VECTOR PHOTONICS

Surface Coupling Lasers using InP as an integration Platform

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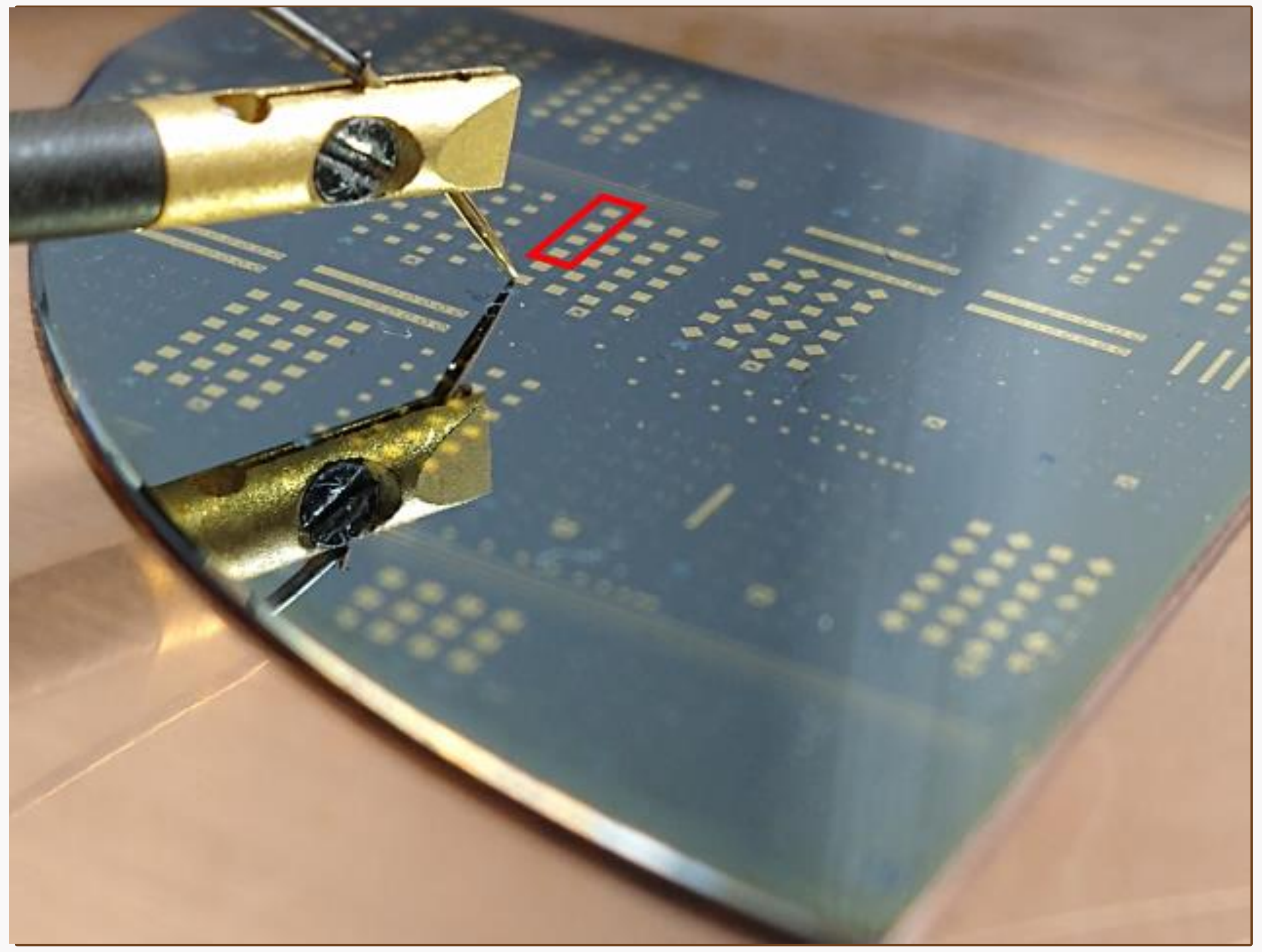
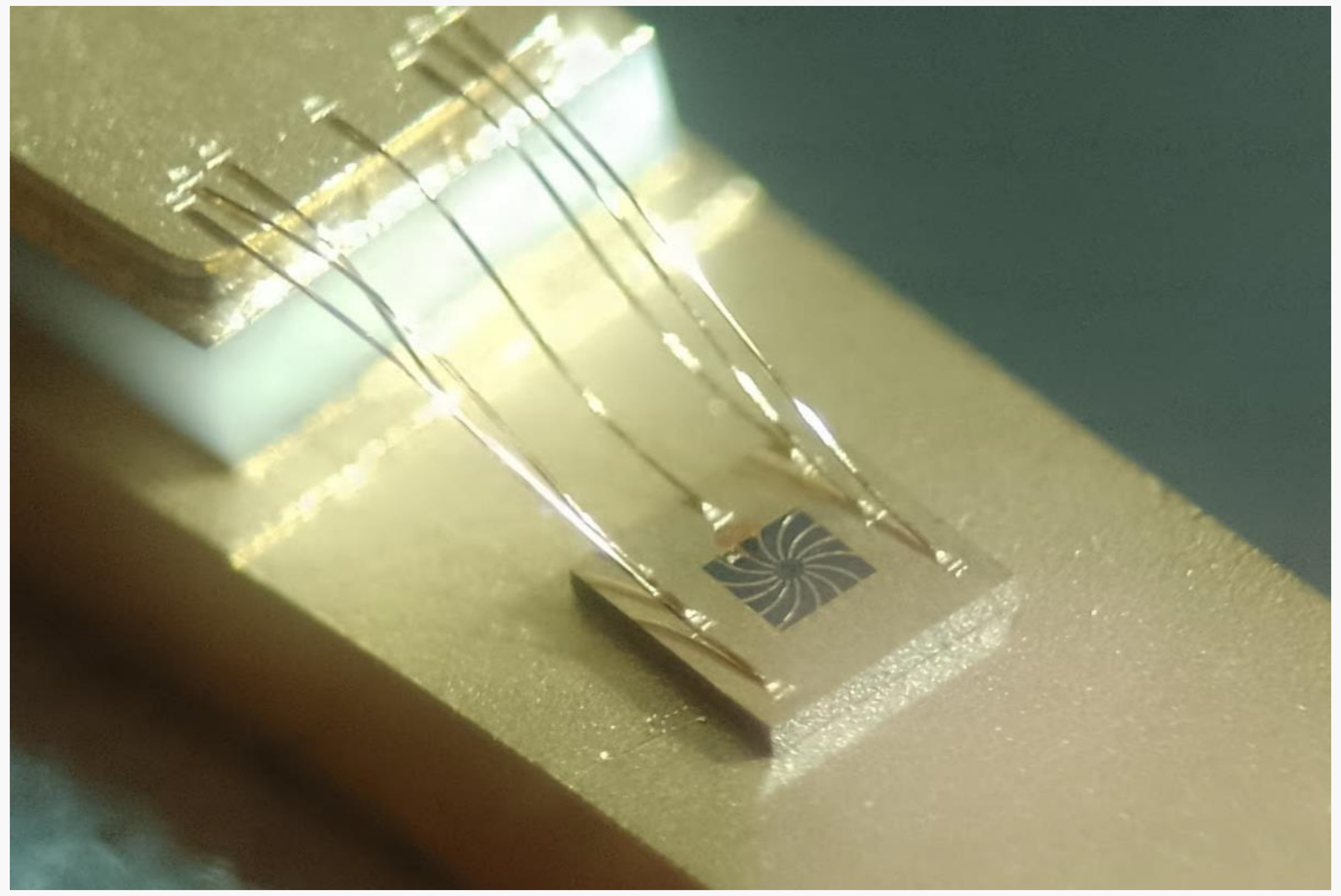
Outline

- Company
- Markets and Applications
- Surface Emission
- PCSEL Challenges
- Photonics Integration: coherent array technology
- Summary

Company

- Vector Photonics is Fabless Start-up Company based in Glasgow Scotland
- The company was founded in 2020 as a spin out to commercialize PCSEL devices that had been developed at the University of Glasgow, UK
- The company is a Seed Stage Company that has raised over £4.1 MM in Private Equity and £5.7.MM in Grant funding
- The company is focused on Surface Emitting devices for multiple markets

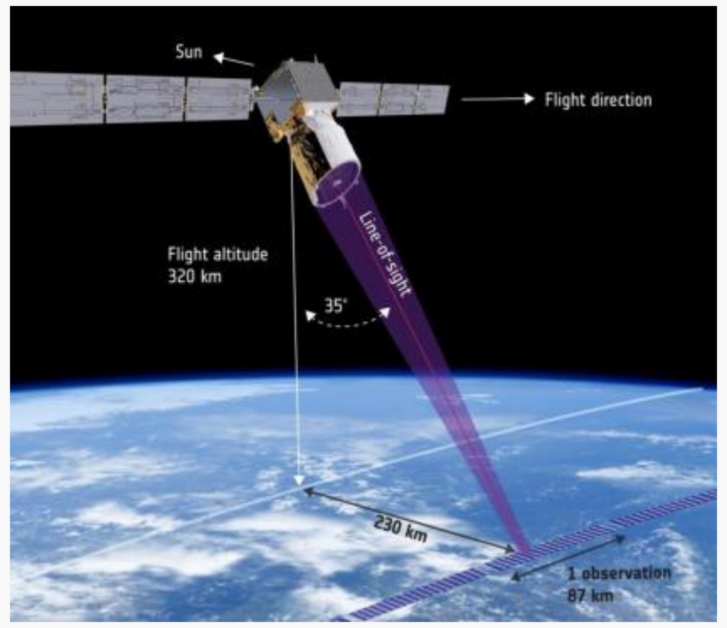


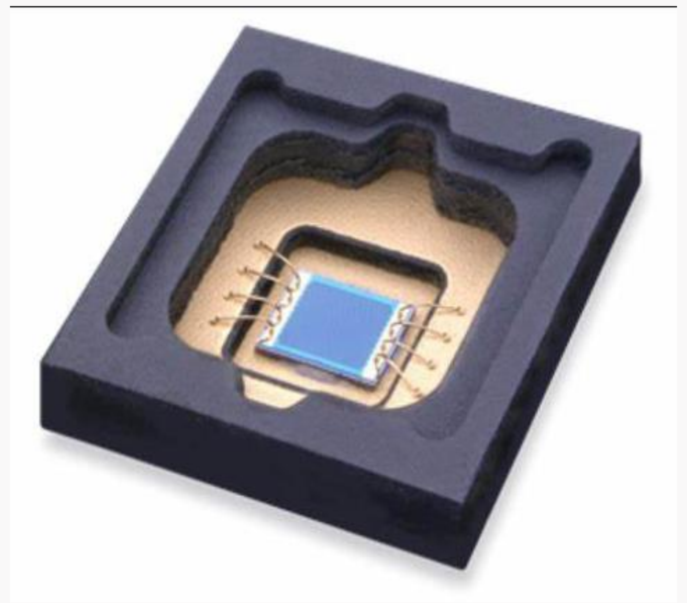


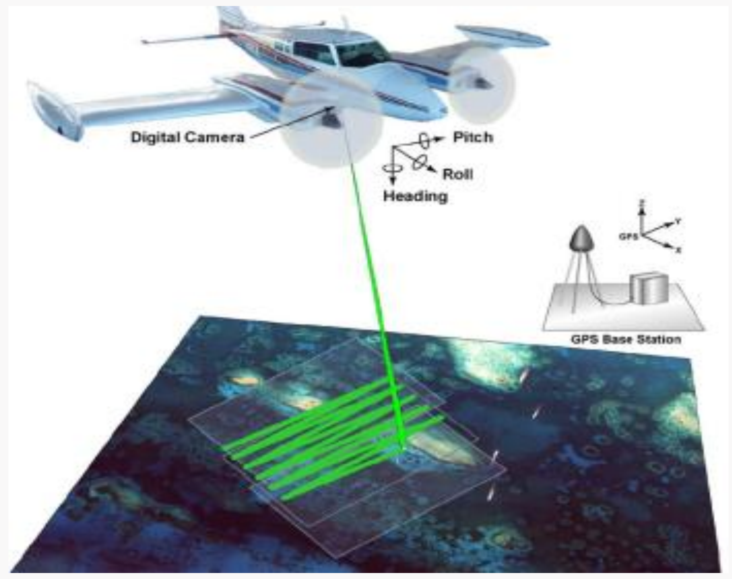
Multiple Markets for Surface Emission

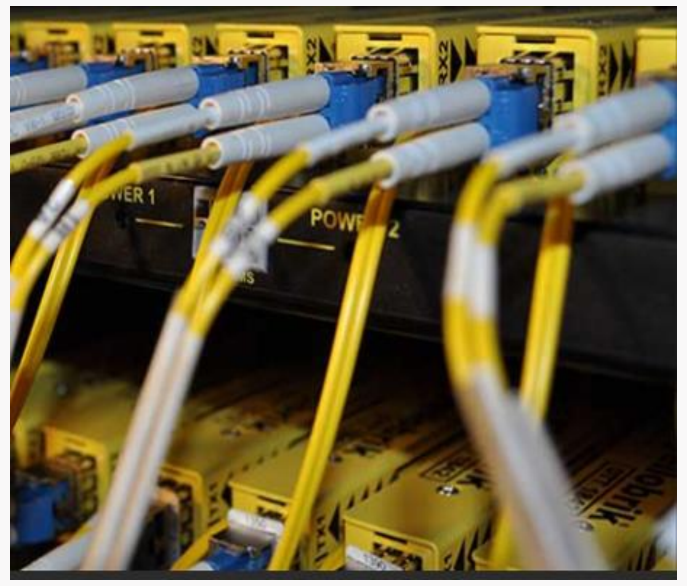
Diverse Markets and Applications

- Data Center Communications
- Free Space Communications
- Medical Devices
- Consumer Electronics
- Cell Phones
- Materials Processing
- LiDAR
- Factory Automation
- Lighting and Projection



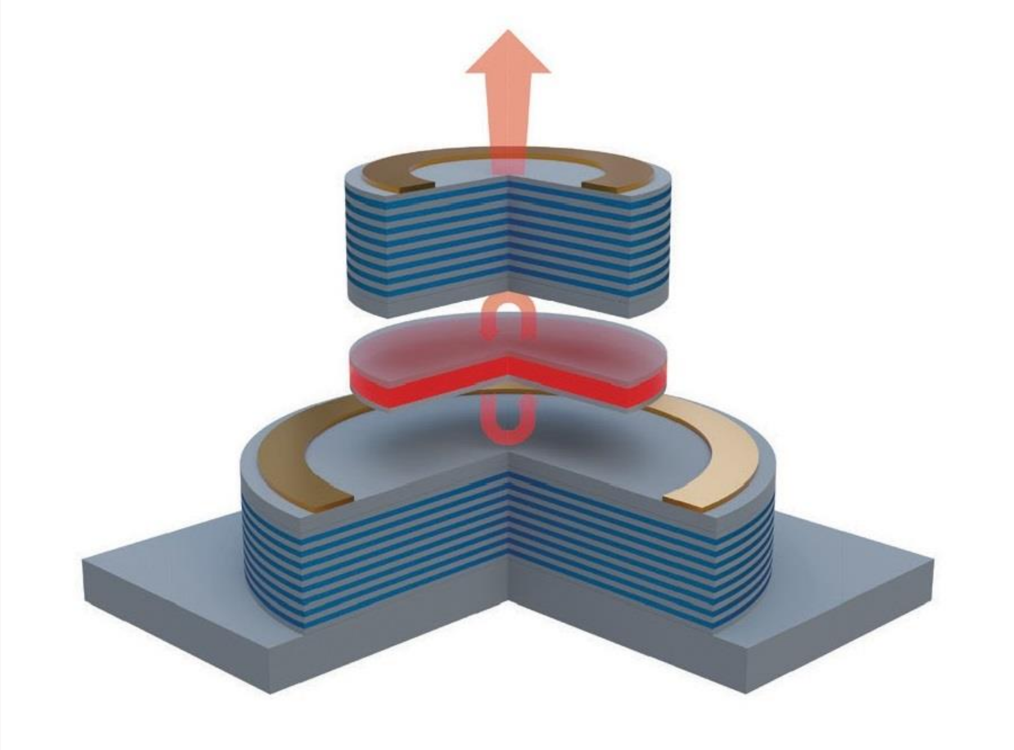



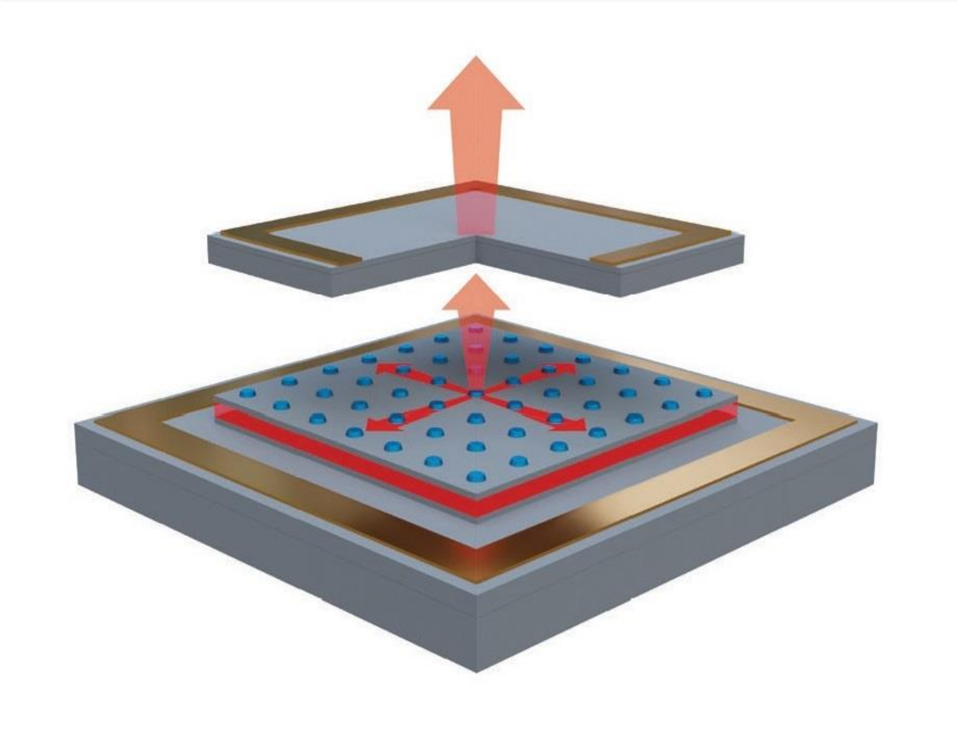
Surface Emission – Challenges

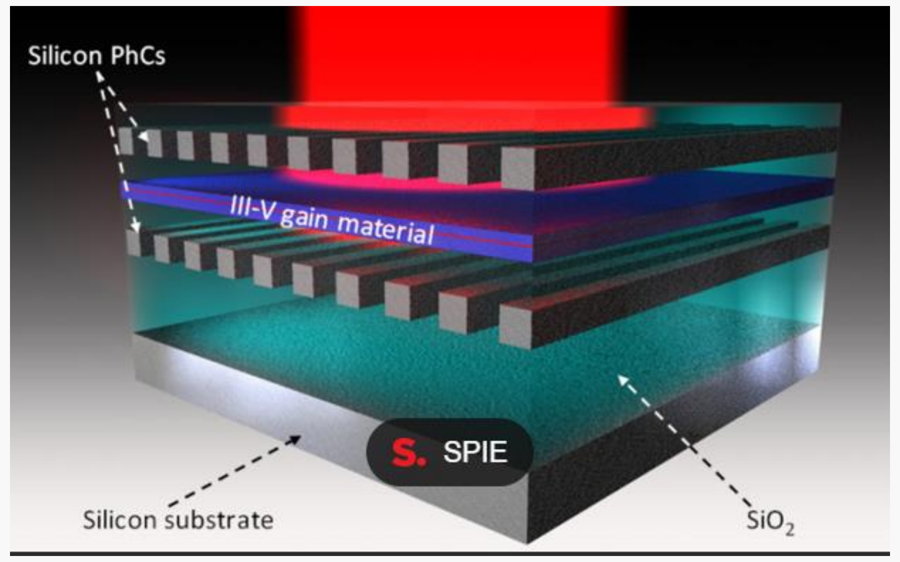
- **Challenges**
  - Power Consumption
  - Modal Performance
  - Surface Emission Efficiency
  - Material System Capabilities
  - Size and Cost
  - Temperature Performance
  - Eye safety

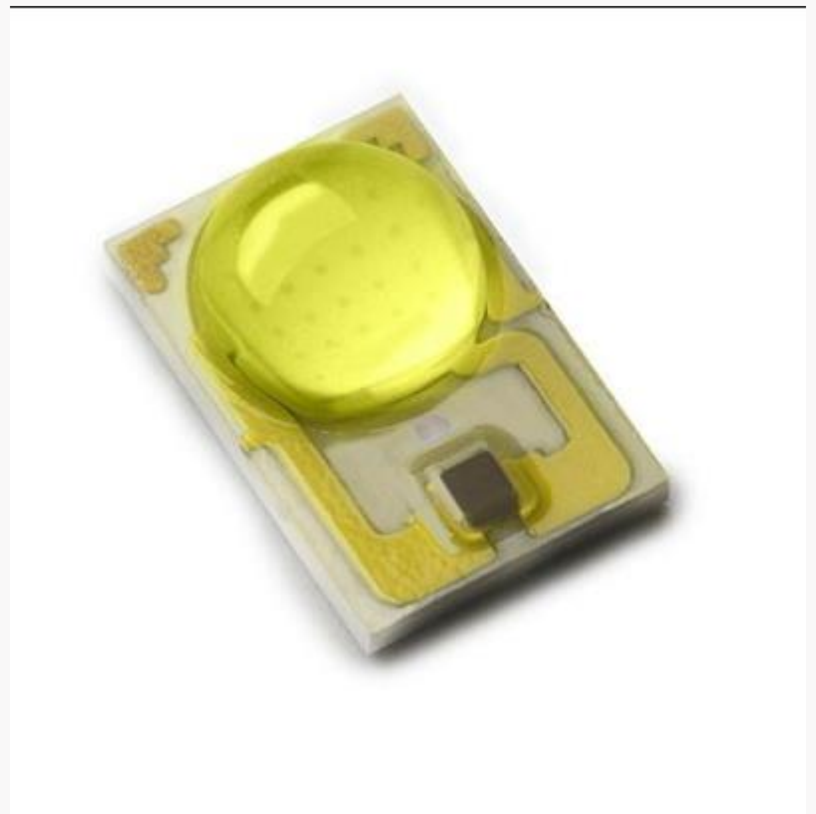
Surface Emission – Choices

- **Discrete Devices**
  - VCSELs, DFB/DBR Lasers, PCSELs
- **Silicon Photonics – SiP**
  - Wafer Bonded Laser, Silicon Bench, Grating Couplers
- **Hybride Dielectric Photonics**
  - Dielectric Platforms with surface couplers
- **Photonic Integrated Circuits**
  - III-V integration
- **Packaging**
  - Bulk Optics, Polymer Optics, Plastic Optics









Multiple Approaches for Surface Emission

Discrete Emitter Technology
PCSELs

PCSEL: Status April 2024

PCSELs were proposed as an alternative approach to VCSELs

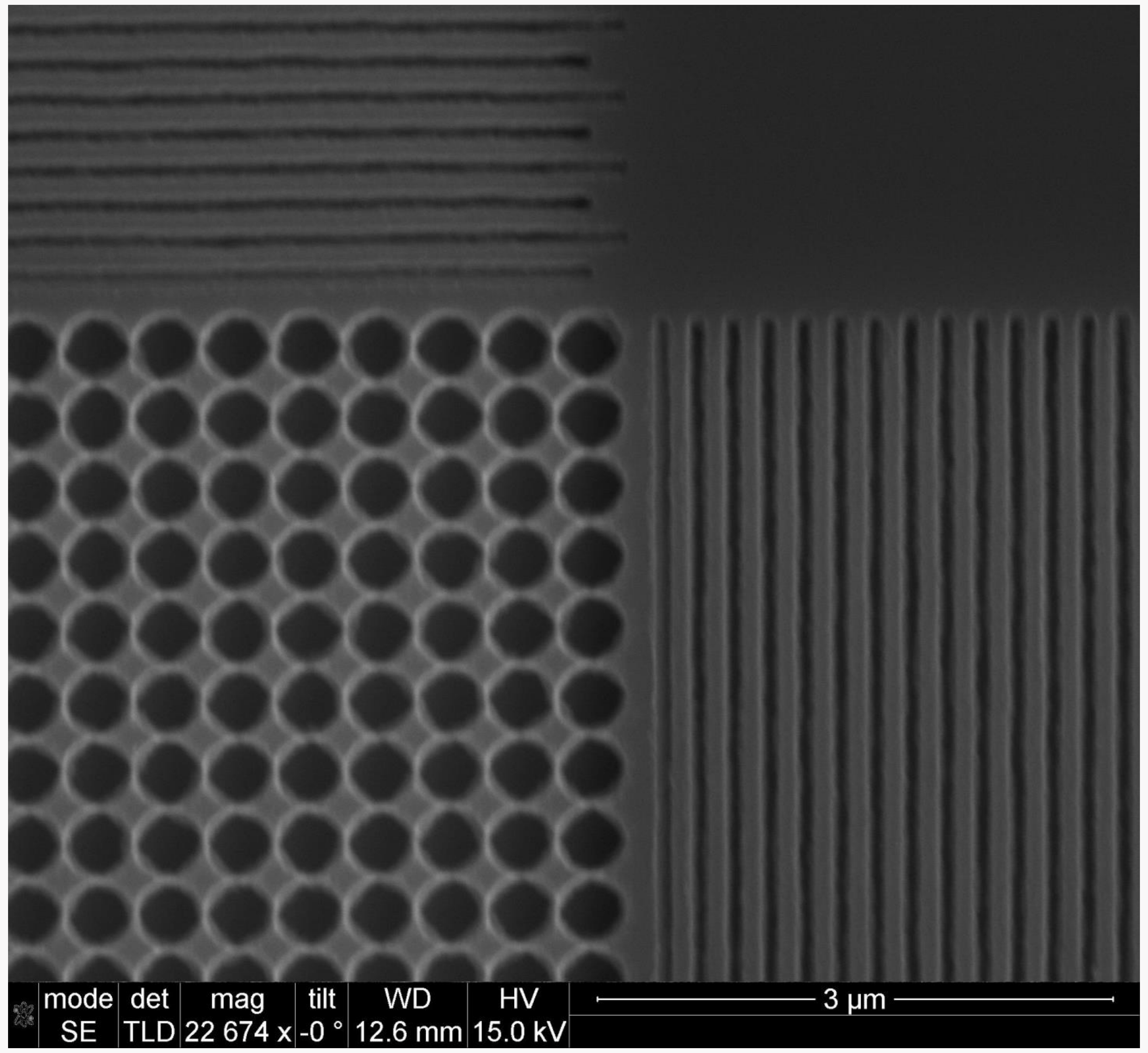
Realization of the technology has been challenging

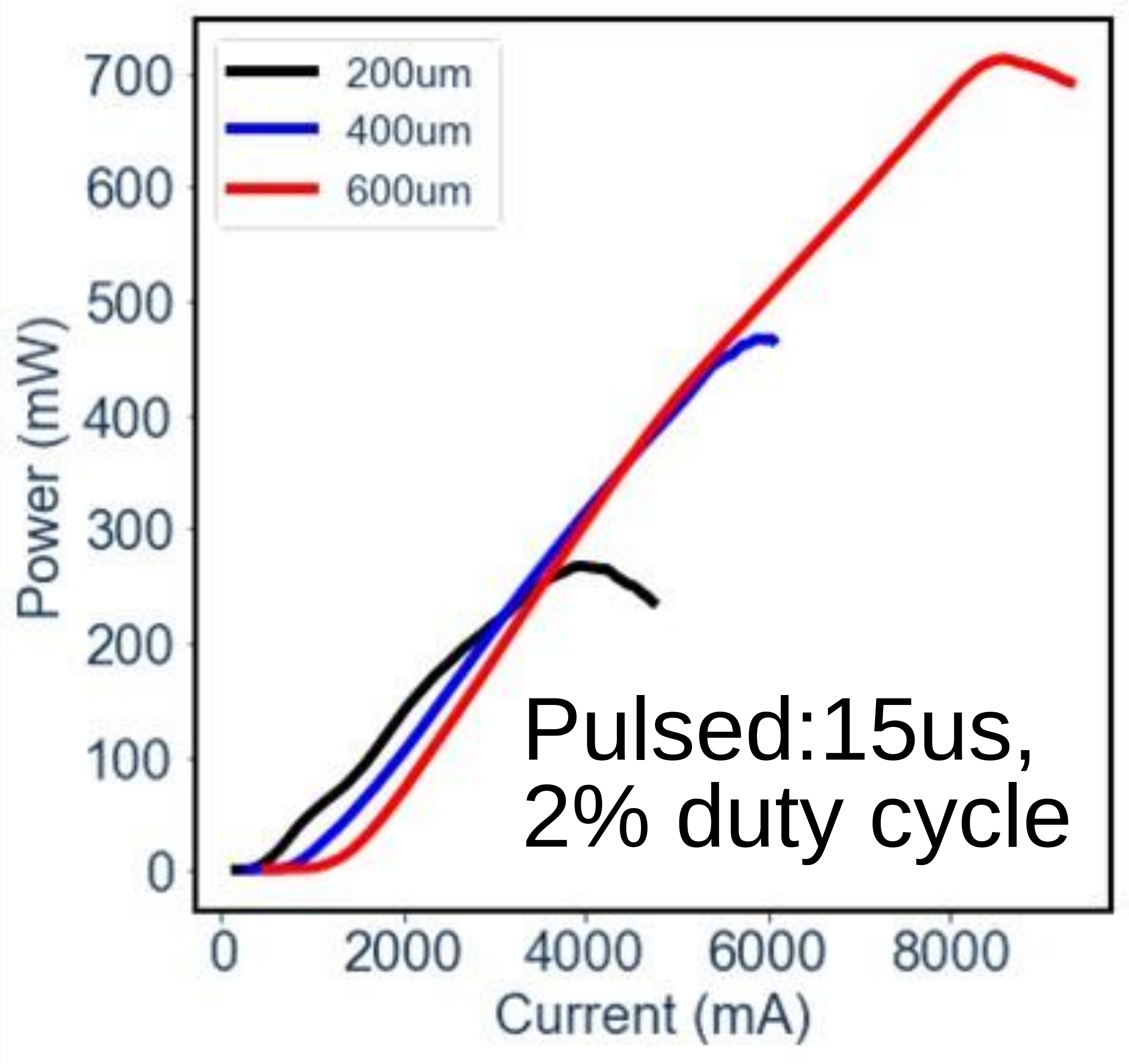
Year	Company	Wavelength	R&D	Product	Threshold Current	Surface Slope Efficiency (@25C)	Index Structure	Type
		nm			mA	(W/A)		
2021	Kyoto	940	Y	N	10000	**0.56**	Air-Gap	Dual Hole Square Lattice
2014	Hamamatsu	940	Y	N	216 (pulsed)	**0.73**	AlGaAs/GaAs	Dual Lattice
2024	**Sumitomo**	1300	Y	N	150 to 300	**0.1 to 0.4**	Air-Gap	Dual Hole Square Lattice
2023	**Sumitomo**	1300	Y	N	230	***0.21***	Air-Gap	Dual Hole Square Lattice
2022	**Sumitomo**	1300	Y	N	320	***0.2***	Air-Gap	Dual Hole Square Lattice
2020	**Sumitomo**	1300	Y	N	120	***A.U units***	Air-Gap	Square Lattice
2017	Truelight	1300	Y	N	62	0.0084	Air-Gap	
2022	**Vector Photonics**	1300	Y	N	950	0.119	InGaAsP/InP	DBR Enclosed Reflector
2023	Hamamatsu	1550	Y	N	810 (pulsed)	0.03	Air Gap	Triangle (Right Angle)
2024	Huawei	1550	Y	N	120	0.09	Air-Gap	Double Lattice

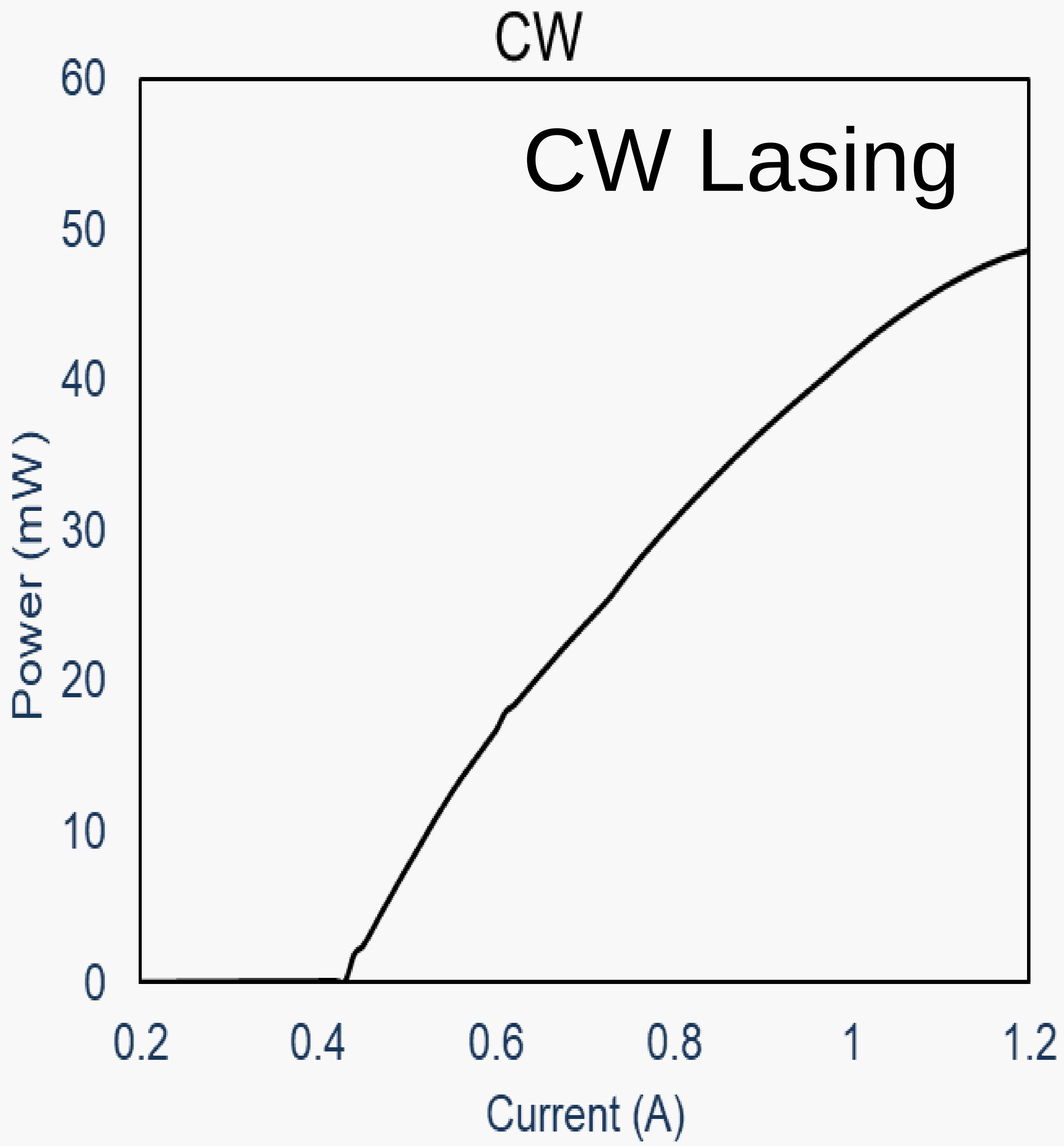
Improving performance – Air Gap Approach

Vector: Licensed PCSEL Technology

- Vector’s Licensed PCSEL Technology





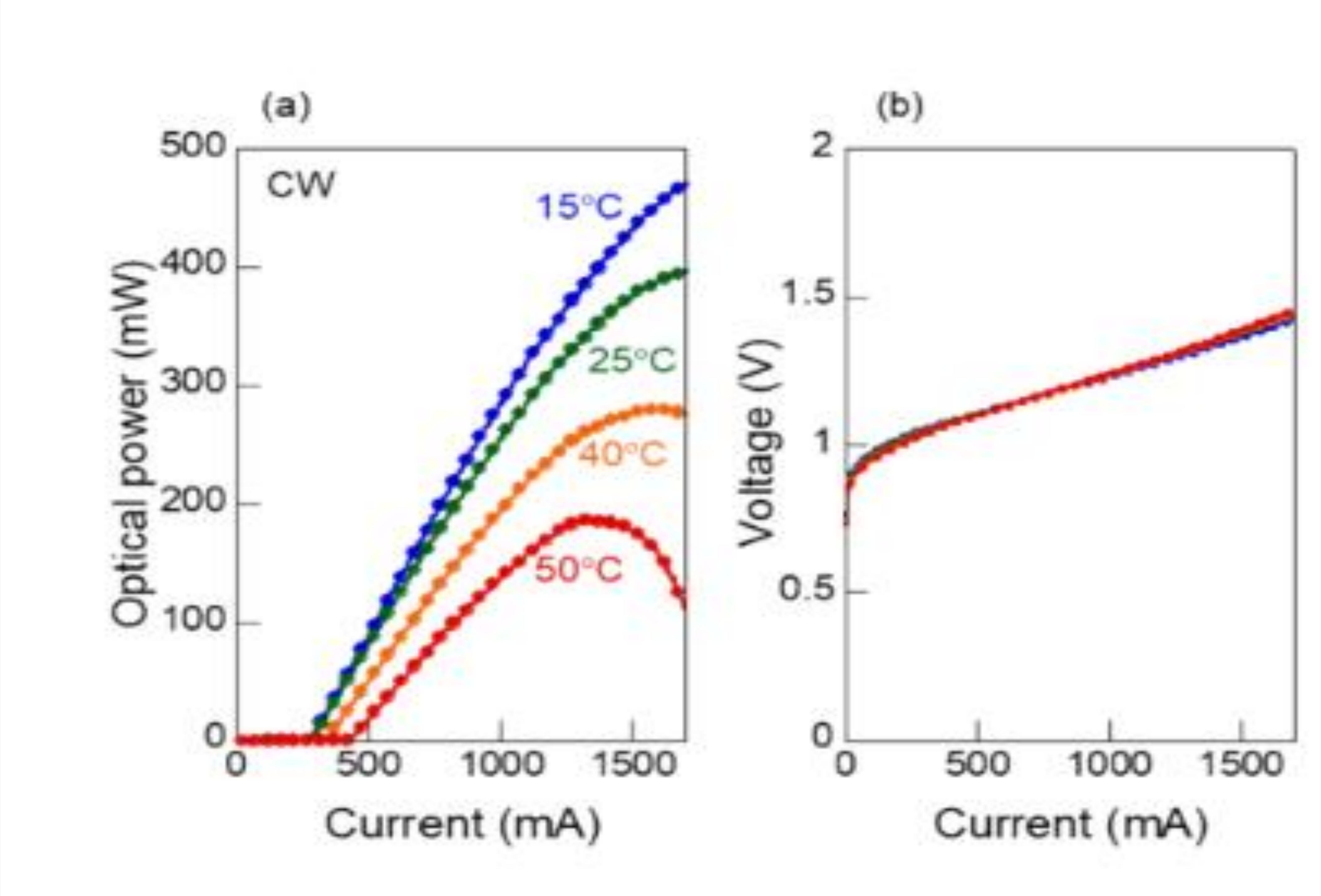


Low Index Contrast DBR Design

PCSEL Challenges – Thermal Efficiency

Power Consumption, Slope Control, Threshold, Material Losses

- PCSEL area is large
- Threshold Current is area dependent
- Drive current is large
- Temperature performance depends on
  - Auger
  - Material Gain
  - IVBA
  - Current Confinement
  - Phase management
  - Junction Heating



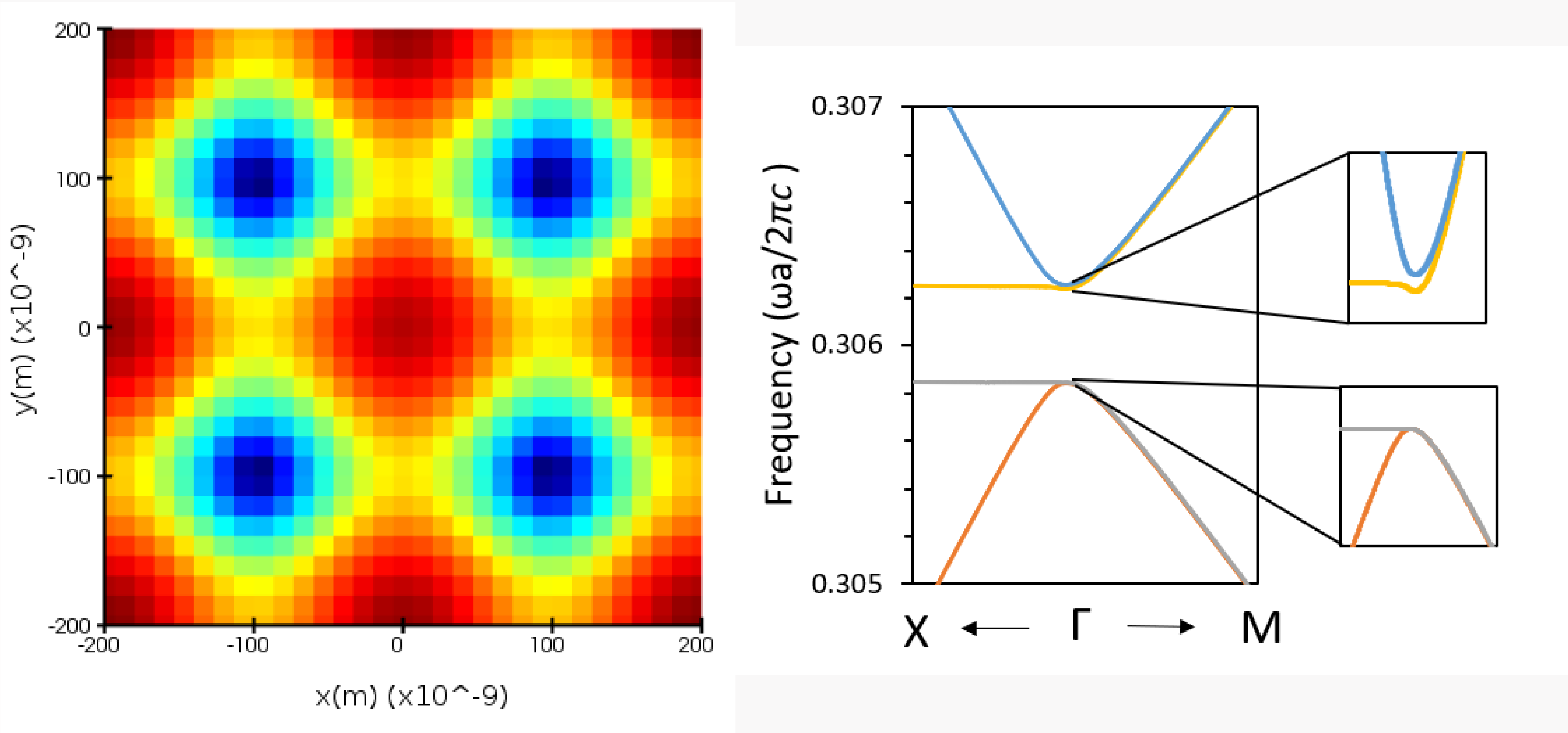
Sumitomo: Optics Express, Vol 32, no 7, 25 March 2024

Thermal Management and Drive Current

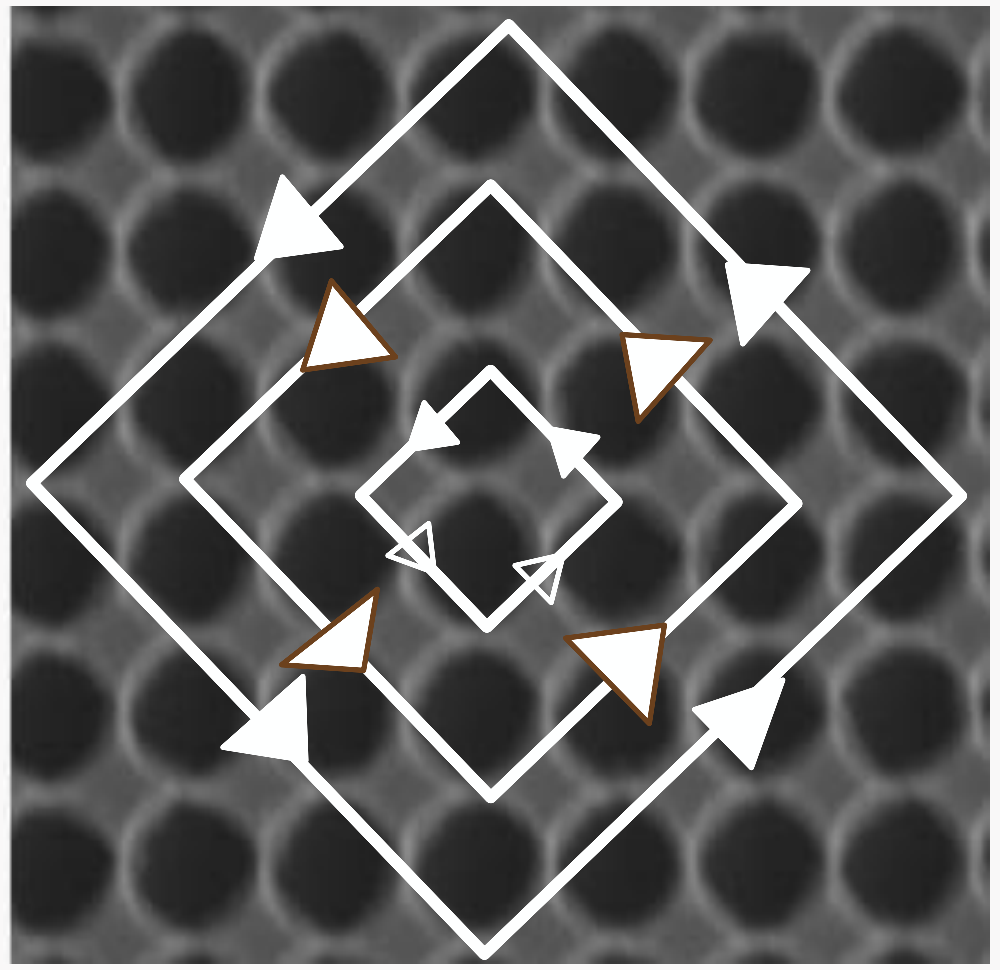
PCSEL: Design Challenges

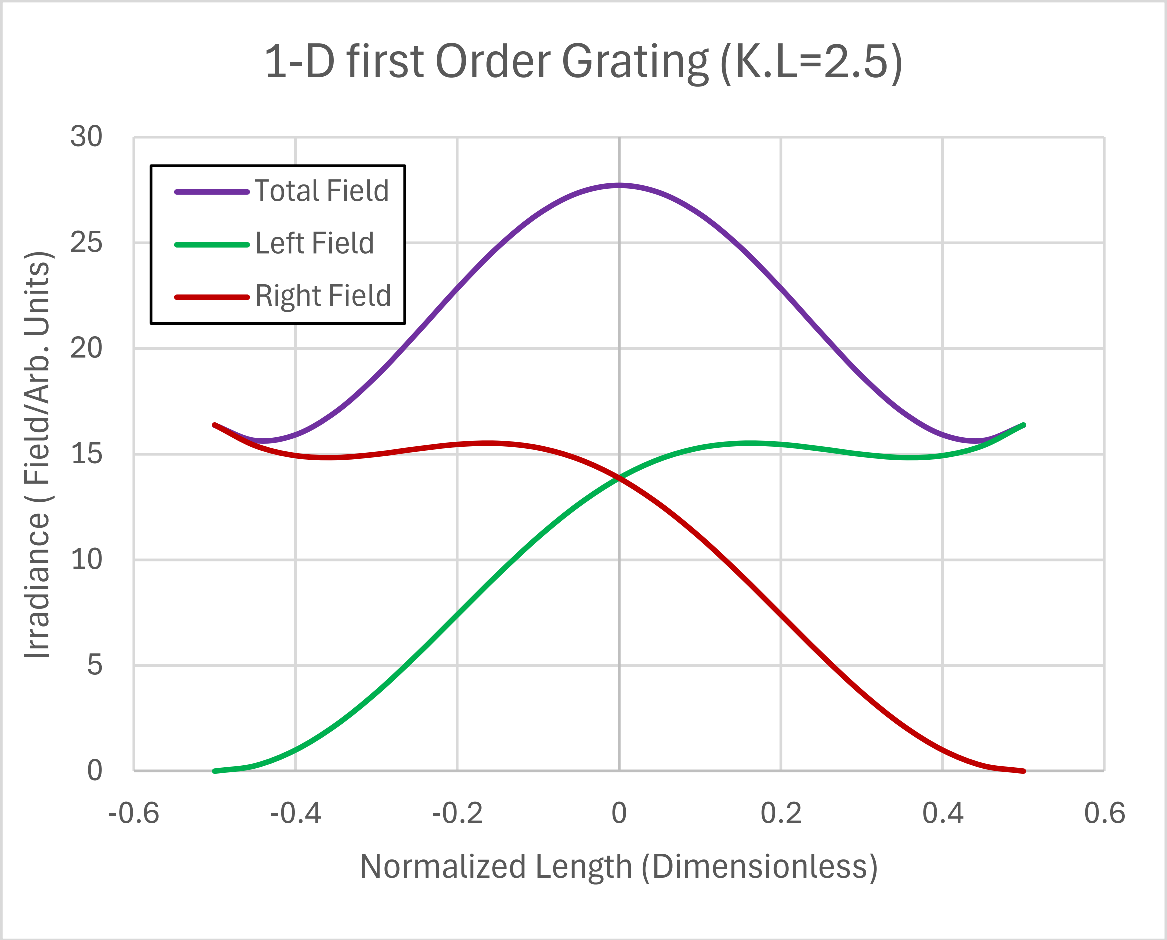
- Simulation and design need understanding of gain and modal loss in 2-D/3-D
- Light confinement and extraction efficiency important to control

Band Structure Approach



Coupled Mode Theory (CMT)

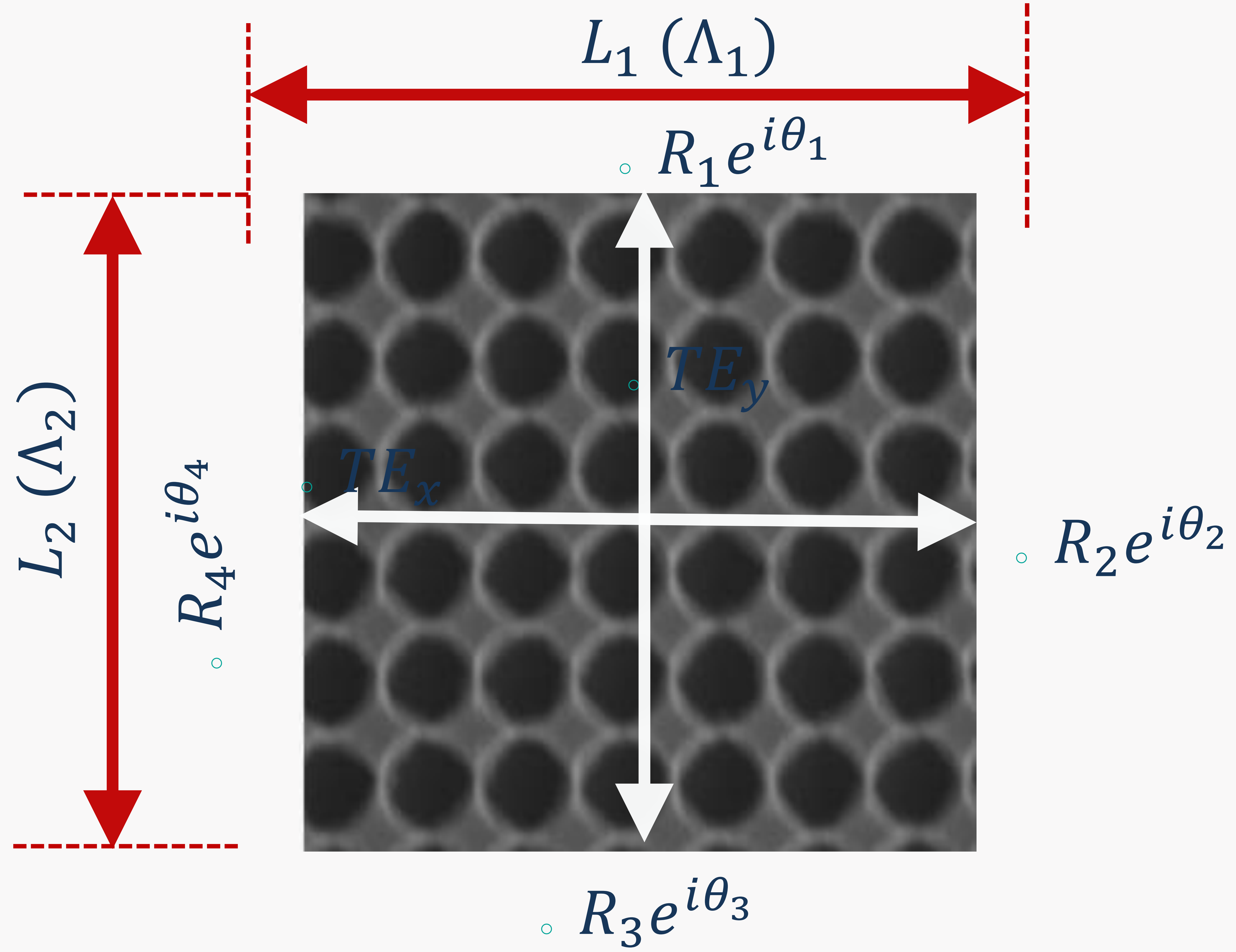




Theory to calculate Modal Gain

PCSEL: Coupled Mode Theory

- The boundary conditions are **Critical**
- From CMT for a **TE Mode** Laser[1]
  - R= 0 kappa = 0 for $\Lambda_x = \Lambda_y$
- **Implication**
  - Complicates the design of the Grating Core.
  - Complicates the Gain Spectrum interaction
  - Complicates Phase Control and Modal Gain
  - Complex Kappa used for radiation loss



Several Manufacturing Challenges

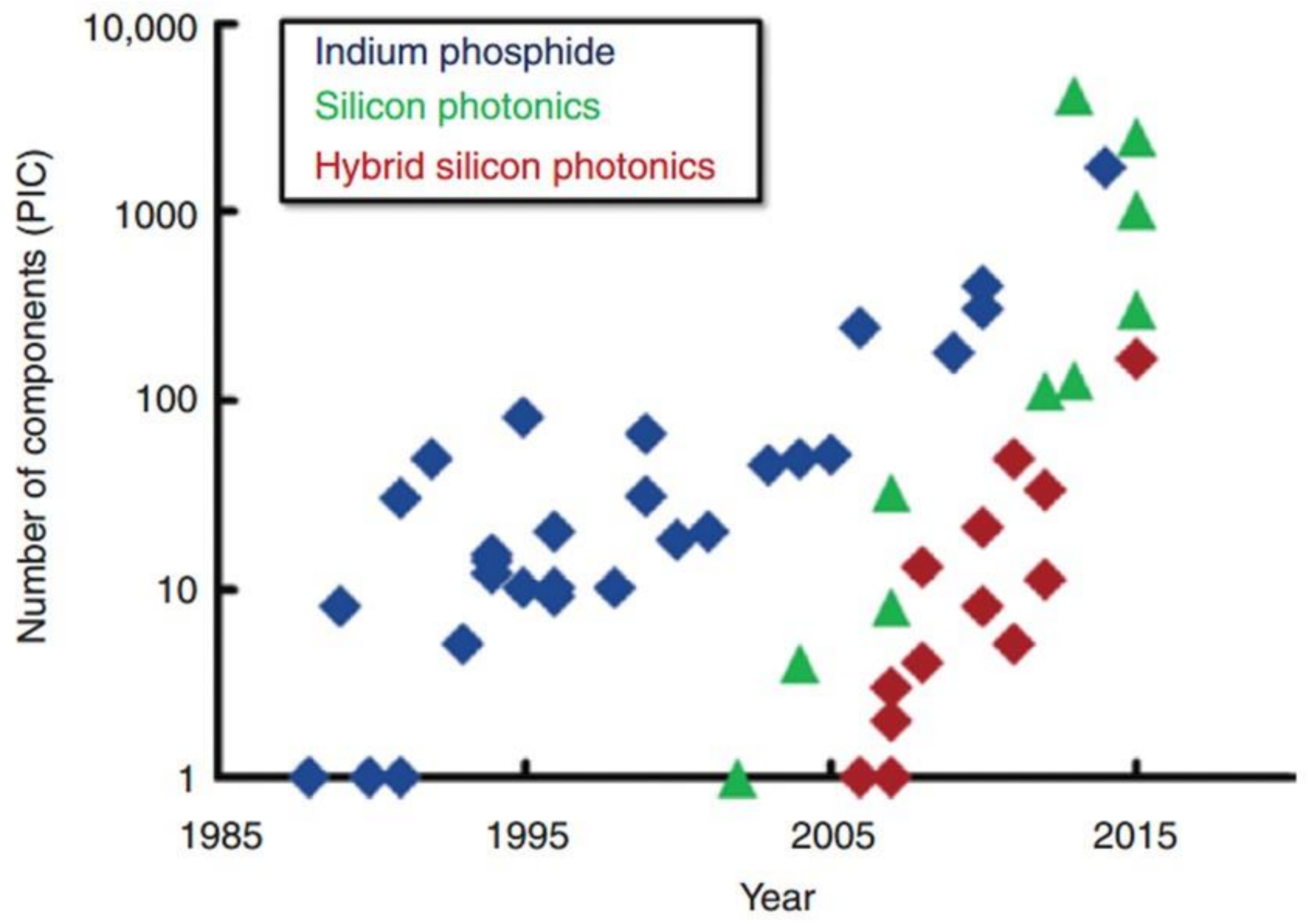
1. M. Toda, IEEE JQE-Vol 26, No. 7, July 1991

Multi-Array Technology
and
Photonic Integration

Surface Emission: Array Technology

- Photonic Integration offers the ability to improve array performance
- III-V integration can provide coherent solutions in a small footprint
- Surface emission is dominated by VCSEL based technologies
- PCSELs and photonic Integration have been unable to displace this core III-V capability

Evolution of the number of components on photonic integrated circuits (PICs)



M. Heck, "Highly integrated optical phased arrays: photonic integrated circuits for optical beam shaping and beam steering", Nanophotonics 2017, 6(1)

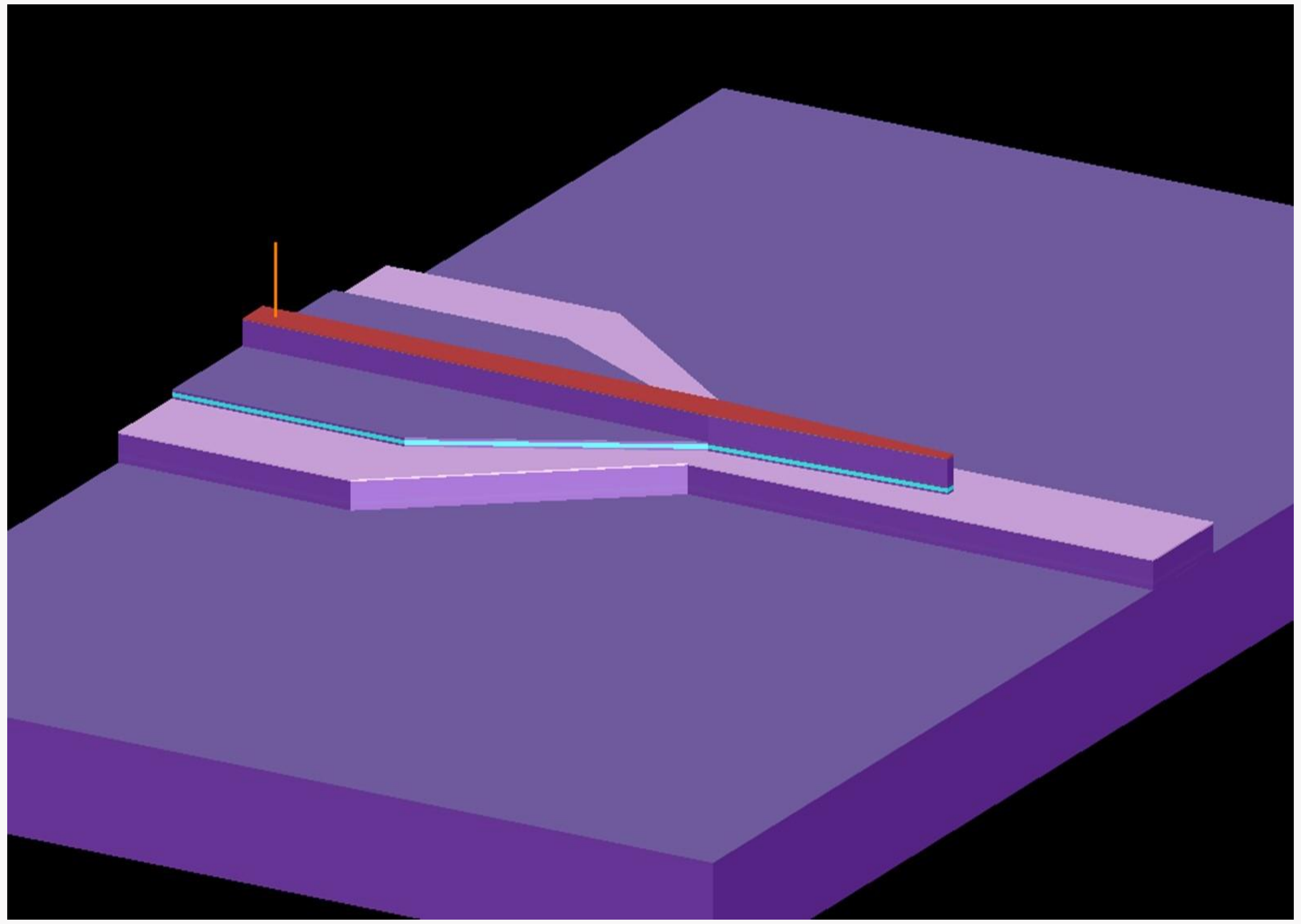
PIC Integration: Surface Emission

- To reduce the complexity a simpler approach to a surface emitting laser is available
- This is based on combining several basic III-V elements
  - Transfer laser energy to passive guides
  - Single or multi-mode lasers for spectral response
  - 2nd order buried surface gratings
  - Low loss passive waveguide integration
  - Index management for the beam power control

Key Elements are design independent

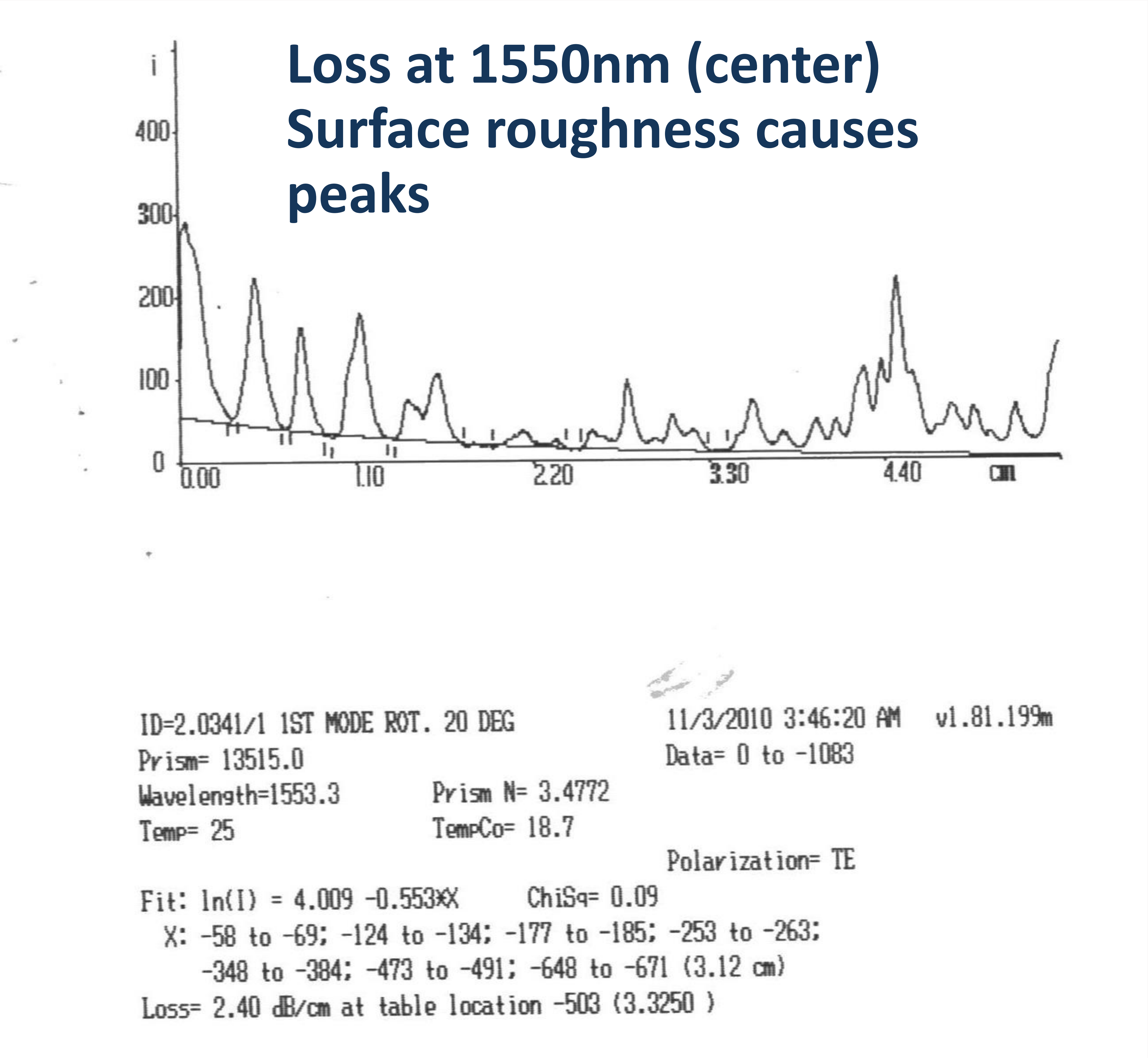
PIC Integration: Gain Separation

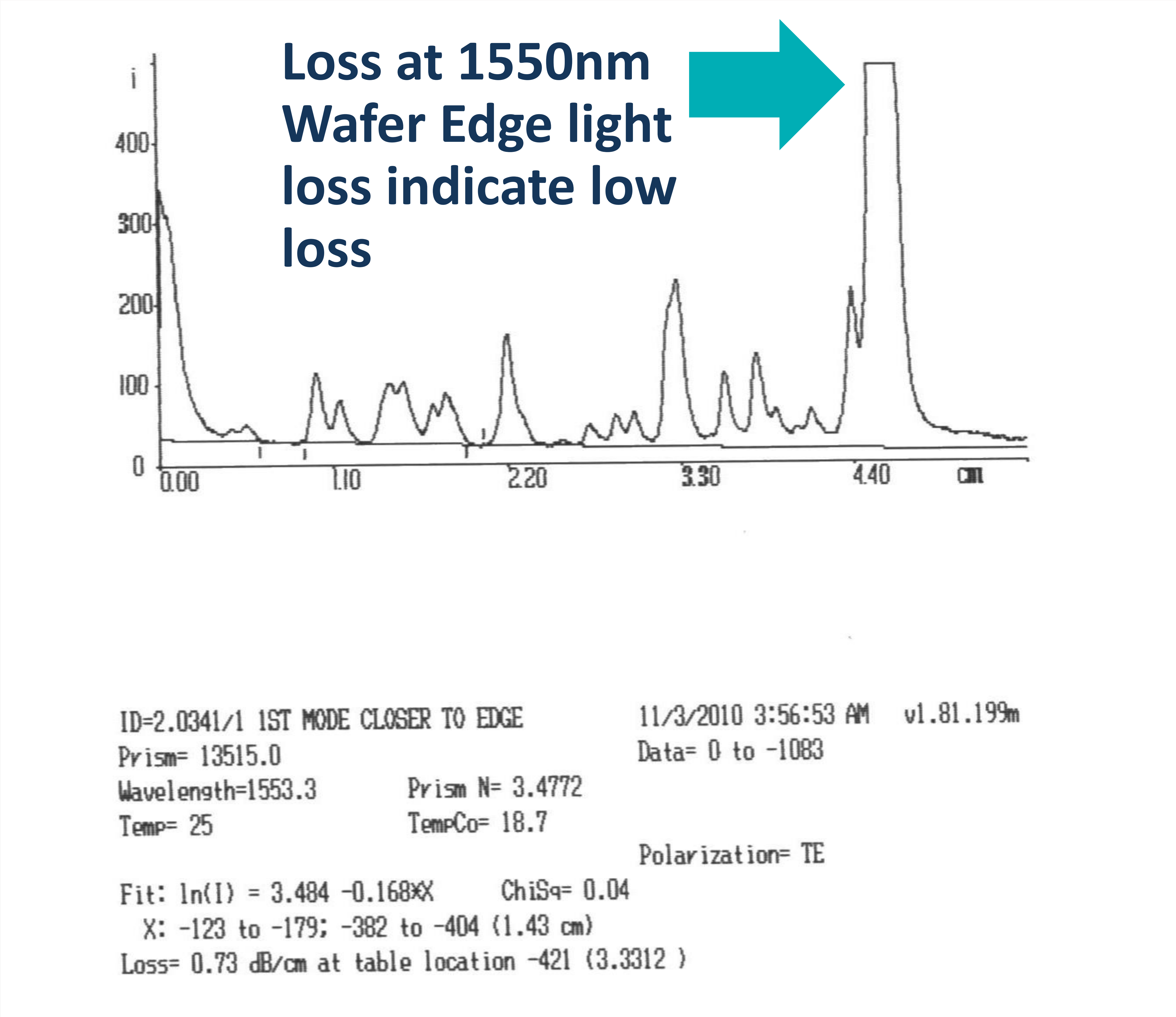
- A high conversion efficiency can be designed for transition to the passive guide
- > 93% single pass efficiency



Transition Efficiency can be optimized to power arrays

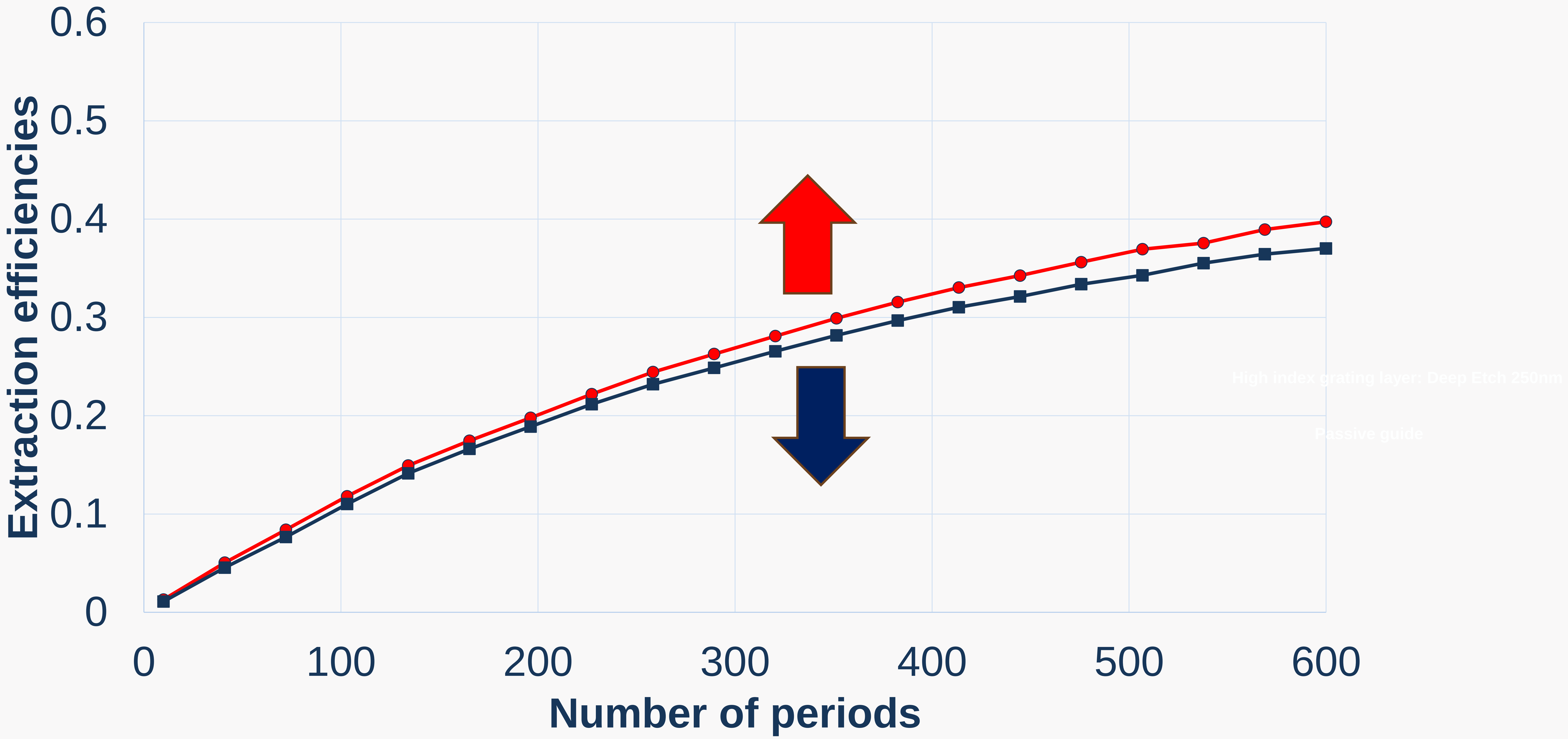
Material Choice: Surface Morphology





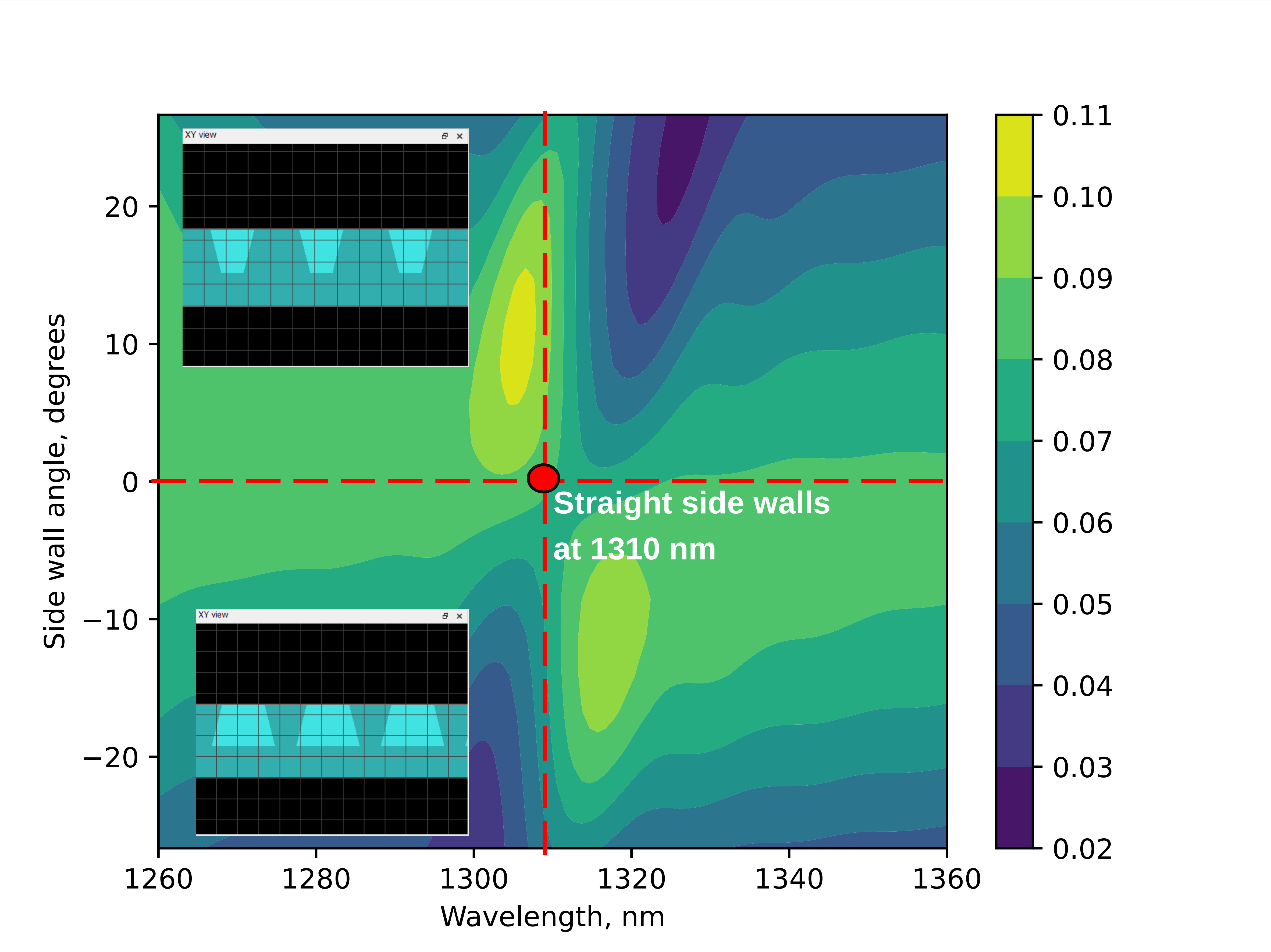
Crystal Surface roughness observable

Buried III-V Surface grating coupler

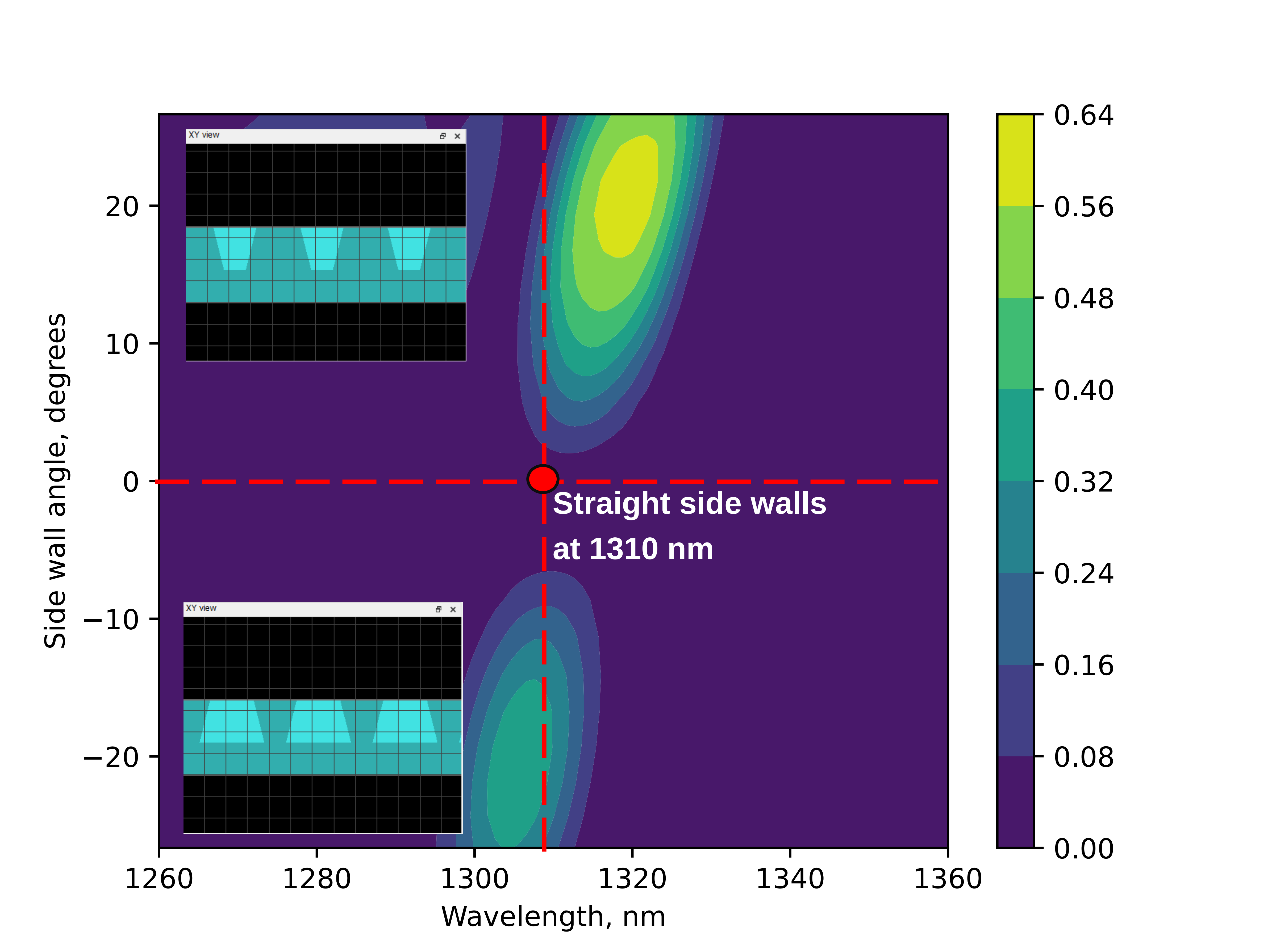


Array designs possible with managed emission intensity

PIC Integration: Reflection Control



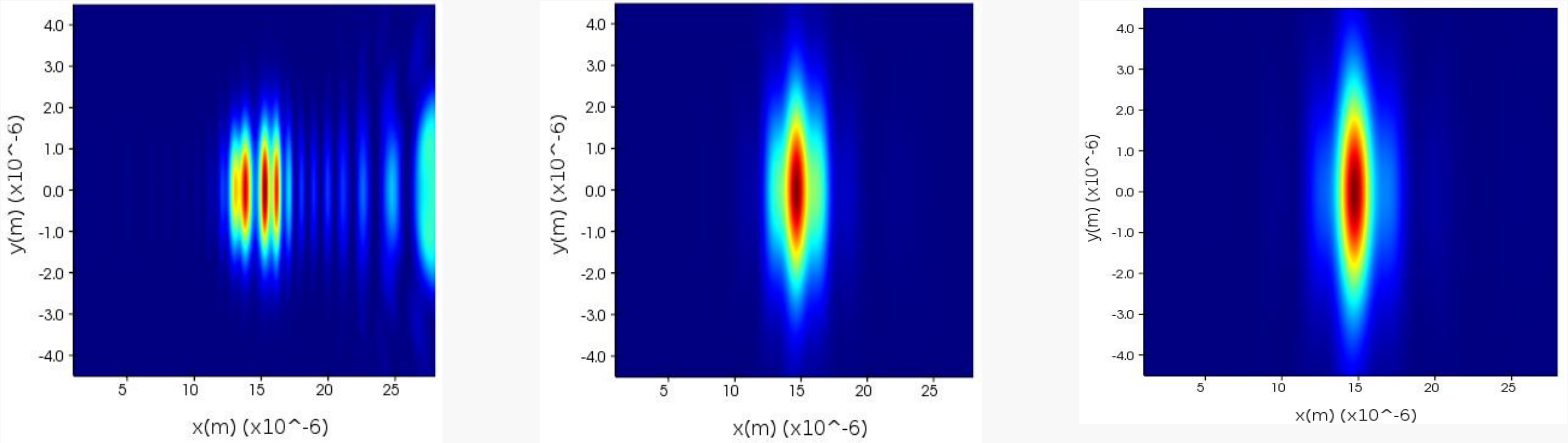
Emission Design Control



Reflection Design Control

Reflection and Surface Emission management

PIC Integration: Beam design



Gaussian Beam Control for Emitters

Summary

- Several alternative methods to enable surface laser emission
- PCSEL technology can address an individual element approach
- Photonic Integration offers the possibility to manage several aspects of the device
    - Power control from a discrete light source
    - Mode Control for each emitter on the passive waveguide
    - Reflection management and Isolation Control
    - Beam Quality
    - Single Emitters and Coherent Arrays
- III-V PIC Integration provides a path to low-cost Coherent Arrays