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Arrays of Photonic Crystal Defect Laser Elements

Dan Dapkus and John O'Brien

The Photonics Center @ USC

Program Concept

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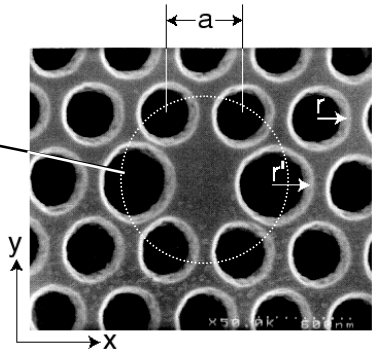
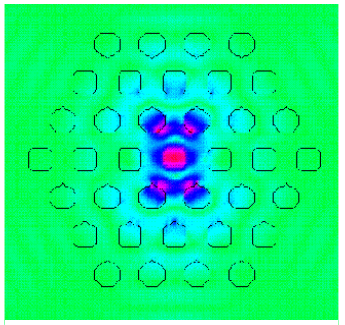
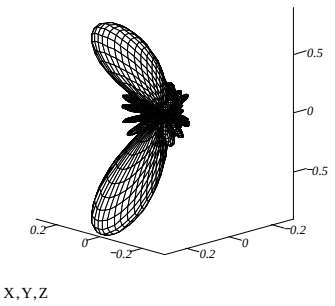
- **Photonic crystal defect elements are basic photonic emitting elements.**
- **Arrays of elements can be formed to “shape” a beam.**
- **Can beam be steered by adjusting phases of elements?**

Photonic crystal defect







Materials Approach

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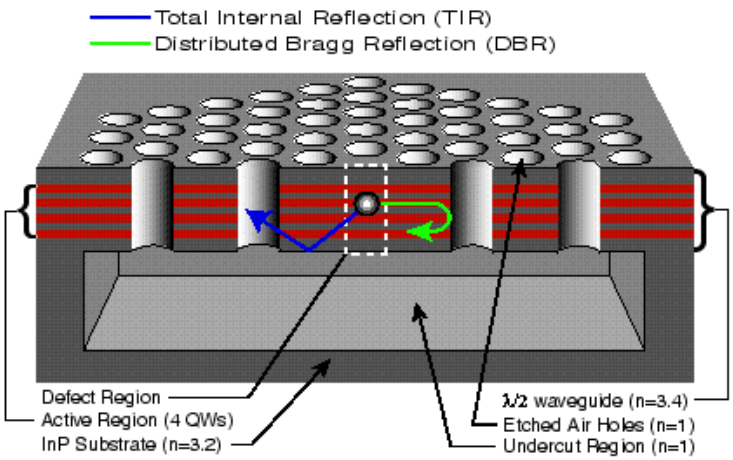
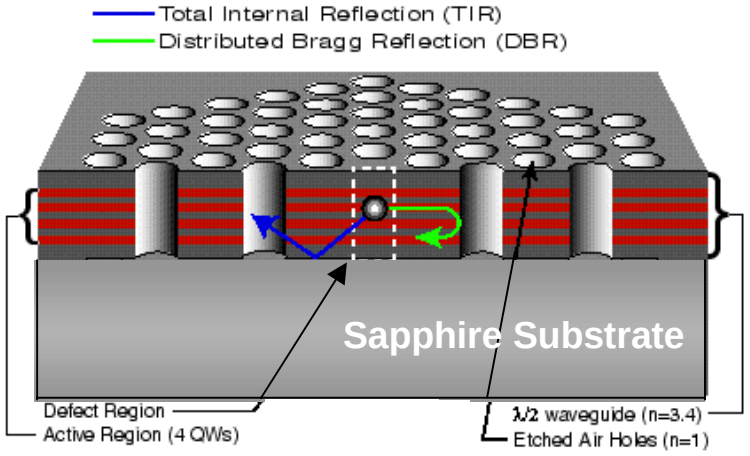


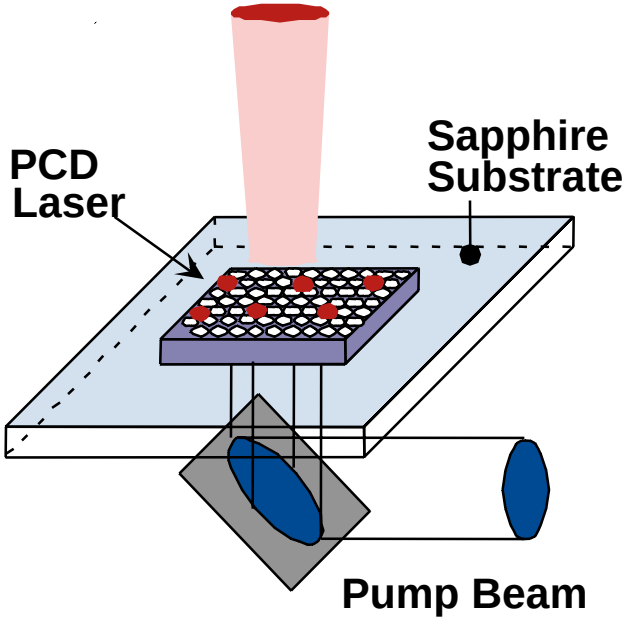


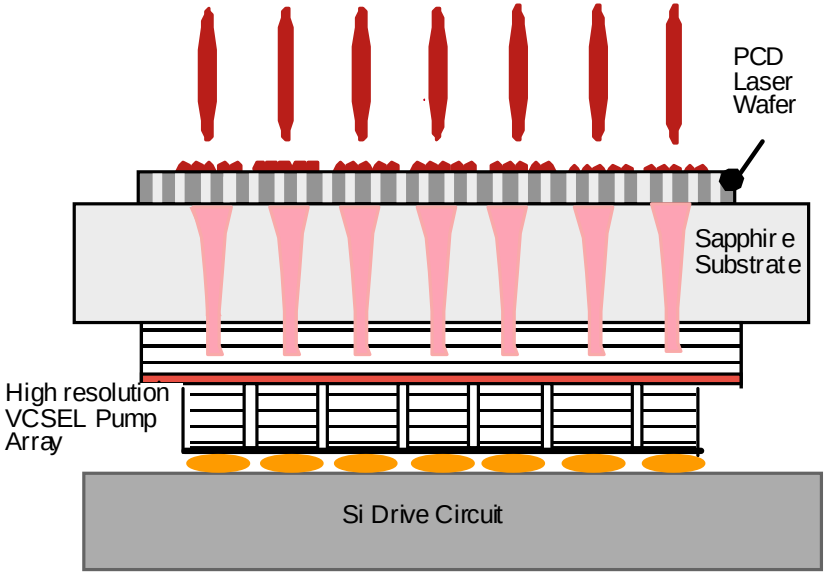
O. Painter, R. Lee, A. Scherer, A. Yariv, J. O'Brien, P.D. Dapkus, I. Kim, Science, vol. 284, pp. 1819-1921 (1999).

This work will utilize a low index, thermally conductive substrate to improve CW performance.

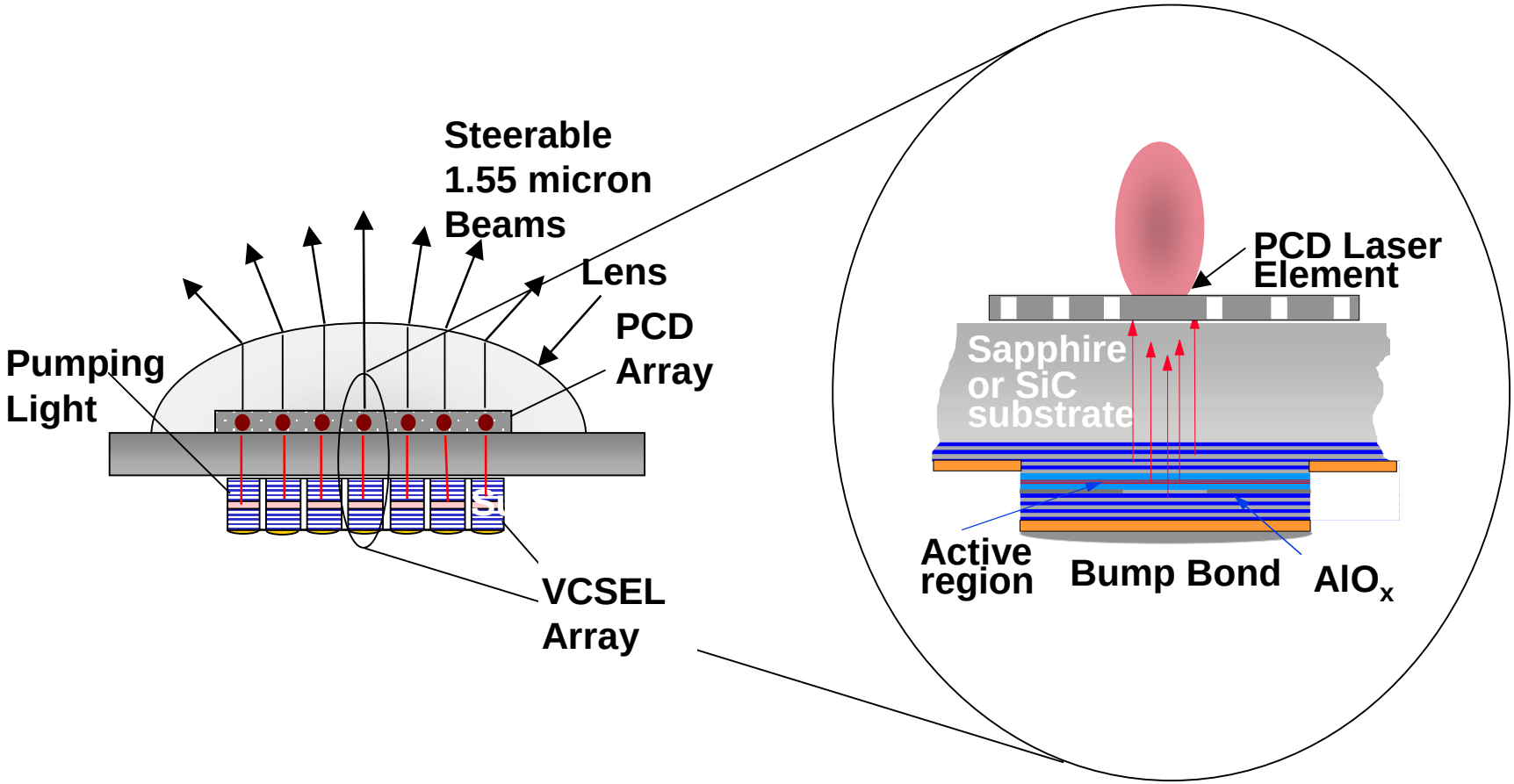
1.55 μm emitting strained QW materials wafer bonded to sapphire

Device Concepts





Scanning Concept



Why Optically Pumped?

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- **Low Optical Loss to Overcome Reduced Gain and Increase Cavity Q.**
- **PCD Design Flexibility.**
- **Utilization of Developed Technology.**
- **Rapid Concept Realization**
- **Pathway to Very Compact Smart Systems.**

Design Challenges

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- Efficient vertical emission requires precise control of Q associated with all emission directions.
- Efficient coherent coupling of defects requires precision fabrication on a local scale.
- Use of sapphire or SiC substrate significantly alters symmetry of cavity.
- Presence of holes introduces carrier loss.
- Presence of holes reduces pumping efficiency.

Wavelength vs. PC Design

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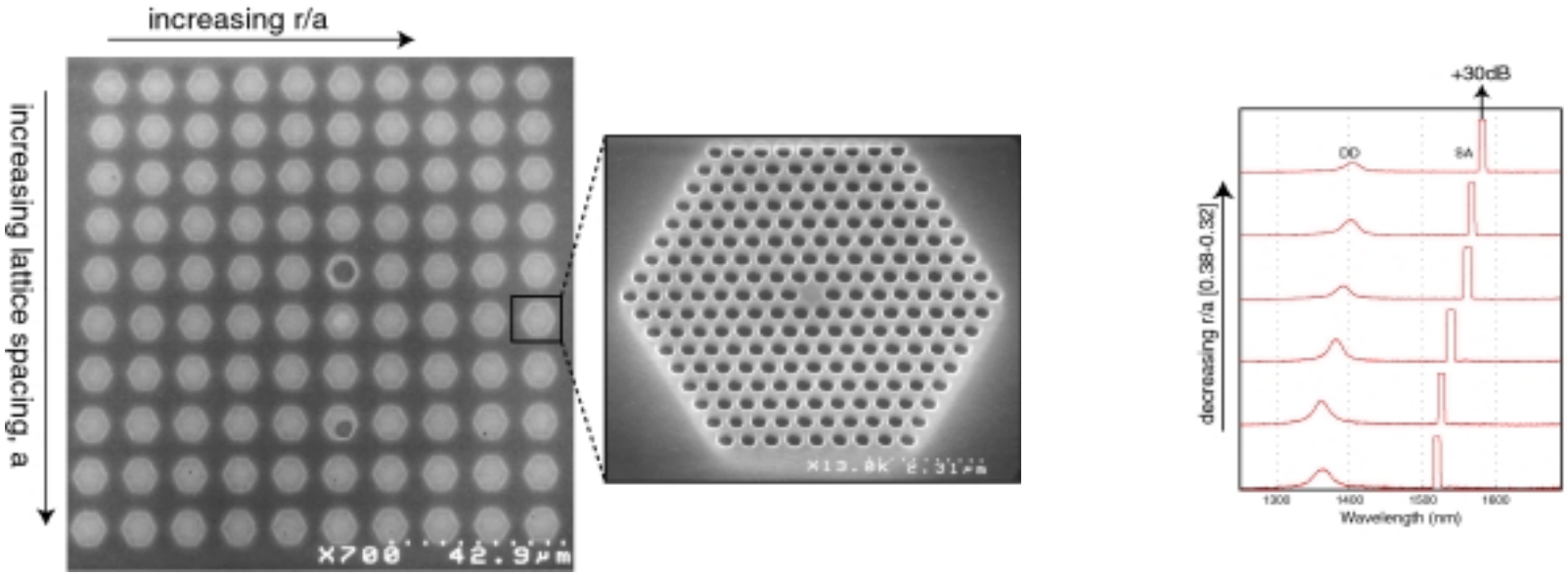

Painter et. al. (Caltech and USC)

E-Beam Lithography and Pattern Transfer

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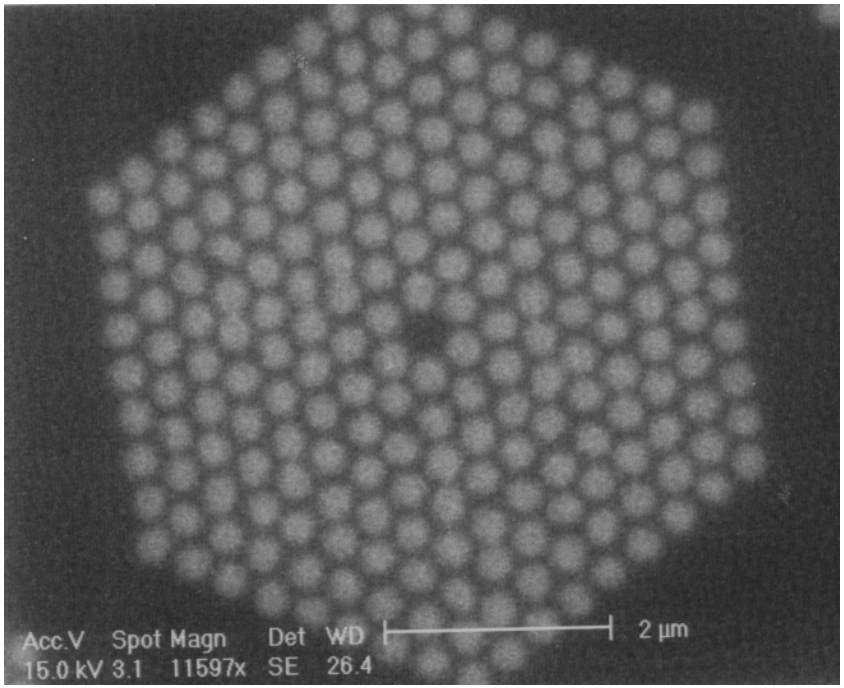
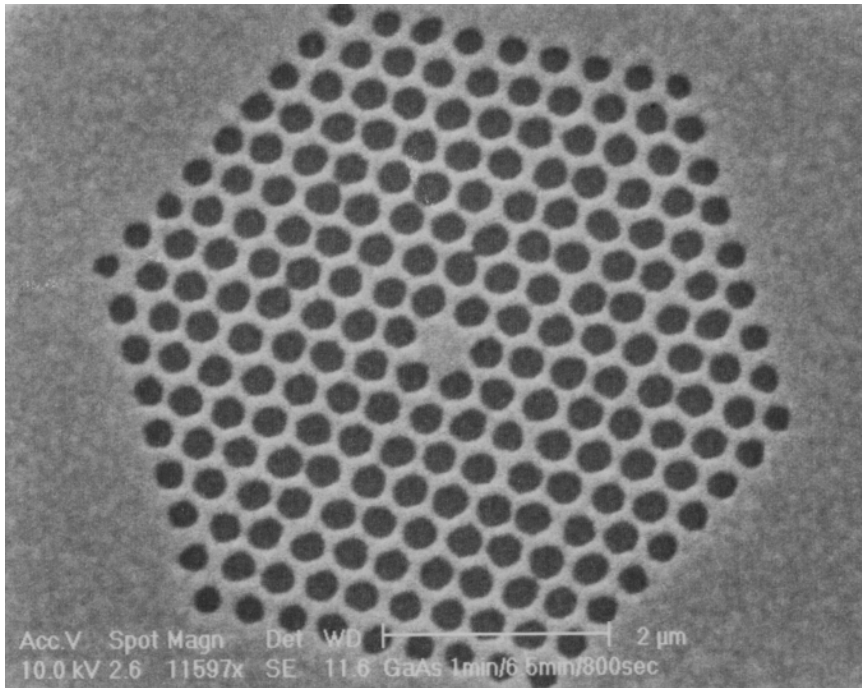
r = 135 nm
a = 400 nm



After Lithography



After RIE Etch

Photonic Crystal Etching

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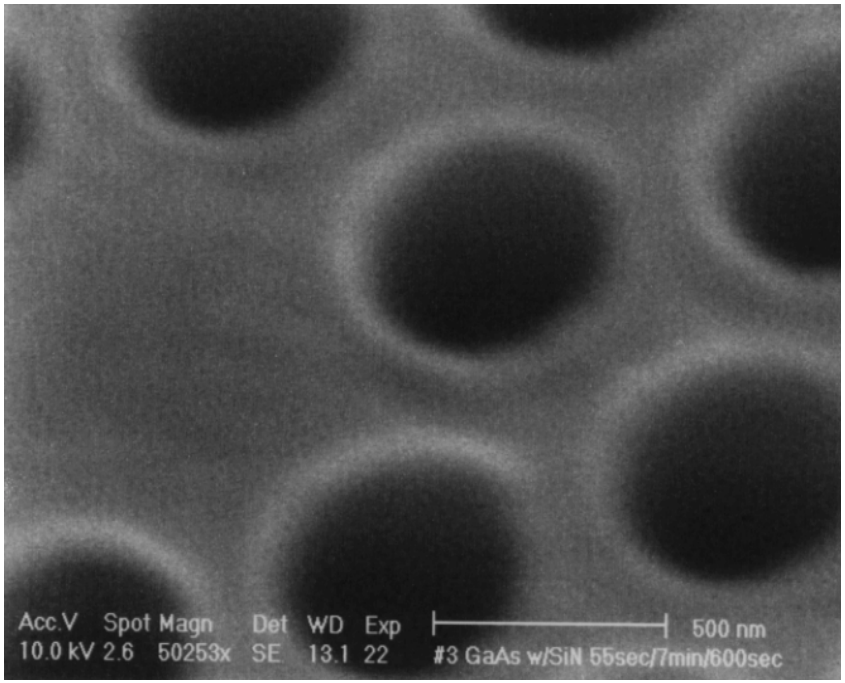

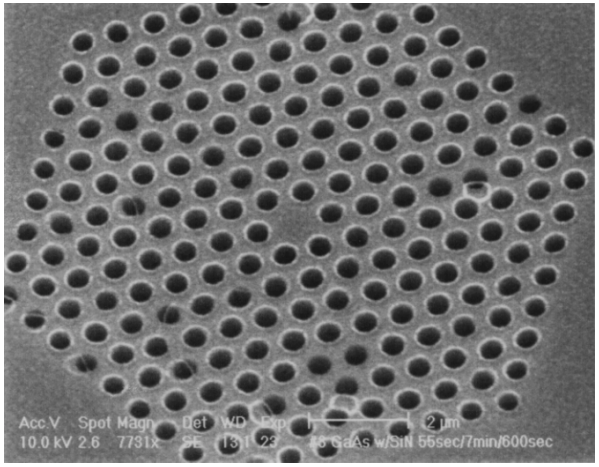

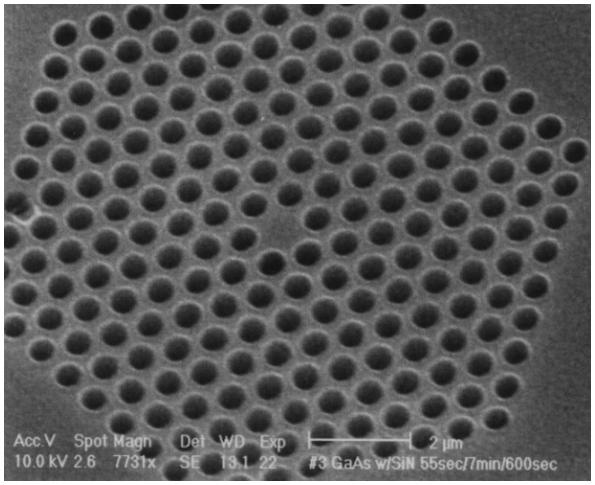

PC Defect Optimization

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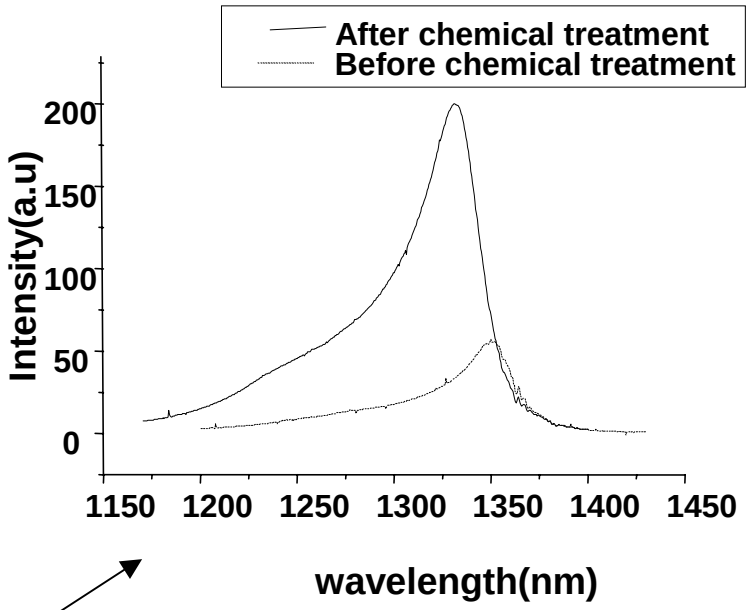
- Near Field Design Optimization
- Directional Q Control
- Pump Absorption Optimization
- Minority Carrier Loss Reduction



3D FDTD Simulation Tools

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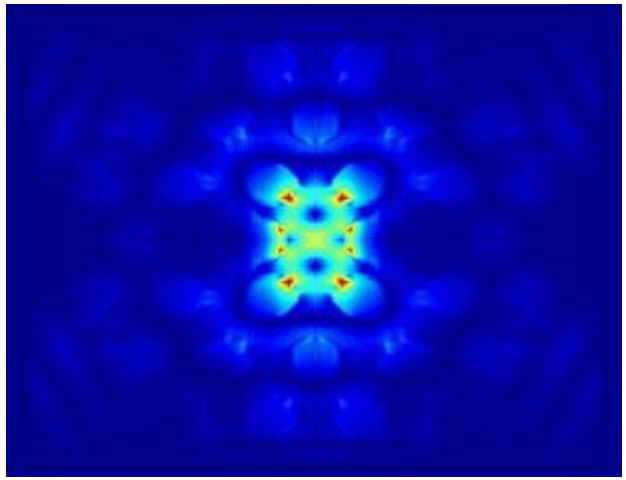
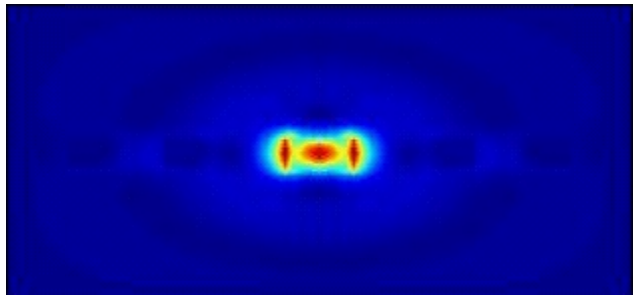


top view



cross section

Far Field Patterns of Defect

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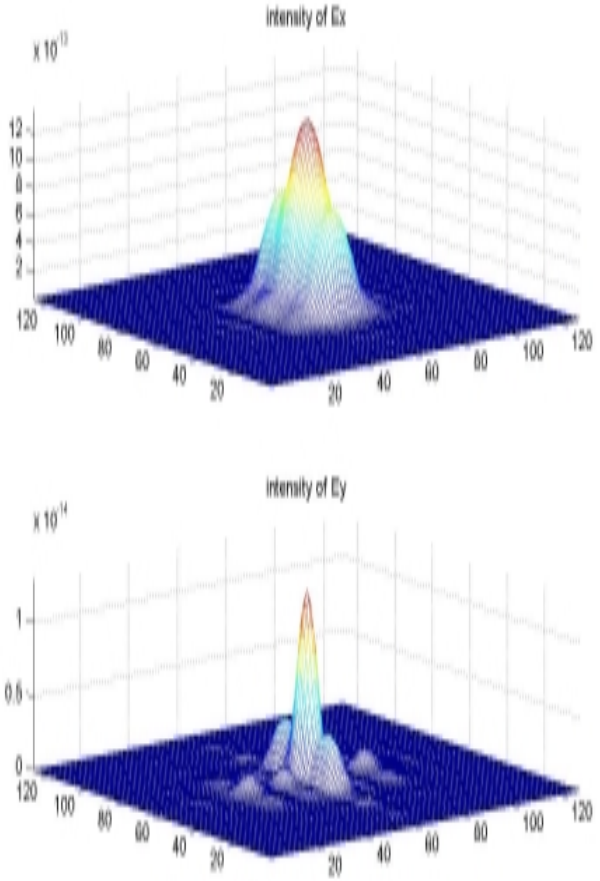
- Asymmetric hole pattern causes highly polarized far field
- Far field of single defect already very directional
- Multiple defect patterns to be calculated.



Electric Field Magnitude in Defect Cavity

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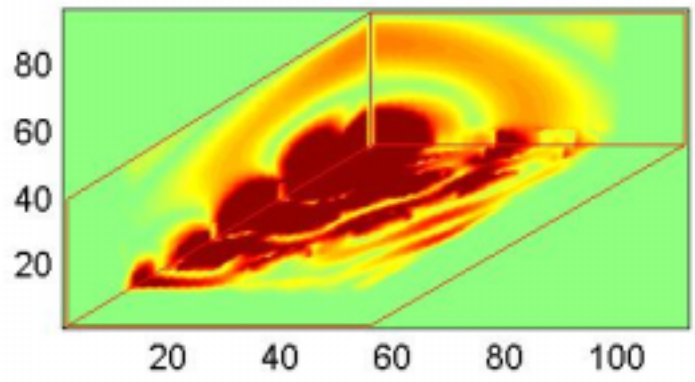
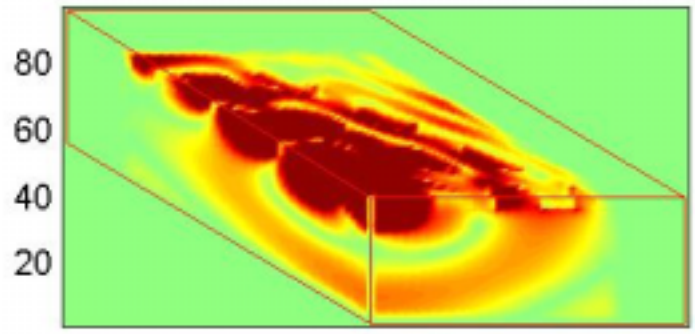
symmetric cladding

top

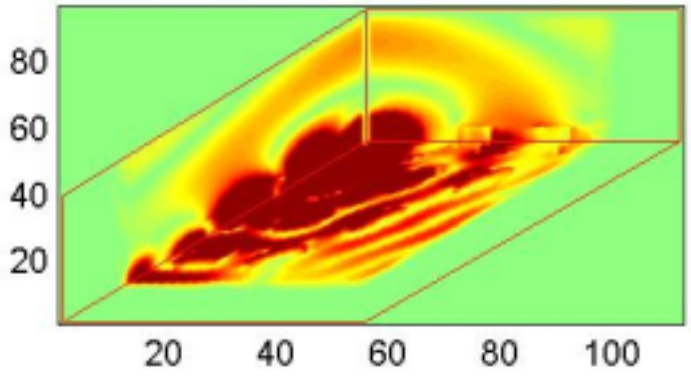


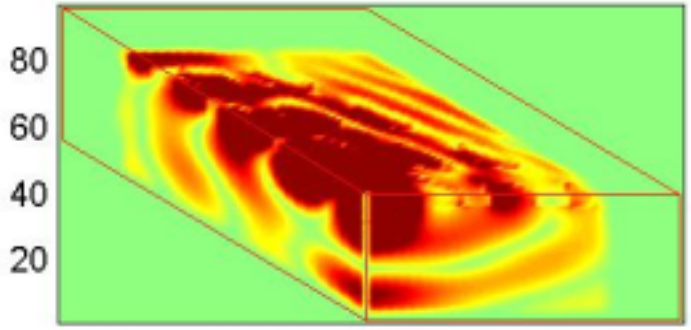


bottom

asymmetric cladding

top





bottom

Q Optimization

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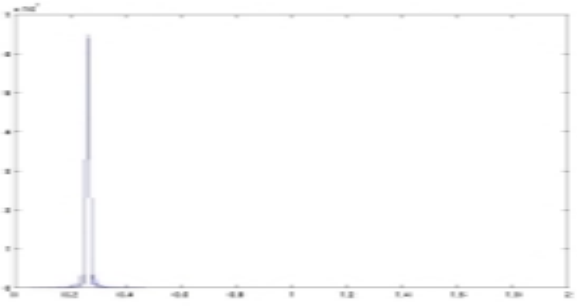
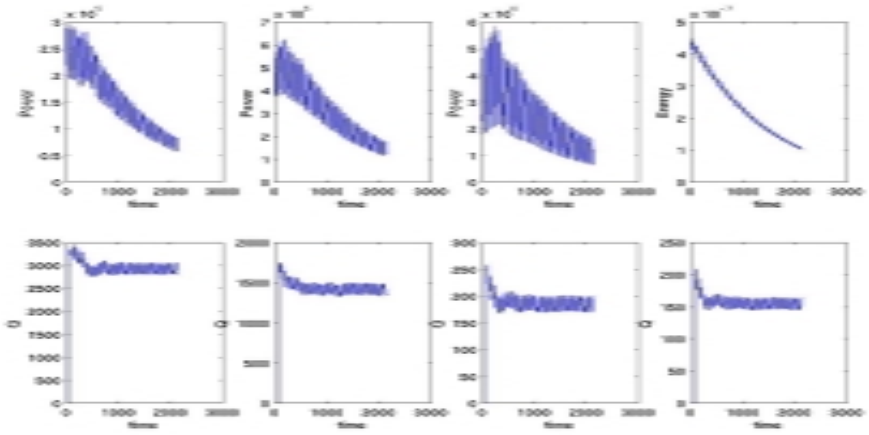
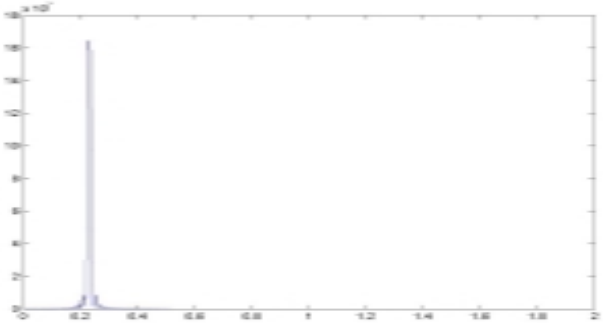


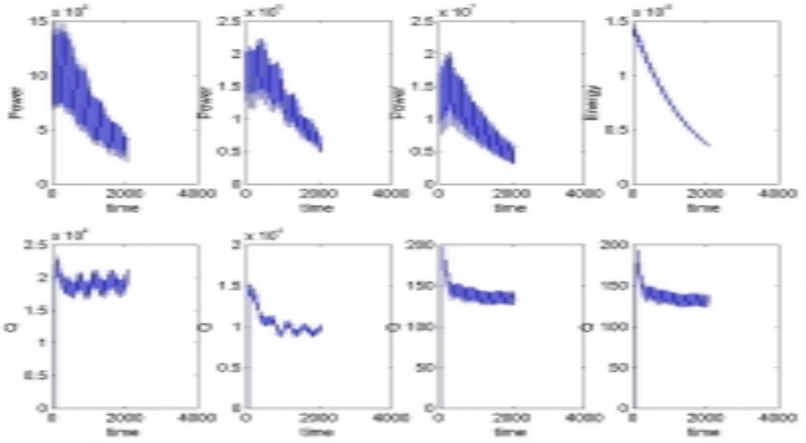
$Q_{vertical} = 944$



Qtop Qbottom Qside Qtotal



$Q_{vertical} = 15555$



Qtop Qbottom Qside Qtotal

Wafer Bonded VCSEL Results

Funded by VLSI Photonics Program

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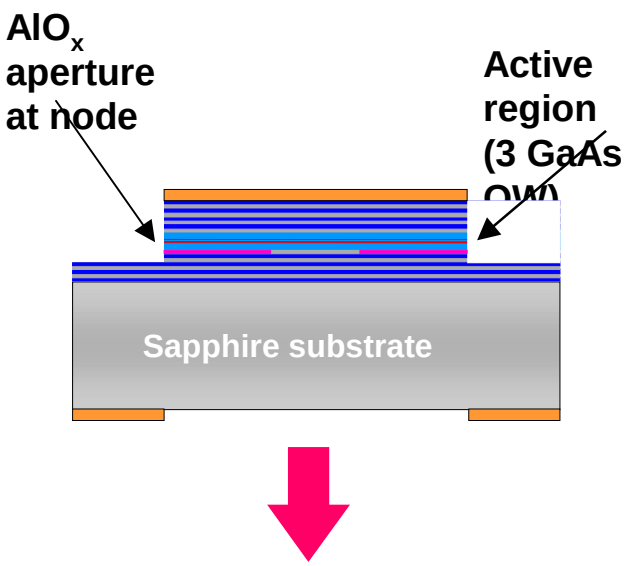

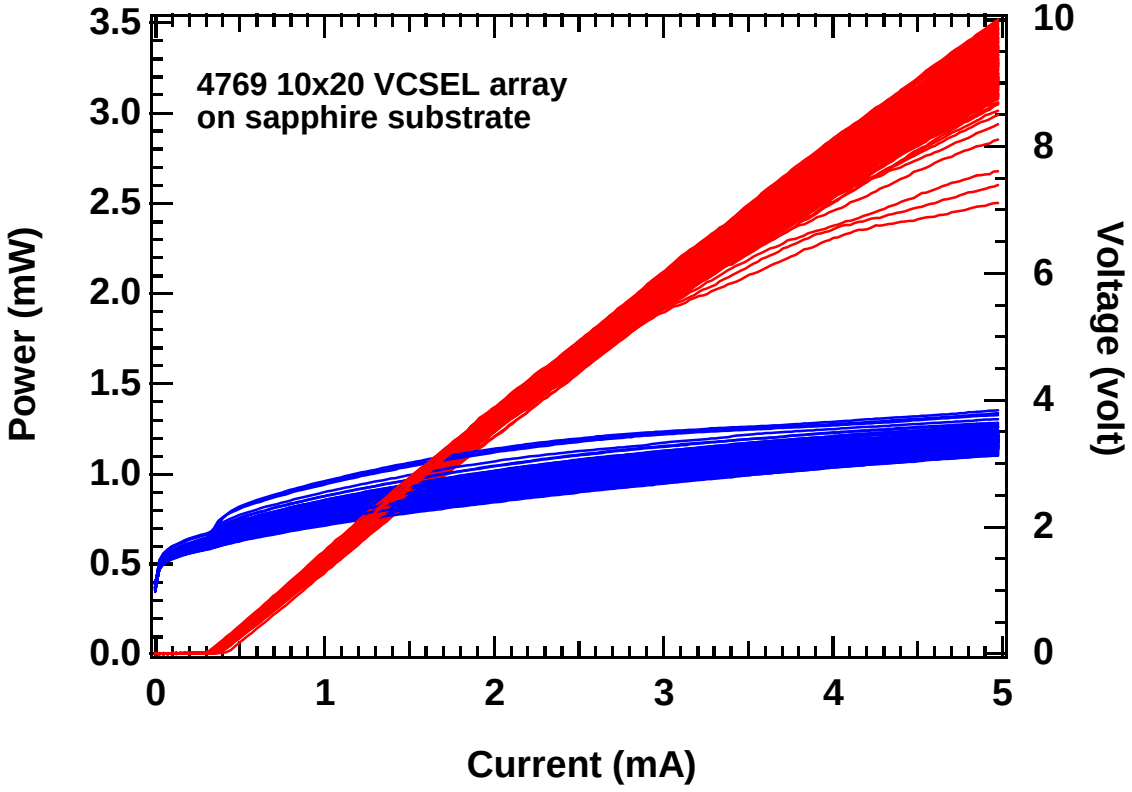

Uniformity of Backside Arrays

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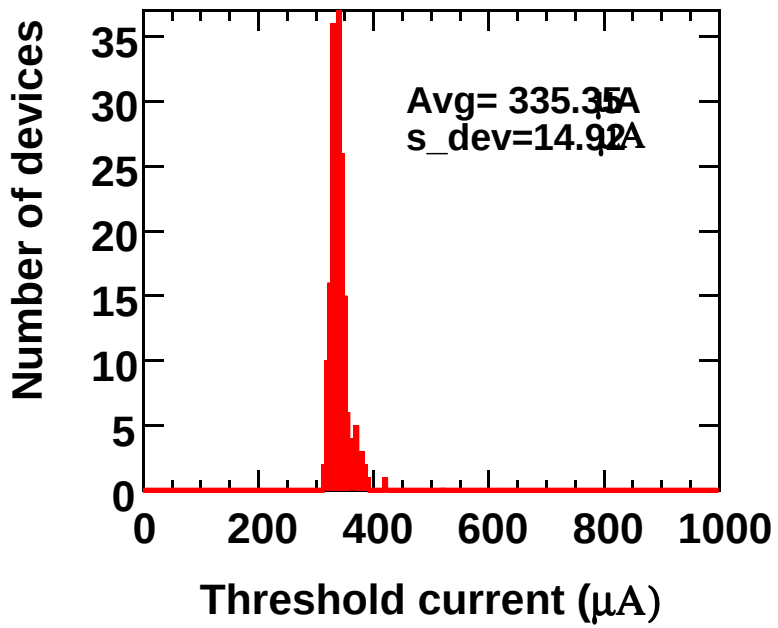

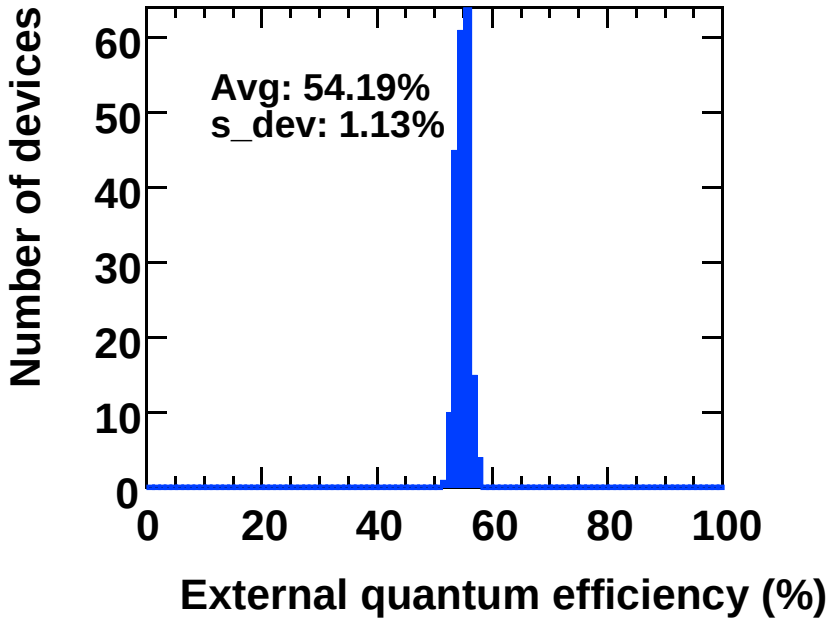

Technology Output

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1. CW room temperature operation of photopumped PCD laser.
2. Heterogeneously integrated VCSEL – pumped PCD lasers with narrow beam output.
3. High spatial density backside emitting VCSELs.
4. Compact, eyesafe, steerable laser source.

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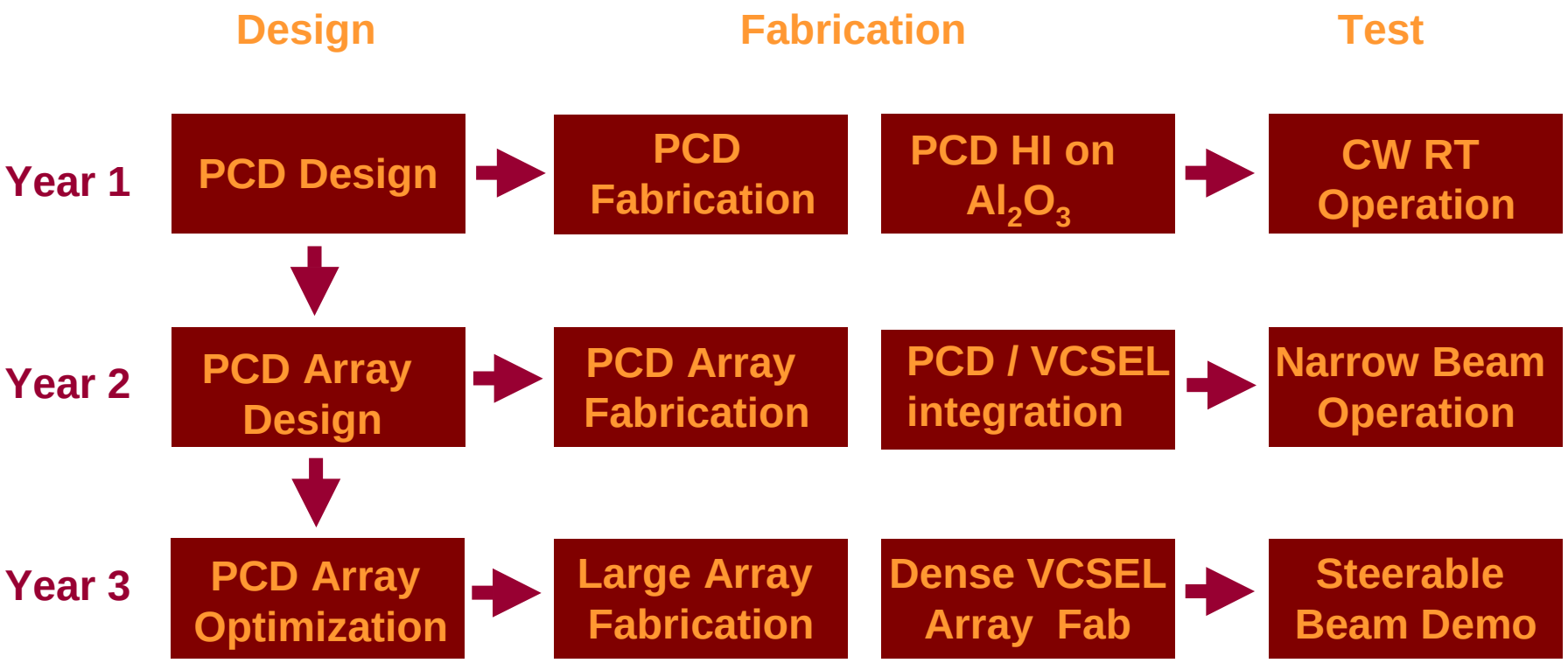

Tasks and Milestones

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- **Task 1 Design and Modeling of PCD Elements and Arrays**
  - Complete analysis of PCD element. 3Q
  - Complete analysis and design of large area PCD array. 6Q
- **Task 2 Growth of PCD Arrays and Heterogenous Integration**
  - Selective area growth of submicron PCD active region. 2Q
  - PCD heterogeneous integration onto sapphire /or SiC. 3Q
  - PCD / Backside emitting VCSEL integration. 6Q
- **Task 3 PCD Fabrication**
  - Demonstrate PCD fabrication using selectively grown active region. 2Q
  - Demonstrate large area PCD array. 6Q
  - Finalize PCD process. 9Q
- **Task 4 Test and Measurement**
  - Room Temperature CW PCD laser. 3Q
  - Optical pumping of large area PCD array. 8Q
  - Steerable beams from PCD arrays. 12Q