2nd URSI AT-RASC, Gran Canaria, 28 May – 1 June 2018

Heterogeneous Silicon Photonic Devices for Wireless Communication Systems

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The advent of the connected society, with 5G wireless networks and the Internet of Things, drives a revolution of access network design. Future wireless networks aim to connect a significantly greater number of users and devices, while increasing their bandwidth with a tenfold (10 Gbps). To realize this goal, a transition to pico-cells and the use of high-frequency carriers is needed. Realizing such a new access network topology is very challenging and new technologies are needed. Microwave photonics can play a key enabling role, offering unique features such as Radio-over-Fiber, microwave carrier generation and ultra-wide bandwidth filters[1]. The main drawback of this technology is that it relies on bulky and expensive components. This drove the emergence of Integrated Microwave Photonics (IMWP), which combines the functionality of MWP while offering compact and scalable devices. Several systems such as flexible filters and beamforming networks have been demonstrated in IMWP [2], but most of them only with passive components. However, for Radio-over-Fiber applications or optical microwave synthesizers, active components such as laser diodes and amplifiers are needed. InP is the natural platform for this, but cannot offer the same low-loss waveguides as Silicon Photonics. Using hybrid silicon photonics, where InP material is heterogeneously integrated with low-loss Silicon circuits, can offer the best of both worlds.

We have realized both high bandwidth III-V-on-Si lasers for the use as analogue transmitters, as well as state-of-the art III-V-on-Si mode-locked lasers [3] for frequency generation and optical subsampling.
On the other hand, the silicon photonics platforms offers Ge-on-Si photodiodes with bandwidths exceeding 60 GHz. This offers the possibility to realize both transmitters and receivers using Silicon photonics. Using the aforementioned components, we demonstrated a fully Silicon Photonic Radio-over-Fiber link, where the receiver was augmented by co-integration of a BiCMOS TIA. With this link, we demonstrated the transmission of a 16-QAM signal on a 20 GHz carrier over 2 km of SMF with a bit rate of 10 Gbps [4]. The use of IMWP has interesting applications beyond terrestrial wireless networks, such as in communication satellites were size-weight and power consumption are of importance. Using a III-V-on-Silicon mode-locked laser in combination with a Silicon Photonic PD and phase-shifters, we realized an integrated photonic mixer/subsampler. With this optical mixer we were able to demonstrate down conversion from Ka-band directly to 1.5 GHz IF. Such devices could have interesting applications in Satelite communication, where LO distribution using fiber can be of interest because of weight and size considerations.

These demonstrations show that the use of hybrid silicon photonics opens the way to a host of new possibilities for IMWP in wireless communication.

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