Product Showcase

OptoDesigner - Photonic chip design suite

Use case presented by professor John Bowers from UCSB
Enhancing Photonic Integrated Circuits with Heterogeneous SOI & III-V Integration

UCSB

WEDNESDAY 22ND MARCH 2017, 11.00-11.30AM
OFC EXHIBITION FLOOR, THEATRE III
Introduction

PhoeniX Software is shaping the PIC industry for years

Timeline

1991  **BBV** – Design services and software
1996  Twente MicroProducts – Design & manufacturing of MEMS, microfluidics and integrated optics
2000  Both acquired by Kymata to develop AWGs - Today part of Kaiam
2003  **PhoeniX Software** formed to focus on software tools for micro and nano technologies
2005  Intro of Photonic Building Block Platform, integrating mask and simulation engines into **OptoDesigner**
2008  Introducing **PDKs** for microfluidics and photonics, now support 30+ PDKs
2013  Co-founded PDAFlow Foundation and silicon photonics group at Si2
2016  **Collaboration** with leading PDA and EDA suppliers, committed to further develop the market
# Introduction

PhoeniX Software is shaping the PIC industry for years

## Timeline

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## Facts

- Pioneer in the development of Photonics Design Automation tools
- Over 25 years of experience in micro and nano technology design, manufacturing optimization and design automation
- Headquarters in the Netherlands with a highly skilled staff
- 300+ customers have used PhoeniX Software tools for the design of MEMS, microfluidics and photonic ICs
- Leadership role in the creation of front-to-back photonic design flows
- 300+ ICs designed using OptoDesigner and fabricated at multiple Photonic foundries MPW programs over the last 3 years
- 500+ tape-outs supported by OptoDesigner (including commercial designs) over the last 3 years
OptoDesigner
most widely used commercial tool for photonic chip design

- Chip and mask layout
  - Including verification (DRC)
- Photonic simulations
- 3rd party interfaces
- Easy to use GUI including powerful domain specific scripting
- Compatible with Process Design Kits (PDKs)
  - Most MPW foundries available
Moving from Research-centric to Product-centric clear signs that PIC technology has reached the tipping point

- Our number of customers continues to increase, recent years sales rapidly shifting towards commercial
  - *OptoDesigner* sales growth +49% CAGR (2012-2016)
  - Companies are expanding teams and increasing the number of design starts
- Active M&A landscape to gain access to photonic technology and expertise
- Commercial foundries are joining and ramping in volume
Developing the PIC landscape we believe in collaboration to lower access barriers to the technology

- Co-developing PDKs and packaging templates
  - Silicon photonics, InP and SiN

- Collaboration with technology brokers and design houses

- Standardization and collaboration with other software vendors
  - Creating integrated design flows

- Investing in training and education of the marketplace

- Collaborative research with academia and institutes
Developing the PIC landscape
we believe in collaboration to lower access barriers to the technology

- Member of AIM photonics
- Training and education
- Knowledge partner
- PDK and tool provider
Developing the PIC landscape
we believe in collaboration to lower access barriers to the technology

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UCSB
UNIVERSITY OF CALIFORNIA
SANTA BARBARA
PhoeniX Software & UCSB collaboration developing advanced PDKs and design routines

• **How PhoeniX Software customers will benefit**
  • PDK with analytical models for specifying optical and group lengths for connectors and to model signal loss as a function of geometry
  • UCSB test chip to verify process impact on analytical model accuracy and relevance for use in design automation

• **How UCSB students, researchers and partners will benefit**
  • Improve collaboration with (industrial) partners by providing a PDK
  • Secure knowledge and increase re-use
  • Shorten layout cycle times
  • Educate a photonic chip design workforce for industry by moving from homegrown to commercial software tools
Enhancing Photonic Integrated Circuits with Heterogeneous SOI & III-V Integration
PDK for OptoDesigner available

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UCSB

PIETRO CONTU, SESILIA KRISWANDHI, REMCO STOFFER
PHOENIX SOFTWARE
UCSB Heterogeneous SOI & III-V Integration Platform

UCSB 2.54 Tbps Heterogeneously-integrated WDM Network-on-Chip

- Fully integrated WDM transceiver network;
- Compact footprint with 300+ active units (48 DFB, 93 EAM, 67 PD) and 120+ passive units (7 AWG, 1X15 MZI switch) in single chip;
- Data rate of 40 Gbps per wavelength channel, showing a potential large capacity of the transceiver array, with 320 (8×40) Gbps per transceiver node, and 2.56 Tbps (8×320 Gbps) for the whole photonic circuit.

InGaAs PIN PD  AlGaInAs DFB  AlGaInAs EAM

8 x 8 x 40 Gbps fully integrated silicon photonic network on chip, Zhang et al., 2334-2536/16/070785-02 Journal, 2016 Optical Society of America

1x8 (De)Mux

Broadband MZI switch array

28 Gbps  40 Gbps

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A four-channel WDM silicon photonic transmitter with integrated lasers and modulators driven by low-power 32nm CMOS drivers, is demonstrated to operate at a data rate of 4x28Gb/s with BER<10^{-12} and power consumption of 10.0pJ/bit.
Integrated Optical Driver for Optical Gyroscope on Si/III-V

- The first integrated optical driver for optical gyroscope ever created.
- Comprises light sources, modulators, photodiodes together with passive components on Si.
- Low size (4.5 mm²), weight and power consumption (< 400 mW).

Mask Layout with **OptoDesigner**

- “Pick and place” fully parametrized building block, including active and passive components;
- Waveguide and metal track routing and smart connectors;

### Integrated Optical Driver
- Edge coupler (SOI)
- Adiabatic 3-dB coupler (SOI)
- Edge coupler (SOI)
- Laser (III-V)
- Photodiode (III-V)
- Modulator (III-V)

### Fully Integrated Gyroscope On-Chip
- Phase matched delayline (SOI)
- Loop mirror (SOI)
- Laser (III-V)
- Phase matched delayline (SOI)
- High speed Photodiode (III-V)
- Modulator (III-V)
Mask Layout with OptoDesigner

- Full Wafer Mask
- Microwave Synthesizer
- Full Gyroscope
- Gain PD Tests
- Laser Tests
- Loss Spirals
- Optical Driver
- Modulators Test
- Wave Meter
- PD Tests

• “Pick and place” fully parametrized building block; including active and passive components;
• Waveguide and metal track routing and smart connectors;
• Automatic DRCs, Booleans and tiling

- Integrated Optical Driver
- Fully Integrated Gyroscope On-Chip

Widely tunable laser (III-V) enables line measurement of phase change

Two phase matched delaylines (SOI) measure rotation angle of gyroscope

Heterogeneous SOI & III-V Integration – PDK Available
UCSB PDK: QuantumDot (QD) Laser will be transferred onto the AIM SUNY Poly platform

- Threshold current > 1 mA
- Output power 180 mW
- Maximum cw temperature 120°C

Low temperature dependency relaxes cooling requirements and thus saves power. It saves space in the datacom racks because it needs less temperature control logic.

**UCSB PDK: III-V EAM and Pindiode**

**ElectroOptic Modulator**
- Insertion Loss ~ 1 dB/cm
- Vpi X L ~ 2 V mm

**PhotoDetector**
- Responsivity 1 A/W @ 1550nm
- Linear regime input powers < 10dBm
- Polarization dependence < 1dB
- Dark current < 10nA @ -2V
- 3 dB bandwidth ~ 30GHz

External modulators provide better wavelength stability of the laser compared to direct (power source) modulation.

Efficient & compact diodes support high frequency operation with good sensitivity, which leads to very open eye diagrams & thus communication line stability against disturbances and noise.

*Zhang et al., “8×8×40 Gbps fully integrated silicon photonic network on chip”, 2334-2536/16/070785-02 Journal, 2016 Optical Society of America*
Lasers are strongly influenced by back-reflection from the circuit. Combining the circulator with a polarization rotator to switch from TE $\rightarrow$ TM, and then using the isolator to block TM is a key system improvement.

- Large Isolation for TM mode $\sim$ 32 dB
- Low Excess loss $\sim$ 2.3 dB
- Wavelength tuning $\sim$ 0.6 nm
- Small footprint $\sim$ 70um x 70um

UCSB PDK: Circulator building block

- Scalable and easily reconfigurable
- Isolation for TM mode ~ 11 dB
- Crosstalk ~ 10 dB

Multiport TM circulator for network on chip and sensing applications

DRC on the fly, while designing

Failure, wrong crosssection for Laser.

Silicon photonics technology does not support a laser, load the III-V technology to your design.
OptoDesigner generates the GDS file automation to create manufacturable designs

Design Intent

On-specs GDS for foundry

Optimizing polygons snapped to the grid to avoid translation and phase errors is very important in photonics.
Automatic assembly of parameterized black box with the IP contents

Pre assembly

- UCSB.QD.laser_BB
  - Laser length um=1800
  - Number P segments=5

- UCSB.QD.laser_BB
  - Laser length um=950
  - Number P segments=4

- UCSB.QD.laser_BB
  - Laser length um=980
  - Number P segments=3

- UCSB.QD.laser_BB
  - Laser length um=800
  - Number P segments=2

Assembly

- UCSB.QD.laser_BB
  - Laser length um=1800
  - Number P segments=5

- UCSB.QD.laser_BB
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  - Number P segments=2

Black box parameters. Designers will not see your fab IP.
Phase matched design characterization

Propagation length of the design is optically specified, not drawn manually.

- $dL = 0.125$ um
- $dL = 0.059$ um
- $dL = 0.017$ um
- $dL = 0.0$ um
UCSB Heterogeneous SOI & III-V Integration – PDK available

8 × 8 × 40 Gbps fully integrated silicon photonic network on chip, Zhang et al., 2334-2536/16/070785-02 Journal, 2016 Optical Society of America
Integrated Photonics Moore’s Law – Scale Up

**Graph:**
- **InP**: Blue triangles
- **Si**: Green circles
- **Heterogeneous Si**: Red squares

**Timeline:**
- 1985
- 1990
- 1995
- 2000
- 2005
- 2010
- 2015

**Number of Elements / PIC**
- Logarithmic scale

**Legend:**
- **InP**: Sun et al., Nature 2013
- **Si**: Summers et al., ECOC2014
- **HSP**: Zhang et al., 2334-2536/16/070785-02 Journal, 2016 Optical Society of America

**Note:**
- 8 × 8 × 40 Gbps fully integrated silicon photonic network on chip, Zhang et al., 2334-2536/16/070785-02 Journal, 2016 Optical Society of America
Summary

• We believe PIC technology has reached the tipping point and exciting times lie ahead of us

• We will continue to make PIC technology accessible by collaborating with universities, technology providers and software vendors developing PDKs and integrated design flows

• An OptoDesigner PDK for UCSB’s Heterogeneous SOI & III-V Integration is now available
NEW RELEASE
OPTODESIGNER 5.1
THE STANDARD SOFTWARE FOR PHOTONIC CHIP DESIGN
START TODAY!

THE STANDARD SOFTWARE FOR PIC DESIGN

- IMPROVED USABILITY
- ADDED FUNCTIONALITIES
- BETTER PERFORMANCE

WANT TO LEARN MORE?
PLEASE VISIT OUR BOOTH

Booth #3538