

Monolithically Integrated Tunable Comb Source using Gain Switched Slotted Fabry-Pérot Lasers

(Student Paper)

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ABSTRACT

A tunable comb generation photonic integrated circuit (PIC) is demonstrated by gain switching a three section device. The PIC consists of a slave laser section and master laser, where the master laser is made up of a gain and a slotted mirror section. The tunability of the master laser was demonstrated by varying the bias across the gain and slotted sections producing nine wavelengths (with a side mode suppression ratio (SMSR) greater than 30 dB) with a tuning range of 1555 nm - 1582 nm. Frequency combs were produced by injection locking the slave laser to the master laser and gain switching the slave laser by applying a high power radio frequency (RF) signal using a signal generator, an RF amplifier and a ground-signal (GS) probe. Combs were generated with line spacings ranging from 3 GHz - 9 GHz.

Keywords: Slotted Fabry-Pérot, gain switching, tunable wavelength, frequency comb, injection locking.

1 INTRODUCTION

Optical frequency comb sources (OFCS) show significant promise in many modern day applications such as spectroscopy [1], space-based instruments [2] and high speed telecommunications [3]. OFCS generate equally spaced spectral carriers. Due to their precise and stable frequency, they can potentially reduce/eliminate the use of guard bands between neighbouring wavelength division multiplexed (WDM) signals [4]. One method of generating frequency combs in a PIC (which is the method investigated in this paper) is by injection locking a slave laser with a single mode master laser and gain switching the slave laser by applying a high power radio frequency (RF) signal.

Injection locking using an external master laser has been demonstrated to reduce phase noise in gain switched lasers [5]. In this paper we demonstrate the integration of a master tunable Slotted Fabry-Pérot (SFP) laser with a gain switched slave Fabry-Pérot (FP) laser in order to reduce phase noise and reduce the output linewidths. These two lasers are monolithically integrated in a strongly coupled master/slave configuration [6], whereby the slave laser is optically phase-locked to the master laser. The single mode characteristics of the laser have been known to improve by on-chip optical phase locking, particularly with increasing the side mode suppression ratio (SMSR) [7]. The master laser is more heavily biased than the slave and so the two sections are operating in an asymmetric bias regime. So while no isolator exists between the lasers, the asymmetry of the operation has been shown to allow for injection locking [8]. The slave laser is then gain switched using a high power RF signal generator to generate the optical combs. The output of the slave laser is analyzed using an ANDO AQ6317B optical spectrum analyzer (OSA), which has a resolution of 0.02 nm, and so the number of comb lines and their spacing can be observed.

2 DEVICE DESIGN

The device itself is made up of three sections, consisting of a master section, a slotted section and a slave section. Slots etched between the three sections of the device allows for electrical isolation and therefore permit independent biasing [9]. The master gain region and slave laser have lengths of 800 μm and 400 μm respectively. The slotted section is 756 μm in length and has 8 slots with an interslot distance of 108 μm .

The lasing material used to fabricate this device consists of 5 compressively strained 6 nm wide AlGaInAs quantum wells on an n-doped InP substrate. The upper p-doped cladding consists of a 0.2 μm InGaAs cap layer, which is followed by 0.05 μm of InGaAsP, lattice matched to 1.62 μm of InP. The ridge and slot features were defined using standard lithographic techniques, with a ridge width of 2.5 μm and a height of 1.7 μm , and a slot

width of $0.88\ \mu\text{m}$, with the ridge etch stopping above the quantum wells. A ground-signal (GS) contact was added to the slave section to allow for the gain switching of the device, where the ground pad makes contact with the n-type substrate via a deep etch through the active region into the n-region.

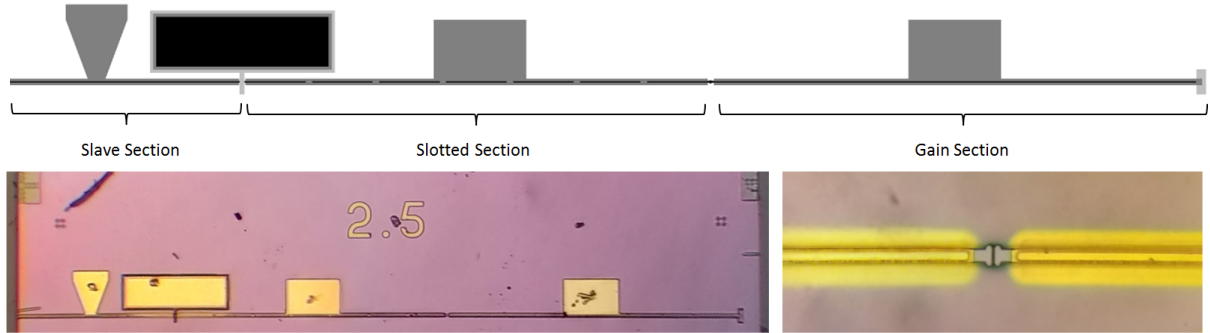


Figure 1. Schematic of device design (top). Microscope image of on chip device (bottom left) and slot (bottom right).

3 DEVICE CHARACTERISATION

Initially, the gain and slotted sections of the device were biased using currents ranging from 20 mA - 200 mA through the gain section and 20 mA - 100 mA through the slotted sections. At each interval the optical spectrum was recorded using the OSA and the SMSR and peak lasing wavelength was recorded; results plotted in Fig. 2. It was found that the master laser, made up of the gain and slotted sections, lased at a single mode (SMSR > 30 dB) and had a tunable wavelength. From the plots attained, the master section produced multiple single mode regions within a wavelength range of 1555 nm - 1582 nm.

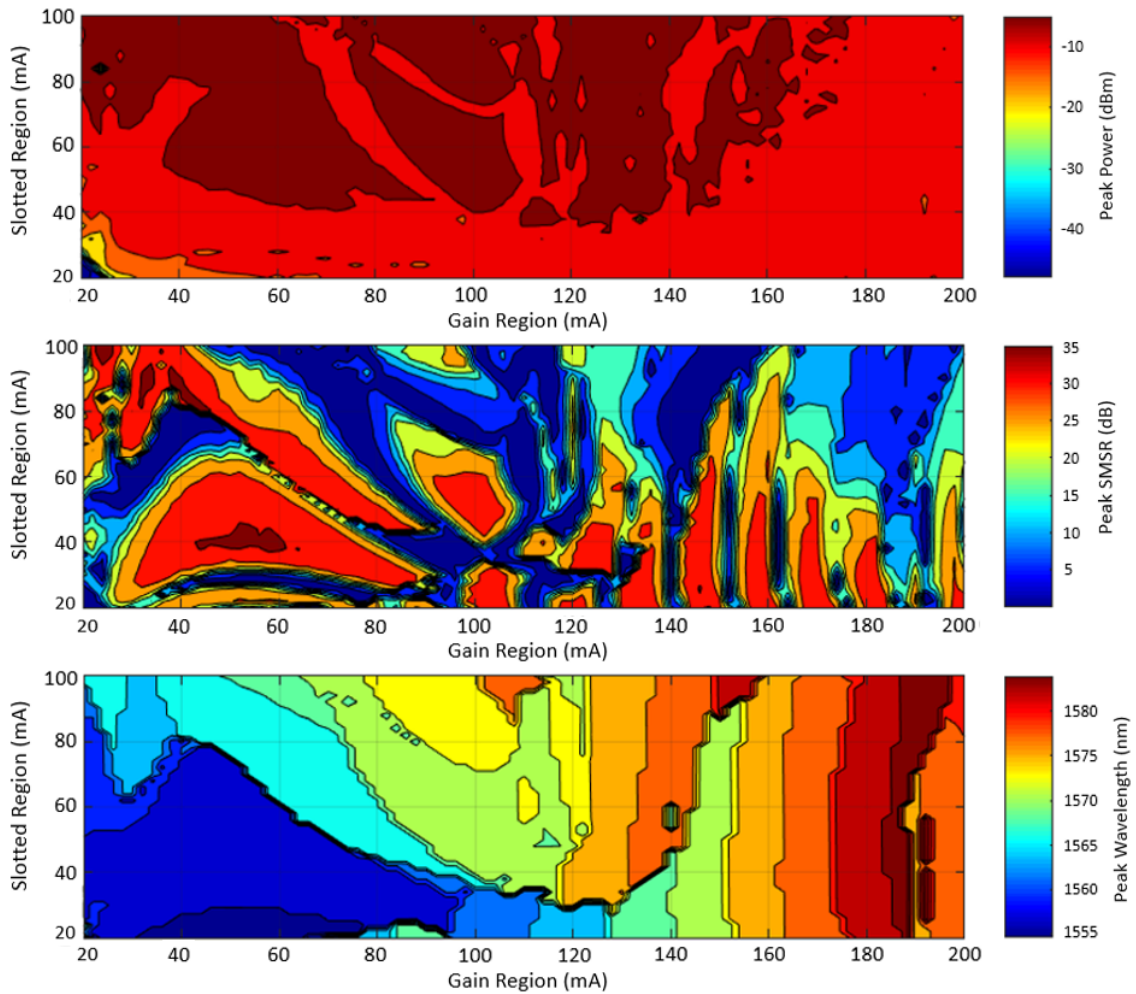


Figure 2. Power (top), SMSR (middle) and wavelength (bottom) of the master SFP while varying the current through the gain and slotted regions.

The slave section of the device was biased and the slave laser was injection locked to the master laser in order to reduce the phase noise. In order to injection lock the slave laser with the master laser, the master laser was biased so that it produced a single mode spectrum. The optimal biasing of the slave laser was found to be at a value approximately at its threshold current (25 mA - 32 mA).

Once injection locking was achieved, a strong RF signal was applied to the slave section to allow for gain switching to occur. Frequency combs were attained with line spacing between 3 GHz - 9 GHz. The best combs had a free spectral range of approximately 5.75 GHz, such as shown in Fig. 3. In Fig. 3 the comb spectrum was attained by biasing the gain, slotted and slave sections at 179 mA, 28 mA and 27 mA, respectively. We observe 8 comb lines within 4 dB of each other.

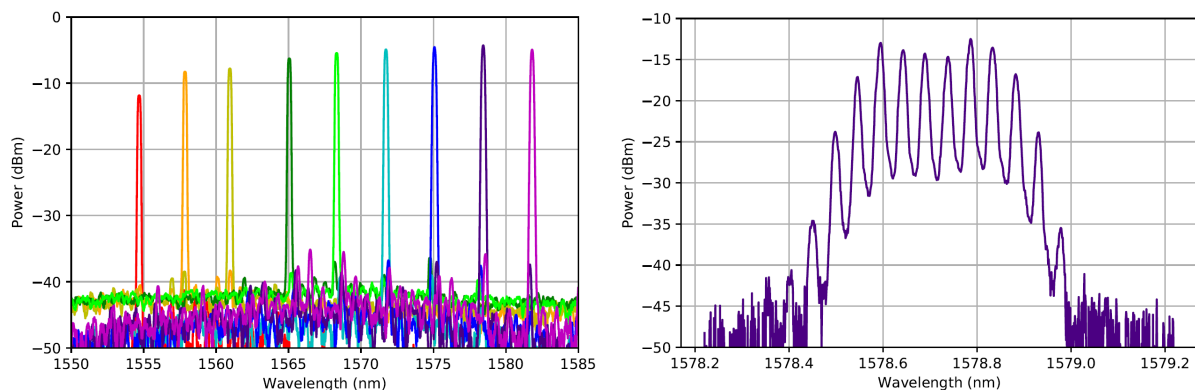


Figure 3. Different wavelengths attained by varying the bias across the gain and slotted section (left). Frequency comb generated at 1578.7 nm with a free spectral range of 5.75 GHz (right).

4 CONCLUSION

An optical frequency comb was obtained from the PIC by gain switching a slave laser that has been injection locked with a single mode master SFP. Due to the reflective defects caused by the slots, the master laser was shown to have a tunable wavelength, producing nine single mode wavelengths across a range of 27 nm. Combs were attained at each wavelength with line spacings ranging from 3 GHz - 9 GHz with optimal comb lines being produced by gain switching at an RF frequency of 5.75 GHz. This resulted in up to 8 comb lines being generated within 4 dB of each other.

ACKNOWLEDGMENT

This work was supported by the Enterprise Ireland commercialisation fund CF-2017-0683A&B, and by Science Foundation Ireland under grants 12/RC/2276 (IPIC), SFI/13/IA/1960 and 14/TIDA/2415.

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