Enabling high-volume production of photonics chips

with

machine learning

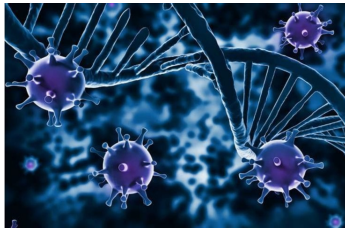
Ksenia Yadav

Enablence Technologies

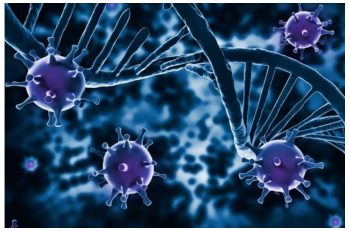
Photonics West 2024

January 30, 2024

Introduction
Advances in machine learning



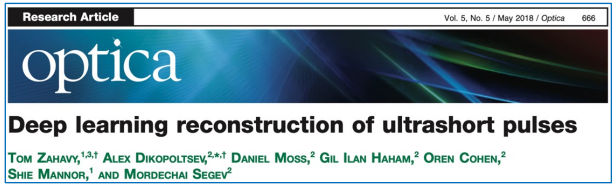
Introduction
Advances in machine learning



ML is able to capture essential features from vast amounts of high-dimensional data

Introduction
AI and ML in photonics

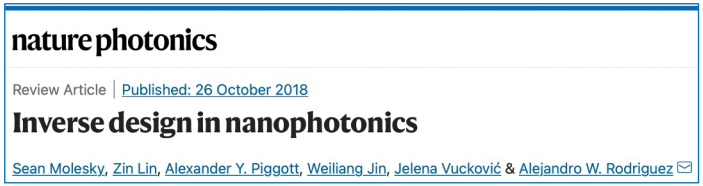
- The photonics industry has began adopting AI and ML techniques to further both research and deployment of optical technologies.
- Advances have been made in:
  - Nanophotonics inverse design
  - Deep learning microscopy
  - Machine learning in optical communication and networking
  - Deep learning in ultrafast optics


Research Article Vol. 5, No. 5 / May 2018 / Optica 666

optica

Deep learning reconstruction of ultrashort pulses

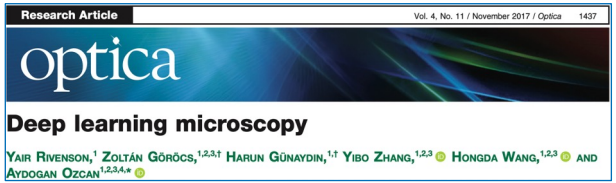
Tom Zahavy,[1,3,†] Alex Dikopoltsev,[2,*,†] Daniel Moss,[2] Gil Ilan Haham,[2] Oren Cohen,[2] Shie Mannor,[1] and Mordechai Segev[2]


nature photonics

Review Article | Published: 26 October 2018

Inverse design in nanophotonics

Sean Molesky, Zin Lin, Alexander Y. Piggott, Weiliang Jin, Jelena Vucković & Alejandro W. Rodriguez


Research Article Vol. 4, No. 11 / November 2017 / Optica 1437

optica

Deep learning microscopy

Yair Rivenson,[1] Zoltán Göröcs,[1,2,3,†] Harun Günaydin,[1,†] Yibo Zhang,[1,2,3] Hongda Wang,[1,2,3] and Aydogan Ozcan[1,2,3,4,*]

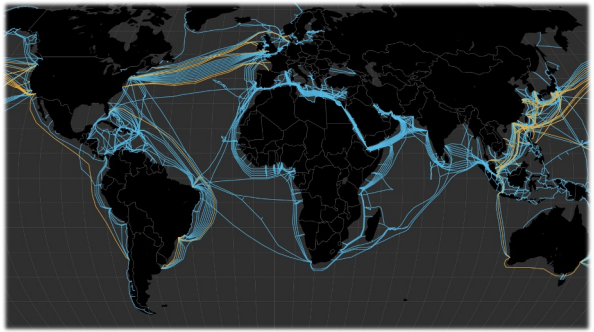

JOURNAL OF LIGHTWAVE TECHNOLOGY, VOL. 37, NO. 2, JANUARY 15, 2019 493

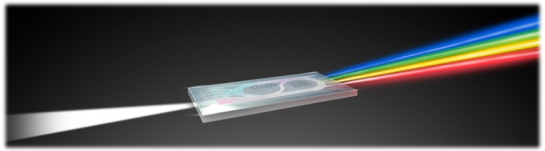
An Optical Communication's Perspective on Machine Learning and Its Applications

Faisal Nadeem Khan, Qirui Fan, Chao Lu, and Alan Pak Tao Lau

Integrated Photonics

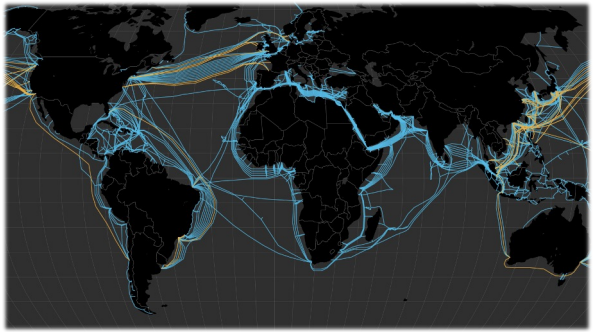
- The widespread adoption of optical communication systems is a key driving force of recent surge in information exchange.
- Optical solutions dominate long-distance communication, and have the potential to transform short-reach links through advanced optical interconnect solutions.

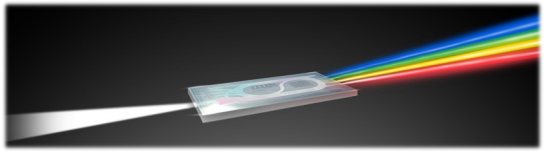




Integrated Photonics

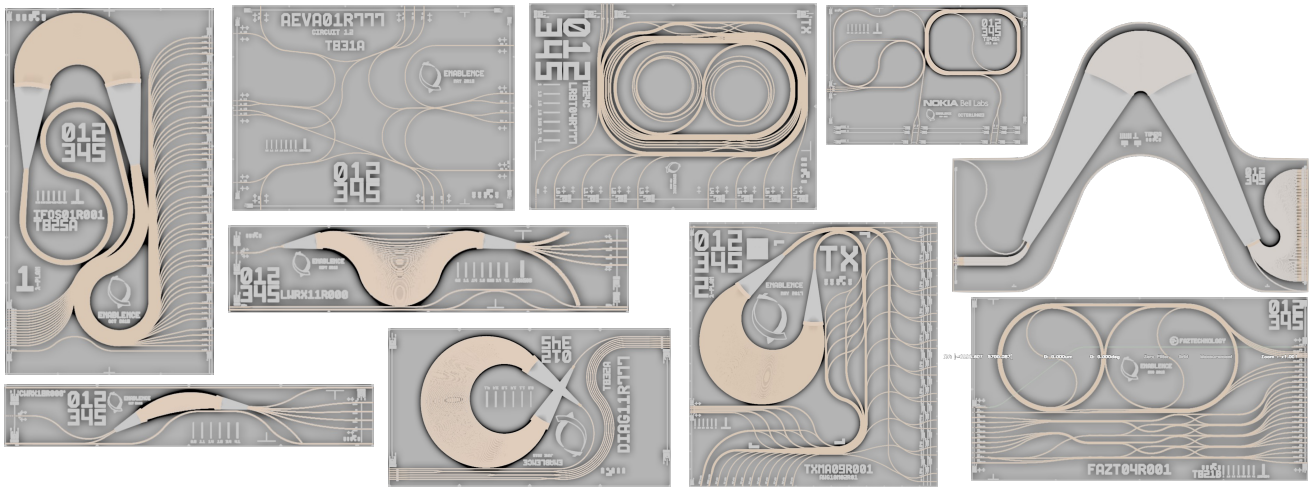
- Today, we present our progress in leveraging the power of machine learning to overcome the biggest hurdles for the widespread adoption of photonic integrated circuits:
  - use of multi-path neural networks as a key tool for transitioning from low-volume prototype designs to high-performing chips in volume production.
  - use of machine learning to predict the performance of optical devices.





Integrated Photonics
Prototype design vs. large-scale adoption

- The transition from prototype design to achieving uniform manufacturing in high volumes is a pivotal phase in any product development process.



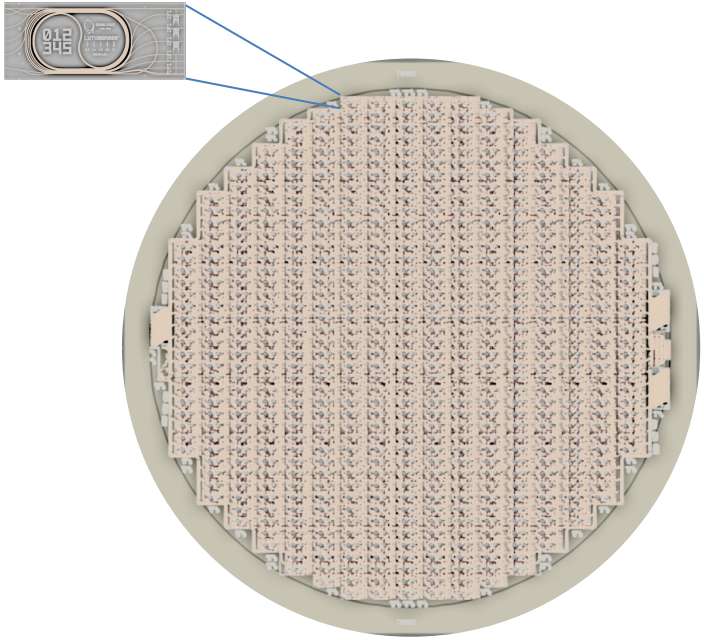
Systems-on-chip in monolithically integrated silica-on-silicon platform

Integrated Optics: Devices, Materials, and Technologies XXVIII

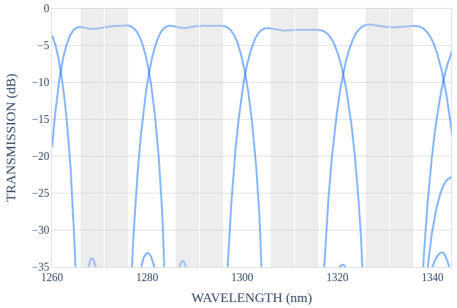
30 January 2024, 11:35 AM, room 304

Integrated Photonics
Challenges for large-scale adoption

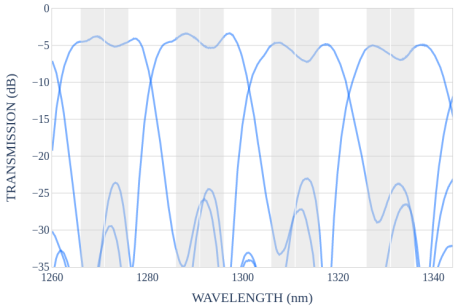
Enablence



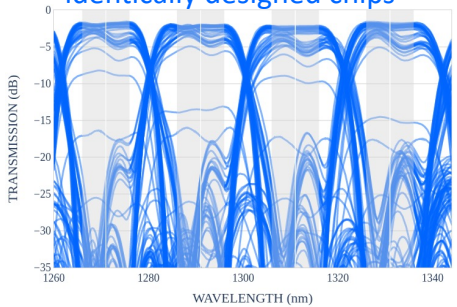
Good performance chip

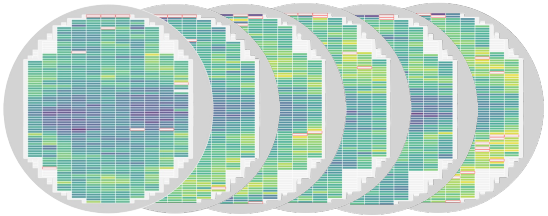


Poor performance chip

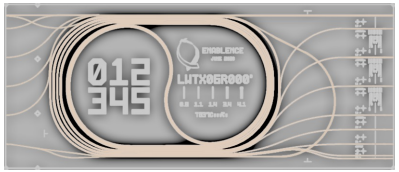


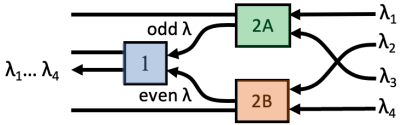
Variation in performance of identically designed chips





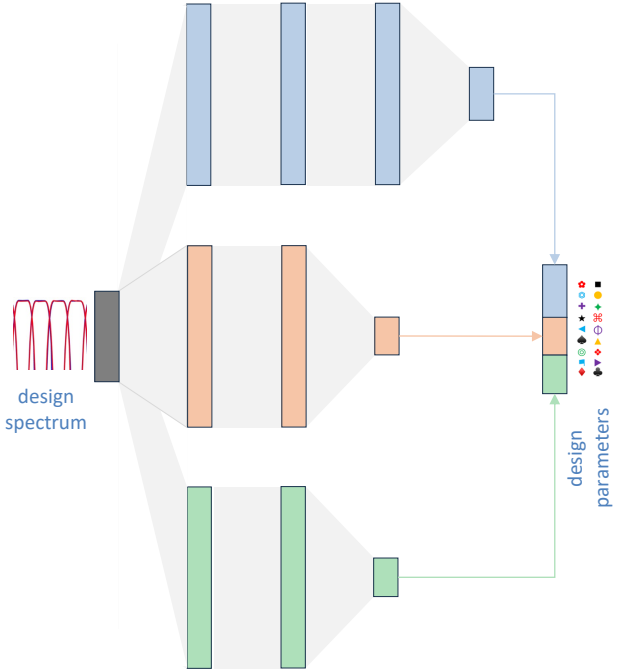
Multi-Path Deep Learning
Photonics chip design optimizations

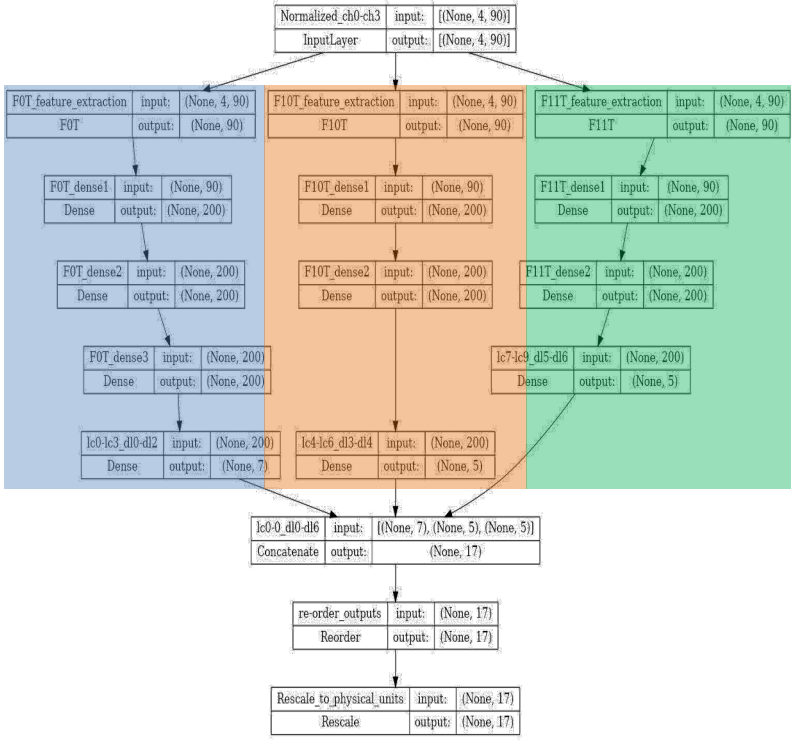




A 4-channel multiplexer:

- Two filter stages
- 7 asymmetric MZIs

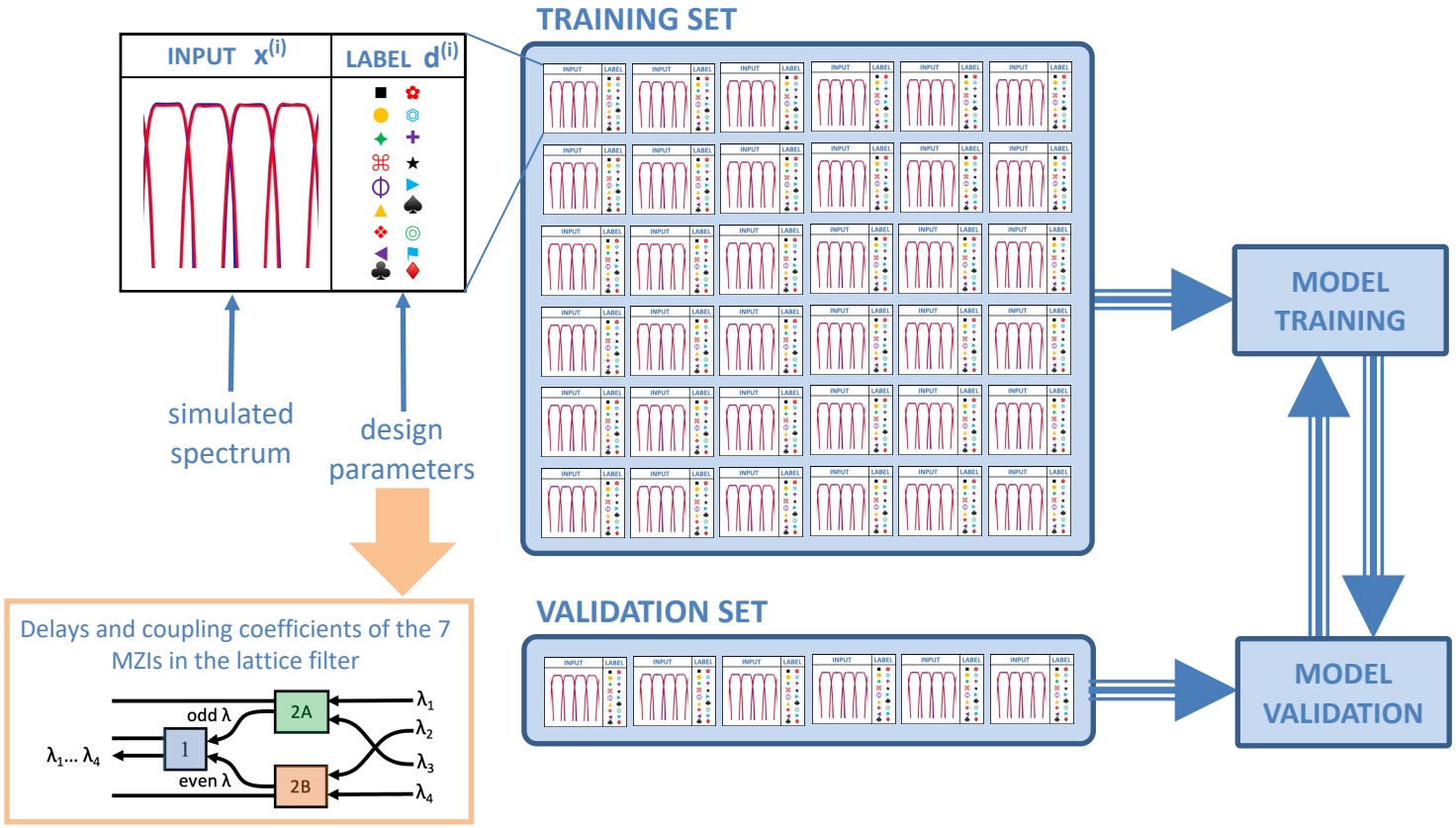




Multi-Path Deep Learning

Photonics chip design optimizations

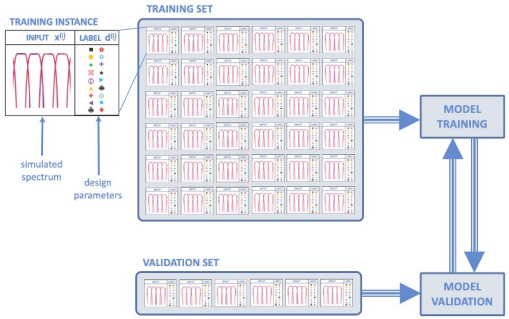
Enablence

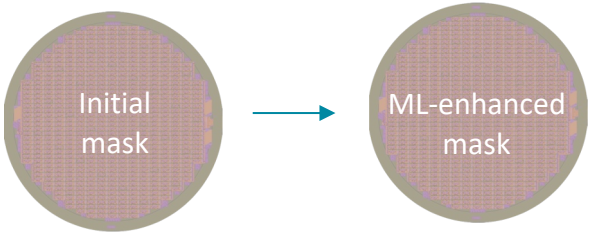


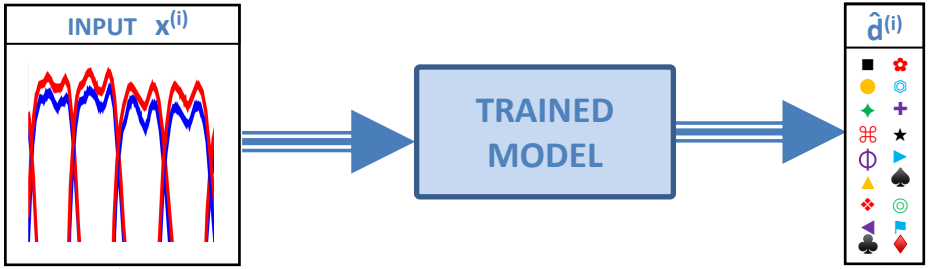
Multi-Path Deep Learning

Photonics chip design optimizations

Enablence





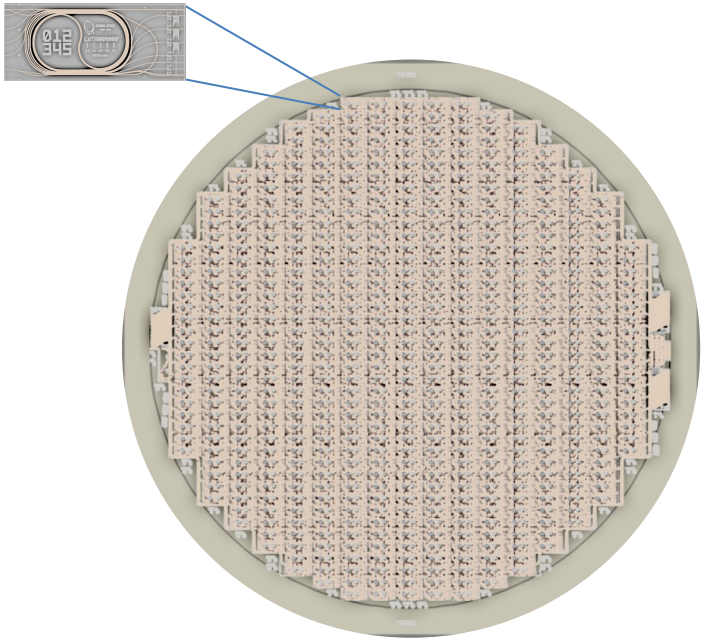


measured spectrum

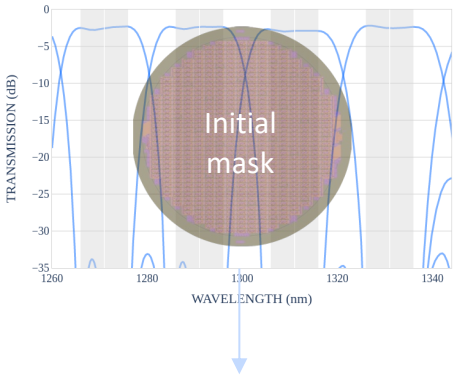
inferred design parameters

Multi-Path Deep Learning

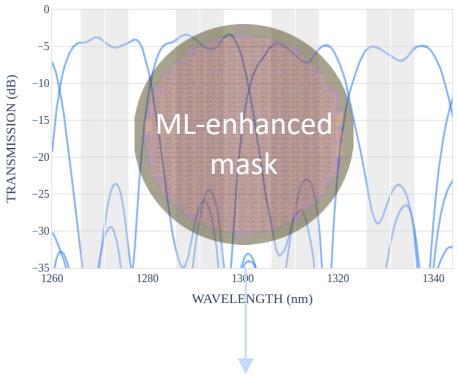
Photonics chip design optimizations



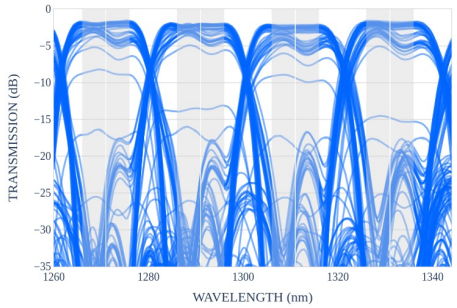
Good performance chip



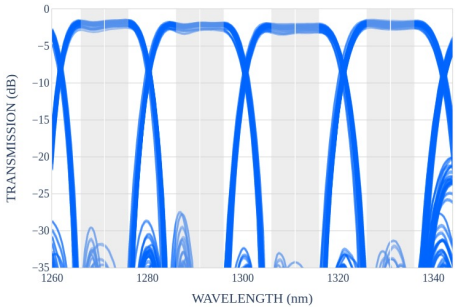
Poor performance chip



Variation in performance of identically designed chips

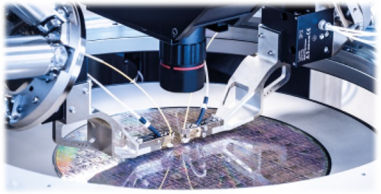


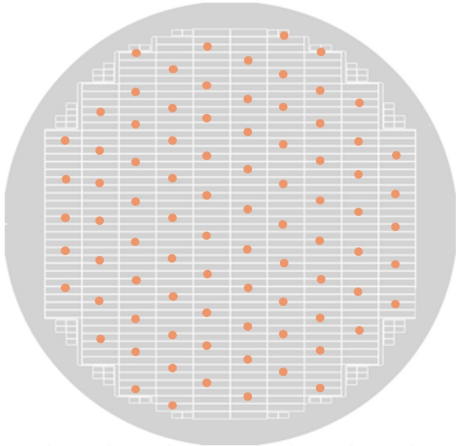
Homogeneity of performance after ML optimization



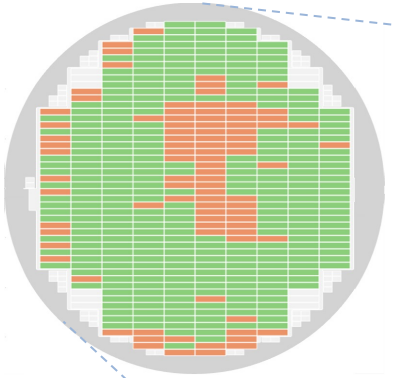
Prediction of Device Performance

Classification based on a wafer probe measurement

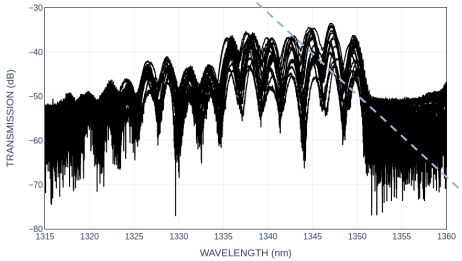




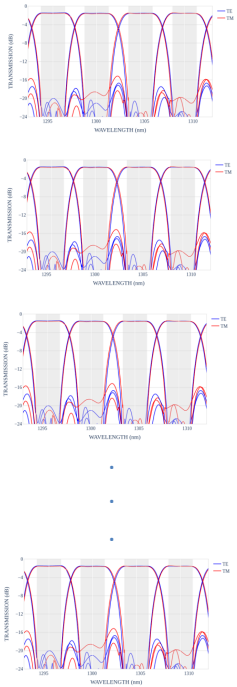
Probed locations on the wafer



Traditional testing PASS/FAIL map



Typical spectroscopic signature



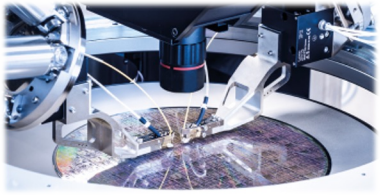
Specification parameters:

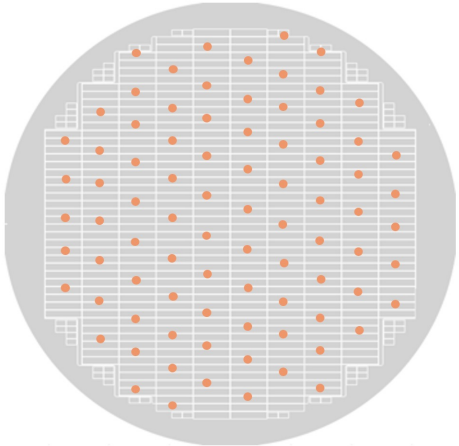
1. Insertion loss
2. IL uniformity
3. Grid detuning
4. Channel spacing uniformity
5. 0.5 dB passband
6. 1 dB passband
7. 3 dB passband
8. PDL
9. Ripple
10. Adjacent crosstalk
11. Non-adjacent crosstalk
12. Total crosstalk

Predicted performance of hundreds of chips on a wafer

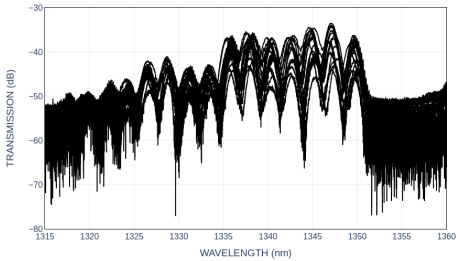
Prediction of Device Performance

Classification based on a wafer probe measurement

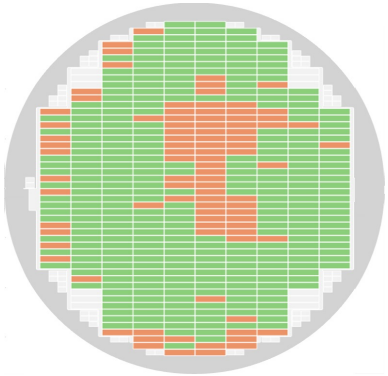




Probed locations on the wafer



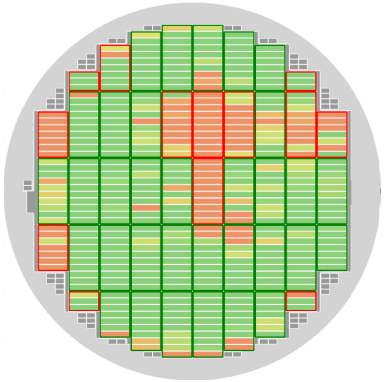
Typical spectroscopic signature



Traditional testing PASS/FAIL map

sensitivity	95%
specificity	68%
accuracy	90%
precision	92%
F1 score	94%
ROC AUC	85%

support vector machine



SVM predicted PASS/FAIL map

Conclusions

- AI/ML has become instrumental in our work in extending the reach of the photonics technology.
- We described how AI and ML have revolutionized the way photonic integrated circuits are designed and fabricated in a high-volume environment:
  - Multi-path neural network optimizes the individual design parameters of hundreds of devices on a mask.
  - A support vector machine (SVM) predicts the performance of optical chips in multi-dimensional space.
- The promising synergy between photonics and AI plays a key role in accelerating research progress in photonics and fostering the widespread adoption of photonic solutions across a diverse range of applications.
- Our current work focuses on the use machine learning to scale the capabilities of our platform to integrated optics solutions in LiDAR and optical computing applications.

Enablence

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

USA

Enablence USA Components, Inc.
2933 Bayview Drive
Fremont, CA 94538

Tel: +1 (510) 226-8900
Fax: +1 (510) 226-8333

Canada

Enablence Technologies, Inc.
390 March Road, Suite 119
Ottawa, Ontario K2K 0G7

Tel: +1 (613) 656-2850
Fax: +1 (613) 656- 2855