SWIR InP-on-silicon tunable laser based on micro-transfer printing

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ABSTRACT

We demonstrate for the first time an InP-on-silicon laser with a tuning range from 1652 nm to 1706 nm realized using micro-transfer printing (µTP) technology. The laser achieves an output power of 1 mW. The laser cavities are fabricated in imec's silicon photonics (SiPh) pilot line on 200 mm silicon-on-insulator (SOI) wafers with micro-transfer printed III-V gain chips.

Keywords: Silicon photonics, InP, Laser, Micro-transfer printing

1. INTRODUCTION

Heterogeneous integration of III-V materials on silicon photonic integrated circuits (PICs) enables compact, high-performance on-chip laser sources, crucial for diverse applications beyond traditional telecom bands. While O-band (1.3 µm) and C-band (1.55 µm) tunable lasers are well-studied,[1–4] the short-wave infrared (SWIR) range offers untapped potential for sensing, spectroscopy, and environmental monitoring.[5,6] Expanding laser tunability into this range is key for on-chip spectroscopy systems targeting gases like methane and carbon dioxide.

Integration challenges arise from material mismatches and coupling inefficiencies between III-V and silicon photonic components.[7] Micro-transfer printing (µTP), a technology available under license from X-Celeprint, Ltd., overcomes these hurdles by enabling precise, high-yield placement of III-V devices onto silicon substrates with minimal material waste.[8,9] This wafer-scale method supports the integration of pre-fabricated III-V components into scalable silicon photonics platforms.

We present a widely tunable InP laser (1652–1706 nm) integrated onto a silicon platform using µTP. The laser achieves up to 1 mW of waveguide-coupled power, as measured using a powermeter. It leverages InP-based SOAs as the gain medium on 200 mm silicon-on-insulator wafers and incorporates micro-heaters for wavelength tuning and output power optimization.

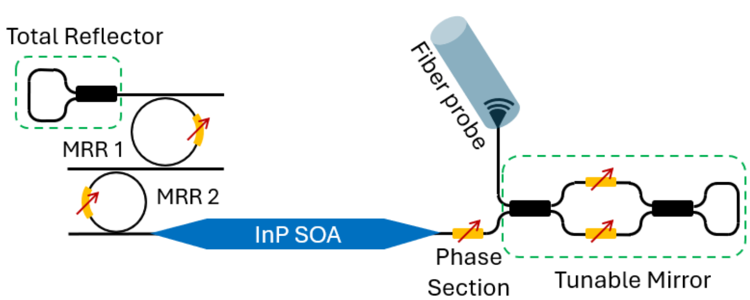

Figure 1. Schematic of the InP tunable laser transfer-printed on a SiPh substrate.

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2. DESIGN

The laser cavity consists of silicon photonic circuits and an InP-based SOA, which is integrated onto the circuit through post-processing using micro-transfer printing. By modifying the composition of the epitaxial layer stack, the gain spectrum can be tailored to longer wavelengths.[10] Table 1 details the epitaxial layer structure used in this work, featuring a photoluminescence (PL) peak centered at 1650 nm.

Table 1. **SOA epitaxial layer stack**

Layer type	Material	Thickness [nm]
P-contact	InGaAs	200 nm
P-doped	InP	1500 nm
SCH	AlGaInAs	50 nm
Barrier × 6	AlGaInAs	10 nm
Well × 6	AlGaInAs	6 nm
Barrier	AlGaInAs	10 nm
SCH	AlGaInAs	50 nm
N-doped	InP	200 nm
Sacrificial 1	InGaAs	50 nm
Sacrificial 2	AlInAs	500 nm

The schematic of the circuit is shown in Fig. 1. The SOA, with a length of 1 mm, incorporates adiabatic tapers on both ends to enable efficient optical mode coupling with the underlying silicon waveguide.[11] A Mach-Zehnder interferometer (MZI) featuring two multimode interferometers (MMIs) serves as a tunable out-coupling mirror. A thermo-optic phase tuning section is included to adjust the cavity mode positions. Wavelength selection is achieved using two thermally tunable micro-ring resonators (MRRs) with radii of 32 µm and 30 µm, forming a Vernier filter. This configuration extends the effective free spectral range (FSR) > 60 nm, providing a tuning range of approximately 54 nm within the targeted wavelength range. The FSR of each MRR is around 4 nm.

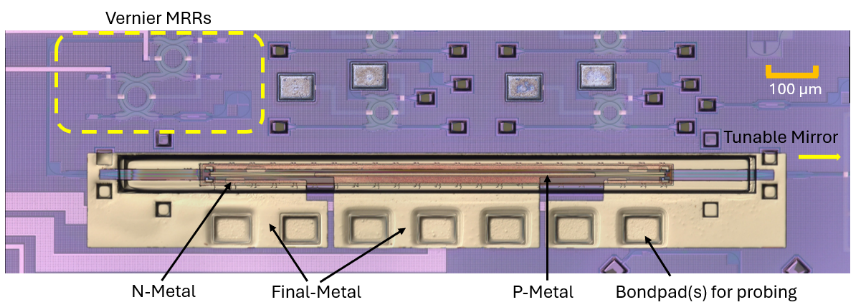

Figure 2. Microscope image of a fabricated laser.

3. CHARACTERIZATION

Fig. 2 shows the microscope image of a fabricated laser. To measure the laser, the n and p contact pads of the laser are connected with probes, as well as the bondpads of the Vernier filter, tunable mirror and phase section.

The full spectral tuning of the demonstrated tunable laser was measured under a constant injection current of 100 mA, and is shown in Fig. 3. The laser exhibits a broad wavelength tuning range from 1652 nm to 1706 nm, covering a total range of 54 nm. The discrete wavelength tuning was achieved through thermo-optic phase tuning of one of the MRRs.

4. CONCLUSION

This paper presents the design and characterization of a widely tunable short-wave infrared InP-based laser integrated onto a silicon photonic platform using µTP. Operating across the 1652–1706 nm range, the laser

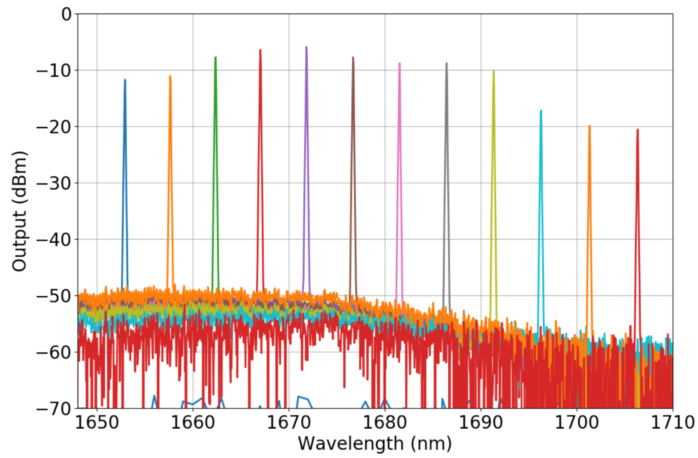

Figure 3. Wavelength tuning result.

achieves a wide tuning range through a Vernier filter. These results highlight the potential of µTP for seamlessly integrating III-V materials with silicon photonics, paving the way for tunable lasers in SWIR applications such as spectroscopy and environmental sensing.

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