

6.5 mW single mode and polarization stable 850-nm VCSEL for silicon photonics integration

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A number of techniques for light source integration on silicon photonic integrated circuits (Si-PICs) have been proposed [1,2], where one approach is flip-chip integration of a tilted VCSEL over a grating coupler (Fig.1, top left). Flip-chip integration enables independent optimization of VCSEL performance, and the tilt eliminates optical feedback to the VCSEL and facilitates unidirectional coupling without the need of e.g. a slanted grating coupler or a prism on top of a rectangular grating coupler. The VCSEL must be single mode and have a stable linear polarization state, since in Si-PICs single-mode Si or silicon nitride (SiN) waveguides are used and many integrated components (grating couplers, splitters, multiplexers, etc.) are polarization sensitive. A high output power from the VCSEL is also desirable to enable a practical power budget for the Si-PIC. In this work we report on an 850-nm single-fundamental-mode VCSEL with stable polarization state for tilted flip-chip integration over a rectangular grating coupler on a Si-PIC with SiN waveguides. A record output power of 6.5 mW with >30 dB SMSR and >20 dB OPSR is demonstrated (Fig.1, bottom -left, -middle and -right). The VCSEL is intended as the light source on a multi-degree of freedom sensor PIC for vital sensing, being developed in the European project PIX4life [3]. The SiN waveguides offer low loss (<1.0 dB/cm) in the 530-900 nm wavelength window which overlaps well with the wavelength regime that is of particular interest for life science applications [4].

We used a conventional GaAs-based oxide-confined VCSEL having a relatively large oxide aperture diameter (~5 μm) to enable a high output power, and thereafter introduced a fundamental transverse mode and polarization state selecting filter by shallow etching into the out-coupling surface [5]. The filter is comprised by a rectangular grating (pitch = 120 nm, depth = 59 nm, fill-factor = 55%) over a circular area, concentric with the oxide aperture, and with diameter (3 μm) about 60% of the diameter of the oxide aperture (Fig.1, top -middle and -right). The lateral extent of the grating area is used to control the transverse mode selectivity while the orientation of the grating lines is used to control the polarization selectivity. By using a sub-wavelength pitch, optical loss and beam degradation due to diffraction are minimized.

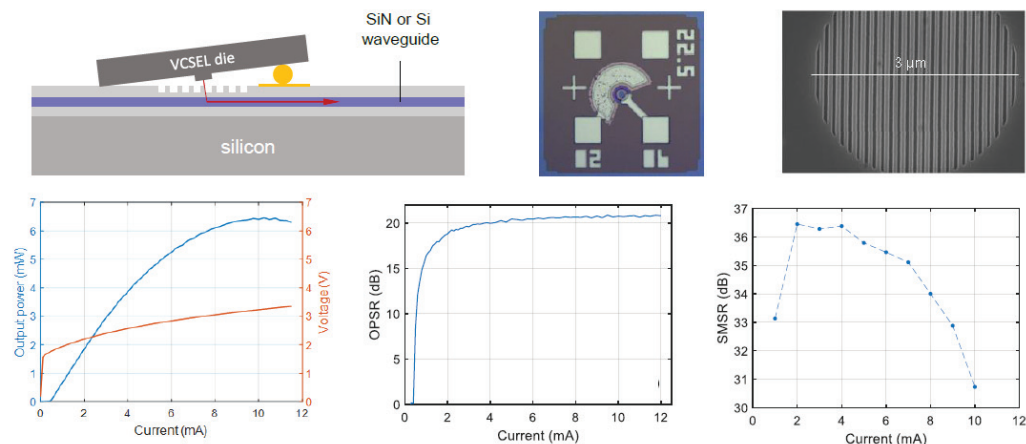


Fig. 1 From top left to bottom right: flip-chip integration, microscope image of VCSEL, SEM image of sub-wavelength surface grating, output power and voltage vs current, OPSR vs current, and SMSR vs current.

References

- [1] Z. Wang *et al.*, "Novel light source integration approaches for silicon photonics", *Laser Phot. Rev.* 11, 1700063, 2017.
- [2] H. Lu *et al.*, "Flip-chip integration of tilted VCSELs onto a silicon photonics integrated circuit", *Opt. Exp.* 24(15), 16258-16266, 2016.
- [3] www.pix4life.eu
- [4] A.Z. Subramanian *et al.*, "Low-loss singlemode PECVD silicon nitride photonic wire waveguides for 532-900 nm wavelength window fabricated within a CMOS pilot line", *IEEE Phot. J.* 5(6), 2202809, 2013.
- [5] Å. Haglund *et al.*, "Design and evaluation of fundamental-mode and polarization-stabilized VCSELs with a subwavelength surface grating", *IEEE J. Quantum Electron.* 42(3), 231-240, 2006.