PhD Proposal:

Silicon photonic integrated circuits 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. Other 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. However, this mature PICs technology is optimized for digital communications and not optimized for photonic-analog communications. Thus, analog performances of building blocks of A-RoF systems need to be evaluated and improved. These silicon photonic components concern optical waveguides, intensity and phase modulators, optical filters and hybrid III-V-Silicon laser sources and photodiodes. The future A-RoF system could be designed to fit in the 5G and beyond fronthaul architectures for an enhanced mobility at a higher data rate. This solution allows cohabitation with other contemplated solutions for the fronthaul such as x Radio Acces Network (xRAN) or Time Sensitive Networking (TSN). We will focus in this thesis on the remote radio units in dense Multiple-Input Multiple-Output (MIMO) communication area where the photonic integrated technology will bring a cost-effective solution.

This study is related to communication system activities of Esycom lab where microwave-photonic solutions are developed to build the new generation architectures.

PhD subject

This PhD position deals with the design of optical communication architectures for high data rate. The built-in components of these links are in integrated photonic technologies designed and fabricated at CEA-Leti such as hybrid laser diode, optical waveguide, SOA, etc. [1], [2], [3]. We will focus on PM-DD (Phase Modulation-Direct Detection) and PM-CD (Phase Modulation-Coherent Detection) optical links. The performances of these architectures will be first evaluated from the state-of-the art integrated photonics components on Silicon. They will be characterized both in simulation and measurement. Simulations will be performed based on the developed models of microwave-photonics components for A-RoF applications that include distortions and noises [4], [5], [6]. New modeling method dealing with User-Defined Models approach will be used for optical waveguides and interconnections. Then, the second step concerns the development of optical devices for high efficiency PM-DD and PM-CD links. 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 third step concerns the introduction of wavelength division multiplexing WDM technology for the high speed and MIMO operations. For this, specific ring resonators which act as a wavelength filter and a frequency discriminator will be integrated in the link. The filter bandwidth is determined by the ring diameter and a linear frequency slope is required to enhance the conversion efficiency of phase modulation to intensity modulation. These resonators are totally fabricated on silicon and will be fully characterized at Esycom experimental platform.

To achieve the last step, photonic component models will be developed for such CEA-Leti integrated technology. Some pre-defined technologies will be simulated including the integration of photonics devices. Simulated performances of the different architectures will be done in terms of EVM regarding to the data rate. This will contribute to identify the impairments introduced by the optical channel and the impact of integrated photonic devices on the different tested waveforms. Measurements will be performed to validate the obtained simulated results. Then, the critical technological limits will be strongly analysed and optimized.

Objectives of the thesis

This thesis focuses on the study of Silicon-based PIC for A-RoF architectures and the development of specific models. The PhD student will contribute to the modeling and optimization of the silicon photonic integrated components. The different key points are:

- Understanding of A-RoF architectures, 5G applications and PICs technology.
- Theoretical consideration of available photonic components: laser diode, optical modulator, optical filter, optical waveguide, optical ring resonator, optical amplifier (SOA), photodiode, ...
- Analog characterization of a selected integrated photonic components realized at CEA-Leti on silicon.
- Development of advanced models of these components combining an equivalent circuit models and numerical methods.
- Design of a A-RoF fronthaul link for 5G applications based on an PM-DD or PM-CD links. A 2x2 MIMO link will be considered and can be extended to 4x4 MIMO link.
- Simulation and characterization of the designed A-RoF system build on PICs to evaluate link performances with an advanced complex waveform.

Candidate profile

Applicants should have 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

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Esycom short 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

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