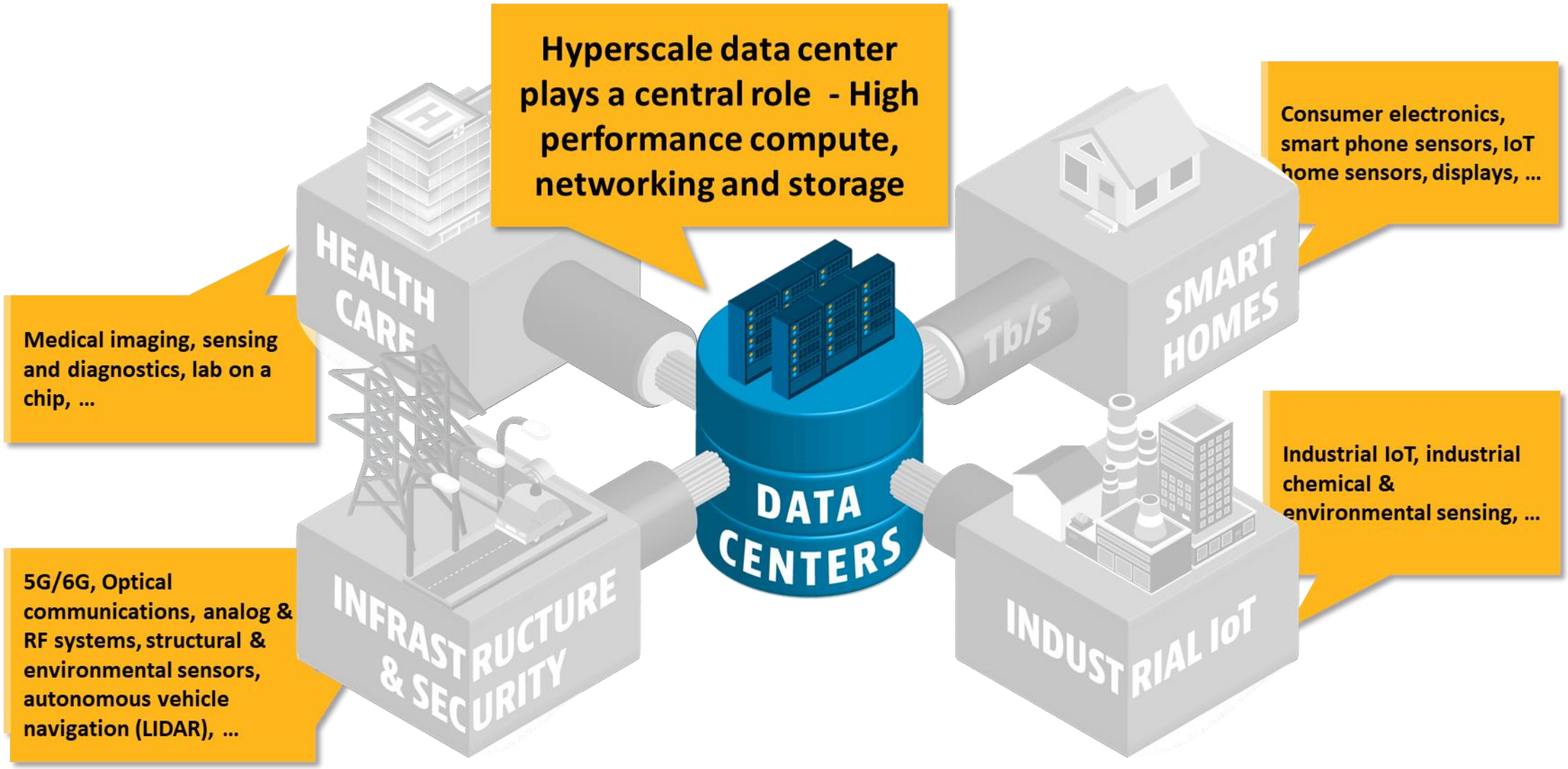
Empowering Future AI Compute with Co-Packaged Optics

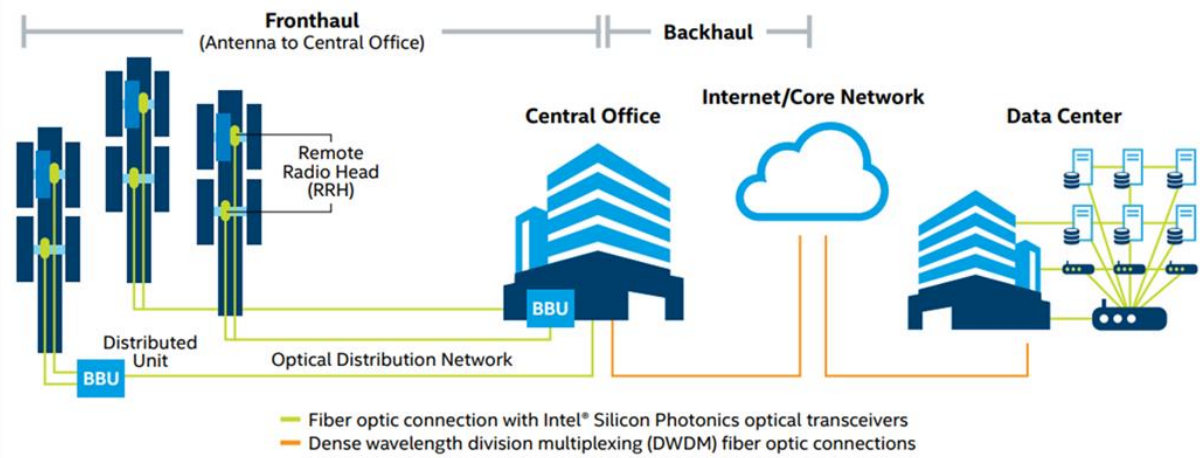
Shin-Sung Kim

Senior Manager Application Engineering

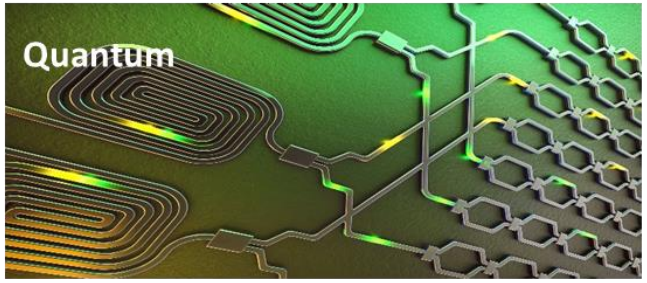
Data – Key Driver for Electronics, Semiconductors & Optics



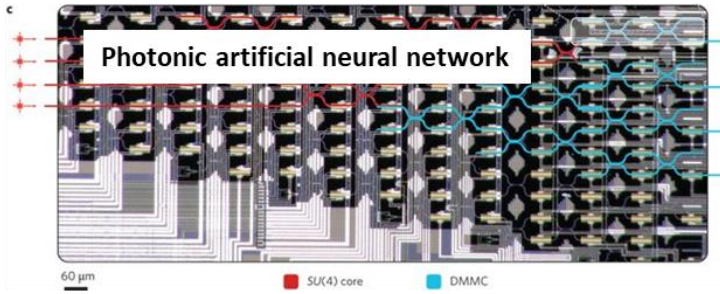
Photonics is a Key Enabler of 5G, Data Centers, AI and More



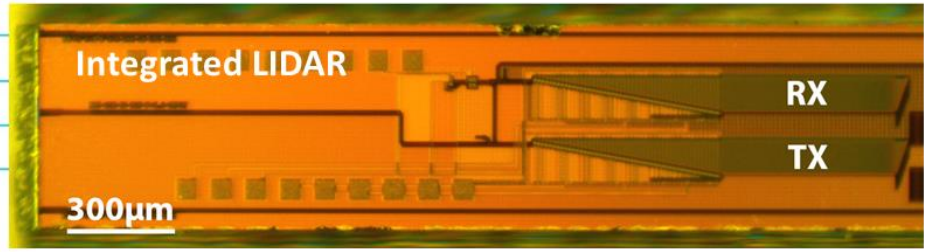
Source: "Exploring 5G Fronthaul Network Architecture Intelligence Splits & Connectivity" 5G Wireless Communications – Silicon Photonics, Intel



https://spectrum.ieee.org/tech-talk/computing/hardware/building-quantum-computers-with-photons
Image: Xiaogang Qiang/University of Bristol



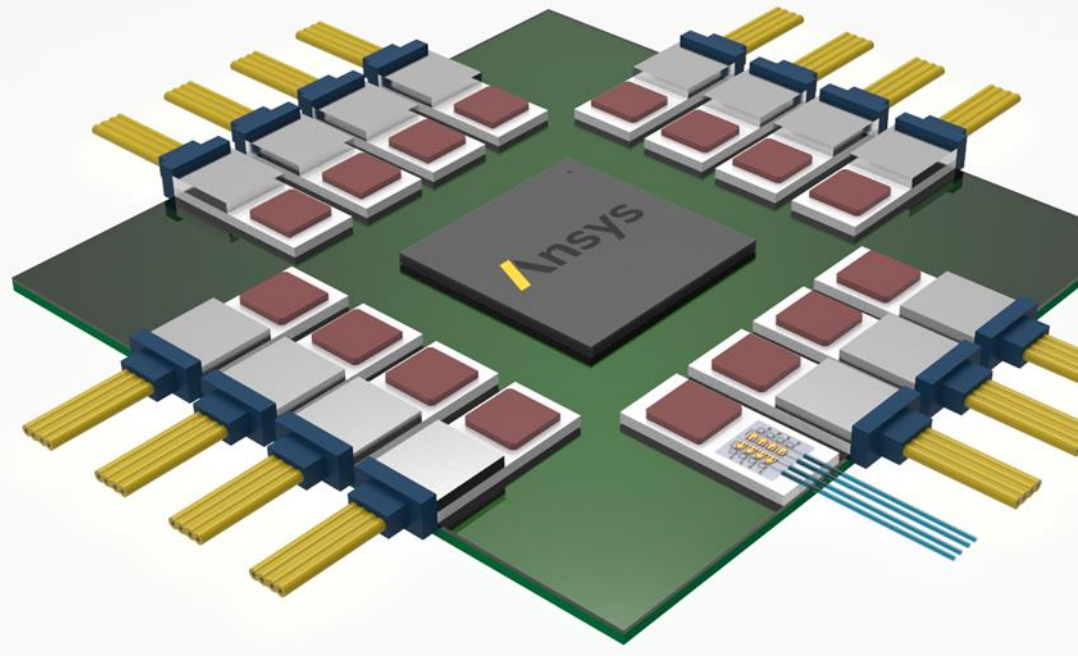
Y. Shen et al. Deep learning with coherent nanophotonic circuits, Nature Photonics, https://doi.org/10.1038/nphoton.2017.93



MIT and DARPA Pack Lidar Sensor Onto Single Chip
https://spectrum.ieee.org/tech-talk/semiconductors/optoelectronics/mit-lidar-on-a-chip
Image: Christopher V. Poulton

Why Co-Packaged Optics?

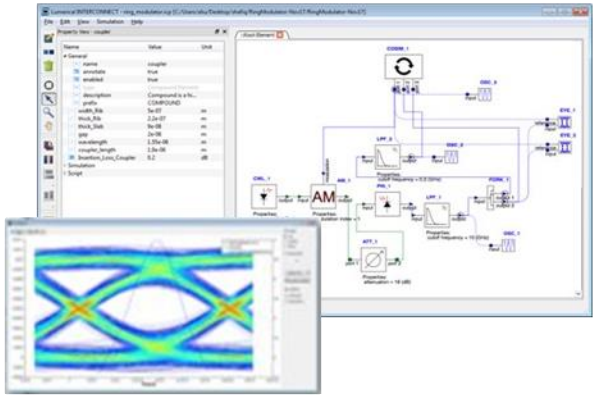
- Co-packaged optics (CPO) considered as a promising solution for data center interconnects
  - Increasing traffic at data center
  - Conventional pluggable optics facing challenges to keep pace
- Replace the electrical links with optical links, move the optical I/O closer to the ASIC and bring down the power and cost.
- Closer integration of photonic and electronic dies introduces new challenges such as heat transfer from one die to a neighboring die.



A Comprehensive Suite of Leading Photonic Design Tools

PHOTONIC INTEGRATED CIRCUIT SIMULATION

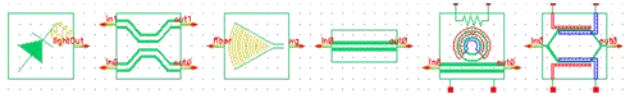
INTERCONNECT



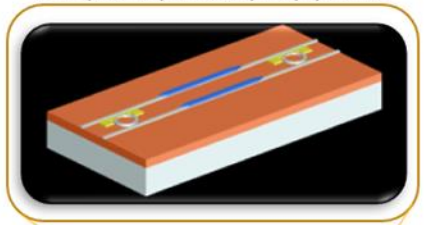
CML Compiler

INTERCONNECT compact models

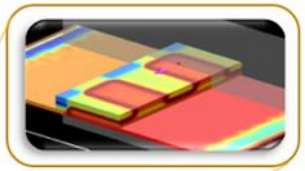
Photonic Verilog-A models (Cadence Spectre)



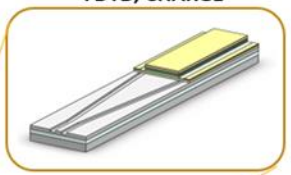
Laser
FDTD, MODE, CHARGE, MQW, TWLM



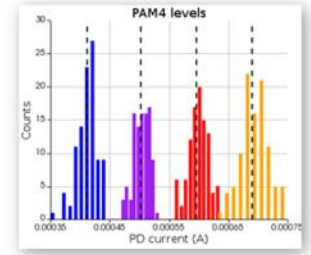
Electro-Optic Modulator
FDTD, MODE, CHARGE

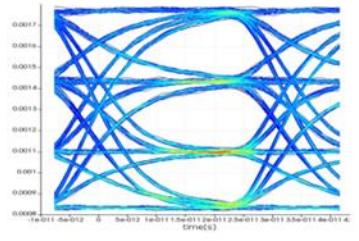


Photodetector
FDTD, CHARGE

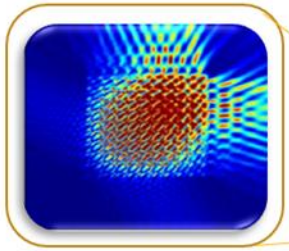


Communication Link
Characterization & Yield Analysis

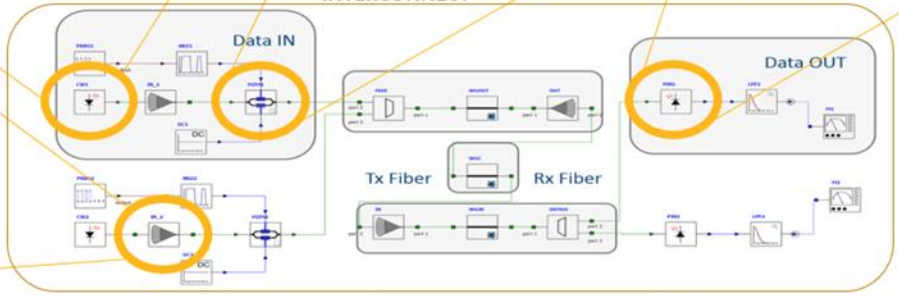




Grating Coupler
FDTD, MODE

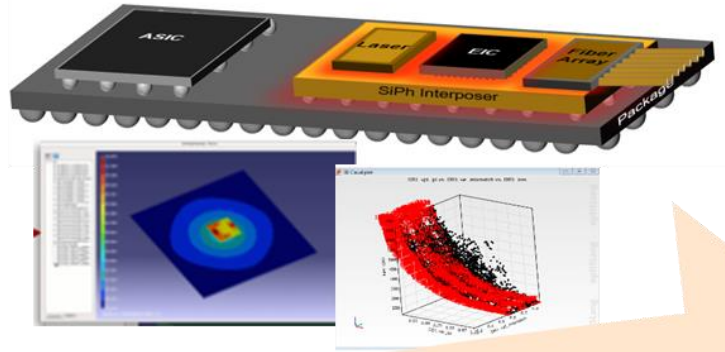


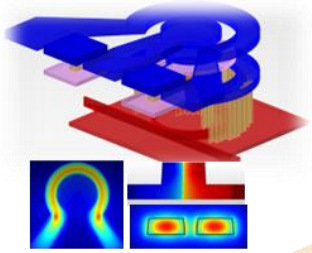
Transceiver
INTERCONNECT

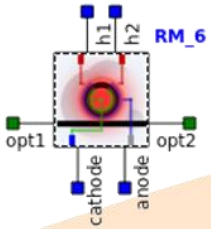


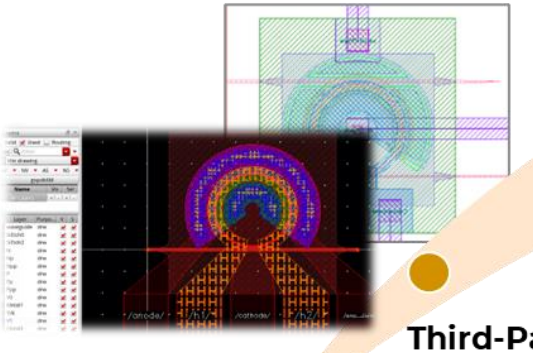
Open Ecosystem | Automation | Optimization | Cloud & HPC Acceleration | Foundry PDK Enablement

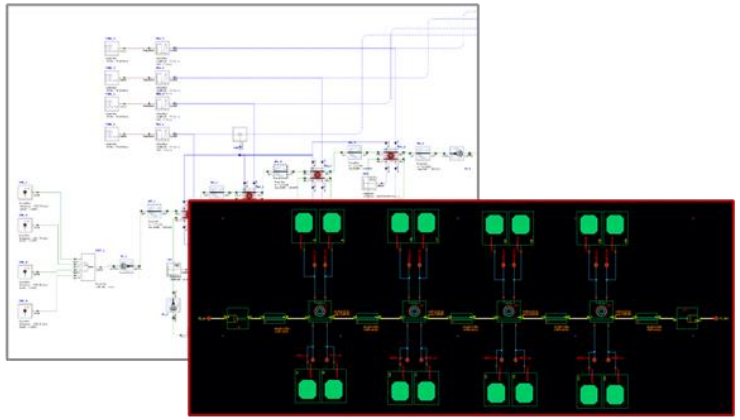
Ansys Comprehensive Solution











Multiphysics and Multi-scale Flows for Co-packaged Optics

Schematic-Driven Flows for Circuit Designs

Photonic Compact Model Generation

Photonic Multiphysics Simulations

Third-Party Photonic Component Layout Flow Solutions

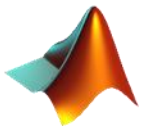
Multi-Platform Approach Combining Best-in-Class

Design Tools

Ansys / LUMERICAL

+ Optics: Zemax, Speos
+ Electronics: HFSS, …
+ Semiconductors: Redhawk-SC, …

cadence SIEMENS



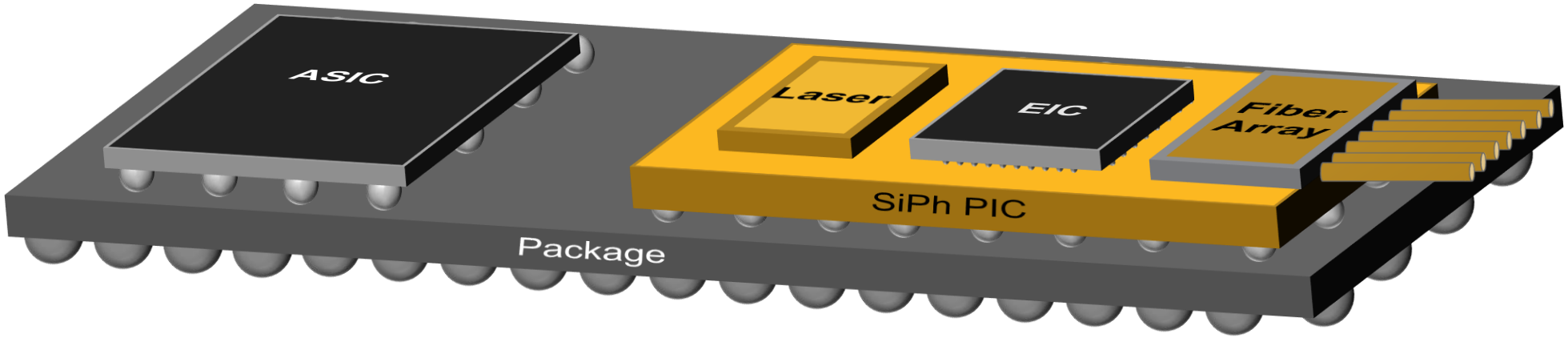
python™

Foundries

SOI wafers, fab equipment, test, assembly, and packaging, MPW service providers, design houses, IP, academic community …

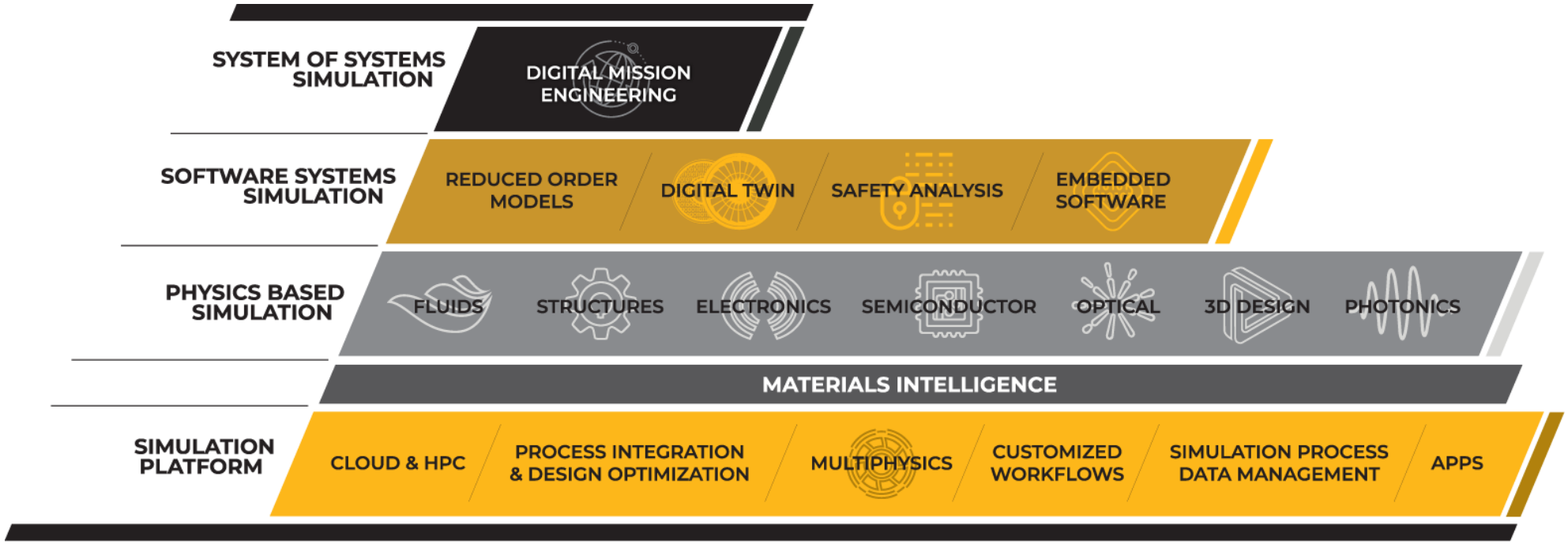
Co-Packaged Optics - Challenges

- Multi-physics and multi-scale problems
- A holistic workflow is desired to ensure their performance in the full package



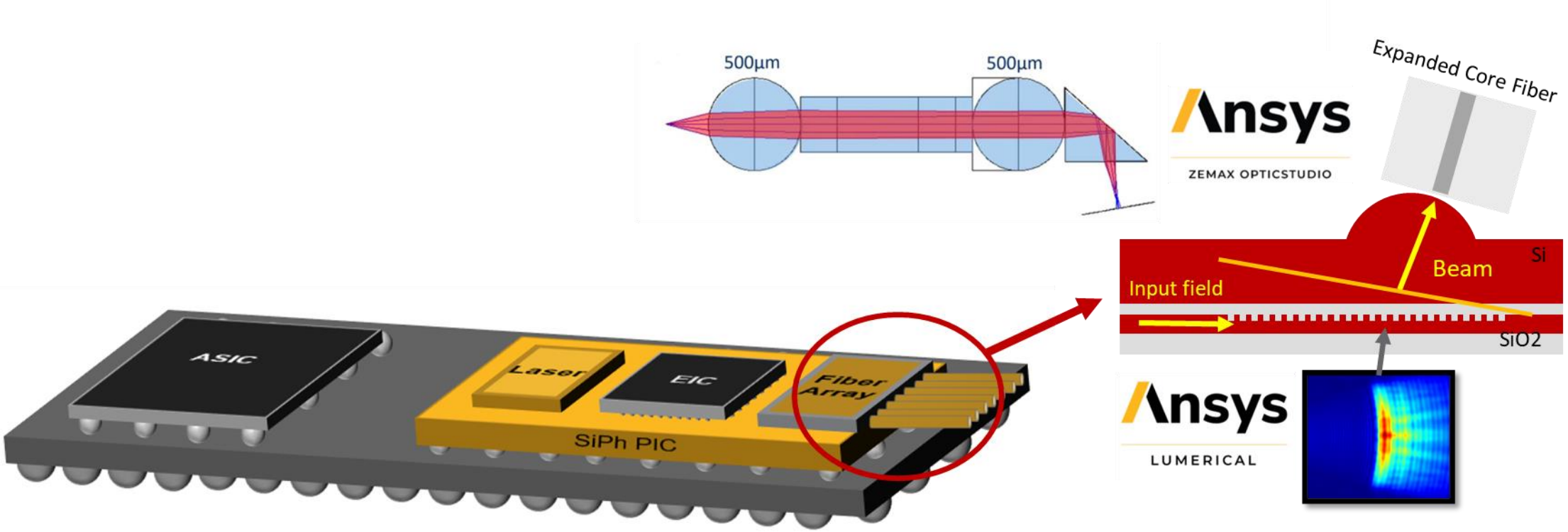
Modern Optical Product Design requires Multiphysics Simulation

- Customizable solutions is required. No single solution that fits all problems.
- Ansys provides Best-of-Breed simulation across all major physics.
- Ansys is a dedicated collaboration partner for the development and continuous improvement of leading-edge multi-physics and multi-scale workflows for optical/photonic components and systems.



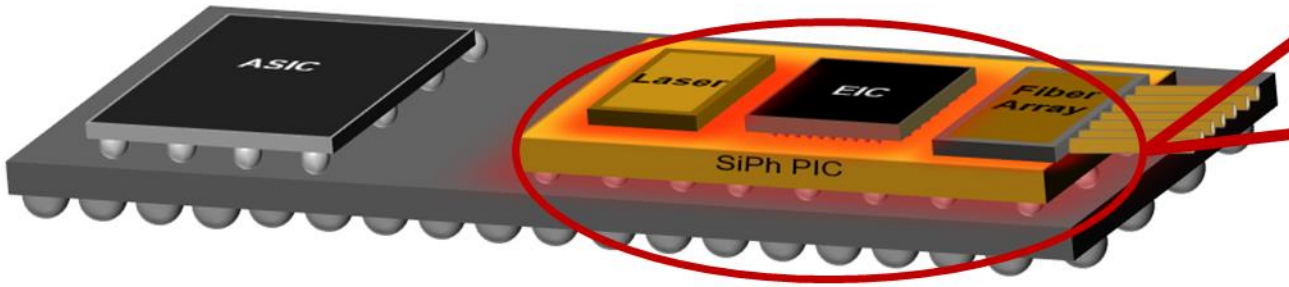
Optical I/O Coupler Simulation

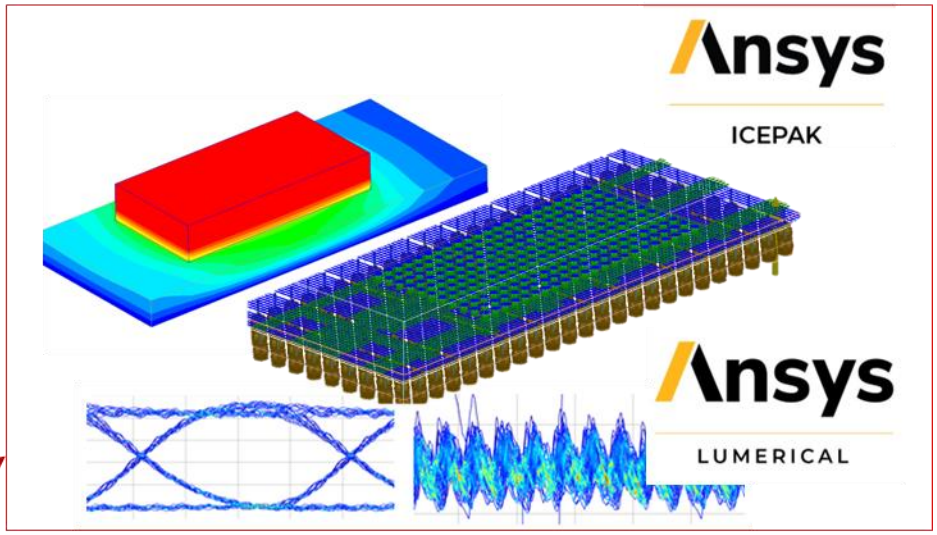
- Goal: Robust and efficient coupling of photonic components to optical fiber or another photonic components
- Ansys **Lumerical** and **Zemax** offer interoperability that enable engineers to accurately account for both nano-scale and macro-scale optical effects in their devices, using wave-optics and ray-tracing simulation tools.

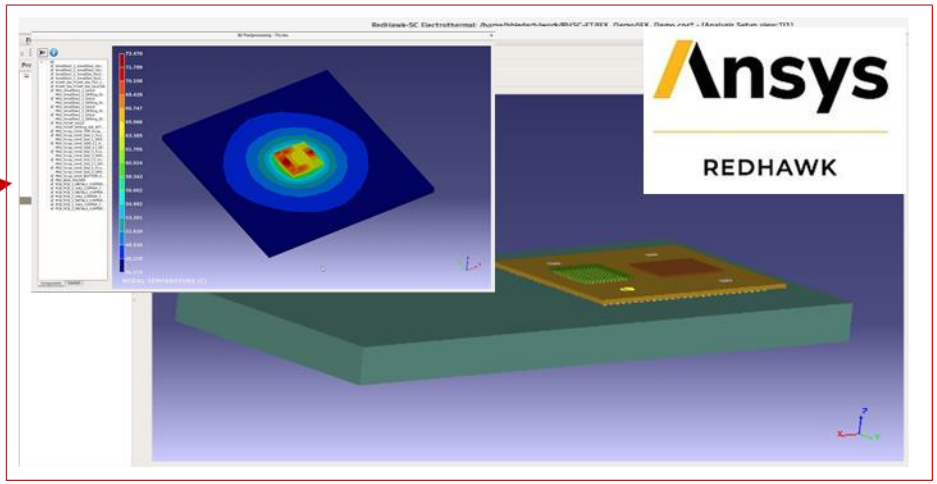


Thermal Analysis

- Proximity of photonic and electrical dies makes the thermal effects very important, especially as the size becomes smaller.
  - PIC components such as resonance of micro-ring is very sensitive to the temperature
  - Assessment and stabilization of PIC elements considering the heat coming from the rest of the system (for example EIC)
  - The performance of EIC and the overall 3D IC package can be also affected by the heat generated from the PIC
- Ansys **Icepak** and **RedHawk-SC Electrothermal** together with **Lumerical** for thermal analysis of 3D-IC designs including photonic integrated circuits.

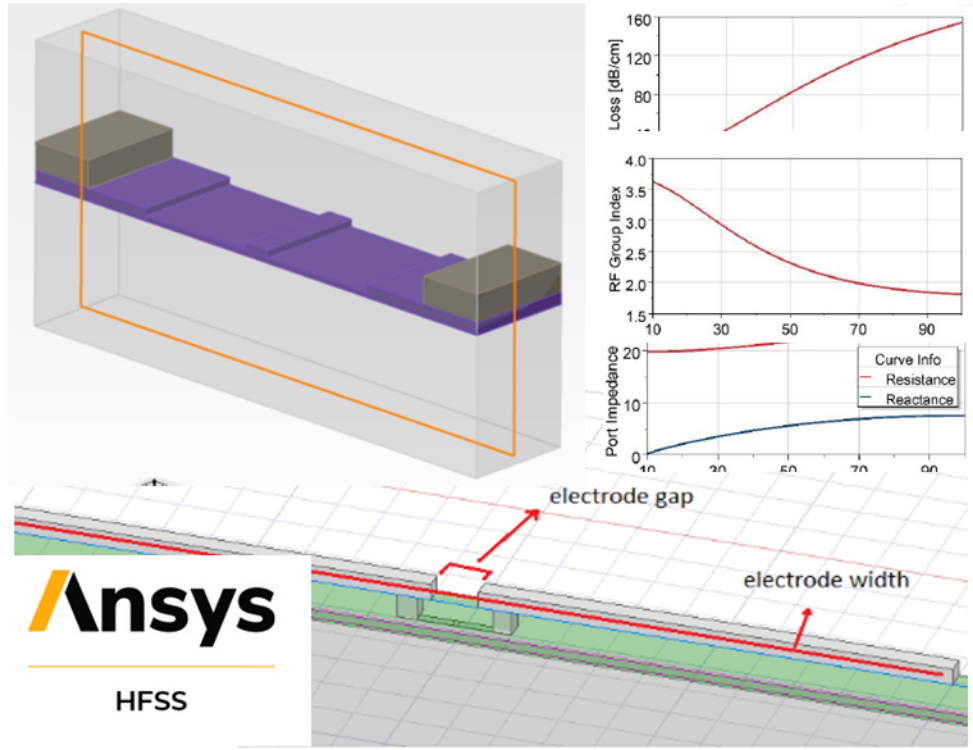


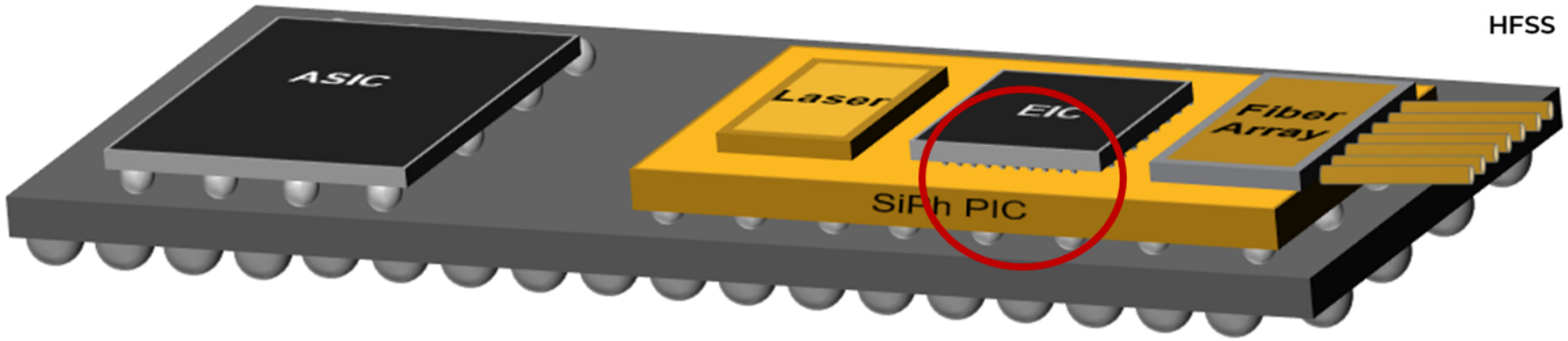




RF analysis

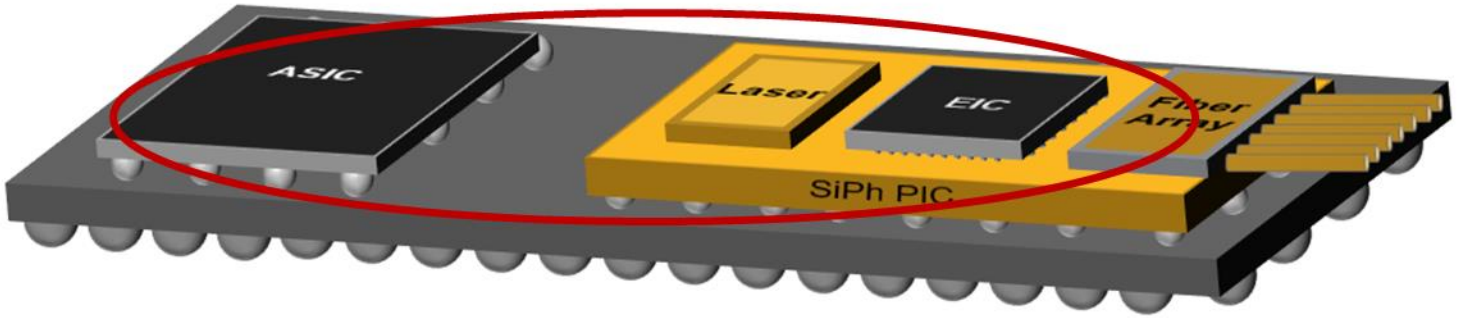
- The high-speed data transfer in CPO pushes the limits of the performance of RF connectors
- HFSS for RF connector design and S-parameter extraction
- S-parameters used in PIC simulation
- Ansys **Lumerical/HFSS** workflow provides a full picture of parasitic and loading effects
  - Minimize signal degradation
  - Optimize the overall functionality of the integrated circuit.

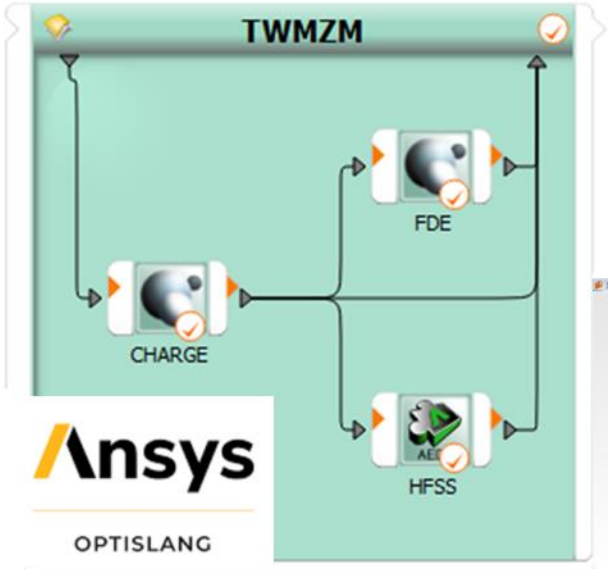


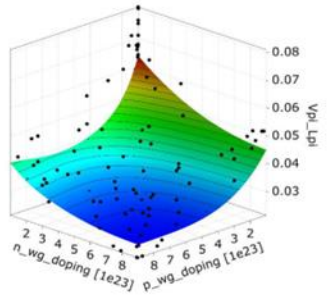


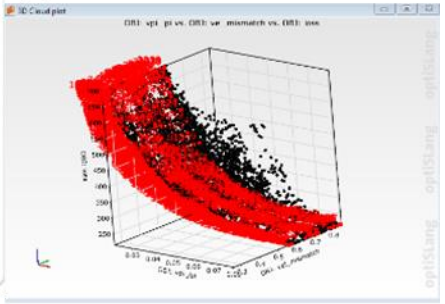
Optimization

- Mach-Zehnder modulator optimization requires multi-physics and multi-solver workflow.
- Ansys optiSLang:
  - Automated workflow
  - Integrates with other Ansys tools and third-party tools
  - State-of-the-art optimization algorithmss and sensitivity/robustness analysis









Key Takeaways

- Ansys Lumerical offers best-in-class solutions for PIC design through a multi-platform approach.
- Ansys Lumerical offers workflows with other Ansys tools for multiphysics and multi-scale simulations for advancing co-packaged optics.