ECIO 2016
18TH EUROPEAN CONFERENCE ON INTEGRATED OPTICS 2016
18–20 MAY | WARSAW | POLAND

Unidirectional Operation of a Monolithically Integrated Mode locked Semiconductor Ring Laser

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Introduction

Unidirectional operation is desirable attribute of a ring cavity laser. In fibre or bulk form this can be realized by applying discrete optical isolation techniques within the cavity. For monolithically integrated semiconductor lasers, the first monlithic integration of an optical isolator was reported by G. Takahashi *et.al.* in 2010 [1]. However, these are complex components which are difficult to integrate and are not available in the foundry used [2] in this work. Instead, we have realised unidirectional operation through the control of timing of the driving signals of the integrated laser. 4 GHz repetition rate pulses with a duration of 7ps and an energy of 0.24 pJ are generated.

Device Structure

The QW semiconductor ring laser was fabricated based on the InP Foundry developed within the EU *PARADIGM* Project. A schematic diagram for the device is shown in Figure 1. The laser consists of three separate SOA sections which each have a length of 1000 µm. In the vicinity of each long SOA section, there are four short SOA sections of 50 µm length which act as saturable absorbers when reverse biased. At the output of the laser cavity, a Mach Zehnder modulator is integrated to control the intra-cavity power ratio which enables the mode locking operation regime to be adjusted and optimized.

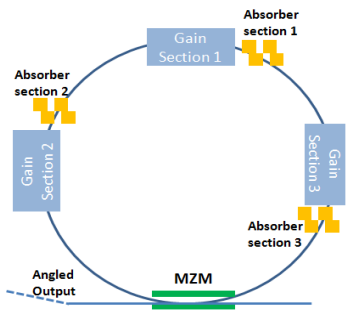

Fig.1. Schematic diagram of Semiconductor ring laser.

Results and Analysis

Figure 2(a) shows the RF spectrum for passive mode locking operation, with corresponding pulse durations of 11 ps and energy of 0.15 pJ. To realize unidirectional operation, electrical delays are added to each of the RF pumping signals. With appropriate delays, the signals are in-phase for clockwise propagating pulses and out of phase for counter-clockwise pulses. As a result, the counter propagating signals are greatly suppressed resulting in unidirectional operation. The improvements in

performances can be observed in Figure 2(b) and (c) which shows that noise power near the fundamental harmonic is reduced by more than 10dB. Figure 2(d) shows the comparison of the autocorrelation traces. With in-phase pumping signals applied, the pulse width is reduced from 11 ps (red) to 7ps (black) with a corresponding energy increase from 0.15 pJ to 0.24 pJ.

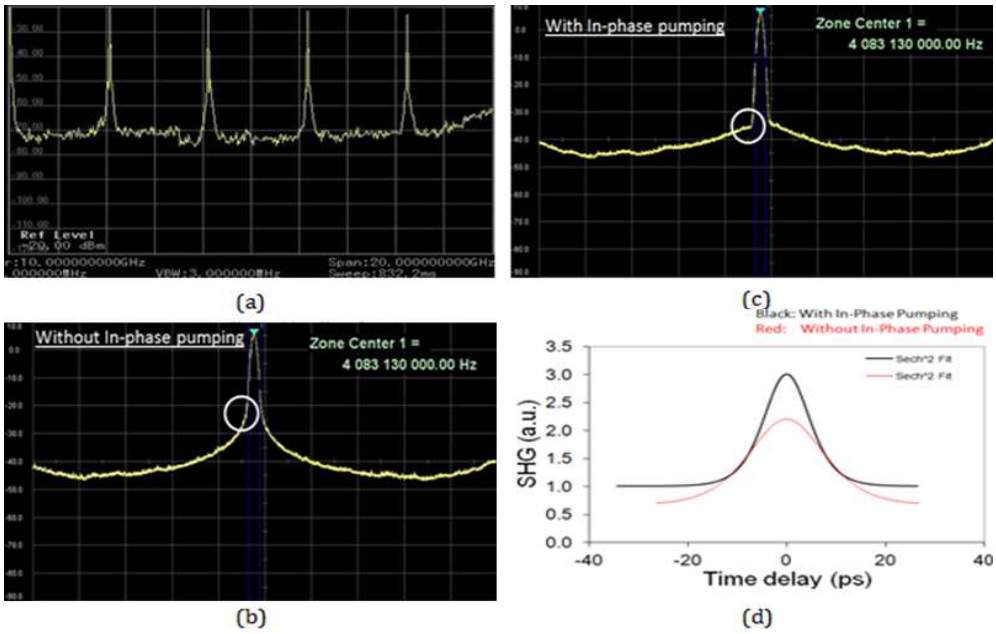

Fig.2. (a) RF spectrum of passive mode locking operation (b) Without in-phase pumping (c) With in-phase pumping (d) Autocorrelation profile comparison

Conclusion

Unidirectional operation in a monolithically integrated semiconductor ring laser has been successfully realised for the first time without the integration of complex optical isolation components, by applying in-phase RF pumping signals.

Acknowledgement

The research leading to these results has received funding from the European Community's FP7 programme under grant agreement ICT 257210 PARADIGM.

References:

[1] G. Takahashi *et.al*, "TM mode waveguide isolator monolithically integrated with InP active devices", ICIP&RM, 206(1):1-4, 2010

[2] M. Smit *et.al*, "An introduction to InP-based generic integration technology," Semiconductor Science and Technology, vol. 29, p. 083001, 2014.