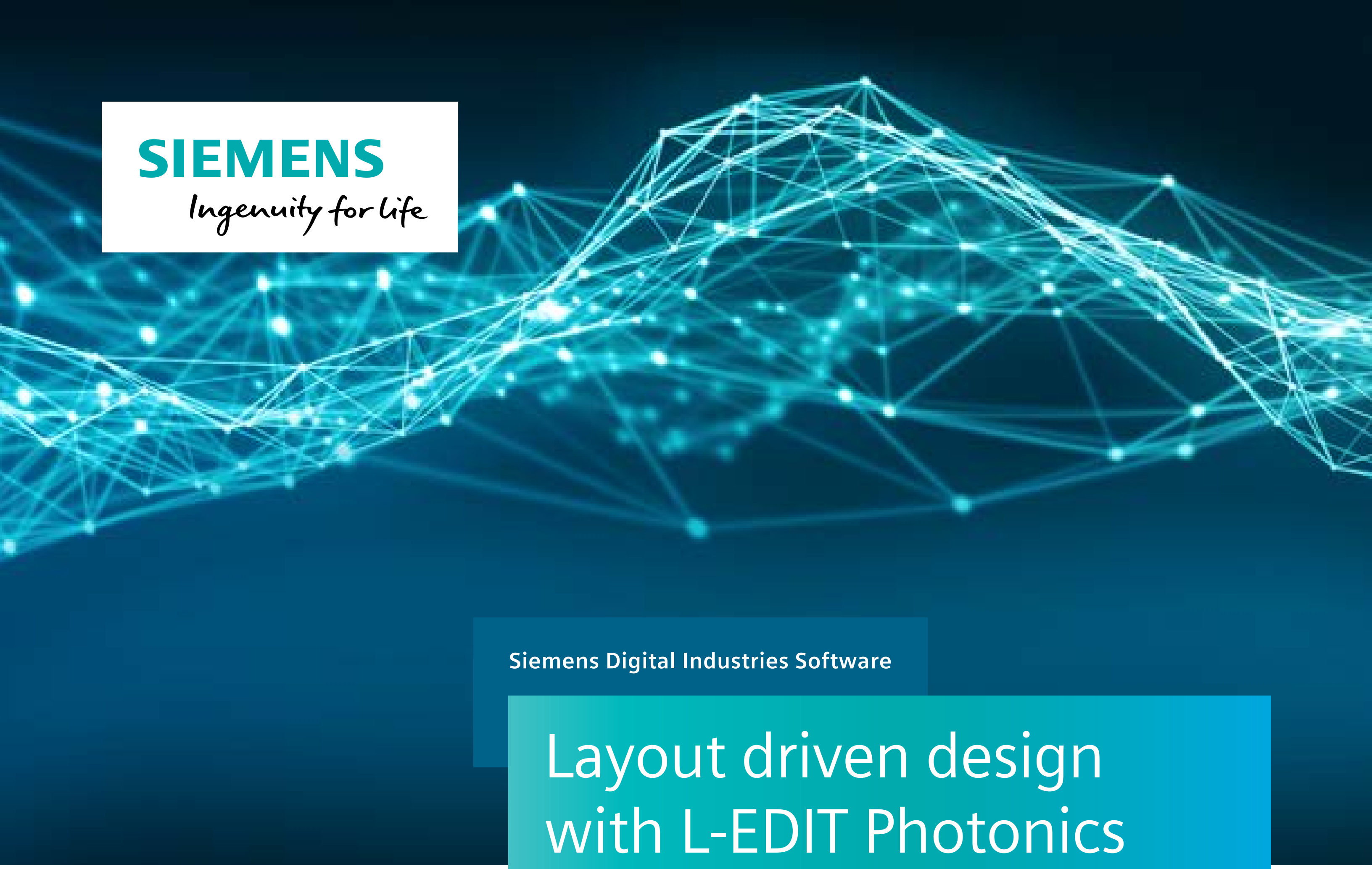

Siemens Digital Industries Software

Layout driven design with L-EDIT Photonics

Custom IC design

Executive summary

Advances in integrated circuit technology and fabrication have made it possible to leverage traditional CMOS fabrication processes and materials and apply them to the design of Photonic Integrated Circuits (PICs). The combination of PICs with traditional electronic integrated circuits, called integrated photonics, is the ability to move, modulate, and detect light on a single IC. While there is a very established CMOS IC design flow with mature EDA tools, we are only now seeing the same efficiencies, reliability, and scale emerge for photonics design. Even for relatively simple designs, photonics presents physical and analytical challenges that require unique, dedicated methods that traditional electronic IC design does not employ.

Jonas Flueckiger

Introduction

Using light to move information is nothing new. Fiber optic communications networks have been widely employed in data and telecommunications systems across the world for years. Advances in integrated circuit technology and fabrication have made it possible to leverage traditional CMOS fabrication processes and materials and apply them to the design of Photonic Integrated Circuits (PICs). The combination of PICs with traditional electronic integrated circuits, either via monolithic integration or a hybrid design approach, has helped to improve the capacity to move large amounts of data in communication networks, while reducing cost and power consumption. Integrated photonics, which is the ability to move, modulate, and detect light on a single IC, is gaining traction outside of the communication market and it is seeing success in fields such as healthcare (sensing and optical coherence tomography), LIDAR, and quantum computing.

PIC design challenges

While there is a very established CMOS IC design flow with mature EDA tools, we are only now seeing the same efficiencies, reliability, and scale emerge for photonics design. Until now, photonic IC design would typically include less than 50 components and is was often layout driven, completed by the same designers that developed the fundamental components. Even for such relatively simple designs, photonics presents physical and analytical challenges that require unique, dedicated methods that traditional electronic IC design does not employ.

As figure 1 shows, most photonic structures require smooth bends and curves that are not used in electronic IC design. In addition, layouts for mask fabrication are polygon based and defined on a grid with a given resolution. Special care must be taken when arbitrary curvilinear shapes are discretized in order to maintain a well-defined, smooth sidewall. This is true for the components themselves and the for waveguide routing. Routing requires a curved format instead of rectilinear/ Manhattan-style routing (common in electronic IC design) in order to ensure that light stays in the waveguide.

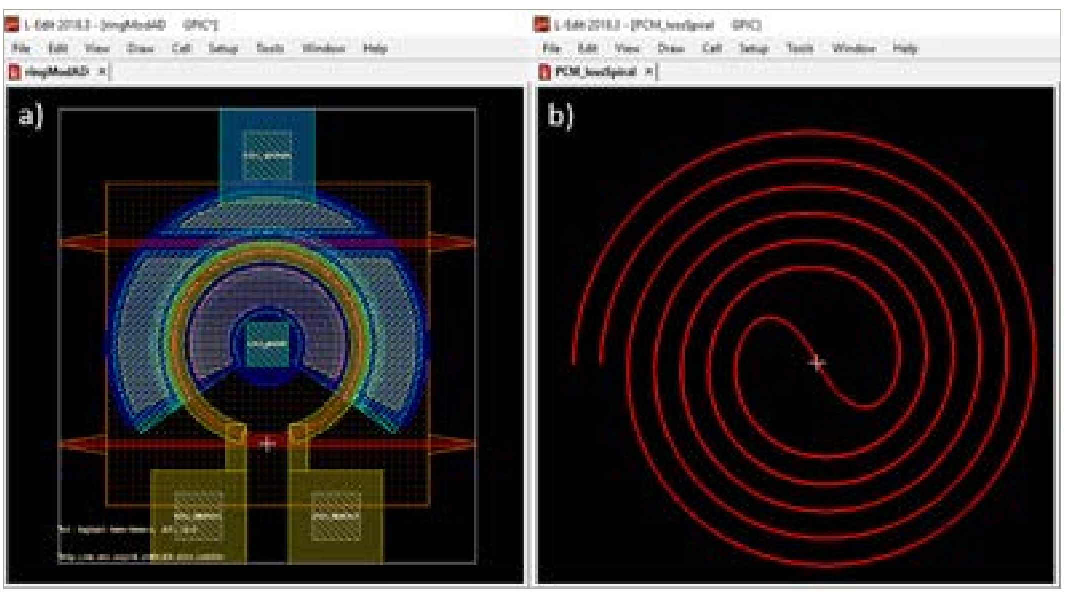

Figure 1: Examples of curvilinear photonic components. a) Electro optic ring modulator and b) spiral waveguide. Both examples are Python based parameterized cells.

Tanner L-Edit, with the inherit ability to perform advanced curve editing and its native OpenAccess support, has the capability to address these challenges in photonic layout design. The L-Edit Photonics option to L-Edit provides photonic design automation including native waveguide routing and photonic netlist extraction.

The waveguide routing tool in L-Edit Photonics uses a library of building blocks figure 2), to convert a Manhattanstyle path into a curvilinear waveguide with predefined minimal bend radii. The tool automatically detects waveguide crossings and replaces them with a 4 port crossing component.

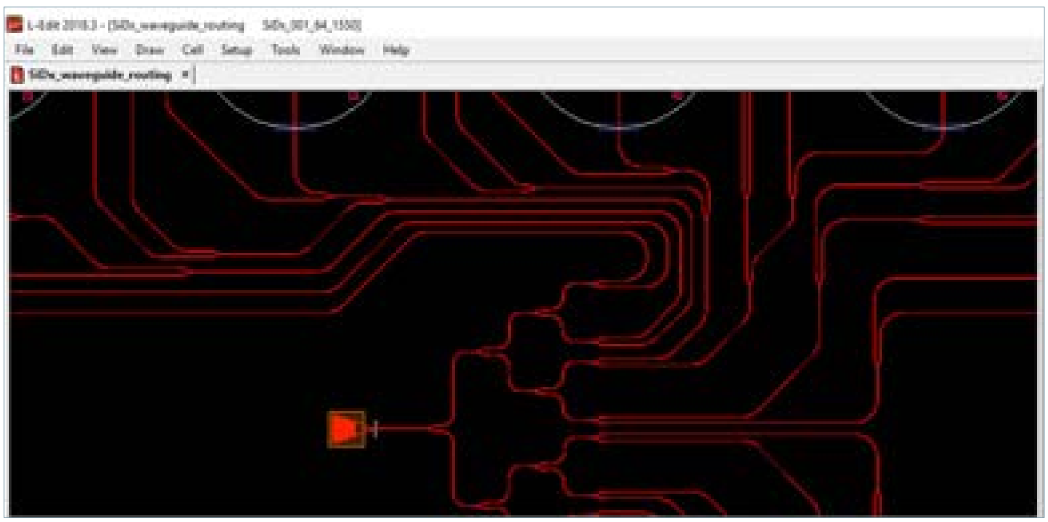

Figure 2: Waveguide routing between photonic building blocks.

Mentor's generic photonic PDK (GPIC)

Most electronic IC design work is focused on system design, enabled by the availability of Process Design Kits (PDKs) offered directly from the foundry. A PDK is a library of fundamental components, design-rules, and processes that typically also include compact models for circuit simulation. The maturity and availability of photonic PDKs is still an area of ongoing effort and companies often have their own proprietary libraries. To facilitate this effort, Mentor has developed a fully interoperable Generic Photonics PDK, referred to as the "GPIC" PDK. The GPIC PDK aims to provide a vehicle for tool demonstration and for academic training in integrated photonic design methodologies. It is not tied to a foundry process, but lends itself as a quick-start technology package that enables photonic researchers to configure it to their needs by adding their own innovative, Python based parameterized components to target their designs to multiple foundries.

The GPIC PDK leverages parameterized building blocks based on Python that allows easy reconfiguration to meet the technology requirements of most photonics foundries. Figure 3 shows an example of two custom photonic components that are derived from existing GPIC elements. Figure 3a shows a thermal tunable filter in a double bus configuration and figure 3b shows a simple ring resonator used in sensing applications. The blue area indicates the region where the silicon oxide is removed to expose the waveguides to various environmental conditions.

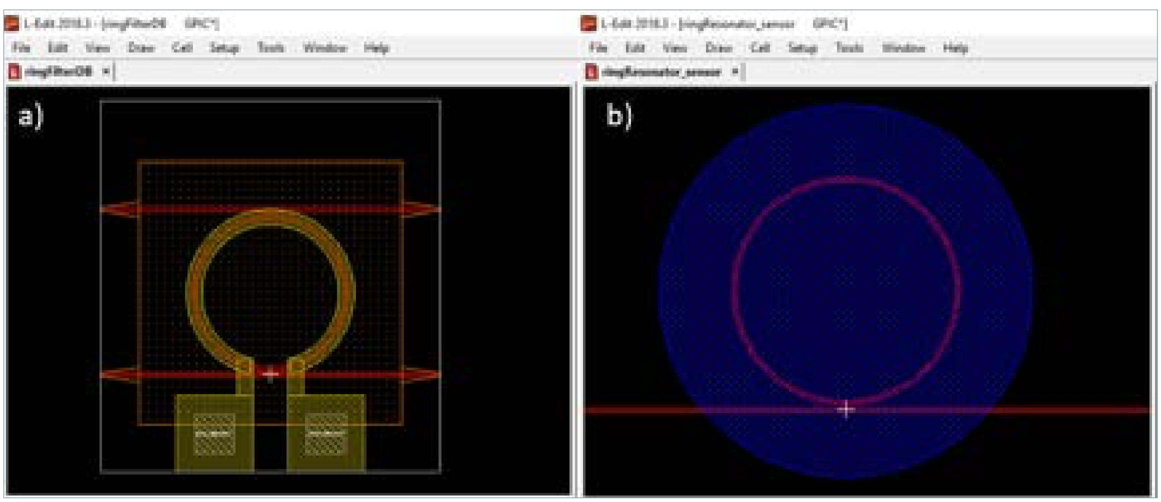

Figure 3: GPIC derived custom photonic components. a) Thermal tunable ring for filtering and b) simple ring resonator for sensing. Both components are Python based parameterized cells.

L-EDIT Photonics and beyond

With relative little development effort, a photonic designer can derive a custom component library using the GPIC PDK as starting point. By dragging and dropping components, the designer is able to string them together and build circuits and systems using L-Edit Photonics. Figure 4 shows an example layout of a 4 channel WDM transmitter including edge couplers, ring modulators, and photo detectors quickly created in L-Edit Photonics. Waveguide and electrical interconnects are routed using the photonic routing capability of the tool.

This example shows that using the automation of L-Edit Photonics, with its routing capability, and the component library, reduces design time and layout errors. However, to really achieve "first time right" designs it is important that:

- The component library is well characterized,
- The design framework also includes simulation capabilities, both on the component, and circuit level, and
- Verification methodologies like LVS and DRC support photonic design.

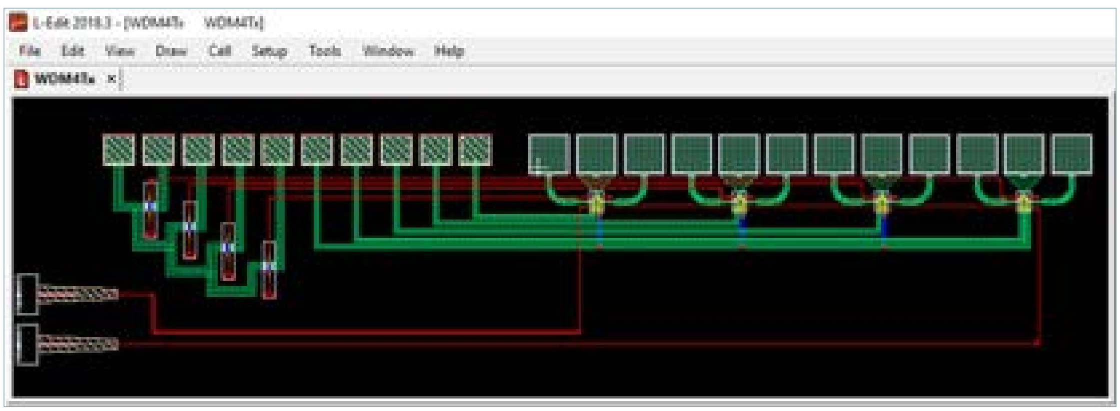

Figure 4: A 4 channel WDM transmitter layout that employs edge couplers, ring modulators, and detectors from the GPIC PDK

Siemens Digital Industries Software

Headquarters
Granite Park One
5800 Granite Parkway
Suite 600
Plano, TX 75024
USA
+1 972 987 3000

Americas
Granite Park One
5800 Granite Parkway
Suite 600
Plano, TX 75024
USA
+1 314 264 8499

Europe
Stephenson House
Sir William Siemens Square
Frimley, Camberley
Surrey, GU16 8QD
+44 (0) 1276 413200

Asia-Pacific
Unit 901-902, 9/F
Tower B, Manulife Financial Centre
223-231 Wai Yip Street, Kwun Tong
Kowloon, Hong Kong
+852 2230 3333

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About the author

Jonas Flueckiger received a B.S. and M.S. degree in Microengineering from Ecole Polytechnique Fédérale de Lausanne, Switzerland, and a Ph.D. degree in Electrical and Computer Engineering from the University of British Columbia in 2015. He has co-authored 50+ publications. Jonas is currently VP of Engineering at SiDx, Inc. which is a medical device company that is modernizing blood group testing to speed care and reduce cost.

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