All Optical Wavelength Conversion Based on Injection Locking in InP Ring Laser

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Abstract. *A wavelength converter based on an InP ring laser is demonstrated which requires no external probe signal. Conversion at 100Mb/s results in a wide open eye with a speed limit arising from the recovery time of the natural lasing mode of the long ring cavity (2mm)*

Introduction

All Optical Wavelength Conversion (AOWC) is a key technology for future optical packet switching networks [1]. Popular among AOWC schemes are those based on non-linear effects in Semi-conductor Optical Amplifiers (SOAs) [2] as those can be monolithically integrated. In many of the suggested implementations for AOWC the interaction of two laser signals, pump and probe, is required for the transfer of information from one signal to another. Other methods relying on modulation of a laser cavity by an external laser source such as a semiconductor fiber ring laser are based on Four-Wave-Mixing effects which require both high biasing current of the SOA and high optical power of pump signal[3]. Integrated solutions such as those based on Fabry-Perot Lasers and injection locking [4] require mirrors as part of the laser cavity limiting the placement of such WC in most integrated designs (usually to the end cleaved facet of the chip for simplicity). Recently published work [5], has suggested the use of ring lasers under unidirectional operation for wavelength conversion, but this operation mode of the ring lasers requires relatively high pumping current for sustainable uni-directionality [6].

In this paper we report on the operation of a wavelength conversion scheme which is utilizing a monolithically integrated semiconductor ring laser. The suggested structure is a very compact one and can be made potentially two orders of magnitude smaller if disc lasers are employed[5]. A data signal modulated onto an external optical field and injected into this laser structure via one of the laser's two output waveguides will lock the ring laser to its wavelength, thus completely suppressing the natural lasing mode. An inverted optical signal at the wavelength of the ring laser is thus obtained.

Experimental Set-up and Results

The experimental set-up used is shown in Figure 1. The InP ring laser was placed in a probe station and powered using two different current sources to provide maximal flexibility in optimizing single mode operation. Since the ring laser was fabricated on an all active Q1.25 InP chip, both the ring and the waveguide to which the laser light was coupled had to be electrically pumped. Pumping currents of 320mA and 350mA for the ring and waveguide respectively insured a single mode lasing fiber coupled output power of -8dBm with side mode suppression of approx 18dB (see Fig. 2). The device was cooled to a temperature of 10°C which resulted in lasing at a wavelength of

1548.1nm. The tunable laser's output was set to 1550.05nm & 5dBm, to co-inside with a longitudal mode of the ring laser so that injection locking will occur.

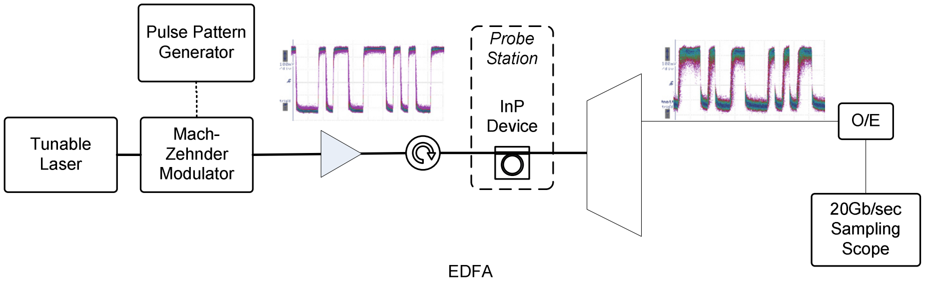

Figure 1 - Experimental Set-up

The laser's output was modulated with a PRBS of 2^7-1 at a speed of 100Mbit/s using a Mach-Zehnder modulator and then amplified using an EDFA with an output power of 8dBm, and a gain of 20dB. The coupling losses into the chip are expected to be 6-10dB, so that actual power coupled to the laser ring structure is around 0dBm. The wavelength converted signal, coming out of the other side of the chip was picked up along with the original signal, filtered with a 100GHz DWDM demultiplexer and then converted to an electrical signal using an APD receiver with a 2.5Gb/s bandwidth.

In Fig. 2, the spectra of the ring laser with and without injection of a modulated signal are shown. The solid line shows the lasing spectrum for the free running laser which is single mode with a suppression of 18dB for the next strongest lasing mode. Under modulated injection the natural lasing mode is shown to drop by 4dB (compared to an expected 3dB for a 50% on-off modulation). This extra 1dB power loss is due to slow recovery time of the natural lasing mode. Also visible in Fig. 2 is the co-incidence of the injected laser with a longitudal mode of the ring cavity.

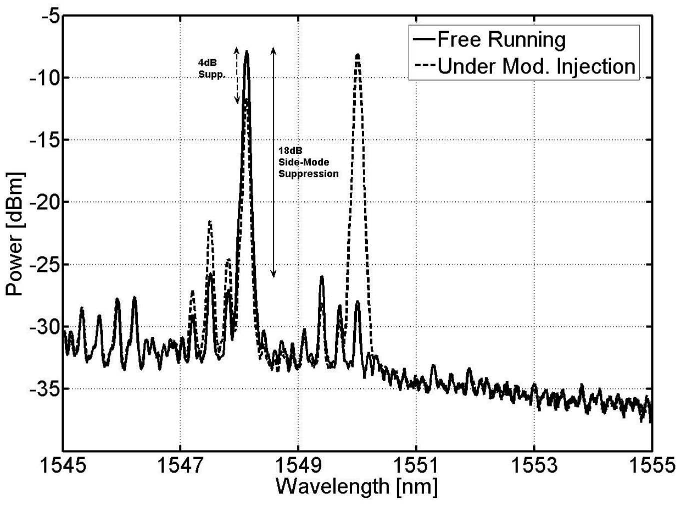

Figure 2 - Lasing Spectra

Finally in Fig. 3 eye patterns for input and output signals are given showing the fast suppression under injection (fast fall time) and slower recovery of the natural lasing mode (slow rise time).

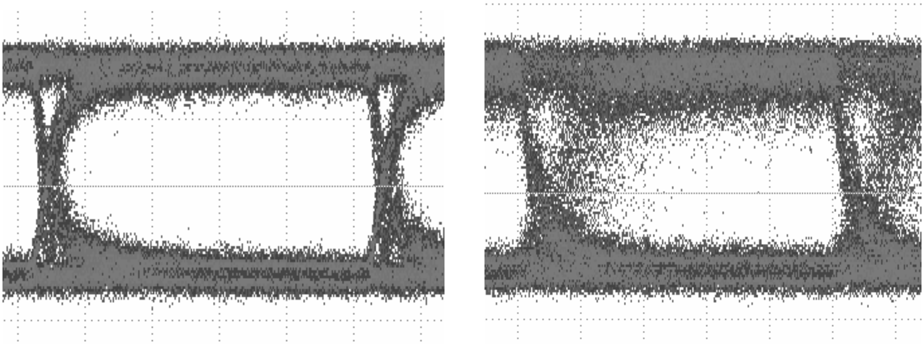

Figure 3 - Input (left) and output eye patterns at 100Mb/s

Discussion and Conclusions

A novel wavelength converter based on injection locking of a semiconductor ring laser is introduced. High extinction ration due to complete suppression of the ring's free running lasing mode is a key advantage while the relatively slow recovery time, of the same lasing mode, limits operation speed. By reducing the ring's size to a few microns in diameters, as was already demonstrated, the same scheme could be used for wavelength conversion at 10Gb/s and perhaps 40Gb/s.

References

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