Universally printable single-mode laser on low-index platforms

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Abstract: Heterogeneous laser integration usually entails a platform-dependent process flow and design. We experimentally show a single-mode laser that can be printed on all platforms with $n_{platform} = 1.7 - 2.3$ without changing the design or process flow.

1. Introduction

Integration of lasers on photonic platforms is critical for numerous applications such as ranging, spectroscopy, and RF photonics. For indirect-bandgap material platforms this can only be achieved through heterogeneous (on-chip) [1] or hybrid (chip to chip) integration [2] of gain materials. The former is advantageous since it offers better scalability but the latter requires less post-processing on-chip.

Micro-transfer printing is an integration technique that combines the minimal post-processing of hybrid integration with the scalability of heterogeneous integration. Pieces of source material (coupons) are underetched, picked up through adhesion with a PDMS stamp and can then be printed on the target material [3]. The unique advantages of this technique are the possibility of processing the material before printing and the simultaneous printing of multiple coupons using arrayed stamps which can scale up the throughput of the process.

Earlier demonstrations of transfer printing of III-V amplifiers on Si, lithium niobate (LN), and Silicon nitride [4–6] rely on the fabrication of a low-loss cavity circuit on the target chip to ensure round trip gain and achieve lasing operation. The requirements for this cavity change across different integrated optical platforms which causes variation in the laser performance. To ensure efficient evanescent coupling, from the platform material to the III-V amplifiers and back, adiabatic tapers were etched in the III-V. Tapers used in [4] to evanescently couple to and from the III-V amplifiers cannot bridge the large index gap between SiN (n=2) and the III-V materials (n=3.5) so an intermediate layer of silicon (Si) with tapers was introduced in [7].

2. Design and measurement results

Here, we propose a universal approach to address the existing challenges for making integrated lasers. By creating the laser cavity inside the intermediate Si layer we ensure more consistency over the process.

We pattern a shallow etched, quarter-wave shifted distributed feedback (DFB) grating on the Si coupons before printing(Fig. 1). These gratings can be patterned very reliably because mature SOI processes can be used and post-selection is possible.

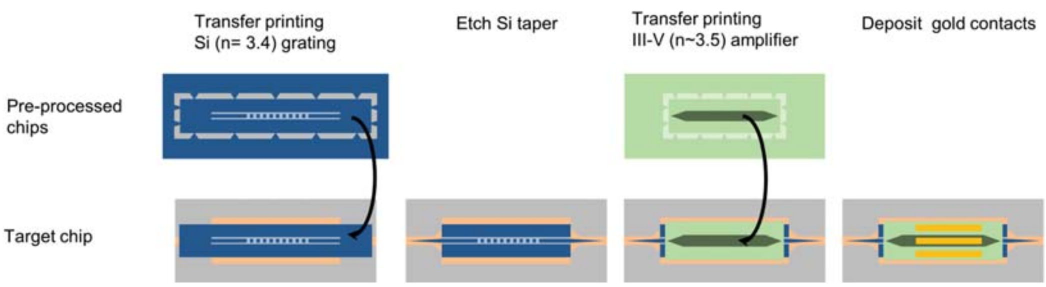

Fig. 1. Schematic of the two-step transfer printing process to print a DFB laser

The devices are printed onto an X-cut LNOI wafer with a 600nm-thick device layer on top of 2um thermally grown SiO2. The device layer is etched 300nm to form slab trapezoidal waveguides and then cladded with 800nm of inductively induced chemical vapor deposition SiO2. We deposit an AlOx etch stop layer (35 nm) and a BCB adhesion layer (70 nm). The pre-patterned Si (400nm) coupons are then transfer printed on an LN pedestal and fully etched to define the Si tapers. After this we again deposit an adhesion layer of BCB (70nm) and the amplifier coupons are printed. Finally we deposit a few microns thick layer of BCB, etch vias and deposit the final metal to contact the laser (see Fig.1).

This process can be repeated for any low index material, with little changes to the grating pitch and the tapers, allowing us to use the same pre-fabricated coupon chips for different platforms. This is because, inside the laser cavity, the mode is almost completely confined in the Si and III-V layers so the effective index will be affected only very weakly by the platform index. For a platform with buried oxide the center wavelength of the DFB stopband only changes 65 pm when changing the refractive index of the waveguide material of the platform (platform index, $n_{platform}$) from 1 to 2.5. This means that the pre-processed DFB grating can be optimized and pre-fabricated once and will operate near identically for all low-index materials($n_{platform}$=1-2.5).

The taper between the Si and the platform material is also robust against a change in the platform index: it has ~100% coupling for our LNOI platform and >80% coupling for $n_{platform} = 1.7 - 2.3$.

We have experimentally implemented the two-step transfer printed DFB laser on a LN($n_{platform}$=2.14) on-insulator platform. We measure this laser at different temperatures and apply pump currents of up to 120 mA on the 700 nm long amplifier. The laser shows single-mode lasing at 25°C at 1534 nm in a narrow pump current range, 86-92 mA with a peak on-chip power of only -30 dBm. This low output power is caused by damaged tapers. The on-chip power was expected to be around a mW since we use the same amplifier as in [4, 6, 7] . These damaged tapers also cause broadband reflections which explain the multimode behavior at other currents.

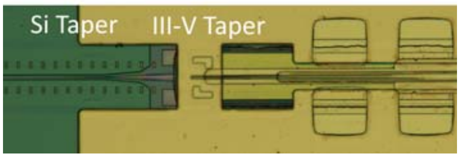

Fig. 2. Tapering section of the transfer printed laser

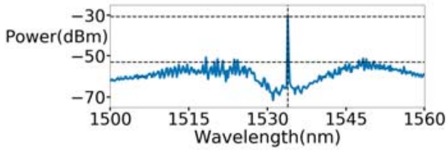

Fig. 3. Spectrum of the laser on LN

3. Conclusion

We have shown a proof of concept device for an integrated single-mode laser design that is universally printable on low-index material platforms. In future work we want to show the universality of this design experimentally by printing the same laser on a SiN platform.

Future efforts will also focus on moving more steps from post-processing on-chip to pre-processing prior to printing. Both the etching of the tapers in the Si and the contacting of the amplifiers could be done on the coupons. This would simplify the processing on-chip to just the two transfer printing steps. These improvements should result in a universally printable single-mode DFB laser, with an on-chip power of around 1 mW. [4,6,7] Additional results will be presented at the conference.

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