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Tunable and variable clock generation up to 1.2 THz by filtering an actively mode-locked 42.5 GHz Quantum Dash Fabry-Perot laser with a reconfigurable filter

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Abstract: We report on the generation of an optical clock up to 1.2 THz using a Quantum Dash mode-locked laser and a spectral filter, selecting two or three lines, which are separated by the desired spacing.

OCIS codes: (060.4510) Optical communications, (230.5590) Quantum-well, -wire and -dot devices

1. Introduction

Generation of stable clock frequency or of high bit rate pulse sources is an important current issue in telecommunication systems. Several methods have been proposed to achieve this aim, using for example Mach-Zehnder interferometers [1] or a fiber optical parametric pulse source [2]. It is also possible to optically multiply the repetition rate of a pulse laser source by spectral filtering, keeping their characteristics of stability and reliability. A highly selective filter is then necessary to guarantee the finesse of transmission lines. This idea has already been proposed for low rates below 10 GHz using Fabry-Perot filters [3] or uniform Bragg gratings [4]. In a previous communication, we proposed a simple technique to generate a very stable optical clock at 170 GHz, using a Quantum Dash mode-locked laser coupled to a tunable multi-line Bragg grating notch filter and SOA [5]. The wavelength of this clock can be selected easily [6], while keeping its quality.

We now extend the method to higher frequencies taking advantage of a recently available tunable commercial filter [WS4000S] to produce optical clocks above 340 GHz. In this communication, we demonstrate the generation optical clocks at very high rates of several hundred GHz and up to 1.2 THz

2. Experiments

The Quantum dash Fabry-Perot mode locked laser (QD-FP-MLLD), previously described in [6], was fabricated at Alcatel III-V lab.. The chip was integrated with a temperature probe and a Peltier cooler into a butterfly module. In these experiments, the laser was actively mode-locked with an optical clock. A standard RZ 33% 42.7 GHz optical clock signal was generated at 1535 nm with a $LiNbO_3$ modulator and injected into the QD-FP-MLLD module through an optical circulator. We take advantage of the laser flat gain and broadband emission spectrum laser in order to select two or three distant lines that generate the desired frequency.

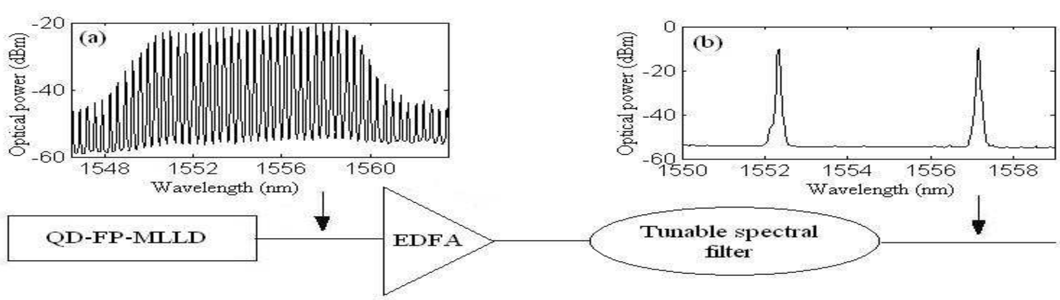

Fig.1. Schematic of the experimental setup

Figure 1 summarizes the experimental setup and gives some associated optical spectra. Spectrum (a) shows the wide spectral comb of the QD-FP-MLLD centered at 1555 nm with a 10 dB width of 13 nm (1.6 THz). The signal of this QD laser is injected into an amplifier and then passes through the tunable spectral filter. This commercial filter enables us to control the shape of the transmission of the filter and also to adjust its phase. We fix the shape depending on the desired frequency. For example, two lines of the emission spectrum of QD laser separated by 340 GHz were selected as shown on spectrum (b). We can see that there are no residual lines and the losses are very low (approximately 2 dB).

At the output of the QD laser, pulses are chirped. The Fourier limit can be reached by compensating the dispersion in order to compress the output pulses. For this, just put the correct phase with the filter.

The purpose of this experiment is to demonstrate the potential offered by spectral filtering. In the future, we can imagine use thermally induced phase-shifts on a chirped fiber Bragg grating as demonstrated at 170 GHz [5] using multi-line tunable notch filter, created by thermally induced phase-shifts on a chirped fiber Bragg grating (CFBG).

3. Selection of two spectral lines

Figure 2 shows the temporal shape of two generated clocks. Their traces were obtained thanks to an optical sampling oscilloscope with a temporal resolution of one picosecond**.** The left figure corresponds to a repetition rate of 345 GHz while the right one is for the doubled frequency of 690 GHz. The two optical clocks have a timing jitter beyond the oscilloscope resolution (150 fs) and the standard half-period are respectively 1.4 ps and 710 fs.

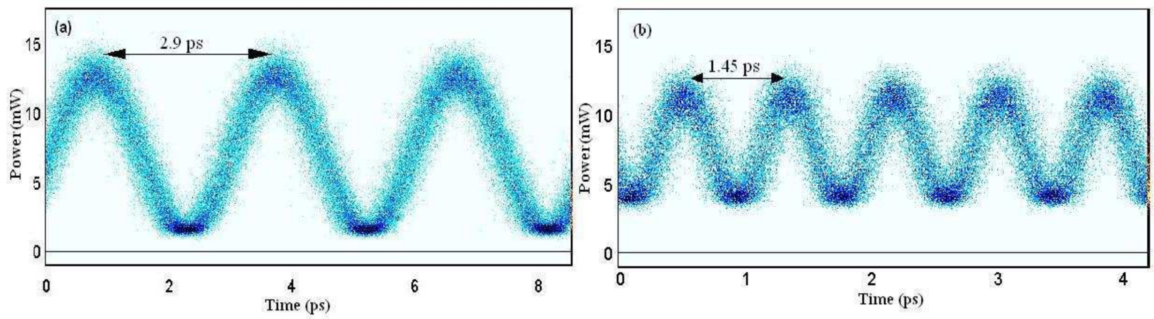

Fig.2. Temporal shape of optical clock at (a) 345 GHz and (b) 690 GHz

For rates above 700 GHz, the measurements are limited by the resolution of the oscilloscope. Nevertheless we can analyse spectrally the generated clock and show that the method can be used to create optical clocks up to 1.2 THz by assuming that the stability is the same. We present the autocorrelation result for this rate and the corresponding optical spectrum in figure 3, where we can note that no residual lines between two main lines are present. The repetition rate of the pulse in the autocorrelation trace is the inverse of 840 fs (1.2 THz) and the width at half maximum is approximately 400 fs.

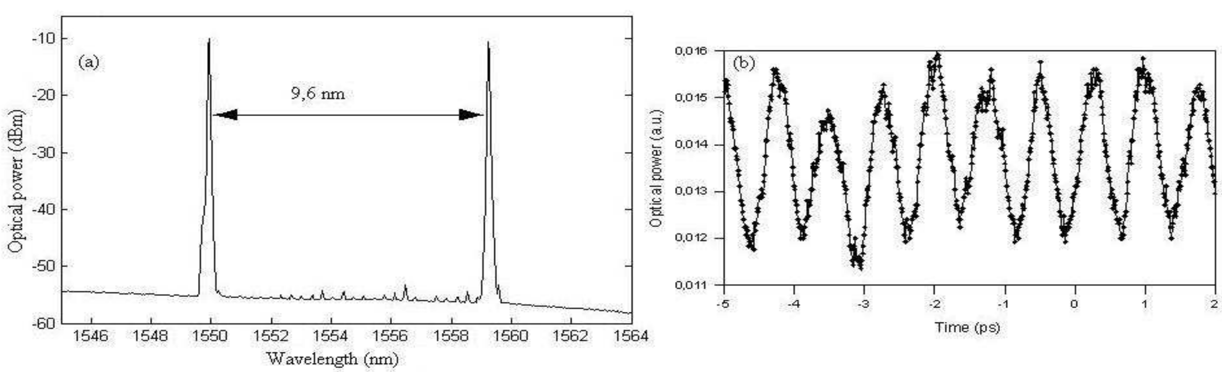

Fig.3. Optical spectrum and autocorrelation trace for a rate of 1.2 THz

4. Clock generation with selection of three spectral lines

For rates below 400 GHz, it is possible to select three spectral lines since the spectral range of 1.2 THz is within the source bandwidth. As expected and well-known from Fourier transform analysis, combining three spectral lines instead of only two shrinks the pulse length. A comparison is given in figure 4 for an optical clock at 340 GHz: the selection of two lines provides a standard half-period of 1.45 ps, while when we choose three spectral lines, the width at half maximum is only 1 ps. This property can be deduced from simple mode beating mathematics combining either two or three modes.

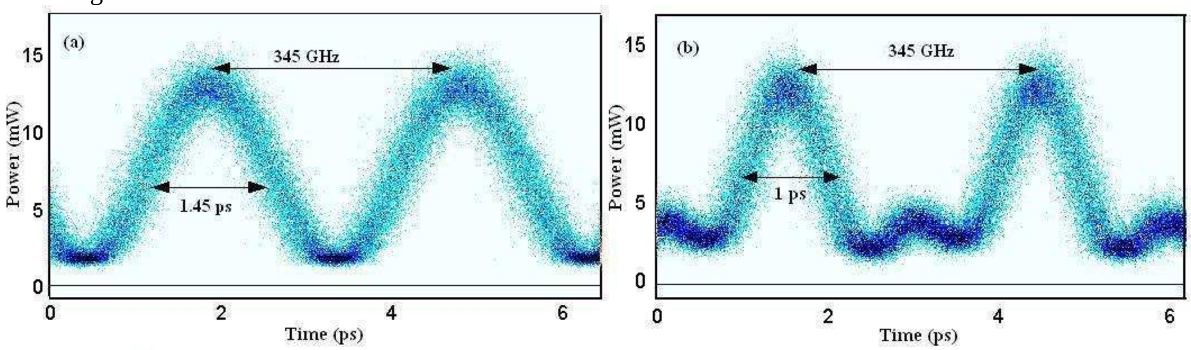

Fig.4. Temporal shape of optical clock at 340 GHz for (a) two lines and (b) three lines

5. Conclusion

We present a simple method to generate stable optical clock at various repetition rates. The quality of the signal is analysed up to 700 GHz and we show that a rate of 1.2 THz can be reached. The system is reconfigurable and tunable over all bandwidth covered by the QD laser. These results show the potential of QD-based MLLDs for THz wave generation.

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