

## Injection Locking Properties of a Photonic Microwave Oscillator Based on a Quantum Dot Mode Locked Laser

Georgios Atmatzakis\*<sup>1</sup>, David Murell<sup>2</sup>, Christos G. Christodoulou<sup>1</sup>,  
and Luke F. Lester<sup>2</sup>

<sup>1</sup> Dept. of Electrical & Computer Eng., The University of New Mexico,  
Albuquerque, NM 87131-0001, USA

<sup>2</sup> Center for High Technology Materials, The University of New Mexico,  
Albuquerque, NM 87131-0001, USA

A quantum dot mode locked laser can generate microwave frequencies, functioning as a photonic microwave oscillator. The advantages of this microwave oscillator include the compact size of the laser device, the low phase noise, the tunability of the output power and frequency as well as the high optical to electrical conversion efficiency. Despite the advantages of this oscillator though, a maximum microwave output power in the order of -10 dBm has been reported so far, denoting a possible need for further amplification of the signal in certain applications. In this work, we propose the idea of power combining of the microwave outputs of multiple QDMLL devices, by using injection locking, as a method to amplify the generated signal. The injection locking properties of the QDMLL device are studied and presented.

The signal amplification can be also achieved by using a power amplifier. This method, has the disadvantage of degrading the linewidth of the generated signal, contrary to the power combining method where the linewidth is improved. In the power combining method, the microwave output power of more than one QDMLL oscillators can be combined only if the free running frequencies of the independent oscillators match to each other. Since the QDMLL resonant frequency is sensitive to any temperature as well as biasing condition variations, injection locking is used to lock the oscillating frequencies together. In this paper, the injection locking properties of the QDMLL microwave oscillator are studied and the “Frequency Detuning (KHz) vs. Injection Power Ratio (dB)” graph is presented. For this purpose, an external microwave signal from a frequency sweeper is injected through a quasi-circulator to the absorber section of the QDMLL device. The quasi-circulator is a microstrip printed circuit, consisting of three quadrature hybrid circuits and six ports with SMA connectors. The main purpose of the quasi-circulator is to provide enough isolation between the strong external signal and the measurement equipment, but also to direct the QDMLL output to the measurement equipment without sending it back to the external source. Both the functionality as well as the configuration of the quasi-circulator are presented in this paper. Furthermore, for the measurement procedure, the QDMLL absorber section biasing voltage as well as the externally applied microwave signal power are varied, to sweep the injection power ratio from approximately 16 to 30 dB. From the experiment, a frequency range of approximately 50 to 350 KHz for the detuning of the QDMLL is demonstrated as the injection power ratio increases.