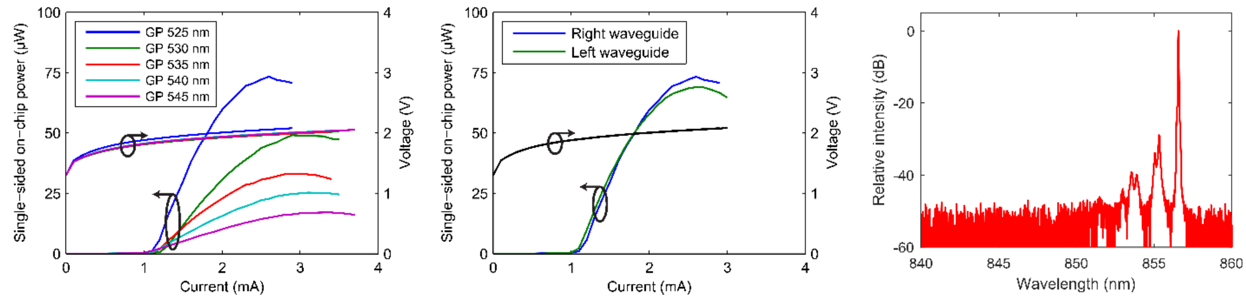
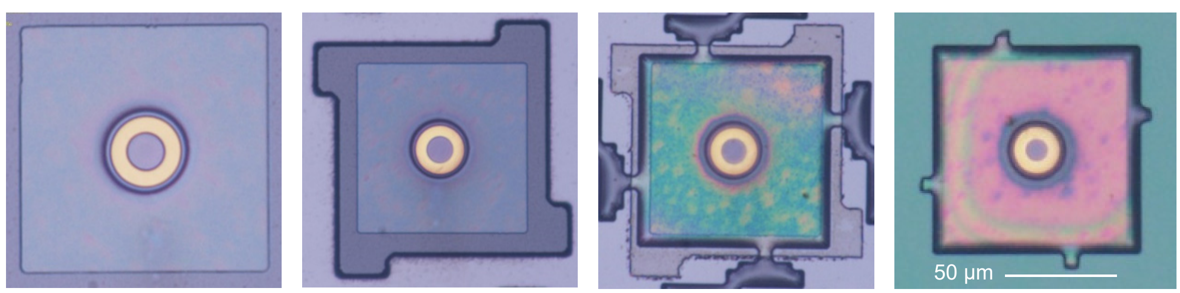


Fig.2 Left: Waveguide coupled power (single-sided) and voltage vs. current for different grating periods (GPs). Middle: Single-ended waveguide coupled power (right and left) vs. current with GP=525 nm. Right: Emission spectrum at 2.5 mA (GP=525 nm).

4. TRANSFER PRINTING

In the fabrication process used, device processing is done after die-to-wafer bonding of the epitaxial structure to the target substrate. With millimeter-scale minimum die size, the efficiency of material use is poor. This also prohibits dense co-integration of different III-V epitaxial layer structures. Transfer printing [5], on the other hand, allows the manipulation of micron-sized thin films such as III-V material or pre-processed device coupons, realized on their native substrate in a dense array, such that they can be printed in a massively parallel way to another substrate, leading to improvement in material use and increase in throughput.

To enable transfer printing, a sacrificial release layer is inserted between the GaAs substrate and the epitaxial "half" VCSEL structure. Fabrication starts with processing of the VCSIL (contact deposition, mesa etching, selective oxidation) on the native GaAs substrate (Fig.3a). This is followed by etching through the sacrificial layer (Fig.3b), attachment of polymer tethers and under-etching to release the coupon (Fig.3c), and transfer printing of the coupon to the target substrate using a PDMS stamp. Fig.3d shows a VCSIL coupon successfully printed on a silicon wafer.



(a) (b) (c) (d)

Fig.3 a) Processed VCSIL on source (GaAs) substrate, b) etching through sacrificial layer, c) definition of tethers and under-etching to release coupon, and d) transfer of coupon to target (Si) substrate through transfer printing.

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