Widely-tunable narrow-linewidth lasers with monolithically integrated external cavity

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Abstract: We demonstrate preliminary results from a monolithically integrated tunable laser with narrow-linewidth. Experimental results show tuning in excess of 54 nm in the O-band as well as significant reduction in laser linewidth due to the external cavity. The measured linewidth with external cavity, currently limited by measurement setup, is around 150 kHz.
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1. Motivation

Photonic integration brings a promise of significant cost, power and space savings in today's optical data transmission networks as well as sensor applications. onolithic integration using heterogenous integration assembles many devices or optical functionalities on a single chip so that all the optical connections are on chip and require no external alignment and has the further promise of improved performance, which we demonstrate here.

Monolithic integration has been demonstrated on both Indium Phosphide (InP) and silicon (Si) substrates. Integration on Si substrates has been a major area of research in recent years as it can further bring the cost down. Heterogeneously integrating III-V materials on silicon also improves the individual device performance, mainly due to lower losses and better lithography.

As optical communications shift to more complex modulation formats, narrow linewidth lasers become a necessity. For example, a 16-QAM modulation format requires a laser linewidth <300kHz [1]. Furthermore for DWDM based systems, lasers have to be tunable to align to certain grid. Tuning can also be exploited in switching scenarios and for improving network resilience to downtime. Another area than can benefit from tunable, narrow-linewidth lasers are sensors and related applications.

There have been several results prior to this work addressing this need [2-4]. Here we show preliminary testing results of a widely-tunable laser on silicon with a monolithically integrated external cavity. The monolithically integrated external cavity is a novel concept that, when properly tuned, reduces the linewidth of the laser by providing strong coherent feedback.

2. Laser design

A schematic view of the laser is shown in Fig. 1. The lasers were designed at UCSB and fabricated using a heterogeneous photonic integration process design kit (PDK) and foundries developed under the DARPA EPHI program [5]. The gain section is inside a 2 mm long cavity formed by loop-mirrors. The lasing wavelength is determined in the tuning section comprising of two ring resonators and a cavity phase section, all of which are controlled by heaters. The front loop mirror (at output of laser) has a 10% reflectivity and the output of the laser is terminated at the facet at an angle of 7° to minimize reflections.

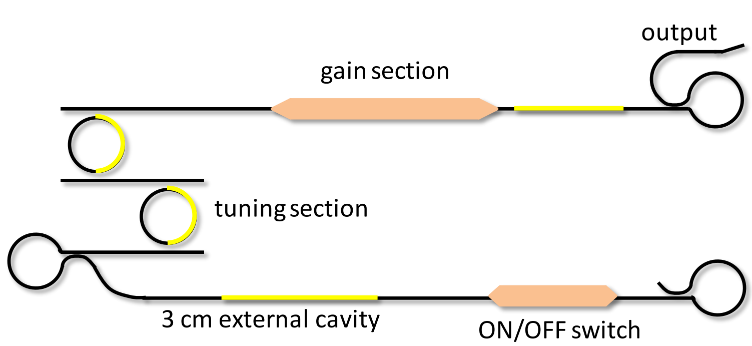

Fig. 1. (left) A schematic view of a tunable laser design with external cavity. Tuners are yellow, SOAs are orange.

The loop-mirror after the tuning section with reflectivity of 60% couples part of the light to the external cavity. In order to allow for long external cavity, a low-loss waveguide platform is needed. Here we utilize optimized silicon waveguides with losses <0.5 dB/cm. The external cavity is 3 cm long and has its own phase adjustment section and an SOA. This SOA is used as an ON/OFF switch with gain. As the propagation losses in Si waveguide are very low, there is a feedback from external cavity even when the SOA is left unbiased. To properly operate the laser in cavity-off regime, we apply 3V reverse bias at the ON/OFF switch. The external cavity is coupled on the side with the tuning section as the rings filter out any spontaneously emitted light from the SOA in the extended cavity. The SOA can be forward biased to reduce the losses, amplify the light, or the extended cavity can lase by itself. This interaction between the master laser and extended cavity is a complex topic that will be shown in more detail in the presentation. In the results reported here we either reverse bias the cavity or have it operated with bias currents below transparency.

The lasers operate in O-band and are tunable over a 54 nm range from 1237.7 nm to 1292.4 nm with high side-mode suppression ratio exceeding 45 dB across the entire tuning range (see Fig 2, left). They deliver 10+ mW of output power (which could further be increased with a booster SOA). The threshold current is in the 30 mA range.

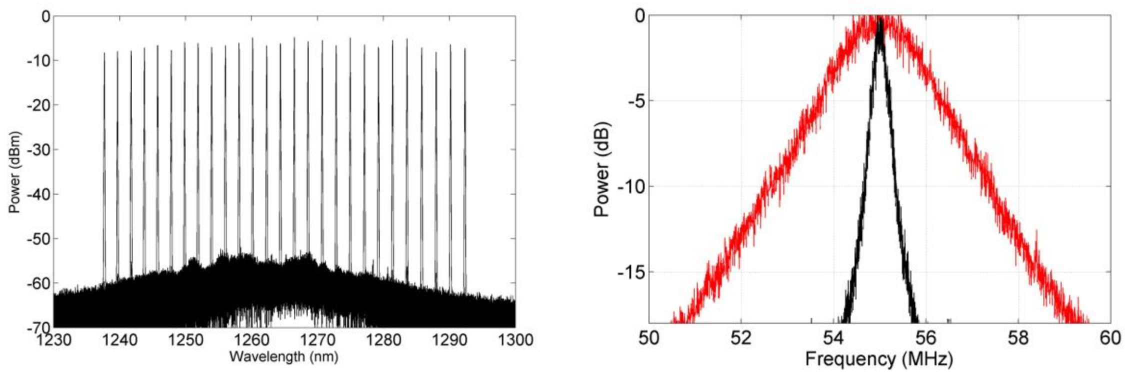

Fig. 2. (left) Lasers are tunable over 54+ nm range with SMSR > 45 dB (right) Linewidth improvement due to extended cavity by a factor of 8 (from 1 MHz to 150 kHz).

The preliminary linewidth measurements using self-heterodyne setup show laser linewidths in the 1 MHz range when the cavity is turned-off. The acquisition time, due to averaging, was around 3 s capturing significant part of 1/f noise. The linewidth consistently improves with removal of reverse bias and providing feedback from external cavity. The optimal bias currents, in this preliminary testing, at external SOA were in 0 – 7 mA range which is below transparency, and the measured linewidths were in 150 kHz range (see Fig 2, right). The best result was 45 kHz. We believe that linewidth results are currently limited by the measurement setup, and we will present the linewidth improvement due to external cavity across whole tuning range.

3. Acknowledgment

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4. References

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