Mutual Injection Locking of Lasers in a Photonic Integrated Circuit

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Photonic integrated circuits (PICs) offer many advantages in the area of photonics. In particular, complex optical systems which were once restricted to large table top setups are now finding their way onto integrated devices. Not only does this vastly decrease the size of these systems, it allows for lower power consumption and reduced cost [1].

We are interested in examining the stable regime of mutually injection locked lasers, which will be applied to the creation of optical superchannels for high bandwidth communications. The monolithic integration of multiple Slotted Fabry-Pérot (SFP) lasers [2] onto a single PIC has been investigated [3]. Injection locking of such a system is highly complex, due to mutual feedback between the lasers. Yet, stable optical-phase locking between two SFP lasers on-chip has been demonstrated for the case where one laser, the master, is much higher powered than the other laser, the slave [3]. In this paper, we investigate the mutual injection locking of two integrated, identical, equally powered SFP lasers while varying the coupling ratio between them.

The PIC consisted of two identical single facet slotted Fabry-Pérot (SF-SFP) lasers coupled together through a 1 mm waveguide interconnect, referred to as the "Variable Optical Attenuator" section (VOA). A schematic of the full device, with each variable parameter labelled, is shown in Figure 1. The single facet lasers consisted of a 650 μm long gain section and a 760 μm long mirror section, comprised of seven etched slots, each with a gap of 0.88 μm and 108 μm separation between the slots. The SFPs were controlled by independently biasing their respective mirror, I_{Mirror}, and gain, I_{Gain}, sections. Forward or reverse biasing the VOA section controlled the amplification or attenuation of the optical signal and hence varied the power coupled between the lasers.

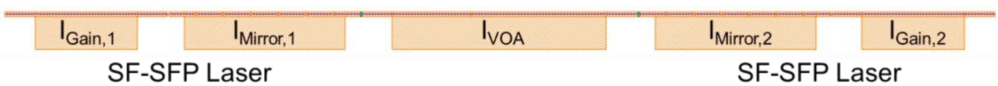
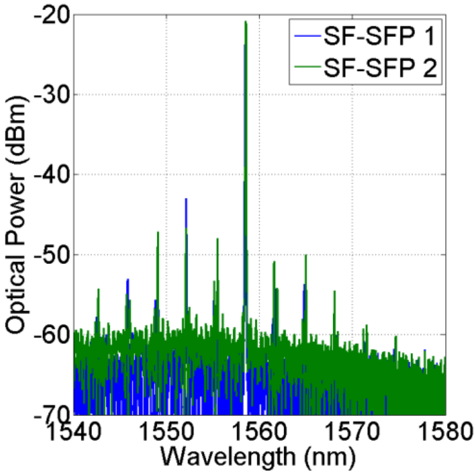


Fig. 1. Schematic of the PIC, with each variable parameter labelled.

Both lasers were biased at a mirror and gain section bias of 40 mA and 65 mA, respectively. At these biases both lasers had very similar spectra, see Figure 2, and output powers. The bias of the VOA section was varied between -1 V and +1V and the behaviour of both lasers was observed on an Optical Spectrum Analyser (OSA), an Electrical Spectrum Analyser (ESA) and a High Speed Oscilloscope (HSO). At a VOA section bias below -1 V, the waveguide interconnect between the lasers was absorbing, therefore the lasers were isolated from each other and behaved as independent lasers. At approximately -0.5 V the VOA section began to become transparent and light could pass between the lasers. The VOA section was fully transparent at a bias of approximately 0.7 V. Above this bias the device behaved as coupled cavity laser from facet to facet. The coupling between the lasers was controlled by sweeping the VOA section bias between -0.5 V and 0.7 V. Various stable locking regions were obtained. Regions of multimode behaviour were also observed. An OSA trace was recorded at each VOA bias. The resulting traces were concatenated and a two dimensional colour intensity plot was generated as a graphical representation of the evolution of the output of the lasers during the VOA bias sweep. The colour intensity plot of the OSA traces from one of the lasers is shown in Figure 2, where the various behavioural regimes can clearly be observed.



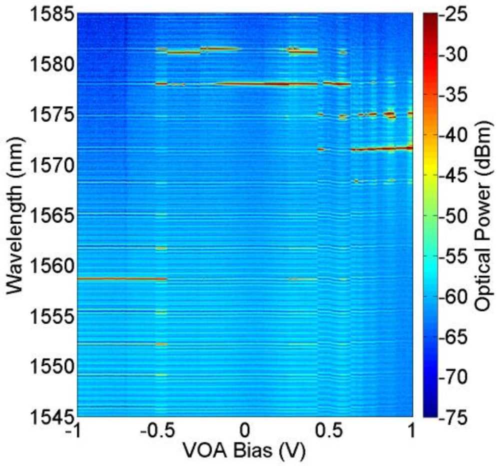


Fig. 2. Left: Free-running spectra of both lasers for mirror and gain section biases of 40 mA and 65 mA, respectively. Both lasers have very similar spectra at these biases. Right: Colour intensity plot of the OSA traces from one of the lasers, recorded while sweeping the bias of the VOA section.

We have successfully demonstrated stable locking between two equally powered SFP lasers on an integrated device. Further work will examine the dependence of the locking behaviour on the length of the delay between the lasers. It is hoped that this work will lead to a better understanding of the injection locking behaviour of lasers in next generation PICs.

References

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