Phase noise and temporal pulse characterisation of a Quantum dash laser

L Cairns, C C Renaud and A J Seeds

University College London

Abstract: In this paper we present the characterisation of the phase noise and temporal shape of a quantum dash laser. The laser generates an optical comb with a line spacing of 24.5GHz, over a 10nm wide spectrum. The device can operate passively mode locked or actively locked to a synthesiser. The phase noise of the device has been measured and compared in both regimes. By actively mode locking the device the electrical line width is reduced from 100kHz to 10Hz. The measured timing jitter of the locked device is 1ps over an integration range of 100Hz to 1MHz. The pulse shape of the device has been measured using a sampling oscilloscope, showing a pulse shape unlike that expected from a mode locked laser. This has been investigated and improved upon using optical filters and single mode fiber.

1 Introduction.

Semiconductor mode locked lasers (MLL) offer some unique features compared to other MLLs. As they offer high gain, they can be very compact with typically millimetre long cavities. This gives naturally high repetition rates. Semiconductor lasers also benefit from wide spectral bandwidths, which allows for very short narrow pulses, down to hundreds of femtoseconds[1]. These properties make semiconductor lasers promising for a number of interesting applications.

There are a number of different sub categories of semiconductor lasers. There is extensive work covering quantum well (QW) based lasers, and also quantum dot (QD) based lasers, however recently some attention has turned to quantum dash (QDash) lasers. QDash lasers are similar to QD lasers however the dot has been elongated, giving the quantum dash. QDash lasers have the interesting ability to be able to passively mode lock without the need for a saturable absorber. Instead mode locking is thought to be achieved via four wave mixing between the modes in the laser. [2]

In this paper the stability of the repetition rate is explored, through measuring the phase noise of a QDash laser. This is measured both passively, and by stabilising the pulse with a RF synthesiser modulating the drive of the laser at the same frequency the laser oscillates at. The pulse shape of the laser is also measured, and explored with optical filters to improve on the shape of the pulses.

2. Experiment and Setup

The synthesiser used to drive the laser has much lower jitter than that expected of the device (10s of fs) and the electrical spectrum analyser also has low jitter (again 10s of fs). This should ensure that the performance of the device is measured and not the limits of the equipment that is being used to test the device. The second synthesiser and electrical spectrum analyser are synced to ensure that there is no drift between the devices. A second synthesiser is required to trigger the sampling oscilloscope, as 24.5GHz is out with the limits of the scopes trigger input. The scope has both electrical and optical inputs therefore it is possible to use the ultrafast photodiode with the scope as well as the electrical spectrum analyser. The synthesiser is connected to the laser via bias T with a bias drive current. When passively mode locked the laser is biased at a set current with no input from the RF synthesiser.

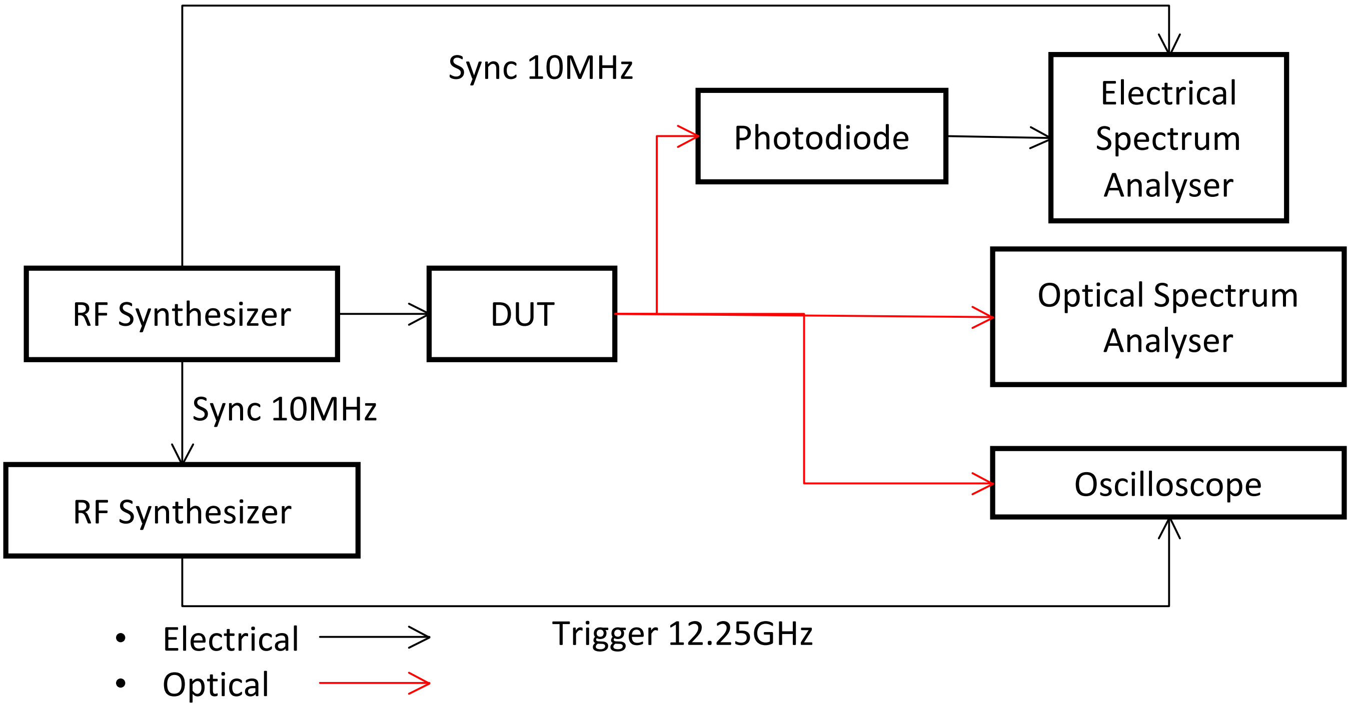

Figure 1 Schematic of the experimental setup

3. Results

The electrical line width of the device has been measured when free running and with electrical injection at the free running frequency. When passively mode locked the signal is prone to drifting and has a line width of 100kHz. When the device is actively mode locked, the signal is stabilised and the line width reduced to 10Hz.

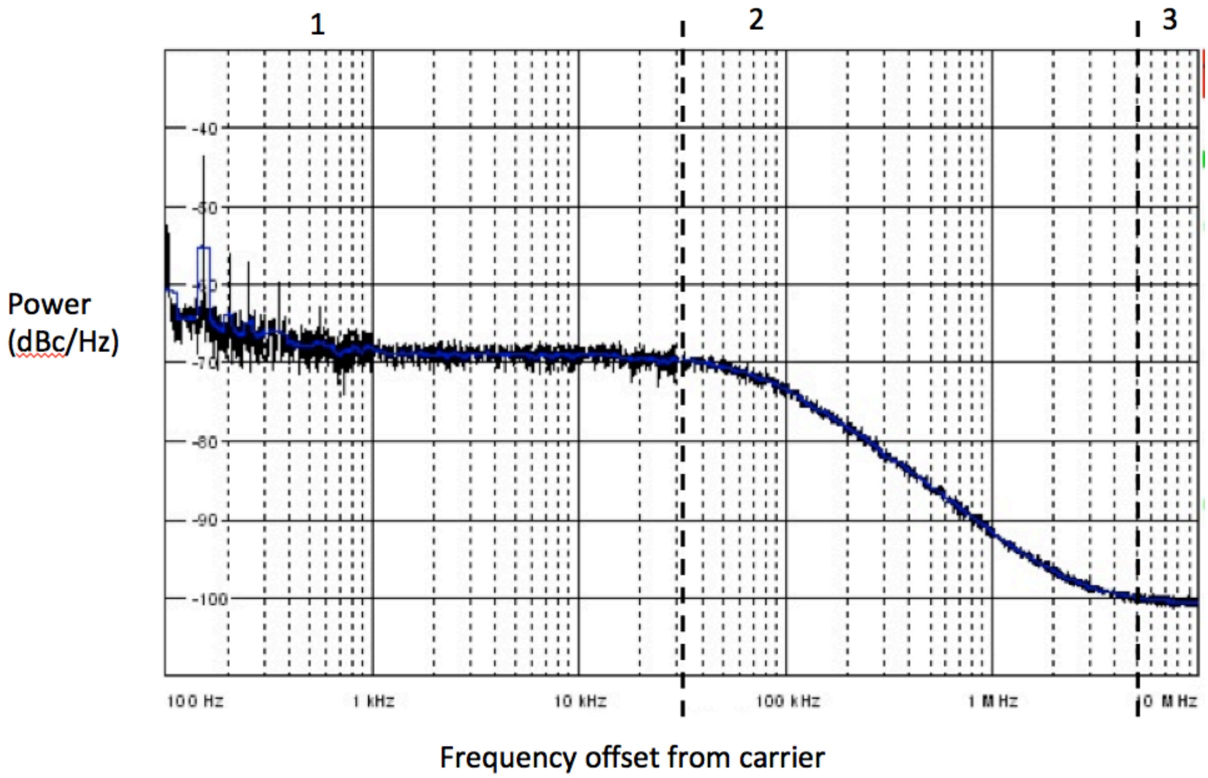

Figure 2 - Showing the single side band phase noise of the device mode locked with 15dBm from the Synthesiser, and at a drive current of 172mA

Figure 2 shows the Single Side Band (SSB) phase noise of the device. Converting the above phase noise plot to timing jitter, gives jitter of 1.1ps integrated over 100Hz to 10MHz. The phase noise shows three shapes, which have been sectioned into three regions for analysis. The low frequency noise from 100Hz to 30kHz offset from the carrier is relatively flat. The power at these frequencies has been lowered by actively mode locking the device. This reduction is due to the synthesiser acting as a restoring force, counteracting influences from mechanical and thermal noise. This represents a more stable signal, which is clear when comparing the electrical line width of the signal when passively and actively mode locked. Using a more powerful signal from the synthesiser could further reduce the low frequency noise, however care should be taken not to damage the device with too much power from the synthesiser. The second section is a slope, this is due to noise from the laser such as spontaneous emission. Active mode locking does not significantly reduce the phase noise in this section, and the phase noise in this region is similar to that seen when passively mode locked. This noise is intrinsic to the device. The last short section from 10MHz, is flat and extends out to higher frequencies. This is due to a combination of the laser power and the properties of the photodiode, and represents the noise floor of the system. This noise floor could be reduced by increasing the power from the laser or using a photodiode with a lower dark current.

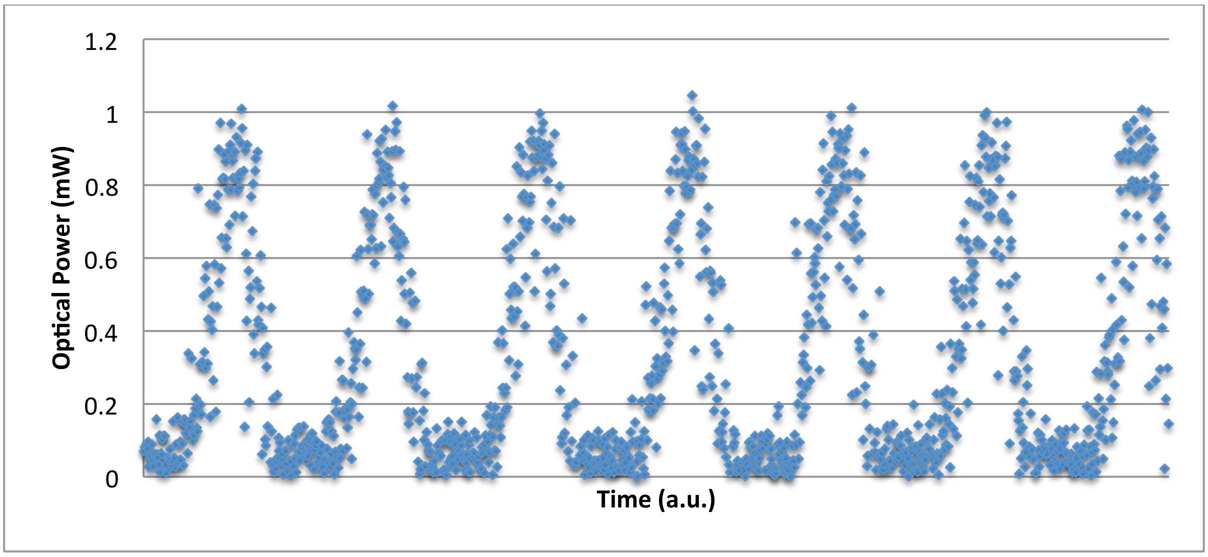

Figure 3 Shows the optical pulse as shown on the sampling oscilloscope, after the pulses have passed through a 1nm optical filter

Pulses observed on the sampling scope directly from the laser show a large DC component and only a small modulation of 24.5GHz relative to the full signal. This is due to the different modes in the laser being out of phase. The phase of the individual modes in a similar device has been measured in ref. [3]. There are two ways that more defined pulses can be created; reduce the number of modes detected at the photodiode, or reduce the average phase between the laser modes. The number of modes can be reduced by using an optical filter, and the phase difference between the modes can be changed by using a dispersive medium, such as optical fiber.

Figure 3 shows a trace from the sampling oscilloscope of the laser actively mode locked with a 1nm optical filter between the laser and the photodiode. This trace is what would be expected from a mode locked laser. However, as this technique uses an optical filter, optical power is reduced from the laser. A 1nm filter has been used and the original spectrum for the laser was approximately 10nm wide, therefore roughly 90% of the original pulse has been lost at the filter.

As discussed above it may also be possible to compensate the phase differences between the modes to reduce the overall difference between the modes by using a length of fiber. This has the advantage of preserving all the modes, therefore minimising the optical losses, neglecting the losses in the fiber. In ref .[4] this method is used and around 100m of single mode fiber (SMF) is used. If a similar length of fiber is required for this device then the losses from propagation 100m of SMF would be small compared to that lost in a 1nm optical filter.

5. Conclusion

We have presented phase noise measurements of a quantum dash laser, showing significant improvement in the stability of the repetition rate of the laser through mode locking with a RF synthesiser. The pulse shape of the device has also been investigated, showing a poor pulse from the laser due to phase mismatching between the large number of modes in the laser. The pulse shape has been improved by using an optical filter. It has been proposed that a length of SMF could be used to improve the pulse shape while also maintain the power output from the laser.

6. Acknowledgments.

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7. References.

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