Silicon photonic integrated laser for fronthaul architectures

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Study context

Photonic Integrated Circuits (PICs) are fast-growing for very high data rate applications. Long distance optical communication and the emerging data centers are quite pioneering in the progress of these technologies and particularly on silicon platform. Systems such as Analog Radio-over-Fiber (A-RoF) benefit from technological progress in optical communications and could gain a great advantage from silicon PICs. The challenge of the communication is now to miniaturize the photonic system as it has been done earlier for the electronic system owing to the development of the microelectronic technology. Nowadays, this objective is based on the development of the PIC whose forecasts for the years 2021-2030 announce an average annual growth rate of 20.5%. III-V technology now accounts for 81.8% of the PIC market share, while only 16% of the PIC market is carried by Silicon technology. In order to follow the objective: smaller and cheaper, the design of photonic integrated circuits on silicon for telecom and for home area network applications is a good challenge, its margin progress in terms of market share being significant. However, today this mature PICs technology is optimized for digital communications and not optimized for analog-photonic communications. Thus, the building blocks of silicon photonic components for A-RoF systems concern optical waveguides, intensity and phase modulators, optical filters and hybrid III-V Silicon laser sources and photodiodes. The future A-RoF system and more precisely, each of the building block, has to be redesigned and optimized to fit in the 6G fronthaul architectures for an enhanced mobility at a higher data rate, and also for LiFi communications. We will focus in this thesis on the hybrid III-V laser on silicon platform where the photonic integrated technology will bring a cost-effective solution.

The main activity of ESYCOM lab linked to the subject is the development of advanced models based on physical parameters of all the Analog-Radio over Fiber (A-RoF) blocks to increase the data rate and to reduce complexity, consumption and cost. The targeted applications concern telecommunication for cities and buildings (outdoor and indoor environments) to build the new generation architectures.

PhD subject

This PhD position deals with the modelling of the optical source for optical communication architectures in integrated photonic technologies. The hybrid laser is designed at III-V Lab and fabricated at III-V Lab for the lasing region and CEA-Leti for the hybrid integration [1], [2], [3]. Because this hybrid source is a major element in a A-RoF system, it will be fundamental to understand the requirements based on the laser characteristics to respect the high data bit rate of A-RoF architectures. As phase modulation link requires laser diode with narrow linewidth, the technological process of the III-V laser on silicone platform will be investigated to determine the main limitations of the light coupling between the two technologies (III-V to Si).

The laser model will be developed from the rate equations of carriers/photons dynamics and the light coupling from the gain medium (III-V medium) to the silicon cavity. The mode profile and confinement, optical losses, optical filters and reflectors will be also considered. These parameters will be considered through advanced modeling considering electromagnetic simulation coupled to rate equations. Once the laser model will be developed, the critical technological limits will be strongly analysed and optimized in order to reduce the future RUN of such hybrid photonic devices during their development.

Objectives of the thesis

This thesis focuses on the study of Silicon-based laser sources for A-RoF architectures and the mainly objective concerns the development of an advanced physical model. The PhD student will contribute to this modeling to accelerate the design of new future hybrid laser reducing the steps of technological RUN. The different key points are:

- Theoretical consideration of hybrid laser diode realized at CEA-Leti on silicon platform.
- Understanding of A-RoF architectures, telecommunication applications and PICs technology.
- Development of advanced models of this component combining an equivalent circuit models [5] and numerical methods.
- Characterization of hybrid lasers to validate the developed model.
- Simulation and characterization of simple A-RoF system build on PICs to evaluate link performances with an advanced complex waveform.

Candidate profile

Applicants should follow a MSc degree related to electronics, microwaves and photonics or applied physics. Skills in optoelectronics and integrated components are beneficial. Experience and knowledge on CAD software, Maltlab, C/C++ programming language, Electromagnetic software will be strongly appreciated.

Contacts and application

Send a CV and a cover letter to:
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Esycom sort description

Esycom Lab has a strong expertise in the following engineering fields: communication systems, sensors and Microsystems. This expertise matches the labs project entitled *Communication systems and sensors for the city, the environment and people*. Six research areas are developed: antennas and propagation, architectures, microwave photonic devices, microsystem analysis, medical sensors, energy harvesting. Three well-equipped platforms are dedicated to the characterization of the developed components and systems. Esycom Lab is labeled CNRS.

References

[1] S. Bernabé, T. Ferrotti, B. Ben Bakir, B. Szelag, F. Gays, A. Myko, O. Castany, B. Charbonnier, M. Epitaux, J. Cornelius, J. Coronati," Integration challenges for Terabit Class Mid Board Photonic Transceivers", IEEE CMPT Symposium, Nov. 2016, Japan, 10.1109/ICSJ.2016.7801292
[2] https://mycmp.fr/datasheet/silicon-photonic-ics-si310-phmp2m
[3] S. Malhouitre, B. Szelag, S. Brision, Q. Wilmart, D. Fowler, C. Dupré, C. Kopp, "Heterogeneous and multi-level integration on mature 25Gb/s silicon photonic platform," IEEE CMPT Symposium, Nov. 2017, Japan, 10.1109/ICSJ.2017.8240122
[4] J.M. Ramirez, et al., "Low-κ, narrow linewidth III-V-on-SOI distributed feedback lasers with backside sampled Bragg gratings," Opt. Express 30, 36717-36726 (2022)[5] W.E. Kassa, A.L. Billabert, S. Faci, C. Algani, "Electrical Modeling of Semiconductor Laser Diode for Heterodyne RoF System Simulation, IEEE Journal of Quantum Electronics, Vol. 49, n°10, pp. 894-900, Oct. 2013, 10.1109/JQE.2013.2274383.