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The Germanium Zener-Emitter for Silicon Photonics

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Si-Photonic transceivers are classified by their operating wavelength, power consumption and integration in Si to sustain cost-effectiveness. Applying Ge as optical active material in a Zener-Emitter structure, has proven to provide a competitive solution for the integrated semiconductor optical amplifier (SOA) on Si [1].

We further exploit the usage of a Ge Zener tunnel diode for electrical pumping (Fig. 1), to achieve population inversion and stimulated emission in an indirect semiconductor material at room temperature by direct Zener band-to-band tunneling (BTBT) [2] (Fig. 2).

We conclude to present electrical pumped lasing in a 1 mm waveguide at 90 mA (5 kA/cm^2) and for the first time mono-mode lasing in a 3.2 mm waveguide at 110 mA (60 kA/cm^2) with maximum output power of the SOA of 1.65 mW (Fig. 3).

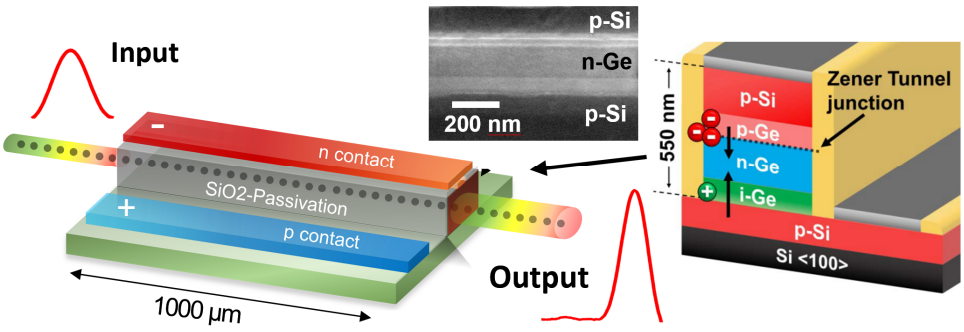

Fig. 1. (left) Two-terminal Zener-Emitter formed by cleaving the rip-waveguide. (middle) SEM-image of the Si-Ge-Si heterostructure with strained relaxed Ge by a SiGe virtual substrate. (right) MBE-Layer sequence with the Zener p-n tunnel diode for electron pumping and p-i-n diode for hole injection. The device provides complete state-of-the-art CMOS process integration by 550 nm device layer thickness.

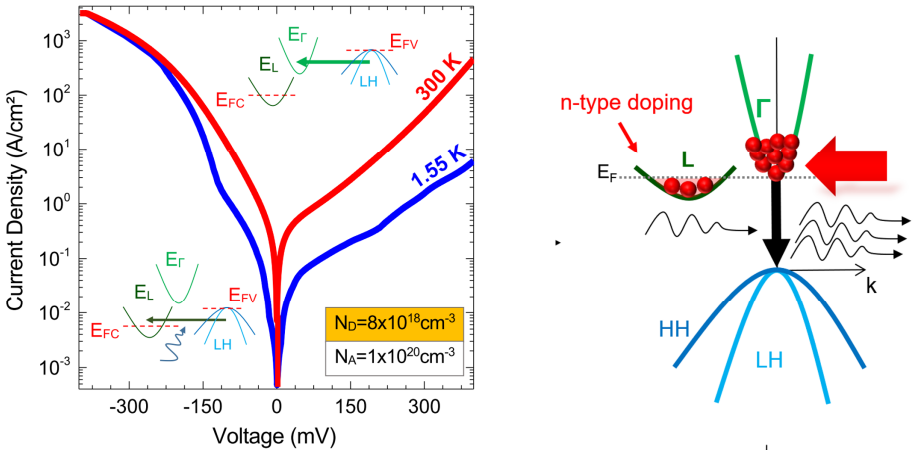

Fig. 2. (left) Ge tunnel diode for direct Zener-BTBT injection. The direct onset is visible by a small kink under reverse bias. (right) Schematic Ge bandstructure with tunnel injection and n-type doping. Stimulated emission is possible with wavelength defined by doping.

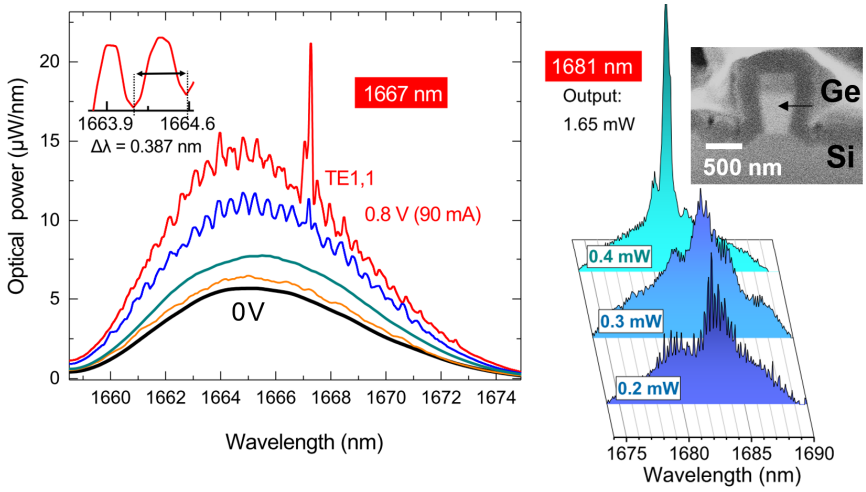

Fig. 3. (left) Optical amplification by the Zener-Emitter under electrical pumping. (right) Mono-mode lasing at 0.4 mW optical signal input, 110 mA electrical pumping (3.2 mm length) and 1.65 mW output power at room temperature.

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References

[1] R. Koerner et al., *The Zener-Emitter: A Novel Superluminescent Ge Optical Waveguide-Amplifier with 4.7 dB Gain at 92 mA Based on Free-Carrier Modulation by Direct Zener Tunneling Monolithically Integrated on Si*, in Proceedings of the International Electron Devices Meeting (IEDM), pp. 22.5, 2016.

[2] K.-H. Kao et al., *Direct and Indirect Band-to-Band Tunneling in Germanium-Based TFETs*, IEEE Transactions on Electron Devices, vol. 59, no. 2, pp. 292–301, 2012.