Loss-Coupled DFB Nano-ridge Laser Monolithically Grown on a Standard 300-mm Si Wafer

Yuting Shi[1], Marina Baryshnikova[2], Yves Mols[2], Marianna, Pantouvaki[2], Joris Van Campenhout[2], Bernardette Kunert[2], Dries Van Thourhout[1]

1. INTEC Department, Ghent University, Technologiepark-Zwijnaarde 15, 9052 Ghent, Belgium

2. IMEC, Kapeldreef 75, 3001 Heverlee, Belgium

The integration of III-V semiconductors on Silicon is one of the key processes needed to build a versatile Silicon Photonics platform incorporating active and passive components. The direct epitaxy of III-V materials on Si can be considered the ultimate strategy to achieve this but, depending on the approach, still faces challenges in reaching sufficient crystalline quality, and/or interfacing with other silicon photonics components, and/or demonstrating electrical injection. Here, we present a loss-coupled DFB nano-ridge laser that is easier to process than our earlier demonstrated devices and opens the road towards electrical injection of these nanoscale lasers. The nano-ridges are epitaxially grown on a standard 300-mm Si wafer using the aspect ratio trapping (ART) technique to suppress defects, for details see [1, 2]. The high crystalline quality of the nano-ridges was proven before through characterization of their material gain [3] and the demonstration of optically-pumped lasing from a DFB cavity with etched gratings [4]. Electrical injection could not yet be demonstrated as depositing a continuous metal contact directly on top of the nano-ridge, only 300nm away from the active QWs, would result in a prohibitively large loss (>300dB/cm). Here, patterned metal gratings are deposited on the top of the nano-ridge instead. This allows to form a pure loss-coupled DFB cavity without the need to etch the III-V material, simplifying the processing and avoiding damaged interfaces. At the same time, this patterned metal grating in the future might serve as a pathway for electrical injection. The optical field of the low loss cavity mode concentrates in the dielectric part of the metal grating. This reduces the simulated loss of this mode to 23 dB/cm. The duty cycle of the gratings is designed to be 0.4 (0.37 as fabricated) for a good trade-off between the coupling strength provided by the periodically modulated metal layer and the cavity loss of the lasing mode. Following epitaxy of the GaAs/InGaAs nano-ridges, only a single ebeam and lift-off step is required to deposit the 5nm/40nm Ti/Au metallic grating layer with 164nm period. Fig. 1 (a) shows the cross-section of as-grown nano-ridges and (b) presents a top view of the loss-coupled DFB laser with metallic gratings on top.

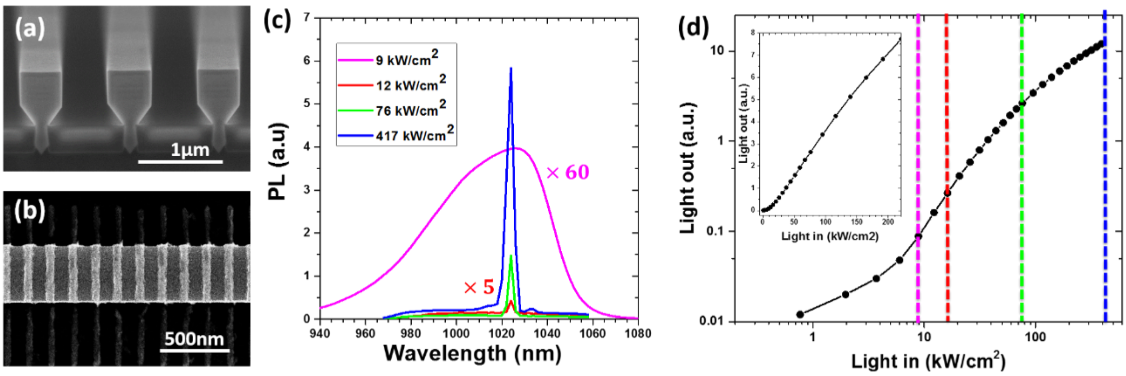

Fig.1 (a) the XSEM of the nano-ridges, (b) top view of the loss-coupled DFB device, (c) Spectra of the loss-coupled DFB device under varied pump intensity, (d) light in-light out curve of the loss-coupled DFB device on logarithmic and linear (inset) scale.

The loss-coupled DFB laser is characterized on a micro photoluminescence (μ-PL) setup, which consists of a Nd:YAG nanosecond pulsed laser (7 ns pulse width, 938 Hz repetition rate, 532 nm wavelength) as pump source, a combination of a polarizer and a rotating half-wave plate (HWP) to adjust the pump intensity and a monochromator to measure the spectrum. The spectra of the laser under increasing pump intensity are shown in Fig. 1(c) and indicate single-wavelength lasing. From the light in-light out curve, shown in Fig. 1(d), we derive a threshold of ~10kW/cm^2, similar to the values obtained for nano-ridge lasers with etched gratings fabricated from the same material [3]. These results prove again the high quality of the material grown using the ART-technique and provide a first feasibility test for the electrical injection of nano-ridge lasers through patterned metal structures defined directly on top of the nanoscale waveguide.

References

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