Systems-on-chip in monolithically integrated silica-on-silicon platform

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Photonics West 2024, SPIE OPTO

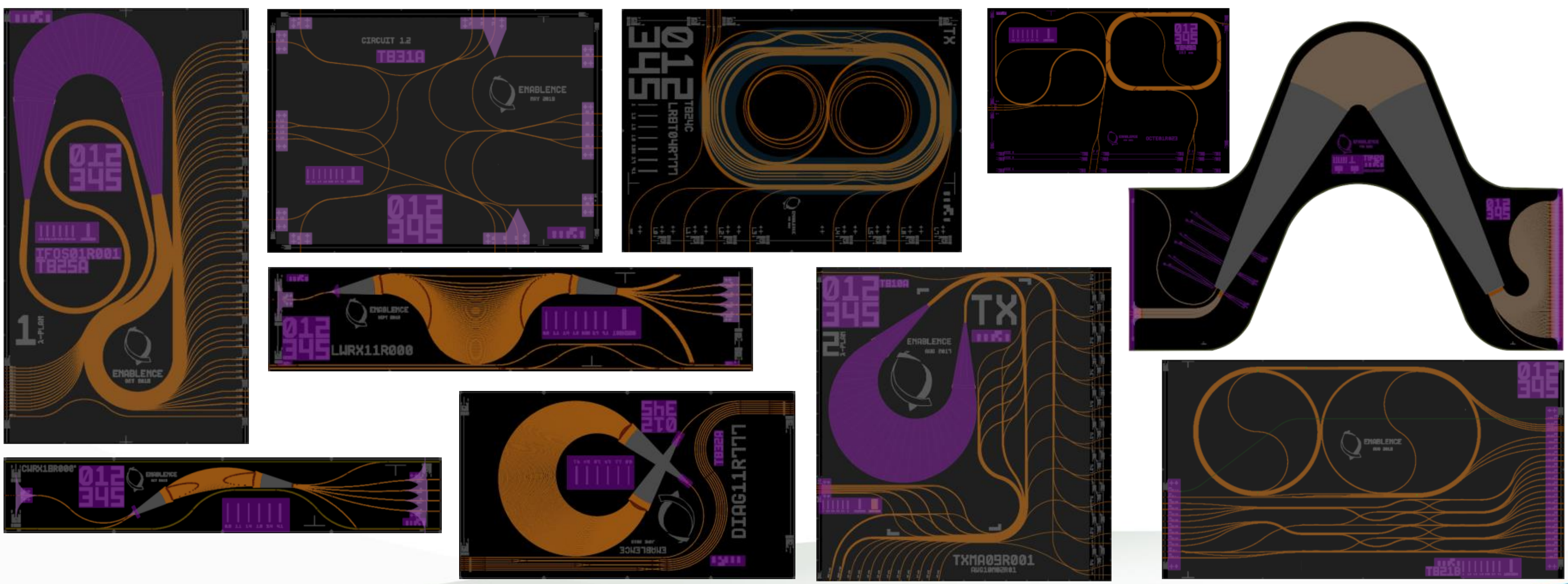
January 30, 2024

Room 304 • 11:35 AM – 11:55 AM

Introduction

PLC Technology

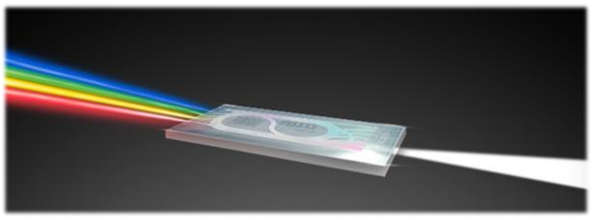
- Integrated photonics has emerged as a key technology to enable advancements in optical computing, high-speed communication, and advanced vision systems.
- Photonic integrated circuits possess high optical performance and are well suited for both monolithic and hybrid integration in a compact form factor, low cost and excellent reliability.

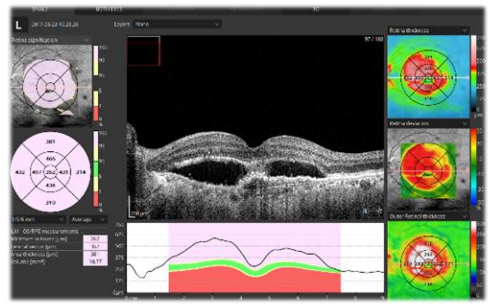


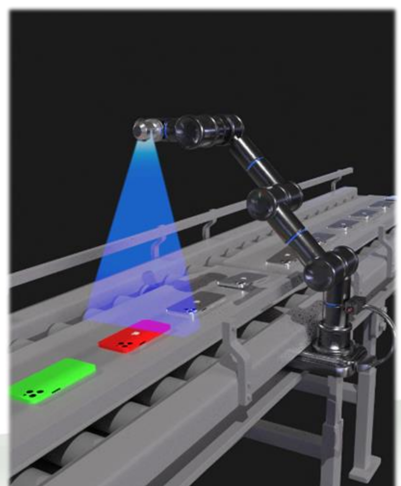
Introduction

Silica-on-silicon PLC platform

- A versatile and low-cost platform with powerful characteristics.
- Widespread applications, including high-speed communication, medical imaging, autonomous driving, environmental sensing, and optical computing.



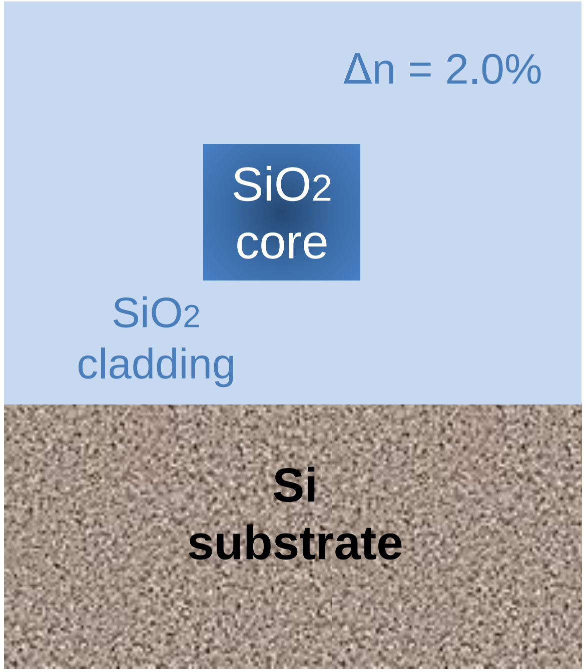




Our PLC Platform

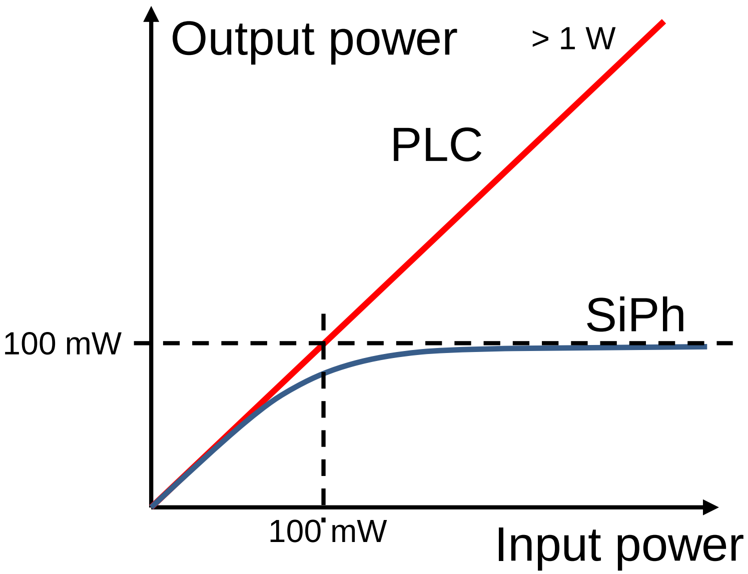
Silica-on-silicon

- Buried silica-based waveguides with a Δn = 2.0% refractive index contrast and typical waveguide dimensions of 3 × 3 µm.
- Fabricated using atmospheric pressure chemical-vapor deposition (APCVD) and reactive ion etching.
- We offer our fabrication services for external clients for rapid prototyping and cost-effective custom solutions.
- Typical performance characteristics:
  - Low waveguide propagation losses (< 1 dB/m)
  - Efficient fiber-to-waveguide coupling (~0.5 dB per facet)
  - Temperature-stable optical performance (< 10 pm/°C)
  - Polarization-invariant waveguides with zero birefringence



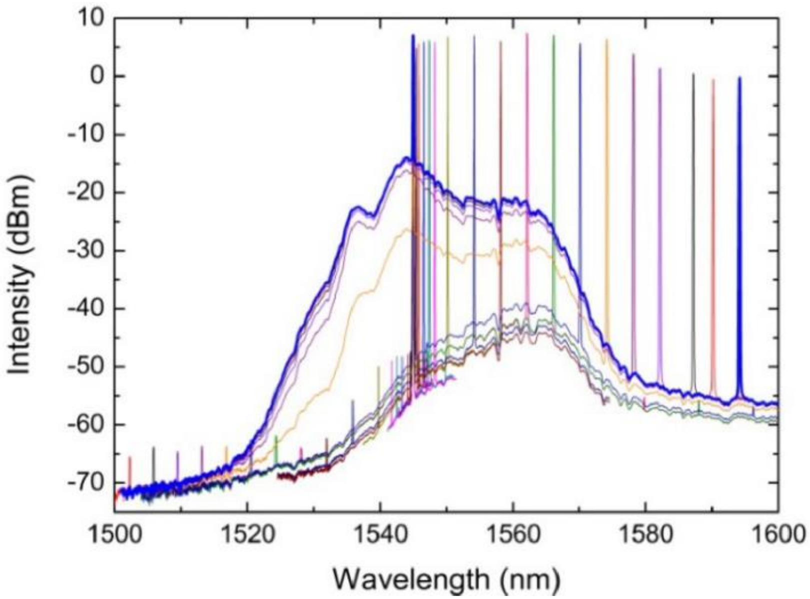
Maximum power and non-linearities

Two-photon absorption



In silicon photonics, two-photon absorption limits the amount of optical power that can be guided through standard single mode silicon waveguides to about 100 mW.

Optical non-linear effects in SiN

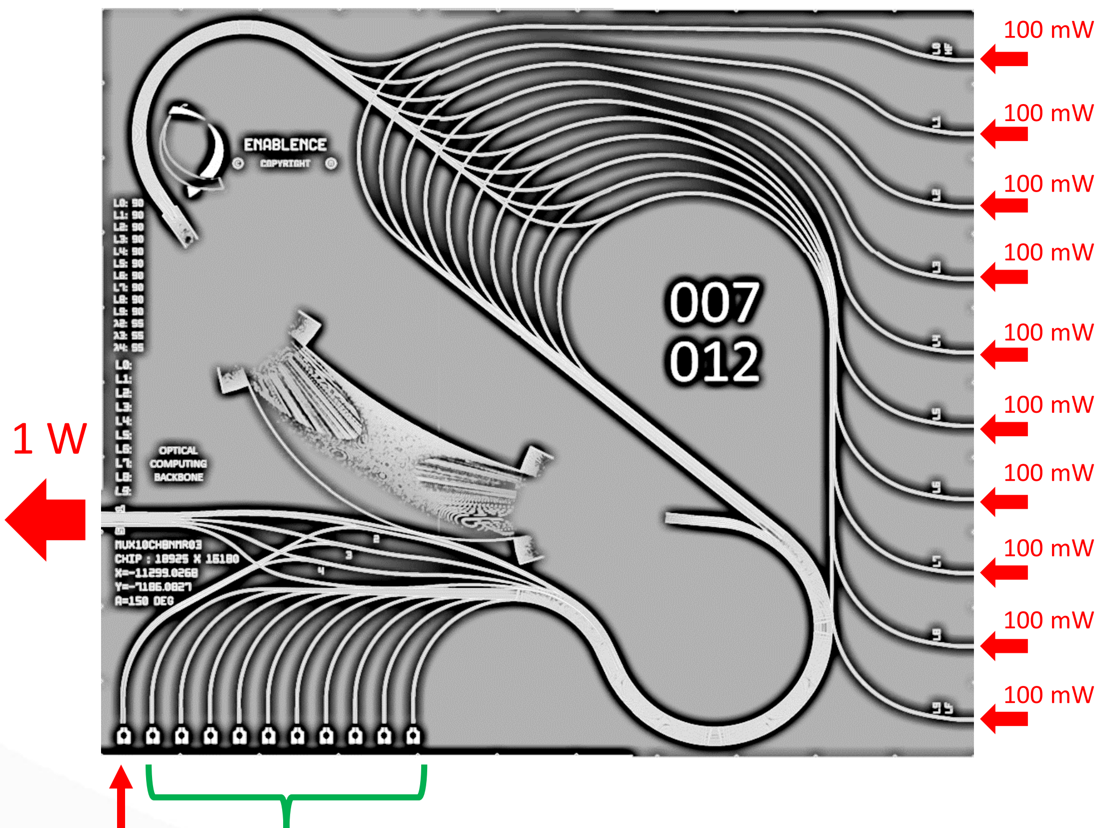


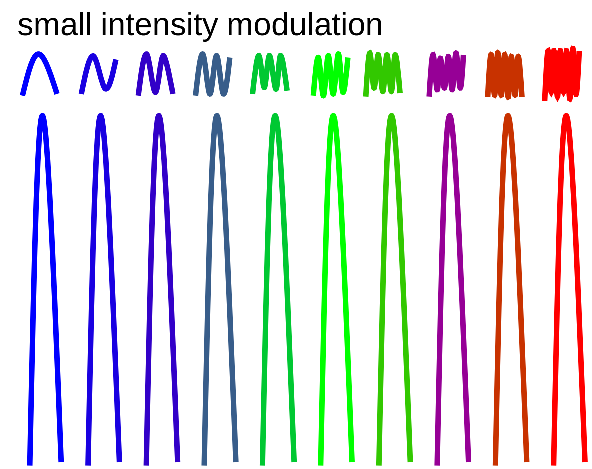
Non-linear effects in SiN waveguides enable a wide range of applications: wavelength conversion, super-continuum generation, frequency comb generation

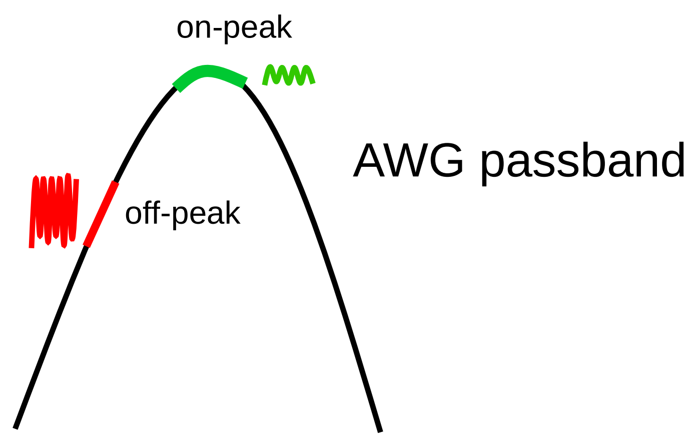
PLCs do not have two-photon absorption or significant optical non-linearities making them well suited for high-power applications such as LiDAR, optical computing, and high-dynamic range microwave links.

Linghua Wang, Weiqiang Xie, Dries Van Thourhout, Yazhen Zhang, Hui Yu, Shaohao Wang, "Nonlinear silicon nitride waveguides based on a PECVD deposition platform," Opt. Express 26, 9645-9654 (2018)

Backbone for optical computing





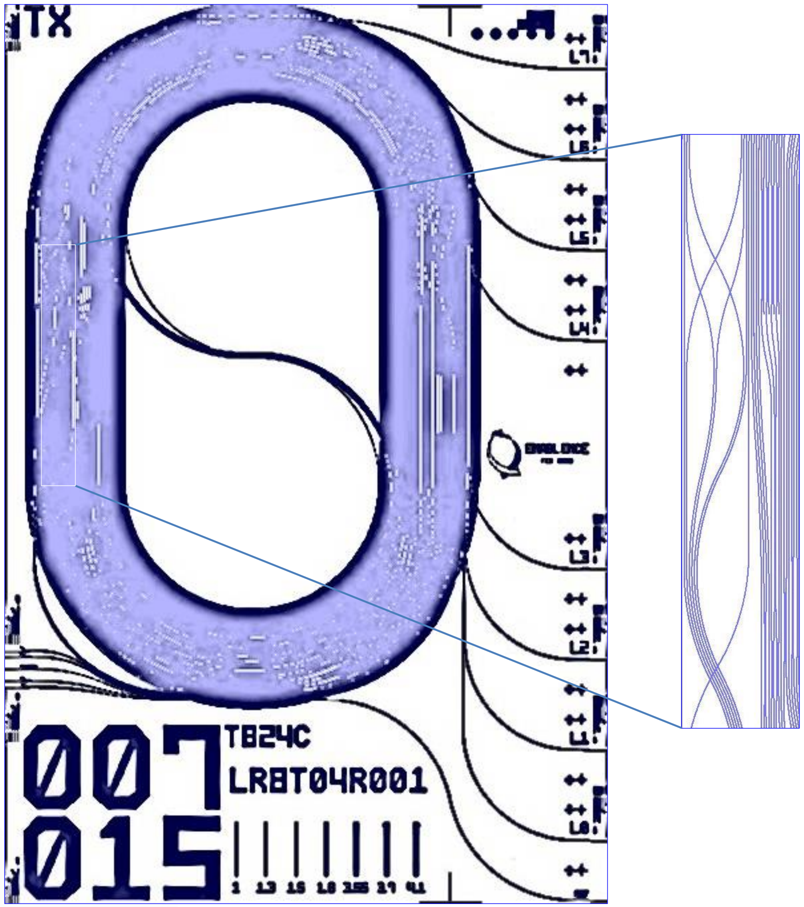


PD_1 … PD_{10} ⇦ Direct measurement of individual LD power

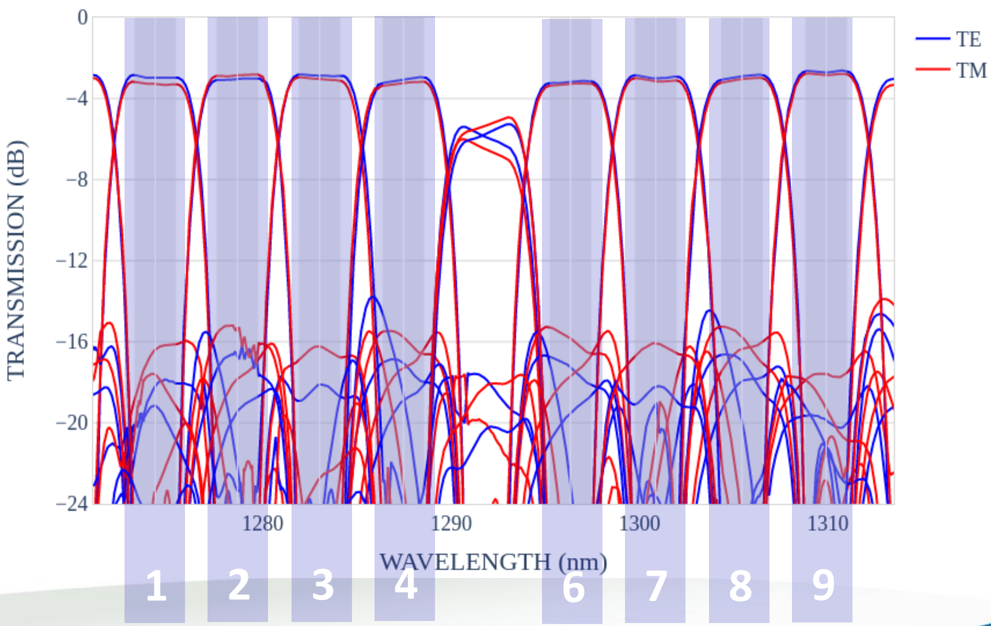
PD_λ ⇦ Inferred wavelength detuning of individual LDs

Ultra-dense architectures

8-channel LAN-WDM multiplexer



- Total device footprint: 0.38 cm^2
- On-chip loss estimated at 0.3 - 0.5 dB
- 1 dB bandwidth of 3.5 nm (80% of the channel pitch)
- Polarization-independent operation across the O-band (polarization dependent loss < 0.2 dB)



Machine-driven design

Progressive abstraction of complexity

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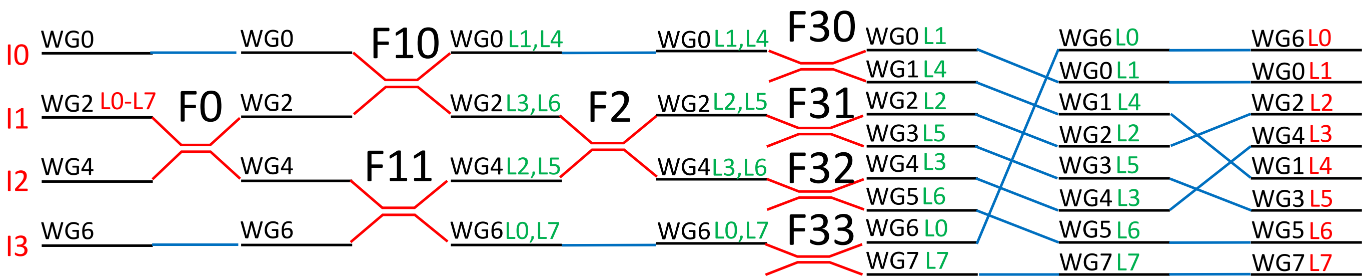
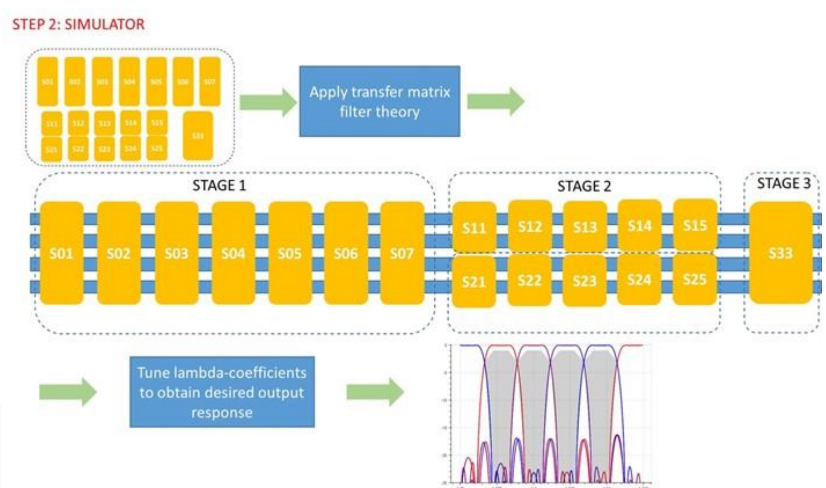
STEP 1: Simplified functional view



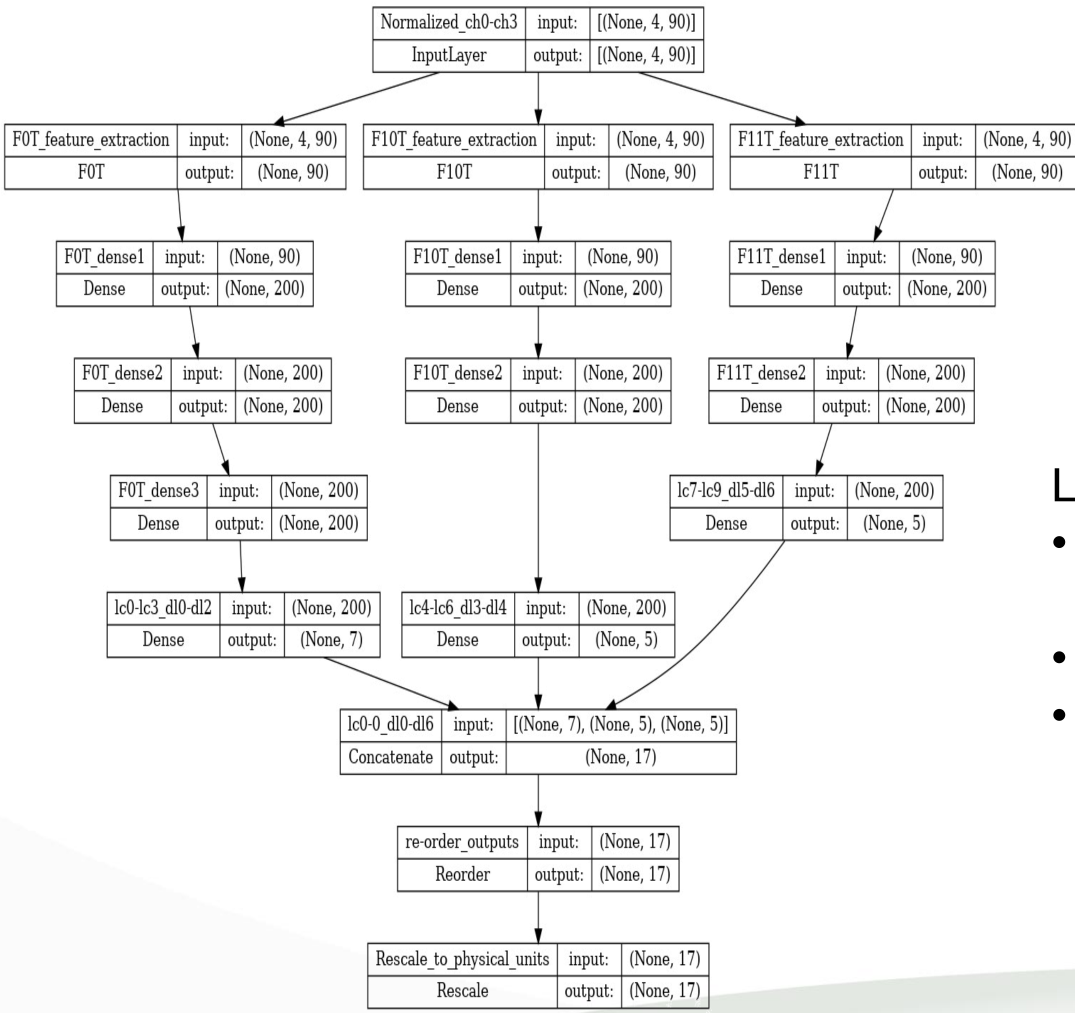
STEP 2: Expanded physical / simulation diagrams



STEP 3: Automated transformer from diagrams to physical layout

ML-driven design

Building custom models



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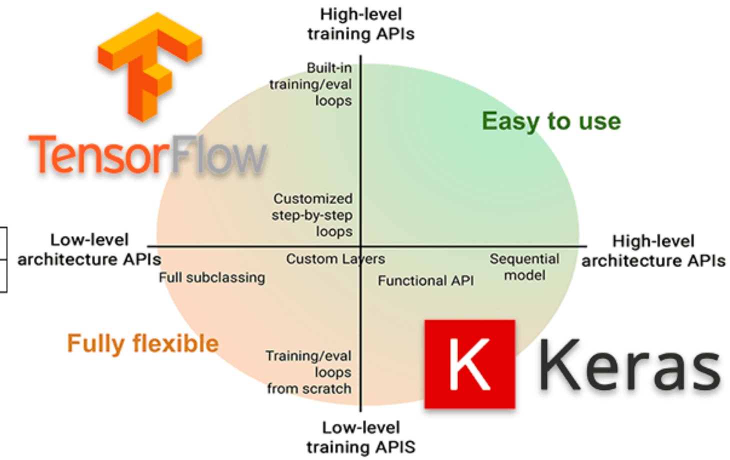


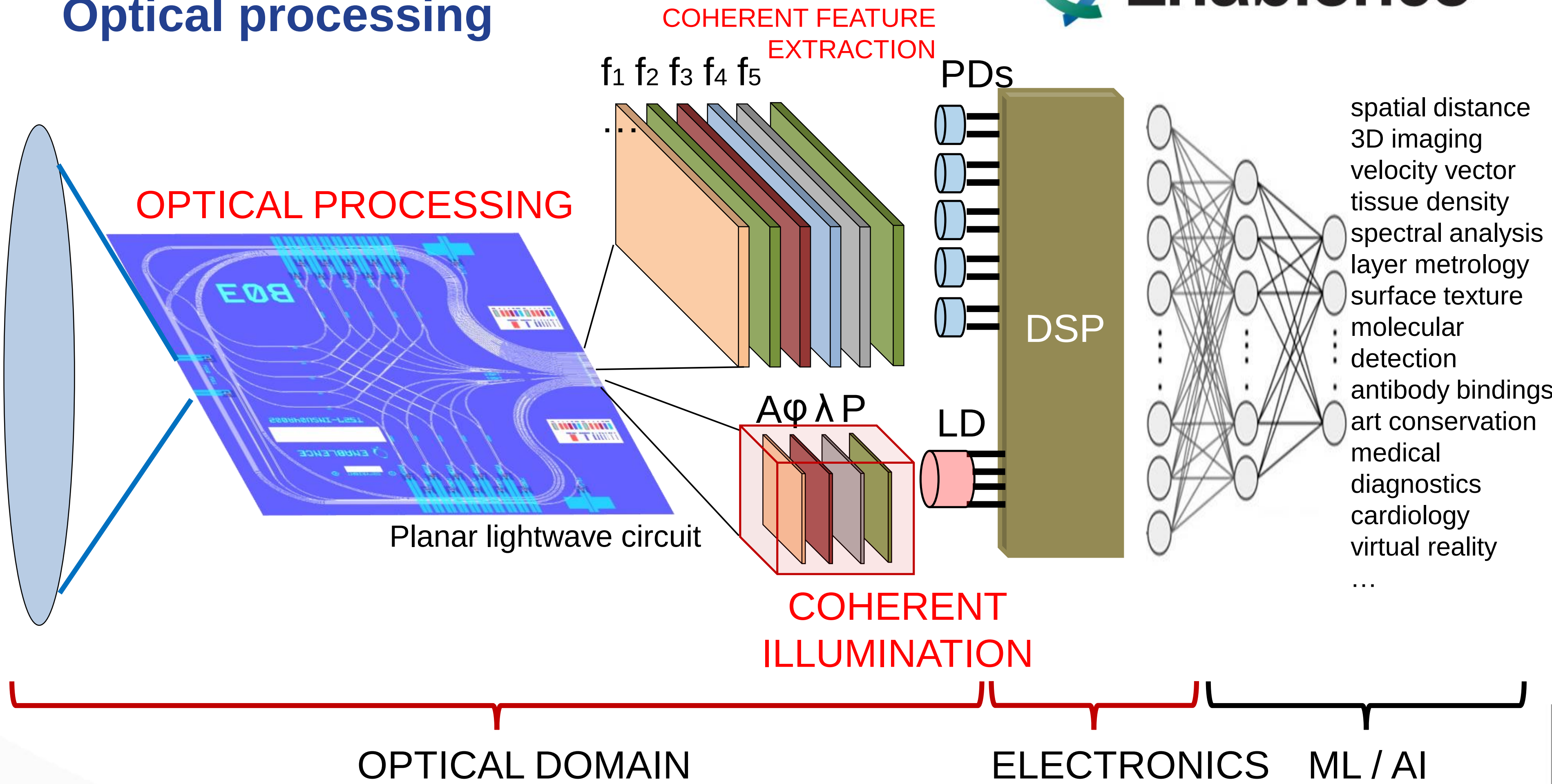
Leveraging ML technologies:

- Adopt Keras API for arbitrary advanced workflows
- Build on top of TensorFlow 2
- Deploy on AWS

amazon web services

Advanced vision

Optical processing



Advanced vision systems use coherent illumination and perform optical processing BEFORE the signal is detected electrically. Rich palette of optical features feed deep ML/AI models to enable a wide range of advanced vision applications

PLCs in Production

Challenges in high volumes

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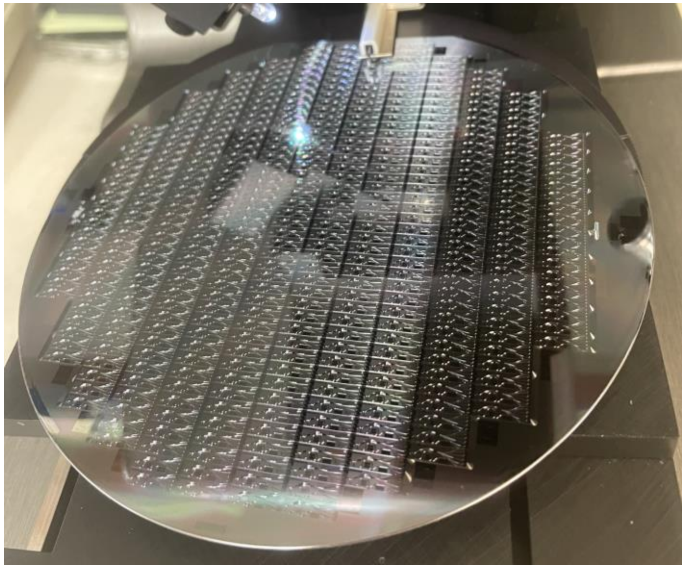
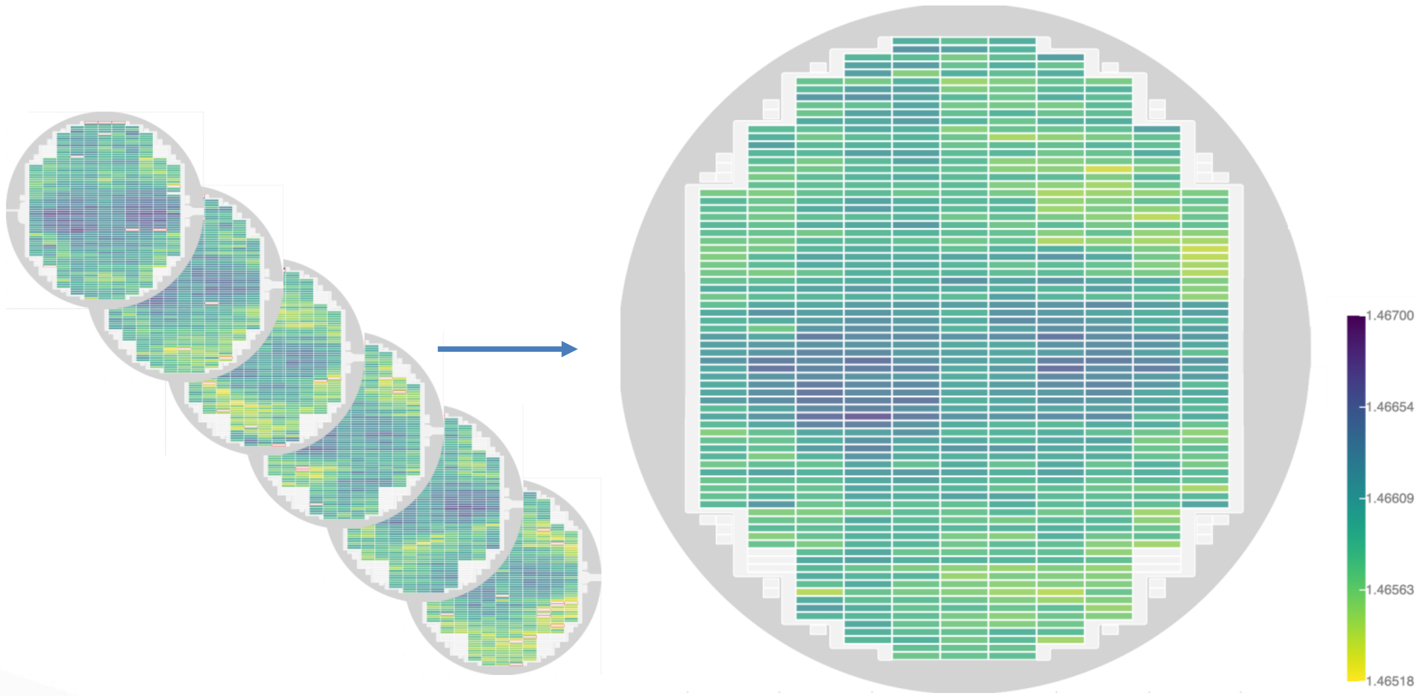
- To achieve high-performing devices, we rely on advanced data analysis that is tightly coupled to our design and fabrication.
- We use machine learning (ML) algorithms to scale the capabilities of the silica-on-silicon PLC platform to high-volume manufacturing, where reproducible performance is critical to the adoption of integrated optics solutions.
- Two challenges to achieving homogeneous performance:
    1. Systematic variability within a wafer
    2. Variations between fabricated wafers



Design optimizations

The challenge of process uniformity

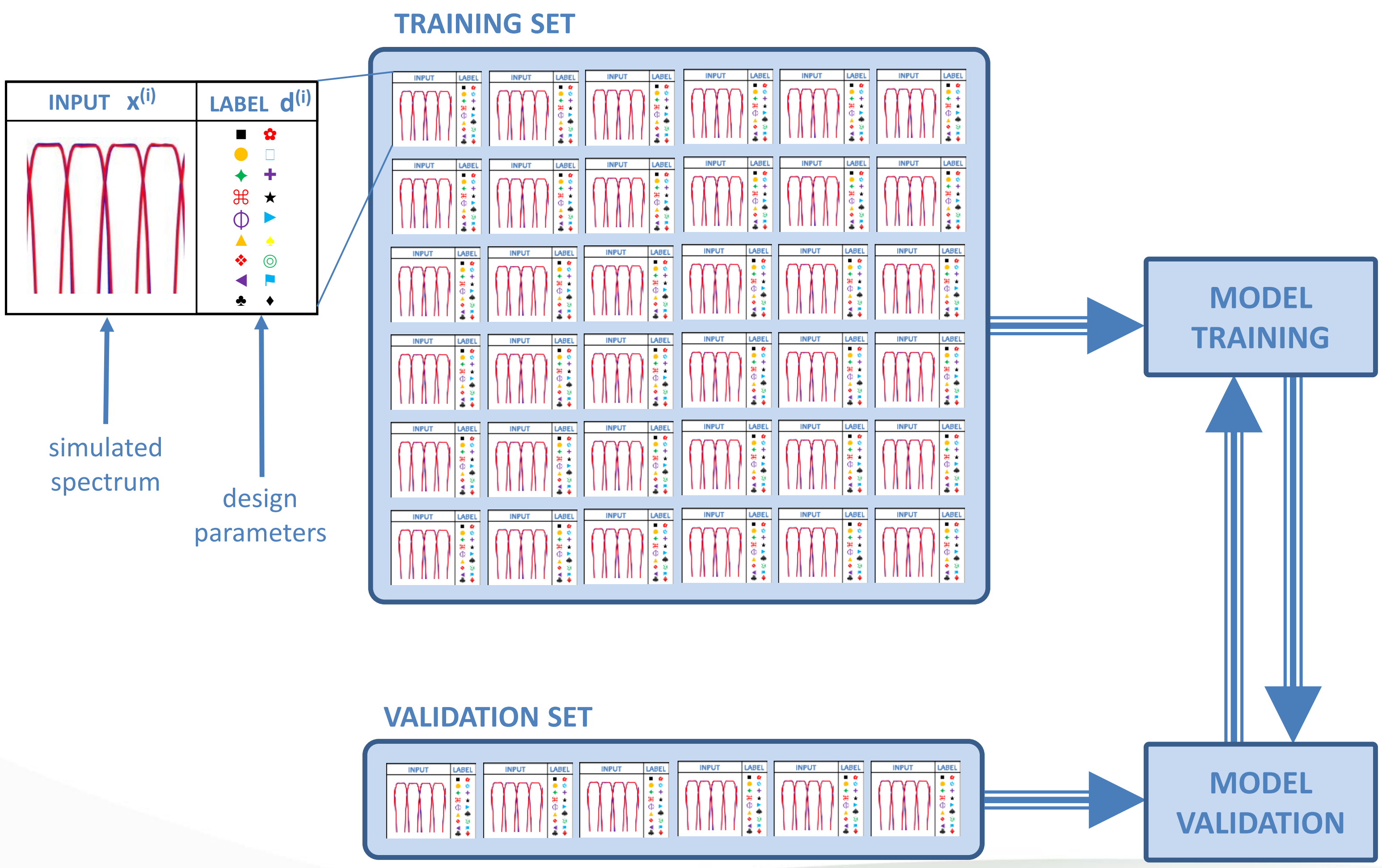
- Process uniformity and consistency is critical in the manufacturing of photonic chips.
- Traditionally, standard statistical methods are used to compensate for systematic process non-uniformities:



systematic index variation

Design Optimizations

Adjustments of design parameters through ML



Design Optimizations
Adjustments of design parameters through ML

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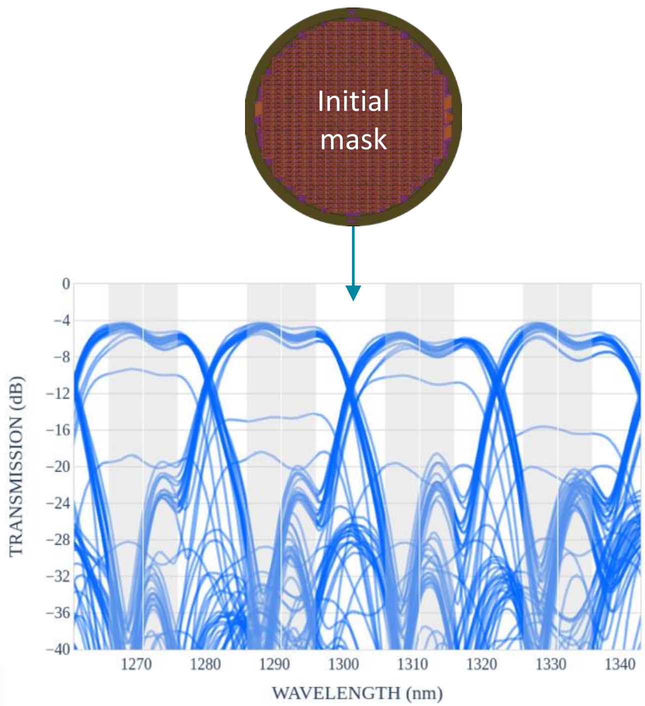
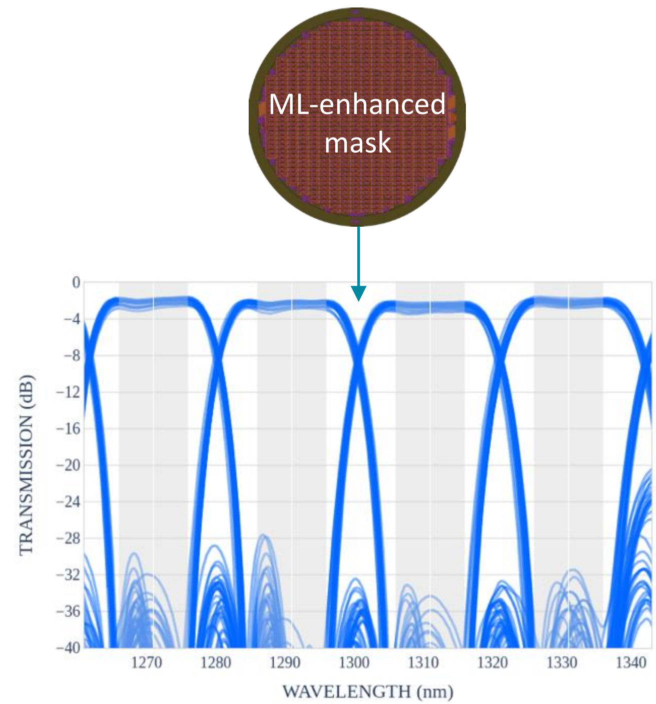
- To validate the approach, we applied it to a production mask with 600 devices:
  - We used the model predictions to insert corrections into each of the chips on the mask, thereby producing a ML-enhanced version of the production mask.



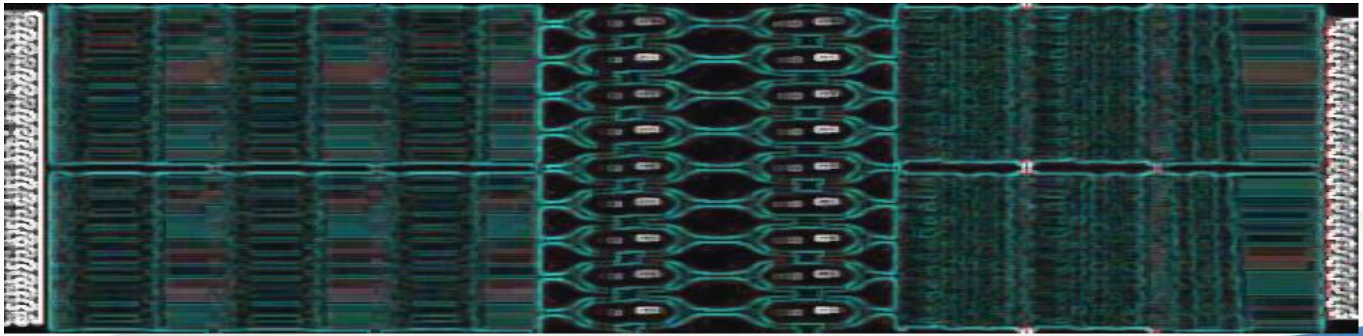
20 worst performing chips in the initial version of the mask.



The same 20 chips in the ML-enhanced version of the mask.

Conclusions

- We described how silica-on-silicon platform is ideally suited for creating systems-on-chip for applications in optical computing and advanced vision.
- We demonstrate how the use of AI/ML revolutionized the way photonic integrated circuits are designed and fabricated in a high-volume environment:
  - The automated layout transformers overcome the complexity of design and physical layer layout enabling novel architectures.
  - Deep neural network multivariate regression models optimize the individual design parameters of hundreds of devices on a mask.
- These approaches combine the strengths of the PLC platfrom with the power of ML to the creation of systems-on-chip and increase the scale and reach of the photonics industry.



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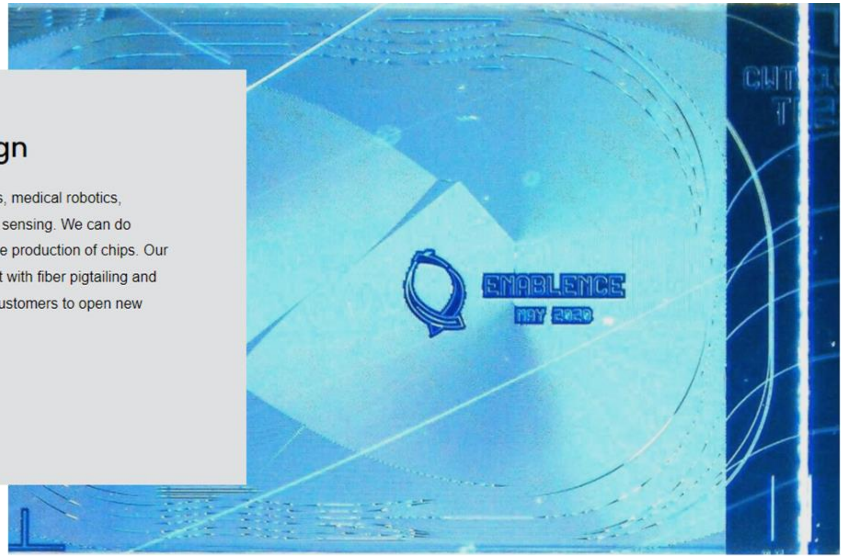

Custom Optical Design

We have built systems-on-a-chip for avionics, medical robotics, automotive LIDAR, 3D mapping, and optical sensing. We can do commercial-grade prototyping or high-volume production of chips. Our mechanical design engineers can also assist with fiber pigtailing and packaging. Through PLC, we can help our customers to open new market opportunities.

Inquire

Fab Services

For clients who wish to implement their own PLC designs, we offer services through our own silica-on-silicon PLC fabrication facility. The client can provide their own photomask, or digital mask data (GDS format). We are known for a quick turnaround from our well-equipped fab.

Inquire

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