Fraunhofer HHI Delivers InP Foundry Calibrated SOA Compact Model with Ansys Lumerical

The demand for discrete lasers, semiconductor optical amplifiers (SOAs), and photonic integrated circuits (PICs) are fueled by growth in leading-edge photonics technologies. With applications including biosensing, lidar for advanced driver-assistance systems (ADAS), connectivity for telecom and datacom networking, and emerging technologies in quantum and neuromorphic computing, highly integrated photonic systems are necessary to meet demanding power and performance targets.

Indium phosphide (InP) processes have long been a mainstay of integrated photonics, providing maximum functionality for photonic integrated circuit (PIC) designers thanks to their support for native gain materials and lasers. As a leading InP foundry, Fraunhofer HHI is strongly positioned to provide users with foundry services to achieve their most challenging design goals through experience and commitment to an open-access model.

To address the growing complexity of PIC designs in recent years, photonic/electronic process design kits (PDKs) have been introduced to raise the level of abstraction for photonics design, enabling unprecedented levels of design scaling, productivity, and confidence at signoff. This has been made possible with the introduction of advanced circuit-level design flows, including the Ansys photonic circuit simulation tool Ansys Lumerical INTERCONNECT.

To accelerate time to market and unlock the full potential of InP PICs, designers need compact models that are accurate and calibrated to foundry measurements. While excellent compact model libraries exist for many passive and active components, designers must rely on simplified black-box models for lasers and gain components, limiting design flexibility and potentially missing important operating characteristics. This can increase time to market as additional design cycles become necessary.

The development of compact and efficient SOAs is a current focal point for the photonics industry. There's a need for system-level models calibrated to foundry measurements, allowing engineers to leverage custom SOAs at the circuit level with the confidence their manufactured circuit will work as expected. The availability of compact models for SOAs has been limited due to the complexity of the physics involved and the challenge of solving the problem efficiently. With a compact model now available that has been parameterized to HHI's foundry, designers can avoid the costly effort of parameter extraction and calibration.

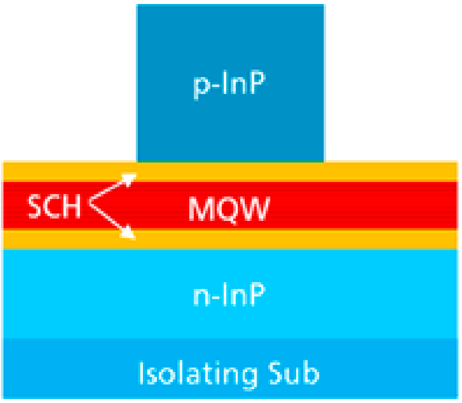
/ Foundry Calibrated SOA Compact Model

Fraunhofer HHI and the Ansys Lumerical team set out to address the need for an accurate compact model for SOAs fabricated in multiple quantum well (MQW)-loaded ridge waveguides. The SOA is a key building block both as a standalone amplifier and as the core of a semiconductor laser. The physics of the SOA involves tightly coupled and highly nonlinear interactions between electronic, optical, and thermal systems, placing challenging demands on the compact model to accurately represent the device behavior over a wide range of operating conditions.

To meet this challenge, HHI adopted Ansys Lumerical's laser simulation solution, including the MQW gain solver and traveling wave laser model (TWLM). The TWLM is an advanced time-domain compact model capable of capturing the full range of physics relevant to SOAs and lasers while achieving the simulation performance required for the efficient analysis of complex PICs. Based on the transmission line laser model and laser rate equations, the TWLM can accurately represent a range of active devices including SOAs and a range of laser topologies such as Fabry-Perot (FP), distributed feedback laser (DFB), and external cavity lasers. It can model broadband noise and nonlinear gain of bidirectional optical signals driven by electronic and thermal inputs.

The development of the foundry-calibrated SOA compact model is the result of a close collaboration between HHI and Ansys Lumerical. With HHI's state-of-the-art fabrication facilities, accurate and repeatable measurements of the devices were performed over wavelength, input optical power, and input current. Based on these measurements combined with simulation and fitting, parameters for the TWLM compact model, such as active layer dimensions, recombination coefficients, modal gain, waveguide loss, and effective and group indices, were extracted, and the results were compared to the measured power gain.

Using Ansys Lumerical INTERCONNECT as a simulation platform enabled the development and refinement of specific experiments to obtain key values for the compact model and accelerated the parameter extraction process through its support for automation.



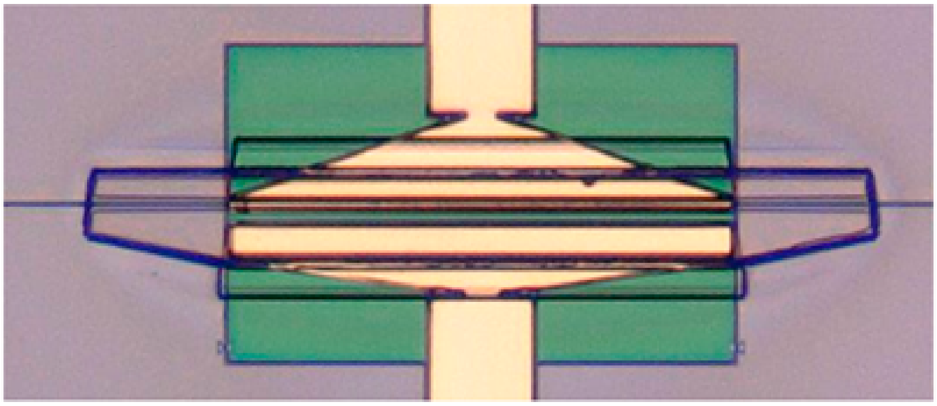


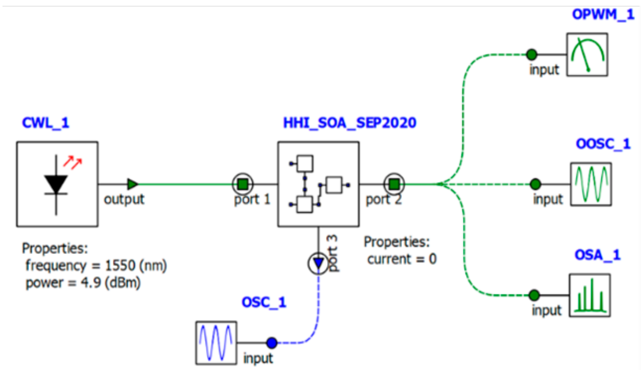
Figure 1. A multiple quantum wells (MQW)-loaded ridge waveguide forms the core of the SOA. On the InP process, HHI can deliver a wide range of active components, including a PIN-SOA with C-band photoluminescence (PL) peak shown in the optical microscopy image of the device.

Moritz Baier, head of the Photonic InP Foundry Group at Fraunhofer HHI, said, "We are excited to now offer a calibrated compact modeling solution for SOAs and lasers based on parameters extracted from measured devices fabricated in our process. We chose leading photonics simulation tool provider Ansys Lumerical as a partner in developing our first SOA compact model to bring our customers unparalleled design flexibility and confidence. The SOA gain block is the fundamental element to let engineers design custom lasers and amplification blocks tailored to their application while saving time-consuming fabrication cycles for initial prototypes."

"Delivering accurate, foundry-calibrated compact models of MQW-based SOAs is a major milestone in building the commercialization environment that our InP customers are demanding to enhance design flexibility and accelerate their time to market," said Ansys Principal Product Manager James Pond.

/ Results

Figure 2 shows a test circuit (left) used to generate power gain results (right) for the SOA compact model. The test circuit consists of a laser source, the SOA compact model, and two analyzers to capture the output signal. The compact model is calibrated for input powers in the range of -20 dBm to 5 dBm, input currents in the range of 0-100 mA, and wavelengths in the C-band. Power gain results in Figure 2 (right) show a good match between the compact model and measurements as a function of input power over several bias currents at the middle of the C band (1550 nm).



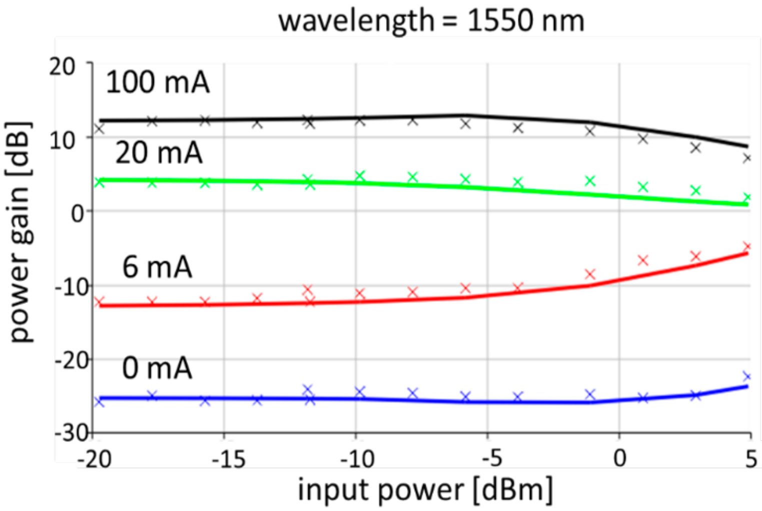


Figure 2. The traveling wave laser model (TWLM) in Ansys Lumerical INTERCONNECT (left) and a comparison of power gain between measurement and simulation for the middle wavelength of the C-band (right).

Figure 3 shows a similar comparison, but for the minimum and maximum wavelengths of the C-band. This demonstrates a close match across the entire C-band between measured results and those simulated using the SOA compact model in Ansys Lumerical INTERCONNECT.

These results demonstrate the flexibility and accuracy of HHI's SOA compact model when used with Ansys Lumerical INTERCONNECT. Customers can now simulate gain in integrated circuits with confidence, leading to reduced prototyping costs and faster time to market.

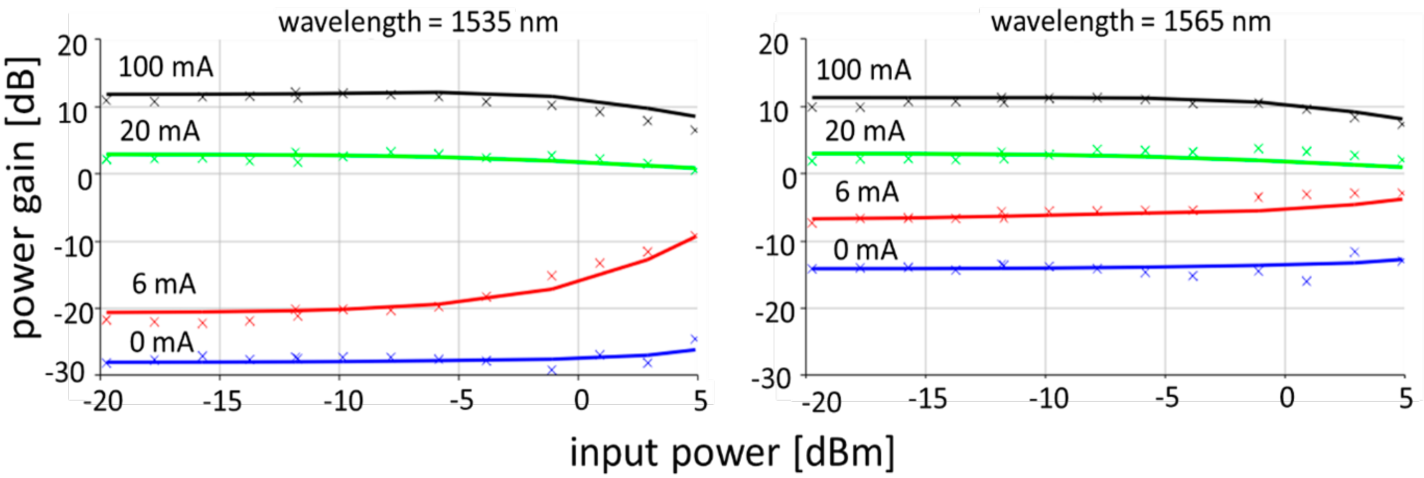


Figure 3. Comparison of power gain between measurement and simulation for the minimum and maximum wavelengths of the C-band

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