Stable 100 GHz Pulses Generated by Injection Locking of Multiple Lasers to an Optical Frequency Comb

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Optical frequency combs (OFCs) can generate a wide bandwidth of regularly spaced modes with high frequency stability. Besides frequency and time metrology, OFCs can also have applications in arbitrary waveform generation and telecommunications by manipulating individual comb modes. We have previously demonstrated using optical injection locking to selectively amplify individual comb modes which are closely spaced (250 MHz) [1]. Over 50 dB of gain was achieved with low phase noise associated with the locking process [2]. The injection locking process maintains the coherence properties of the master laser and therefore by combining multiple lasers locked to different frequencies of a common OFC, pulses can be generated.

In the work presented here, we have locked three semiconductor lasers 100 GHz apart to a 250 MHz spaced OFC using the technique presented in [1]. The lasers were subsequently combined using an arrayed waveguide grating. The relative phases of the signals from each laser prior to combination were controlled using piezoelectric fibre stretchers which were locked using low-bandwidth feedback loops (< 10 Hz). The optical spectrum of the combined signal is shown in Fig. 1a. The weak side-modes are due to the injection locking process and their powers were at least -44 dB below that of the main laser modes; they can be further suppressed by reducing the injected power. 100 GHz repetition rate pulses were observed using an optical sampling oscilloscope as shown in Fig. 1b. A root mean square (rms) timing jitter of 193 ± 6 fs was measured for 64,000 sample traces (measured over 6.4 ms). The rms jitter for 20 combined traces (1,280,000 samples), taken over 3 minutes, only increased to 223 ± 6 fs. This increase in jitter can be accounted for by the performance of the feedback system used to control the relative phase of the lasers, which has yet to be fully optimised. This technique can also be used to generate higher repetition rate signals. One of the key advantages of this technique is that the timing jitter scales down with increasing repetition rate since the phase variance associated with the injection locking process is independent of the spectral spacing between the locked lasers.

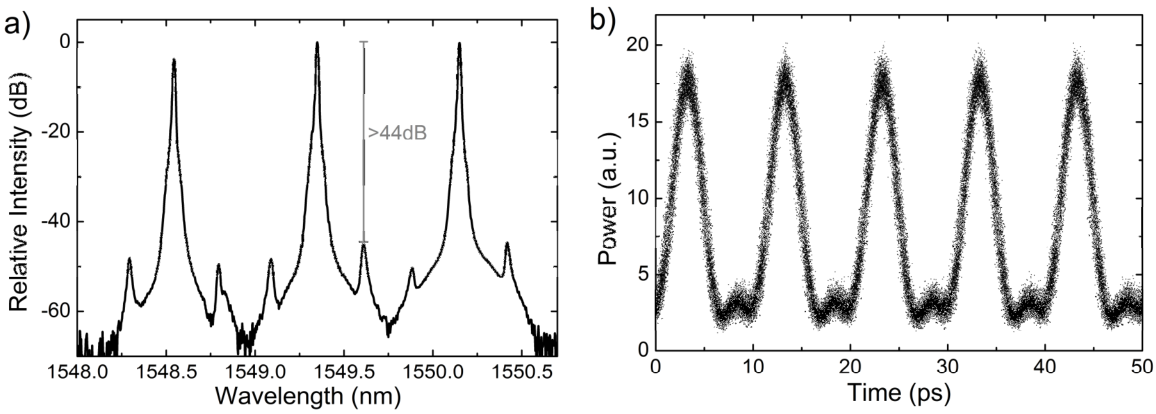

Fig. 1 a) The optical spectrum of the combined signal from the three injection locked lasers. b) The corresponding temporal waveform measured on an optical sampling oscilloscope (64000 samples) showing 100 GHz repetition rate pulses.

We plan to increase the number of lasers locked to the same OFC. By controlling both the amplitude and phase of each laser we will be able to generate shorter pulses. We will also be able to manipulate the shape of the pulses via line-by-line pulse shaping [3]. This will allow us to generate various shaped waveforms such as square-like and triangular-like pulses.

References

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[2] D.S.Wu, *et al.*, "Phase noise and jitter characterization of pulses generated by optical injection locking to an optical frequency comb" in proceedings of Frontiers in Optics (FiO/LS XXVIII), Rochester, 2012, FW2A.3 (2012).

[3] Z. Jiang, D. E. Leaird, and A. M. Weiner, "Optical processing based on spectral line-by-line pulse shaping on a phase-modulated CW laser," IEEE Journal of Quantum Electronics, vol. 42, pp. 657-666, Jul-Aug 2006.