumping allows undoped mirrors and long gain length



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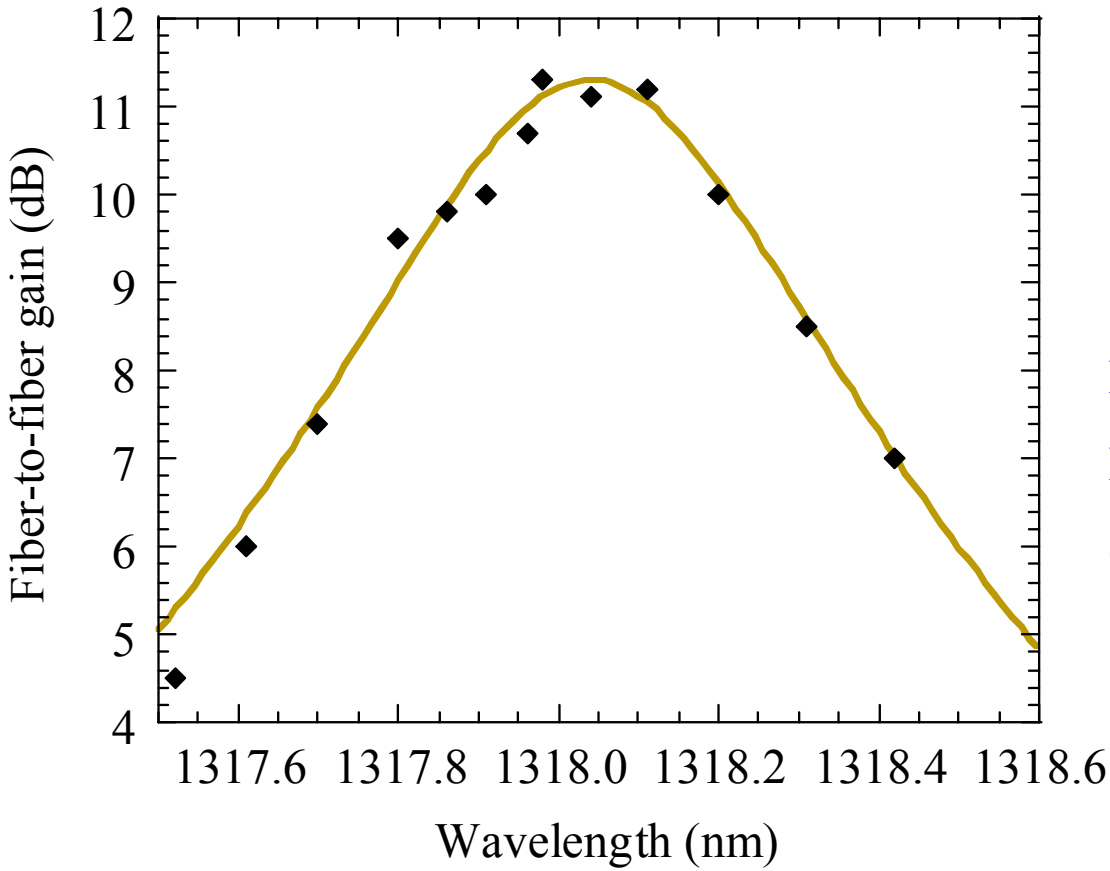
Optical Gain



Max gain :11.3 dB

Bandwidth: 0.6 nm (100 GHz)

(12 top mirror periods)

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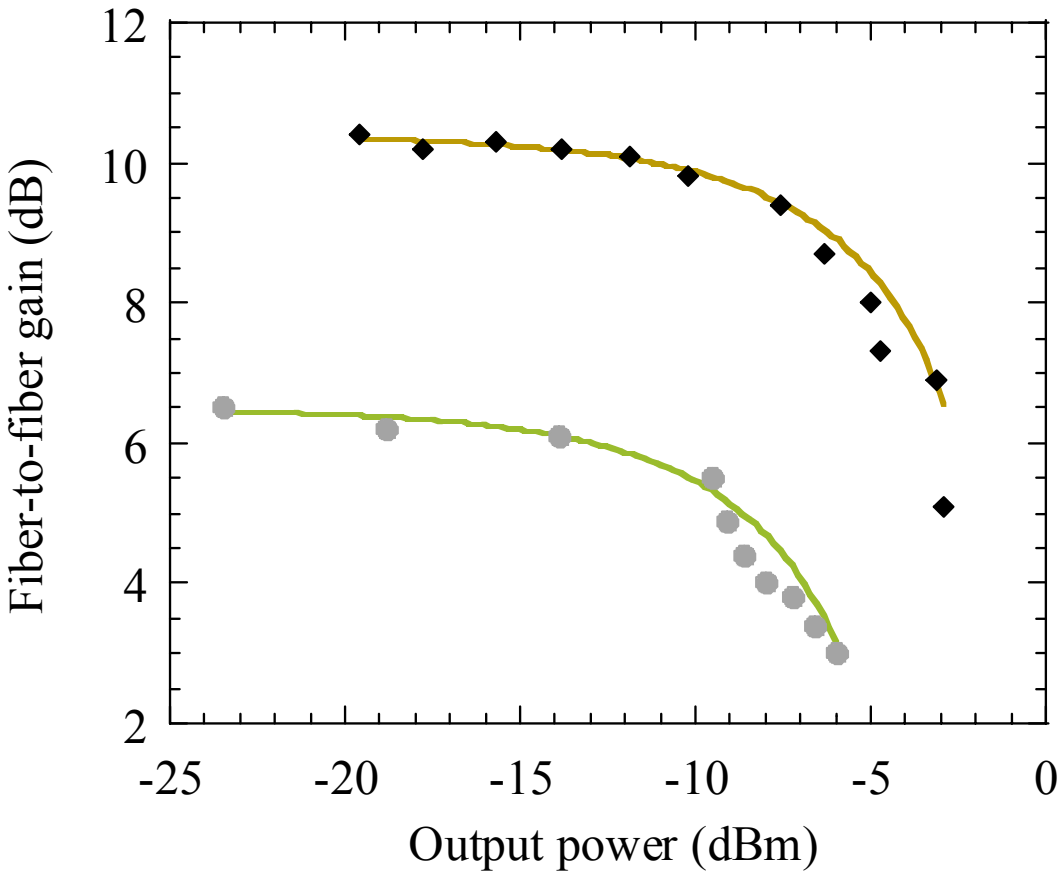
Saturation Power



12 top mirror periods

Saturation output power: -3.5 dBm

13 top mirror periods

Saturation output power: -6.0 dBm

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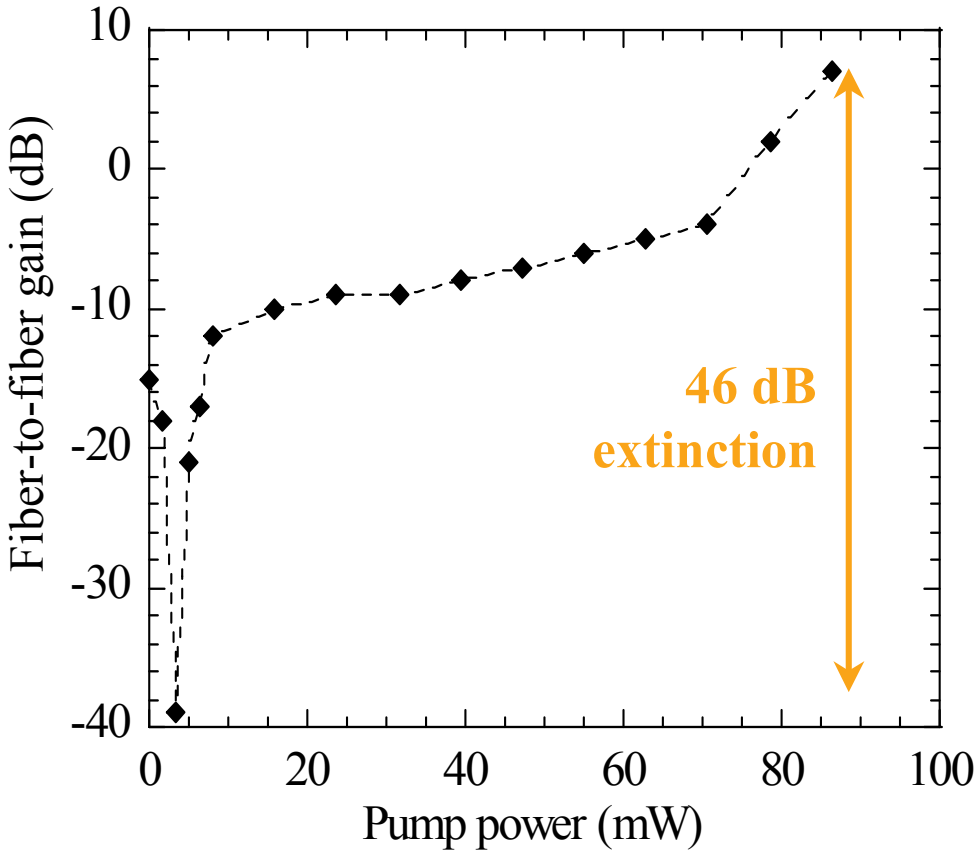
Switching With Gain



Dip caused by interference between cavity mode and top mirror reflection.

Switching with gain compensates coupling loss.

Narrow optical bandwidth prevents ASE buildup in switch arrays.

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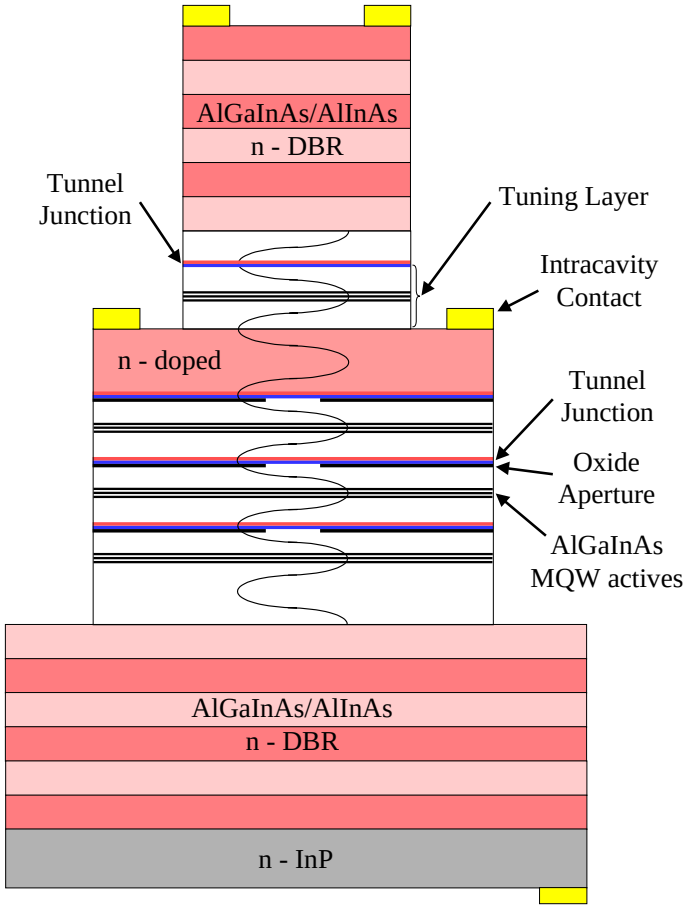
Tunable Bipolar Cascade 1.55 µm VCSOA**



- **Bipolar cascade for high gain**
- **Multiple oxide apertures for scaling to small size**
- **Intracavity contact for tuning**

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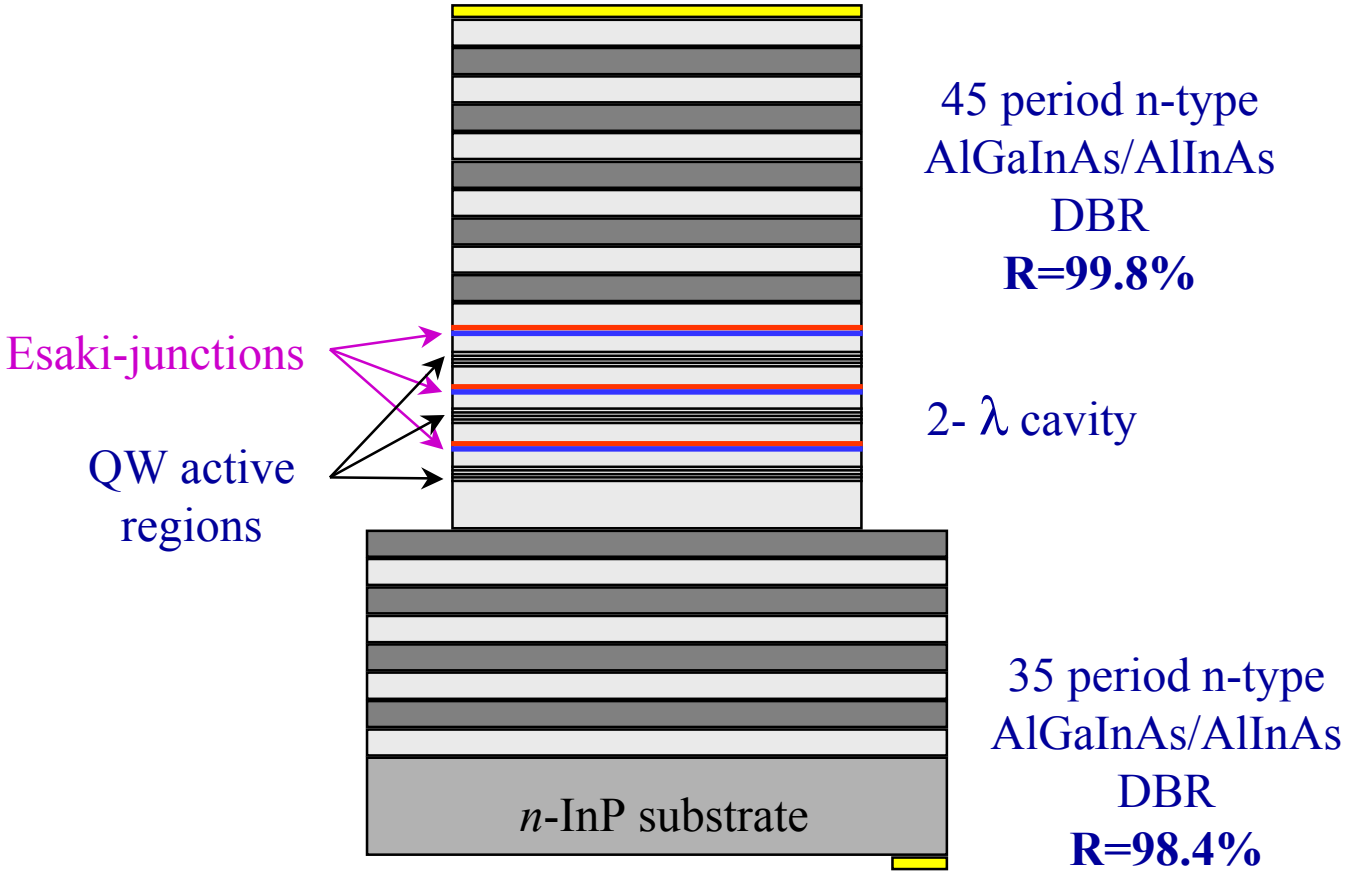
Lattice-Matched Bipolar Cascade VCSEL**



Good quality DBRs

Total thickness of epitaxial layers ≈ 20 mm

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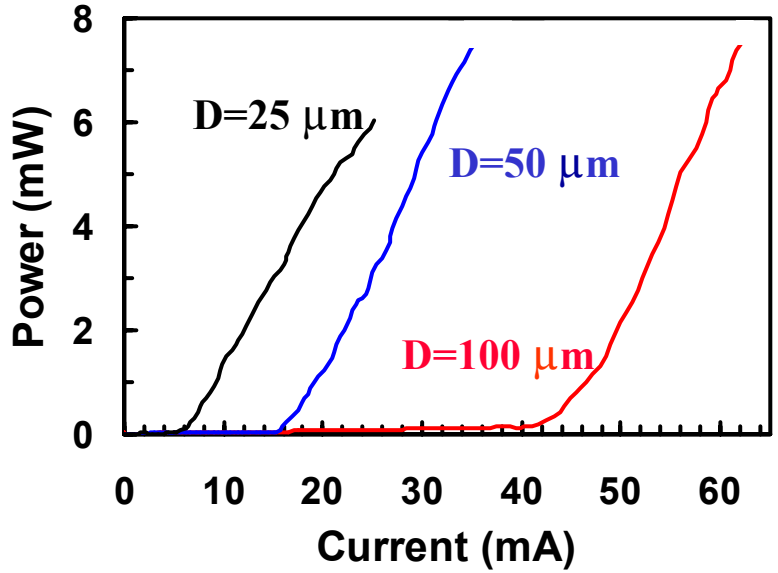
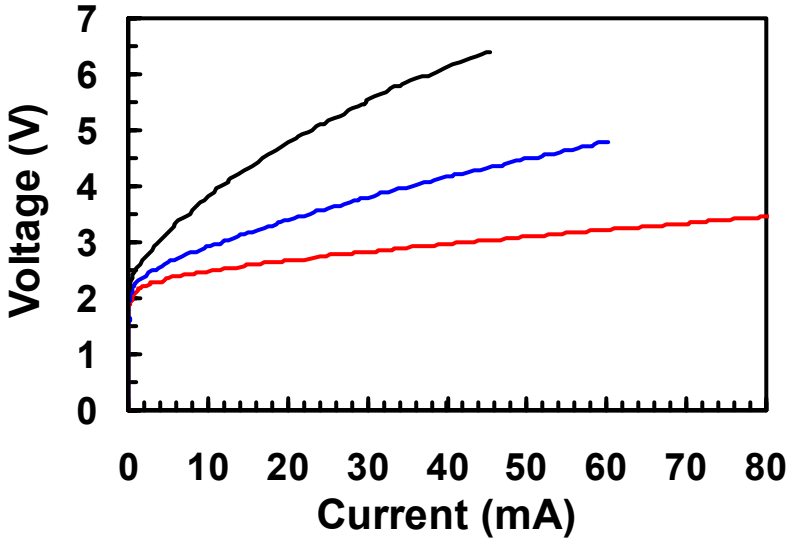
Pulsed Results at 17 °C



- J_{th} as low as 570 A/cm^2
- η_d = 82 % (d = 25 μm)
- P_{out} > 15 mW
- $V_{th} \approx$ 3 V (3hn = 2.4eV)
- $R_d \approx$ 100 W (d = 25 μm)
- $\lambda \approx$ 1.55 μm



- CW Operation up to 8 °C

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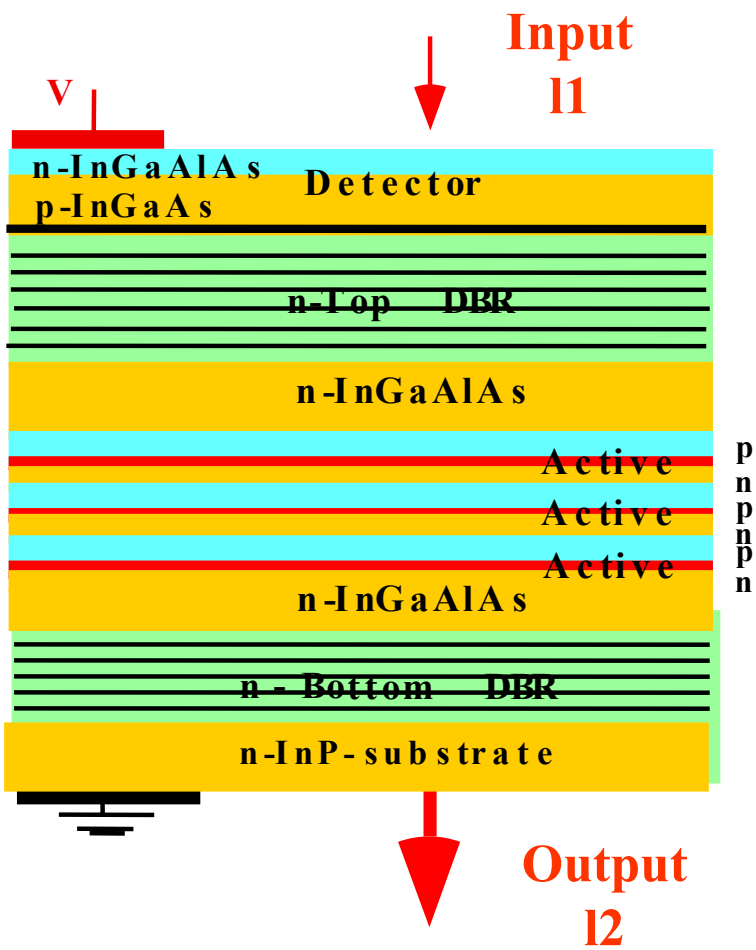
Wavelength-Converting Vertical PNA



- Signal format independent
- 2R regeneration possible with integrated diode network
- Cascade improves SNR
- Tunable output possible

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Summary

•Wafer-Fused WDM VCSEL (4 wavelength arrays with 105 C cw operation) and VCSOA Arrays (11 dB gain)

•Lattice-Matched AsSb VCSEL (1 mW at 20 C with 88 C cw temperature operation) and Bipolar Cascade VCSOA, with Tunability

•Lattice-Matched Vertical Cavity Wavelength Converter, with Tunability

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