System-Aware Simulation Workflows for Co-Packaged Optical Architectures

Majid Ebnali Heidari, Ph.D.
Engineering Manager - Optics, Photonics
SimuTech Group

SimuTech Group Overview

25+ Year Ansys Partnership

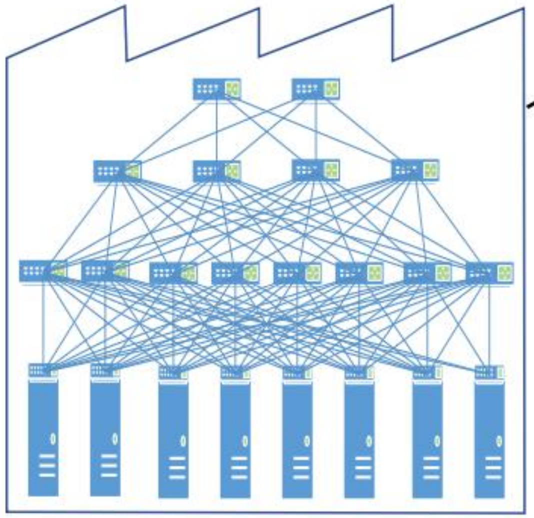
#1 Ansys Partner in North America

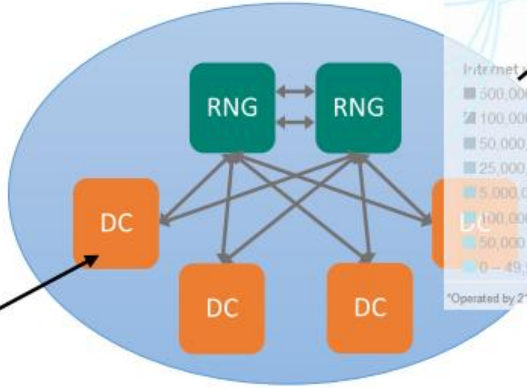
200+ Employees Across US & Canada

900+ Years of Staff Engineering Experience

Operating Optics at scale

Data Center
1 km radius
150,000 servers
120,000 100G optical transceivers



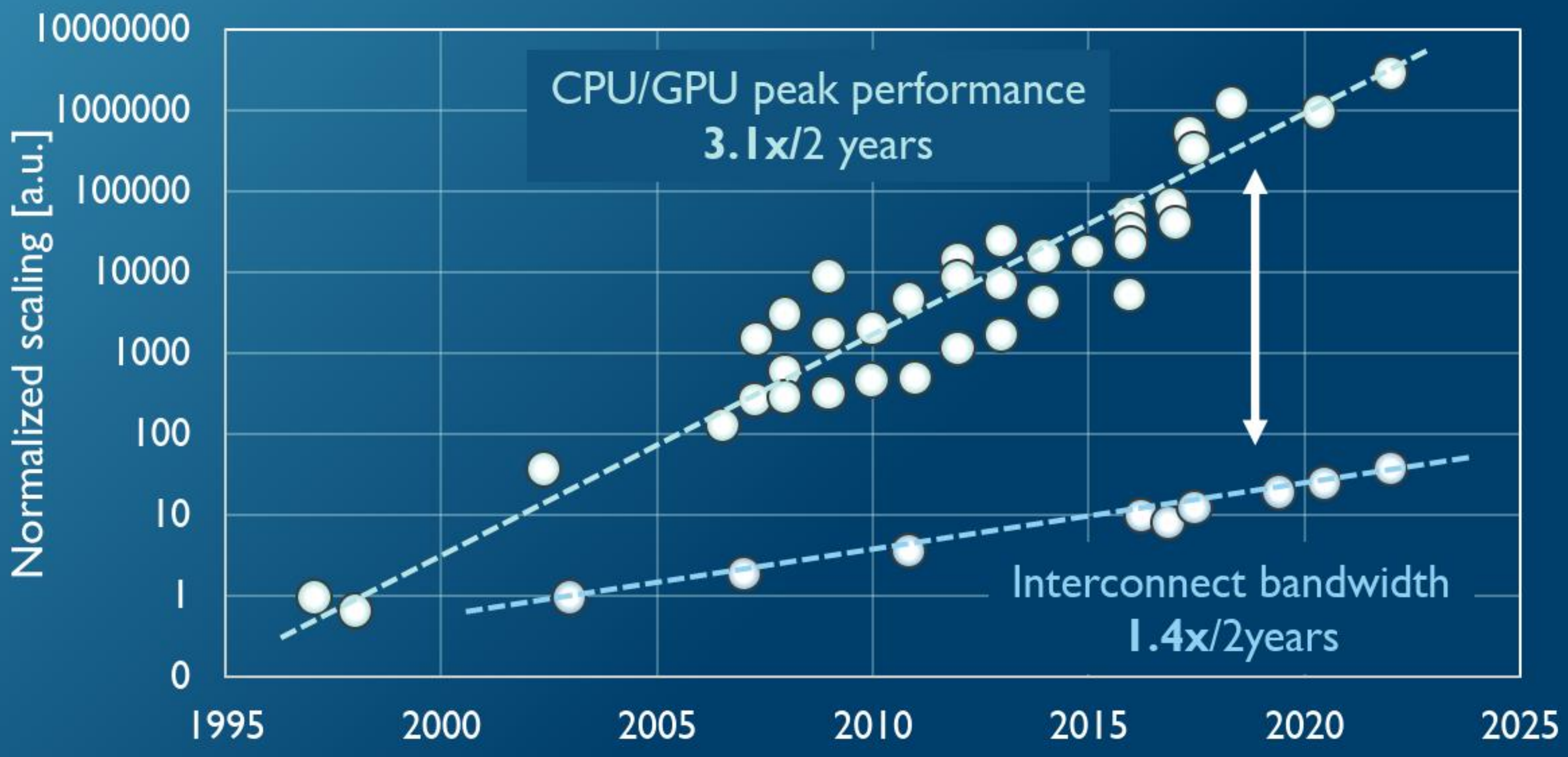


Regional Network
70km radius
512 fibre pairs
2Pb/s

WAN
Data centers in 50+ regions
More than 70,000km of fibre

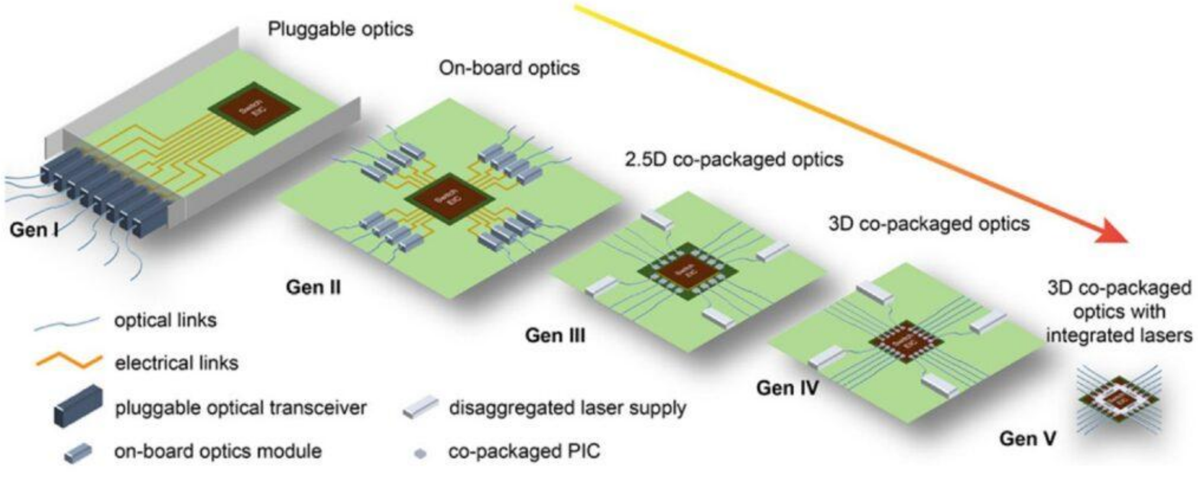
Microsoft

Interconnect Bandwidth and Compute Capability



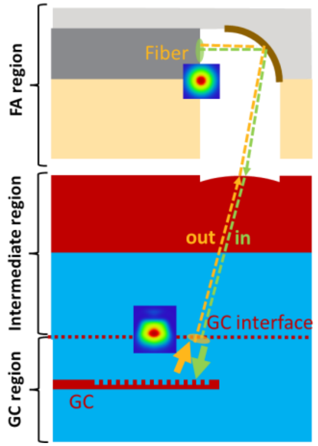
Amir Gholami, et. Al. "AI and Memory Wall", https://medium.com/riselab/ai-and-memory-wall-2cb4265cb0b8

Significant Multiphysics Challenge with CPO Evolving

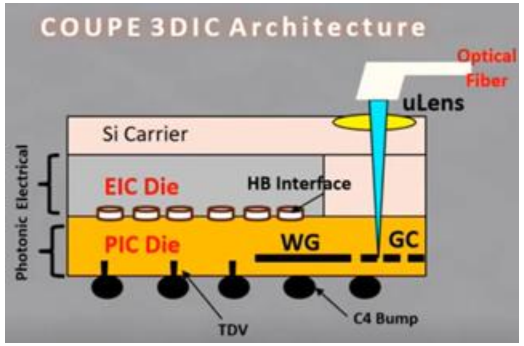


Ref: "Perspective on the future of silicon photonics and electronics" N. Margalit, et.al., Appl. Phys. Lett. 118, 220501 (2021)

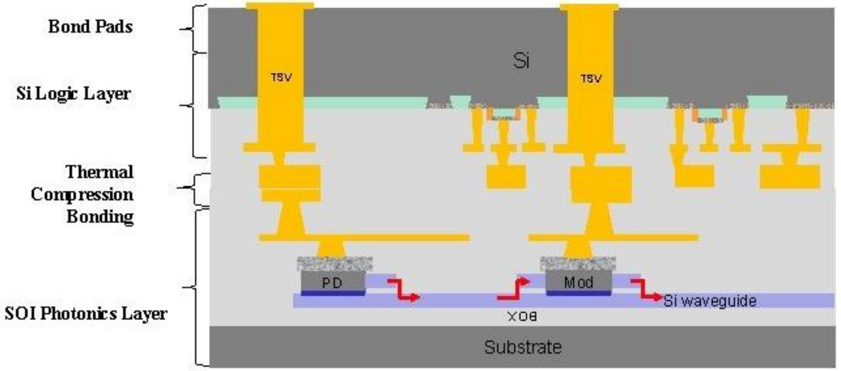
Optical I/O and photonic device simulation



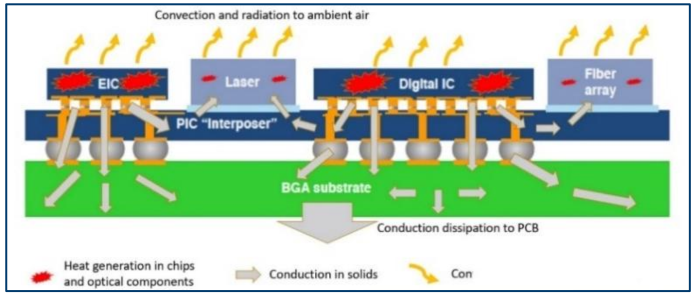
Increased IR drops electromigration



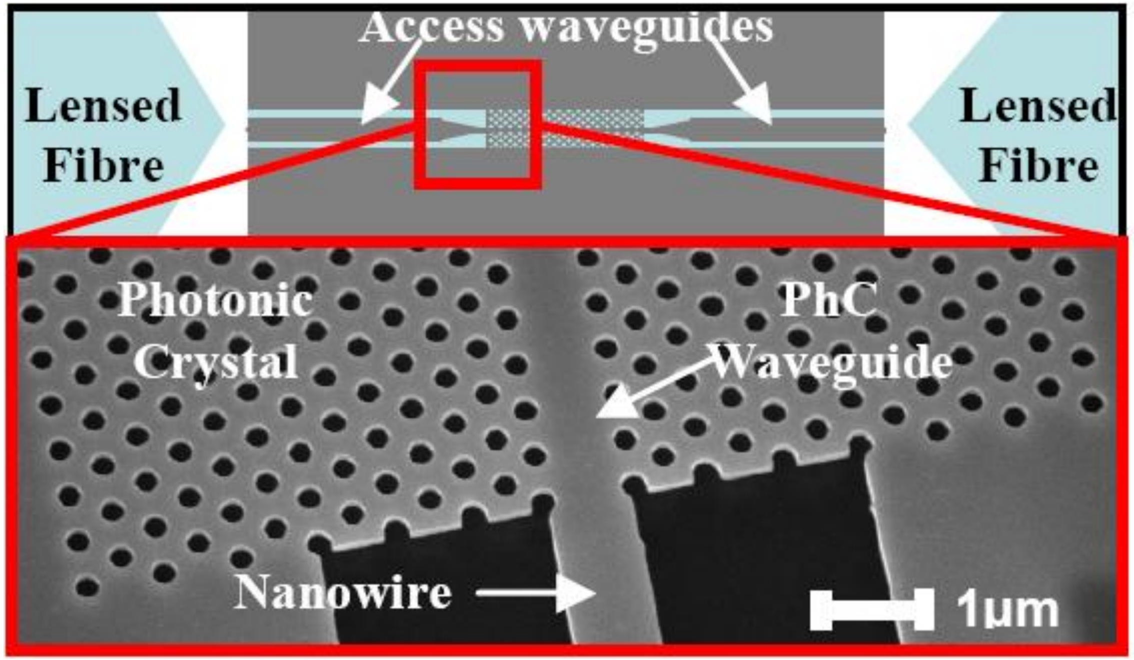
Cross die electromagnetics



Thermal and Stress



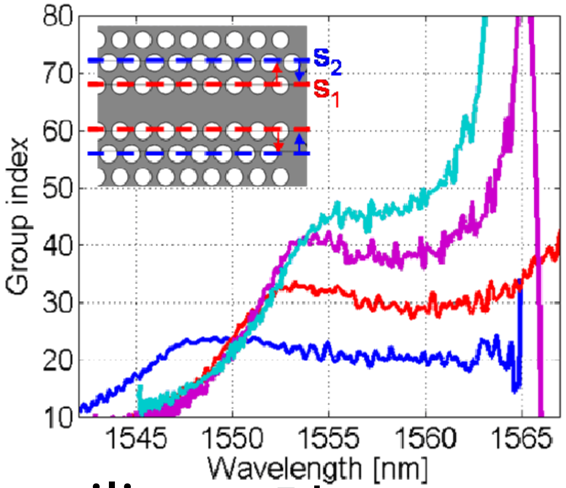
Our Method in the Experiment



Period	1st row shift s_1	2nd row shift s_2	Group index
406nm	56nm	16nm	~20
408nm	52nm	0nm	~30
410nm	50nm	-10nm	~40
410nm	48nm	-16nm	~50

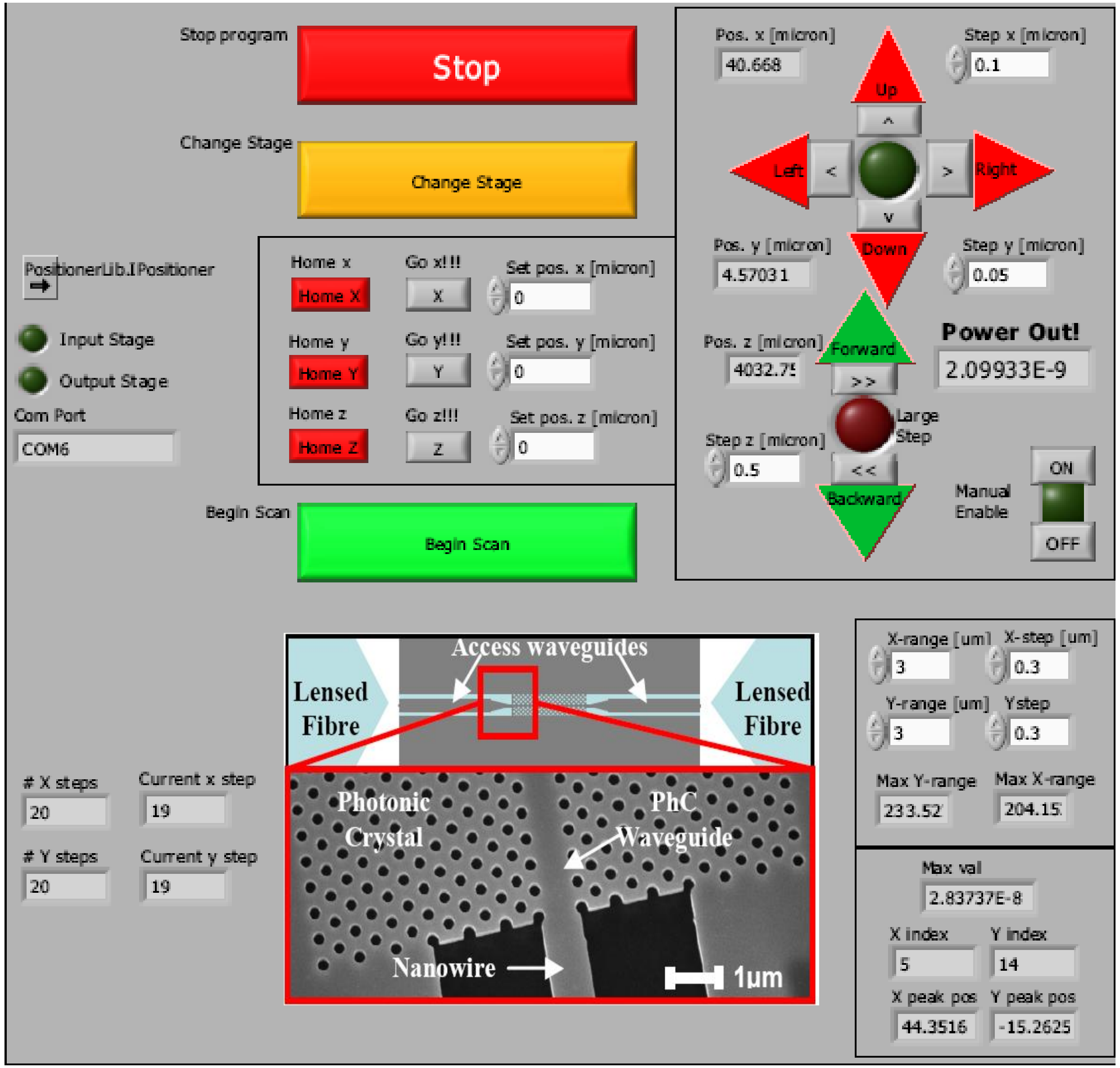
Monat Opt. Express 18, 22915 (2010)

Ebnali-Heidari Opt. Express 17, 18340 (2009)

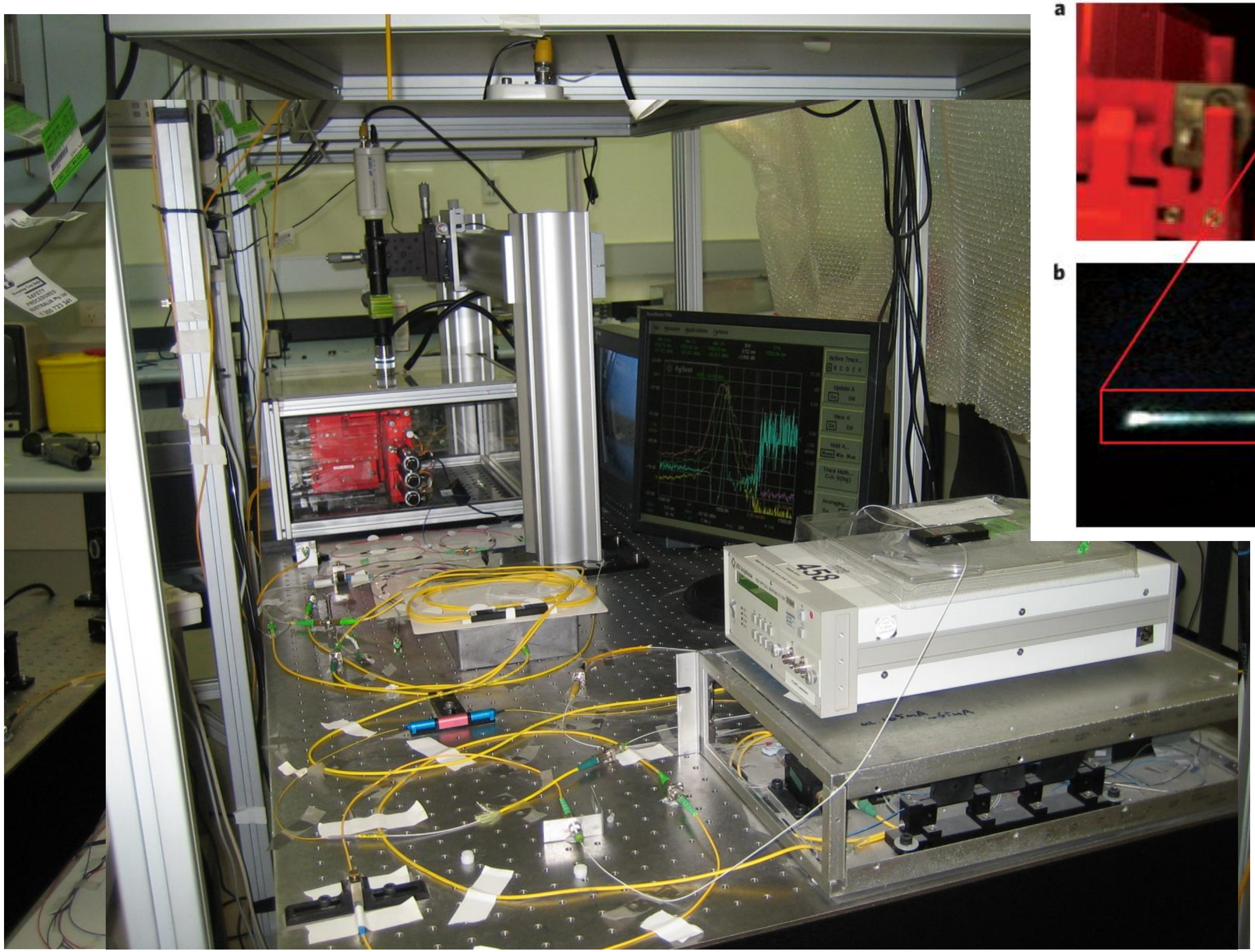


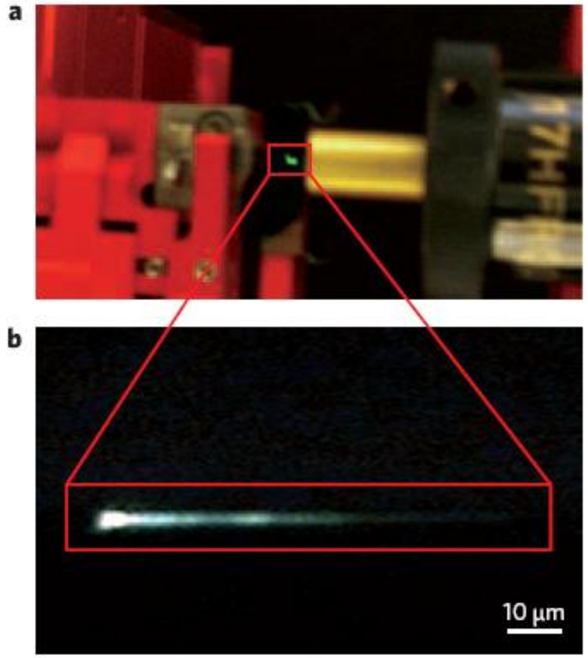
- silicon Planar photonic crystal: Slab (220nm) +2D PhC (air hole lattice)
- Group velocity (c/20 and c/50)

Labview Code for Experiment Design

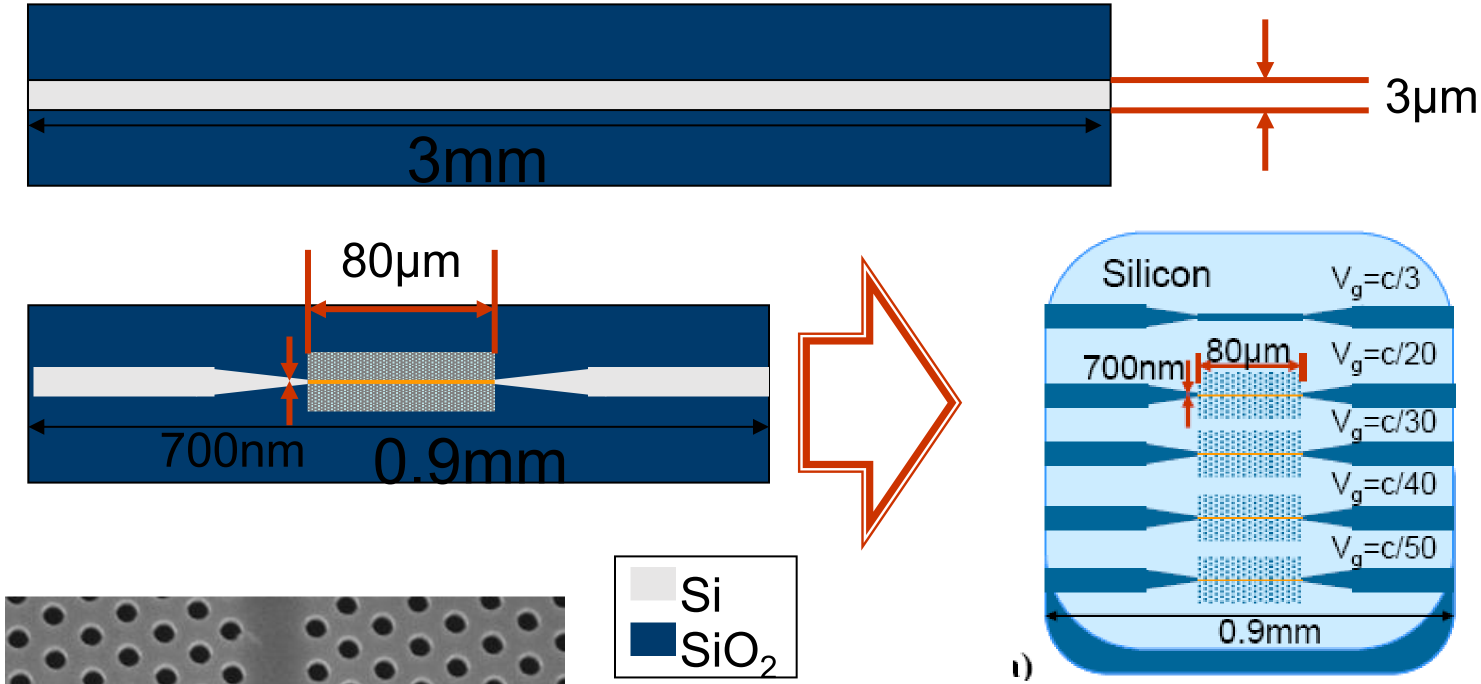


Experiment Design for SPM





PhC Waveguides with Controlled Group Velocity



Ridge

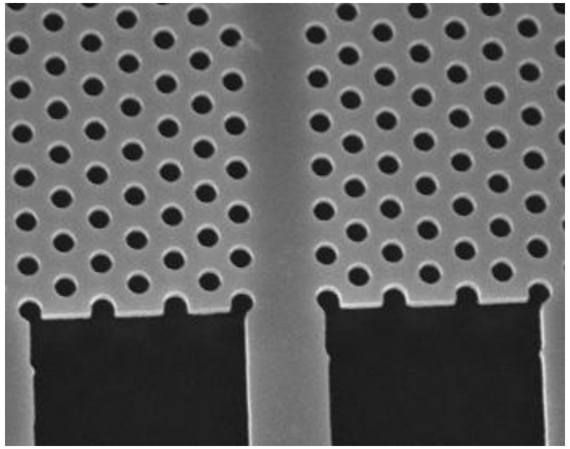
Nano wire

n_g~20

n_g~30

n_g~40

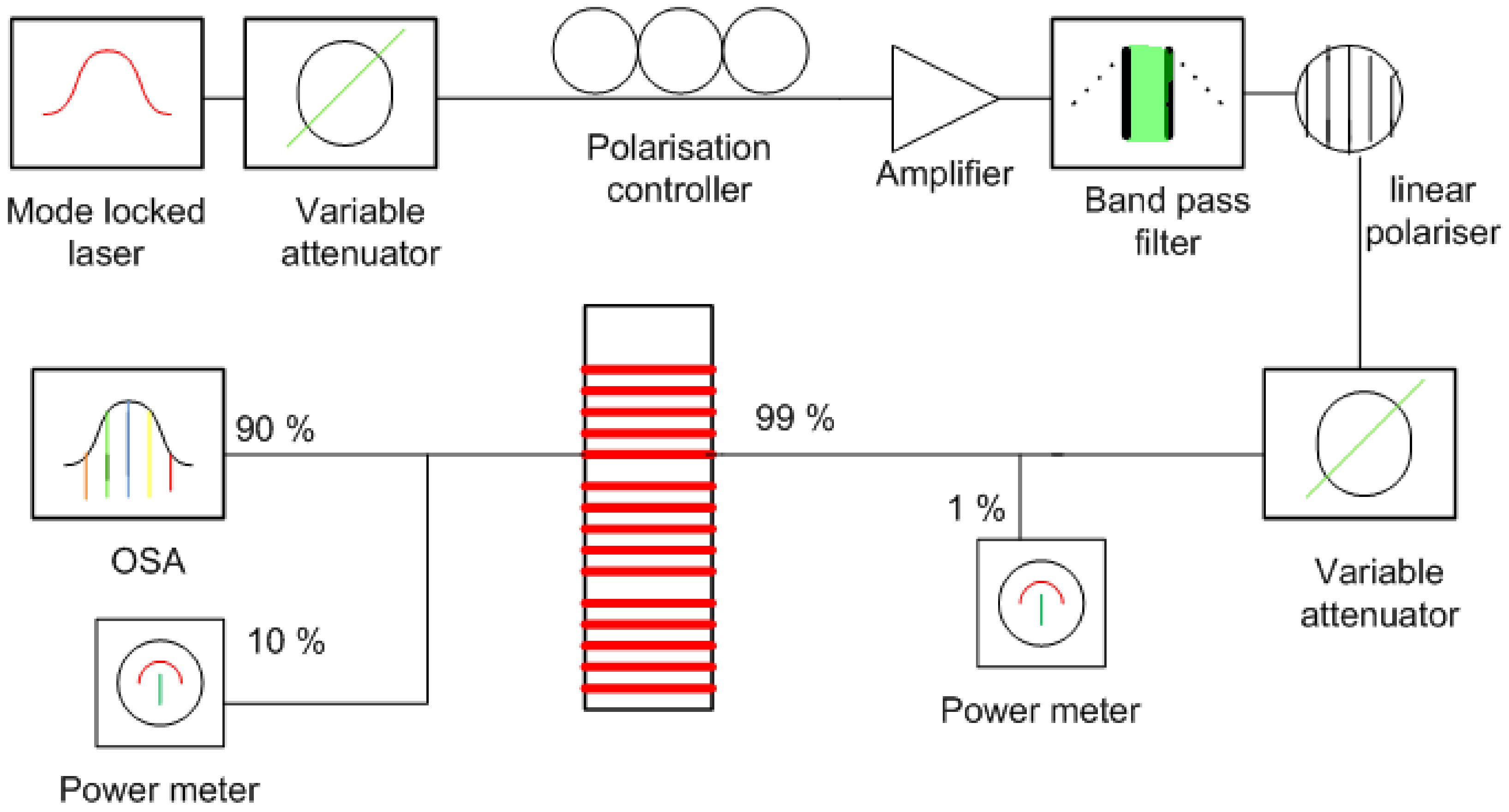
n_g~50



Silicon PhC membrane

- Several engineered PhC waveguides
- Each guide with a different n_g
- Investigate n_g dependence of non-linear effects

Experiment Design



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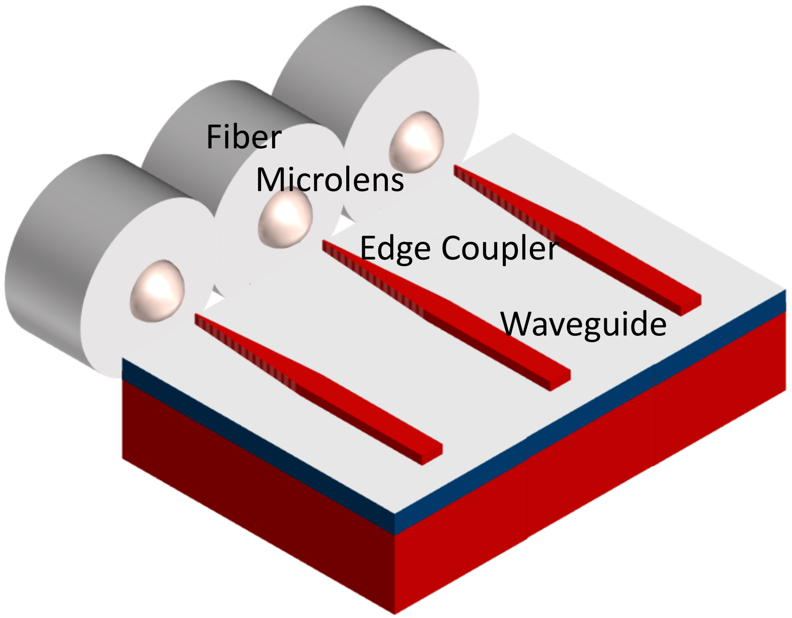
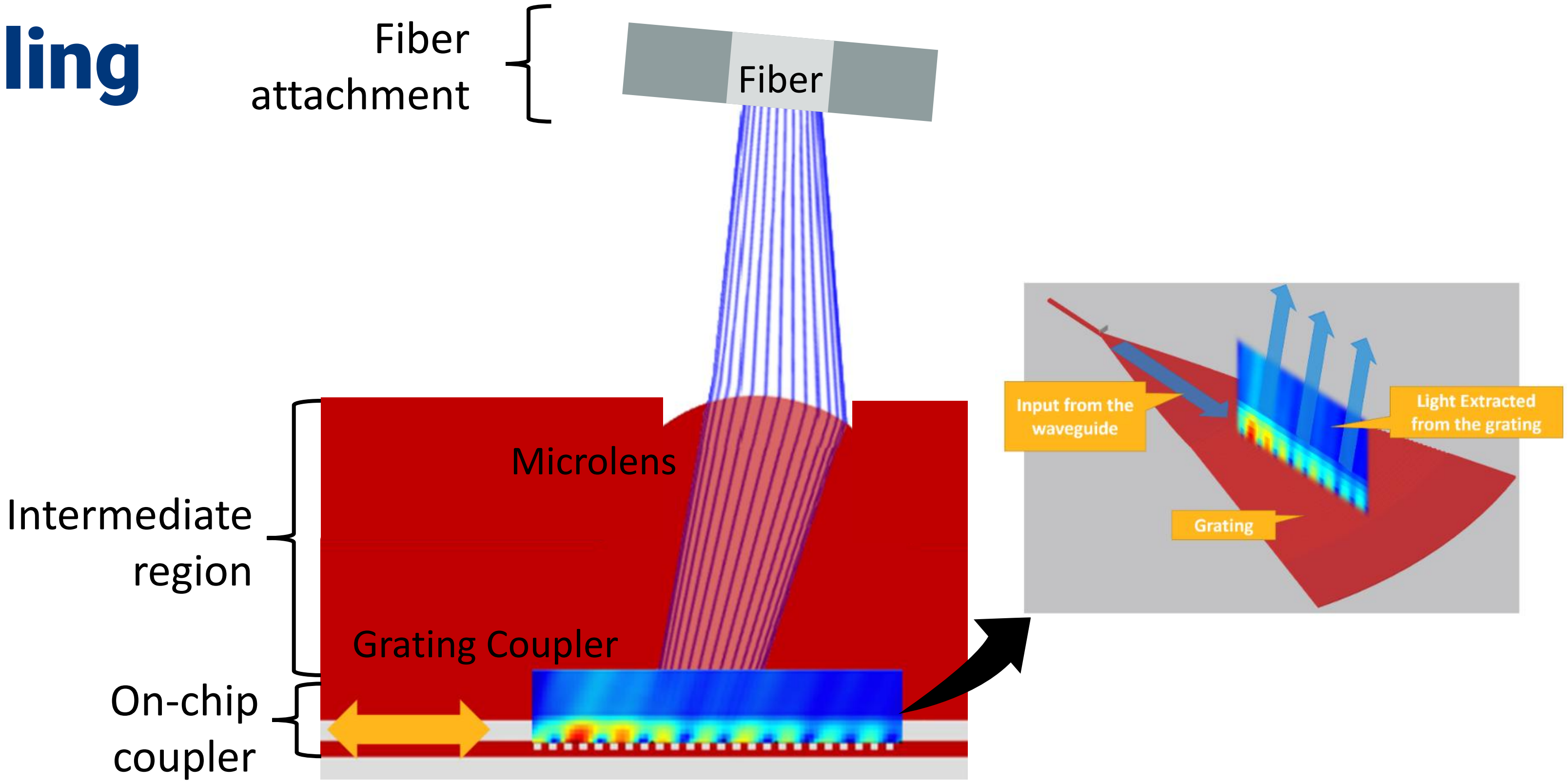
Edge vs. Vertical Coupling

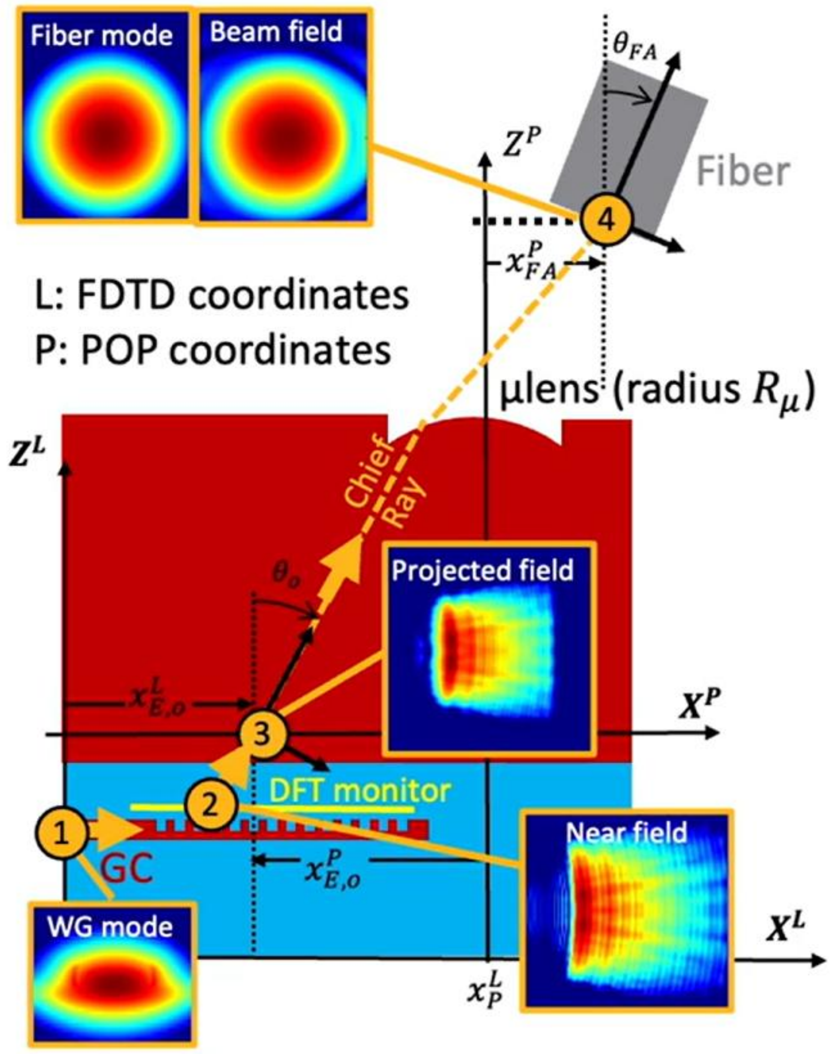




REGION	LENGTH SCALE	DESIGN
On-chip coupler	0.1µm-100µm	Foundry PDK element or custom element with user-provided layout
Intermediate	100µm-1mm	Collimating microlens, AR coatings, etc. Fixed by foundry design
Fiber attachment	100µm-1mm	Typically provided by third party, must be compatible with intermediate region

Physics Simulation Workflow

- **FDTD simulation:** Waveguide mode injected at 1. and near-field recorded at 2.
- **FDTD post-process:** Far-field projection to plane normal to beam direction at 3.
  - *ZBF* data centered at peak intensity ($x^L_{E,o}$)
  - *GC transmission* from power ratio between 3. and 1.
- **POP simulation:** Propagation of *ZBF* data from 3. to 4.
  - *Fiber Coupling Efficiency* from overlap calculation with fiber mode at 4.
  - Vary *microlens location* (x^L_P), *fiber location* (x^P_{FA}) and *fiber angle* (θ_{FA}).



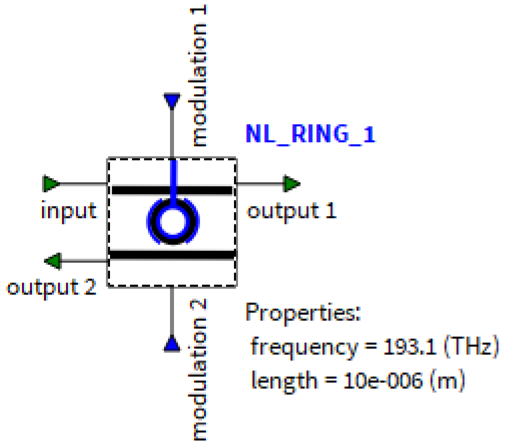
New Nonlinear Ring Modulator Element in Ansys Lumerical INTERCONNECT™

New compact model that accounts for temperature variations caused by self-heating due to:

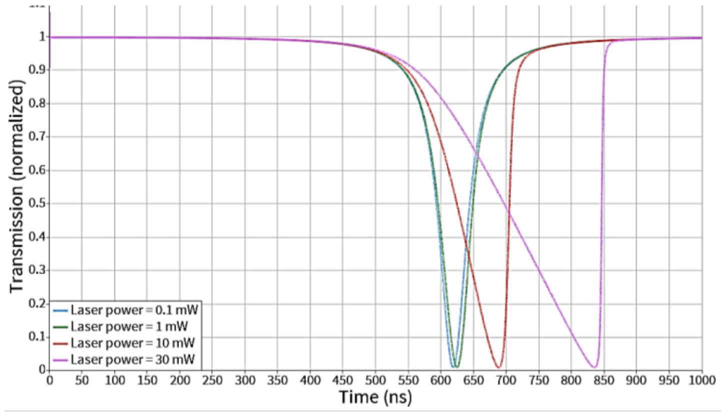
- Linear absorption
- Two-photon absorption
- Free-carrier absorption

Built on the existing Ring Modulator, this model incorporates nonlinear effects arising from free carriers and self-heating effects.

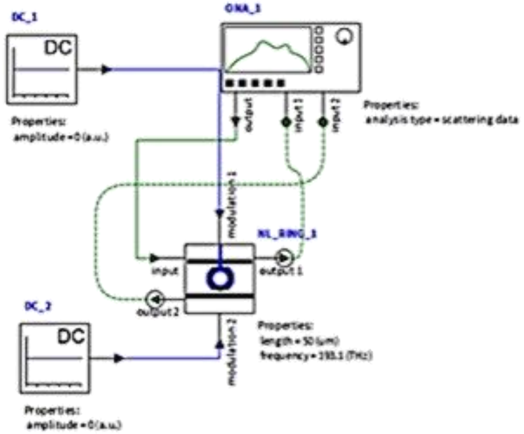
It offers more accurate simulation of silicon microring modulators.



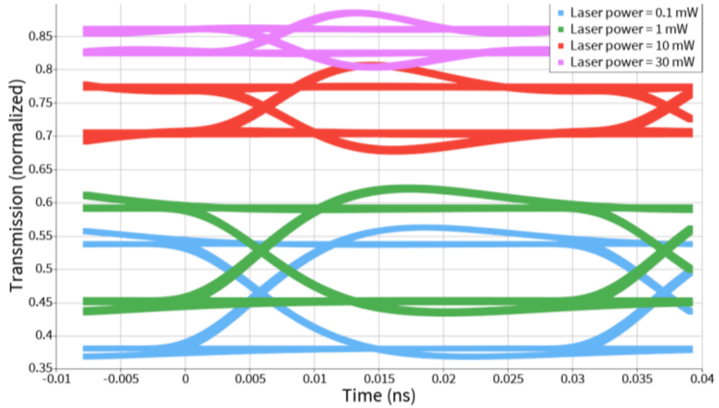
Nonlinear Ring Modulator Element schematic



Parametric sweep result – Transmission over time



Circuit in Lumerical INTERCONNECT to run the model



Eye diagram vs. input power

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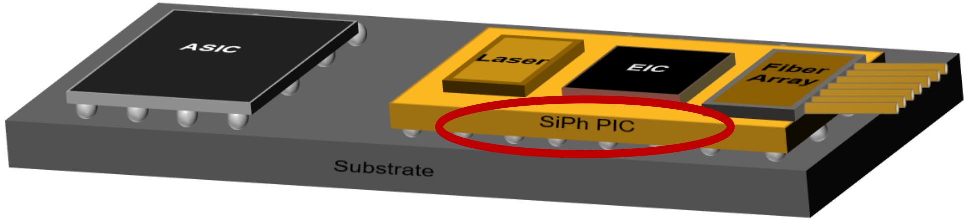
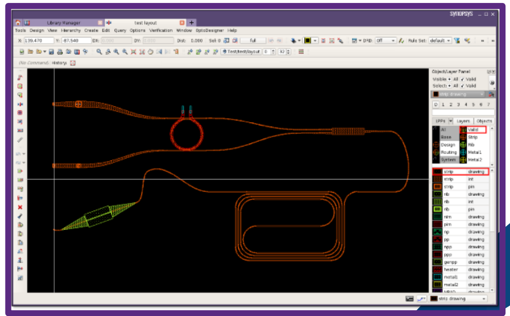
Multi-Platform PIC Design Ecosystem



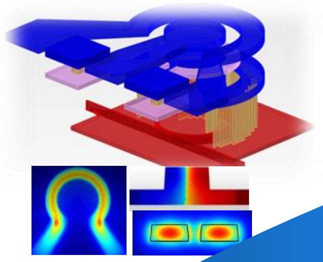
Synopsys OptoCompiler



Support available for other 3rd party layout tools

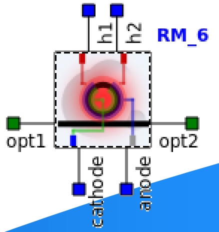
Photonic component layout

Lumerical FDTD/MODE/Multiphysics



Photonic Multiphysics simulations

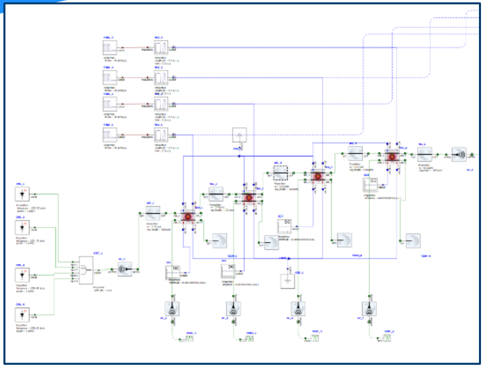
Lumerical CML Compiler

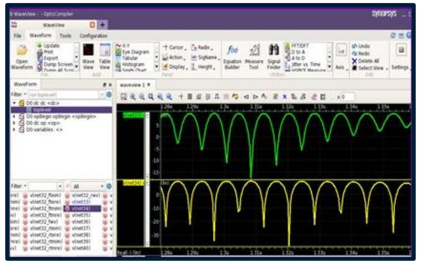


Photonic compact models

Interop with Foundry models

Schematic-driven flows for circuit designs



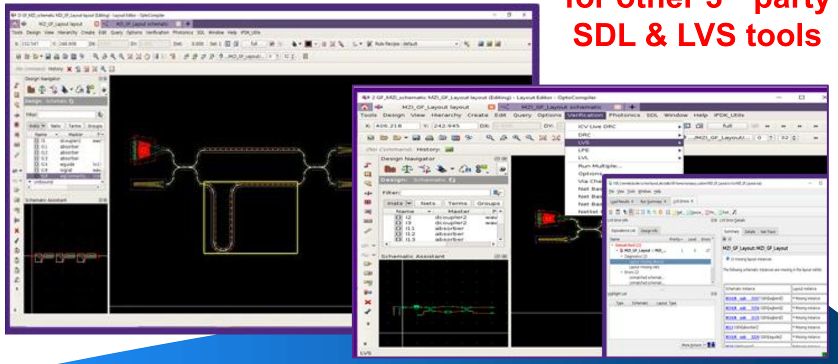


Synopsys PrimeWave

Lumerical INTERCONNECT/Verilog-A
Synopsys OptSim/ PrimeSim

Support available for other 3rd party circuit simulators

Synopsys OptoCompiler, IC Validator

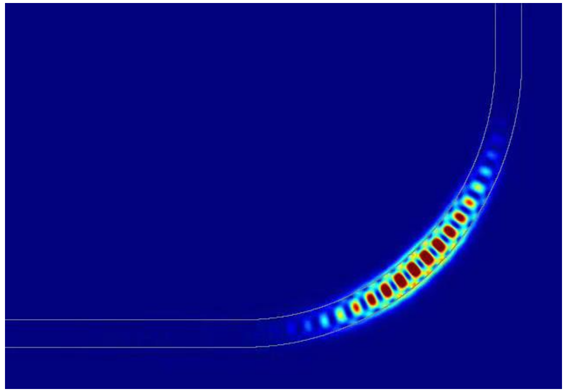


Support available for other 3rd party SDL & LVS tools

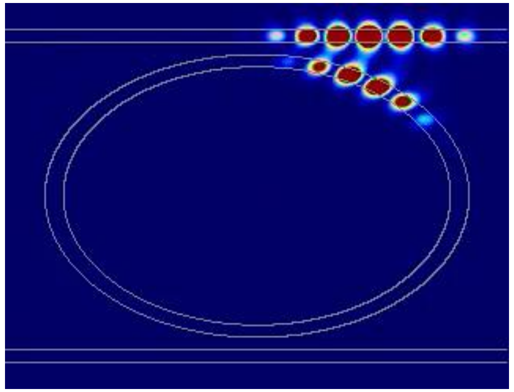
SDL & LVS

Photonic Integrated Circuits (PIC)

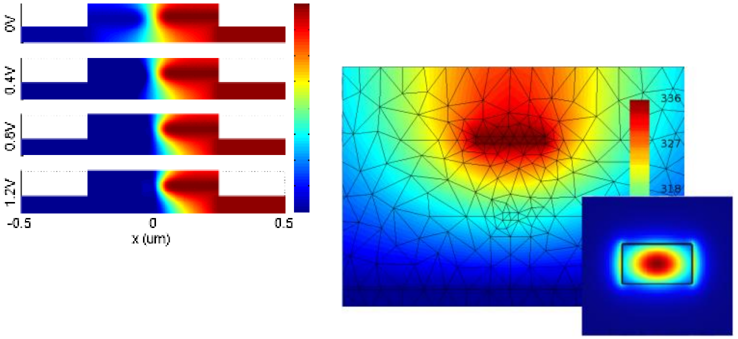
Waveguides



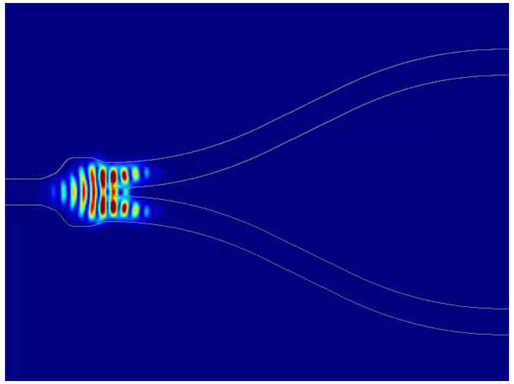
Ring resonators



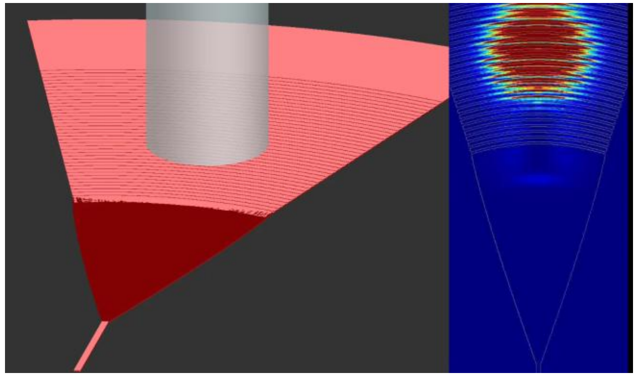
Electrical/thermal phase control



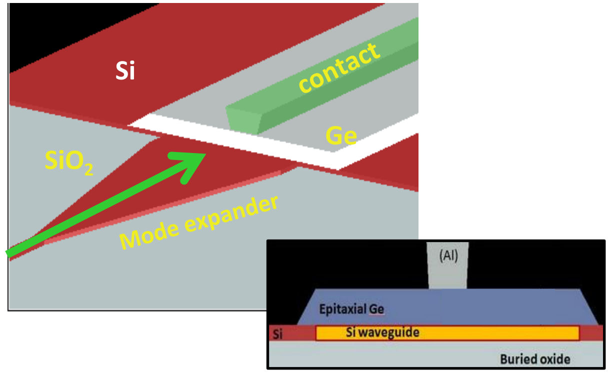
Waveguide coupling/splitting



Fiber-waveguide coupling



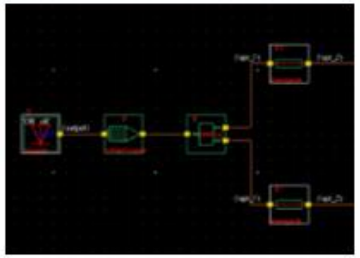
Photodetector



Synopsys OptoCompiler-Lumerical INTERCONNECT Interop for PIC Design and Simulation

Step 1

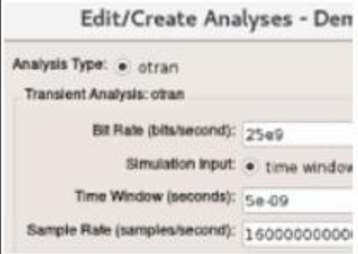
OptoCompiler



Load PDK with INTERCONNECT CML.
Design circuit schematic.

Step 2

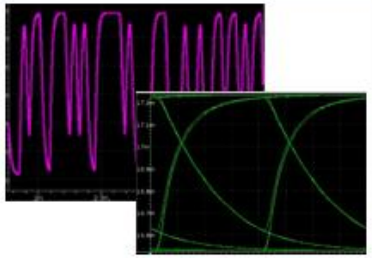
PrimeWave



Configure and launch INTERCONNECT simulation

Step 3

WaveView



View optical signal and photocurrent INTERCONNECT simulation results

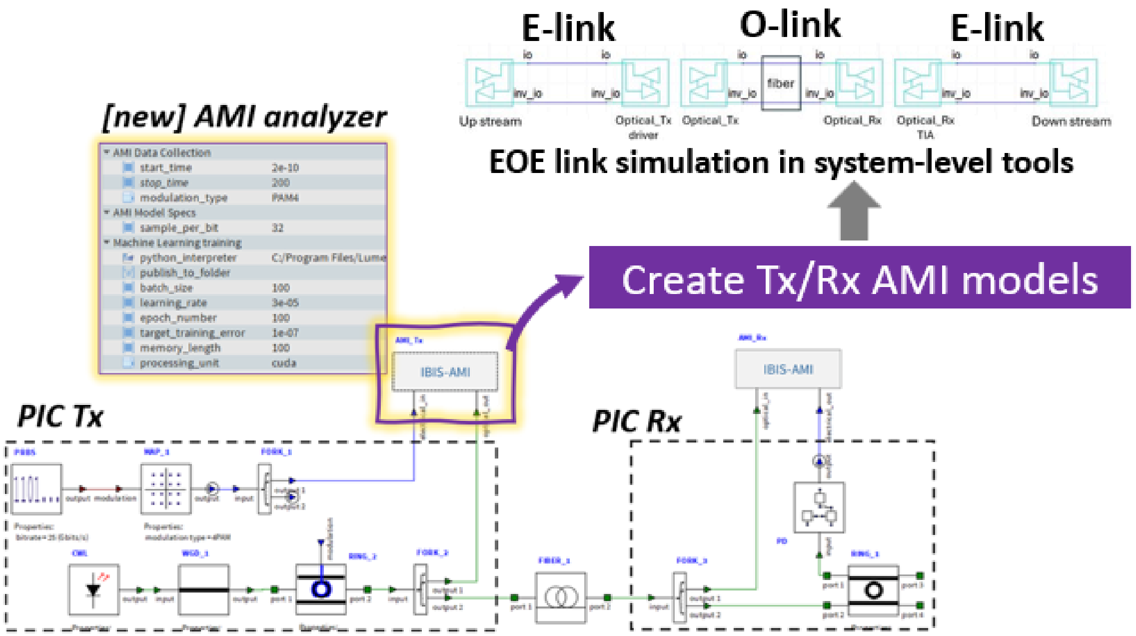
Synopsys OptoCompiler users now can select Lumerical INTERCONNECT solver as photonic circuit simulator in Synopsys PrimeWave

Photonic IC designers draw schematic in OptoCompiler and run INTERCONNECT time domain simulations based on INTERCONNECT Compact Model Library

Engineer • Simulate • Innovate

IBIS AMI models generated with Ansys Lumerical INTERCONNECT™

New solution for creating **IBIS AMI reduced order models** based on **machine learning**.



IBIS-AMI non-linear models as beta feature for 26 R1

- Excellent fitting between INTC sim and ROM
- First AI feature at Ansys Optics

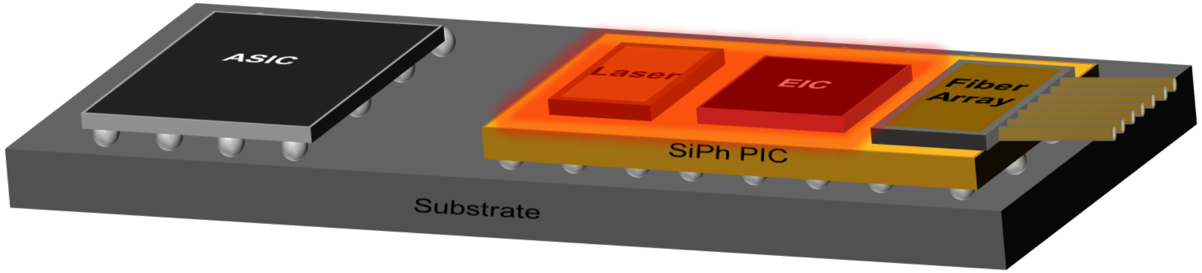
Model generation (INTC + CMLC licenses): Photonic Engineers use Lumerical INTERCONNECT to simulate PIC and extract simulation data, then create the IBIS-AMI models.

Model runtime (free of charge): System designers run Electro-Optic-Electrical (EOE) simulations in SerDes simulators, like Ansys AEDT circuit using the PIC IBIS-AMI models. They do Signal Integrity analysis of high-speed interfaces, and channel simulation to evaluate eye diagrams, BER and jitter.

Synopsys Multiphysics Solutions for CPO

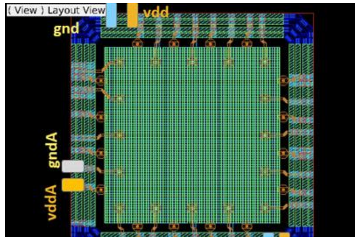
Thermal Management

RHSC / Totem / RHSC-ET / Icepak / Lumerical



ESD Analysis

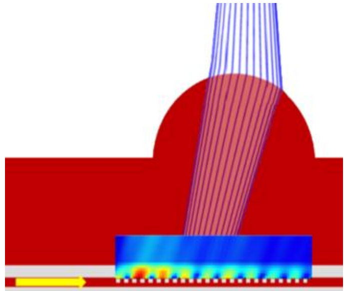
Pathfinder SC



Thermal Aware

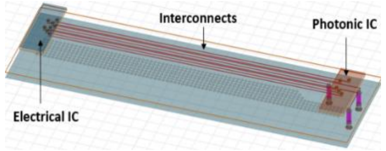
Optical Input/Output

Lumerical / Zemax



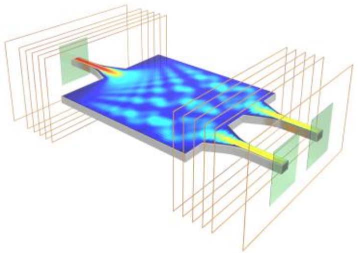
Signal Integrity

RaptorX / HFSS / Lumerical



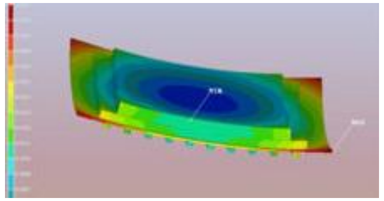
Photonic Components

Lumerical



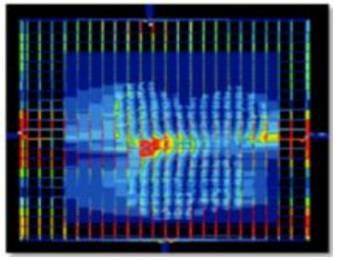
Structural Integrity

Mechanical / RHSC ET



EMIR

Totem / RHSC



Structural Aware

Thank You!

Questions!