Silicon-germanium photodetectors for energy-aware chip-scale communications

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(Invited paper)

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***Abstract*—We report on recent advances in silicon-germanium photodetectors with a lateral p-i-n hetero-junction. We discuss a fast, sensitive and energy-wise operation, demonstrating that this generation of optical photodetectors holds much promises for future on-chip telecommunications.**

***Keywords*—silicon photonics; germanium; photodetectors; opto-electronics; on-chip telecommunications; energy consumption**

Si-Ge-Si Photodetectors

Semiconductor-based photodetectors are key elements to many applications in nanophotonics, providing efficient signal conversion between optical and electrical domains. In modern optoelectronics and communications, III-V and group-IV materials are in the center of performant photodetectors. While III-V detectors were standards in optical communications for many years, silicon-germanium (Si-Ge) alternatives are taking a rapid leap nowadays as mature photonic building blocks within a monolithic and CMOS-compatible platform [1-6].

Si-Ge photodetectors can be seamlessly fabricated using open-access Si foundries, leveraging versatile and low-loss Si platform combined with high-quality Ge epitaxy. From a design and technology perspective, recent breakthroughs in the development of on-chip Si-Ge photodetectors afford definite advantages over III-V counterparts [1], including trustworthy opto-electrical performances and reduced production cost. In this invitation, we report our latest results obtained with telecom-band-operated Si-Ge-Si photodetectors based on lateral p-i-n hetero-junctions [1-6].

The p-i-n photodiodes were fabricated on 200 mm SOIs using Si-foundry tools and processes. Si-Ge-Si photodetectors are combined with a loss-loss butt-coupling light injection [2]. This provides simple and unique integration scheme, favoring better control over the modal confinement, improved engineering of the intrinsic diode zone, and easier fabrication compared to other alternatives. As a result, Si-Ge-Si photodetectors have compact footprint and yield enhanced opto-electrical performances, alongside with much simpler manufacturing that reduces a number of process steps. In turn this supports a full integration of passive and active photonic devices into a well-mastered opto-electronic device library.

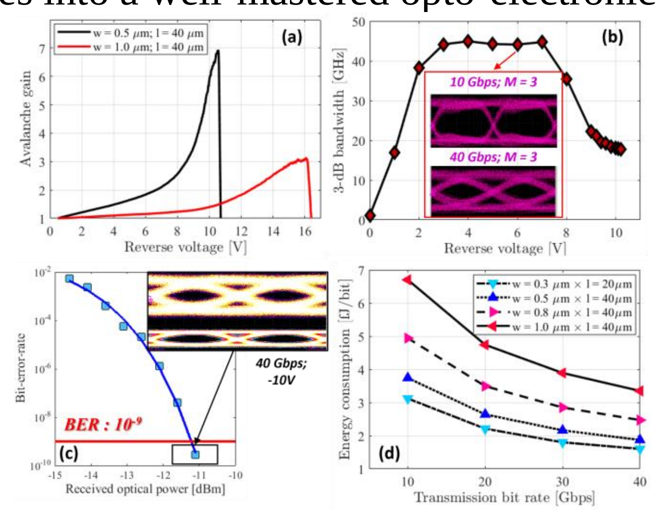

Figure 1: *Avalanche operation of Si-Ge-Si photodiodes. (a) Gain and (b) 3-dB bandwidth vs. reverse bias. (c) BER vs. received power. (d) Energy consumption vs. bit rate.*

Under low-voltage operation, Si-Ge-Si devices yielded small dark-currents between 10 and 150 nA, high photo-responsivity of 1.2 A/W at -0.5V, and fast response beyond 50 GHz [2-4]. High-speed operation up to 40 Gbps was obtained for different biases and device geometries [4]. Optical power sensitivities down to -14 and -11 dBm were measured for link rates of 10 and 25 Gbps, respectively [3]. Avalanche operation of Si-Ge-Si p-i-n’s is shown in Fig. 1. For an avalanche operation, we obtained a substantially better opto-electrical performances for our

Si-Ge-Si photodetectors. This includes high responsivities beyond the limit of quantum efficiency [5], simultaneous high-speed and low-noise operation [6], low optical power sensitivities (-11 dBm for 40 Gbps) [5], and energy-aware photodiode operation with a level of few fJ/bit only, without additional electronics on a chip [6].

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