peter.kaspar@3-5lab.fr
guanghua.duan@3-5lab.fr

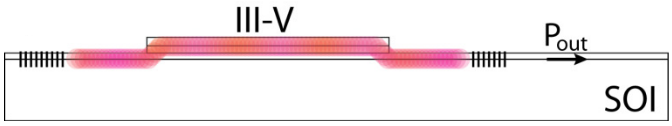
HYSSOP: Project Summary

HYbrid III-V/Silicon laSer for the future generation Of Photonic integrated circuits
March 1st, 2013 – February 28th, 2015

1. Introductory Remarks

There is a broad consensus among a growing number of experts that silicon photonics is a powerful instrument to develop new generations of transceiver equipment for optical fiber networks. A key element for silicon photonics to become a disruptive technology is the availability of practical light sources that are, by preference, directly integrated on photonic integrated circuits (PIC). The objective of the HYSSOP project was to demonstrate such laser sources using hybrid III-V/silicon integration, and to implement demonstrator PICs that show the viability of the proposed technology for future network solutions.

The approach used within HYSSOP to fabricate hybrid III-V/silicon lasers is based on wafer bonding of III-V material on silicon-on-insulator (SOI) wafers containing passive photonic elements, such as low-loss waveguides, filters, mirrors, couplers, and multiplexers. The optical mode transfers back and forth between the III-V and SOI materials, as indicated in the figure.



2. Overview of achievements

Demonstration of hybrid III-V/silicon DFB lasers

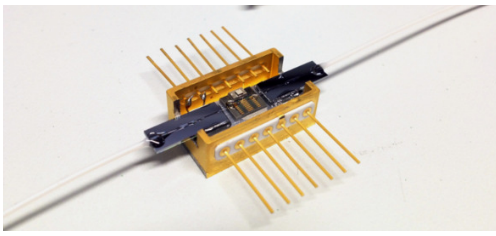
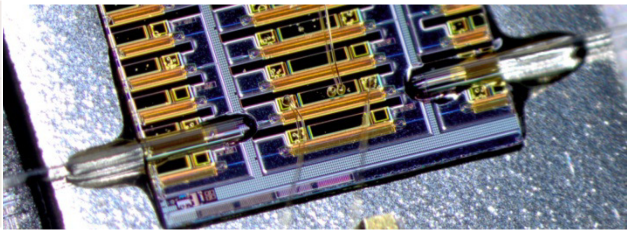
For short distance optical links, an interesting solution on the transmitter side is the combination of distributed feedback (DFB) lasers with silicon-based high-speed modulators. In accordance with the 100 Gbit/s Ethernet standard, lasers with output powers of at least 10 mW are required for a 4x25 Gbit/s transmitter configuration. We demonstrated first DFB lasers in the 1550 nm wavelength range with powers around 25 mW (power in the silicon waveguide), and devices in the 1300 nm range are to follow soon.

Hybrid III-V/silicon tunable lasers with high output power

In metropolitan and long-haul optical networks, the use of advanced modulation formats is of great interest to achieve very high data rates. Silicon photonics is an excellent candidate to provide integrated versions of coherent transceivers for these applications. Tunable hybrid lasers can be employed as transmitter sources but also as local oscillators on the receiver side. Tunability over the C-band and output powers in the order of 10 mW are required. We demonstrated hybrid lasers with a 37 nm tunability range and output powers in the order of 6 mW over the full range. With respect to a previous generation of lasers, we significantly improved the output power, notably by applying corrected optimization rules for the reflectivity of output mirrors. Further improvements are required to meet the specifications. They can be achieved by pushing the mirror design rules to the limits or by integration of optical amplifiers in sequence with the lasers.

Demonstration of hybrid III-V/silicon SOA

As the complexity of PICs increases, the use of semiconductor optical amplifiers (SOA) will receive more and more attention. In contrast to erbium doped fiber amplifiers (EDFA), they can be placed anywhere within a PIC, not just at the input or output. In addition, for a PIC that contains hybrid lasers, hybrid SOAs can be implemented with very little additional effort and cost. We use a rough benchmark of 30 dB of internal gain and a noise factor (NF) of 7 dB for our hybrid SOAs, which are typical values reached by monolithic SOAs on InP. The performance reached by our hybrid SOAs is 28±2 dB of internal gain, and a noise figure around 10-11 dB, which is not very far from the benchmark. The figure shows a packaged demonstrator SOA that has input and output fibers attached horizontally to the SOI chip. Coupling between chip and fiber takes place through vertical grating couplers and a reflection off a fiber facet that was cut at 40°.

For us, the most interesting use of an SOA is to increase the output power of hybrid lasers in order to reach the specifications required for applications in various optical networks. First results with tunable lasers are very promising. Preliminary measurements suggest that, using an SOA at the output of a tunable laser, we will be able to couple 20 mW of output power to a fiber.

Direct modulation of tunable lasers

For access networks, directly modulated tunable lasers are of utmost interest, because they can be a cheap solution for large volumes. We successfully demonstrated 10 Gbit/s transmission through 25 km of sigle-mode fiber. Higher data rates can potentially be reached by using the chirp-managed laser (CML) approach, where a filter is used outside of the laser cavity in order to take advantage of the chirp that arises during direct modulation of the laser (filtering increases the extinction ratio of the modulation). First experiments of CMLs show a lot of promise.

3. Closing remarks

Many important steps have been made to provide hybrid III-V/silicon PICs for applications in optical fiber networks. A next important step is to conduct in-depth reliability assessments and to set up an industrial supply chain for the production of hybrid III-V/silicon devices and circuits. Silicon photonics is a promising candidate to revolutionize the data communication market within the next 10 years. The 3-5 Lab is in a good position to become an important player in this development.

Further performance improvements can be expected from the use of quantum dots and/or quantum dashes instead of quantums wells as the active material of hybrid lasers. It was planned that such advanced materials would be integrated with SOI within the HYSSOP project. This part of the project could not be realized due to a prolonged downtime of the concerned epitaxy system. However, this shortcoming does not diminish the success of HYSSOP. The integration of quantum dots and dashes will be realized in succeeding projects.