720-fs Pulse Generation with 40 GHz Passively-Mode Locked Quantum-Dash Fabry-Pérot Laser

Ramón Maldonado-Basilio[(1)], Sylwester Latkowski[(1)], Pascal Landais[(1)]
[(1)] Research Institute for Networks and Communications Engineering (RINCE)
Dublin City University, Glasnevin, Dublin 9, Ireland. landaisp@eeng.dcu.ie

Abstract *Generation of 720-fs pulses by passively mode-locked Fabry-Pérot lasers is demonstrated. Pulse width is analyzed in terms of the longitudinal modes passing through a variable band-pass filter placed at the laser output.*

Introduction

Quantum-dash mode-locked lasers (QD-MLL) have recently attracted much interest due to their potential applications for optical time-domain multiplexing, all-optical clock-recovery and all-optical waveform generation. Regarding the latter application, pulse generation has been demonstrated using two-section devices composed by an absorber and gain sections. Rafailov *et al*[1] have studied the generation of 5 to 6.5ps pulses at a repetition rate of 21GHz. Xin and co-workers[2] have reported on 2ps pulses at a repetition rate of 5GHz. In these two studies, the devices under test exhibit an optical spectrum centred ~1200nm, with a full-width at half maximum (FWHM) of 14nm and 4.3nm, respectively. Pulse generation has also been demonstrated using Fabry-Pérot (FP) QD-MLL lasers operating at 1550nm. Gosset *et al*[3] have reported 1.1ps and 2ps auto-correlated pulses at repetition rates of 134 and 42GHz, respectively. More recently, investigations on the characteristics of the QD-MLL structure, such as the confinement factor, have also been addressed in order to generate short pulses at 40GHz with a minimum radio-frequency (RF) line-width[4,5].

The aim of our work is to analyse in the temporal and the spectral domains a 39.8 GHz optical pulse generated by a dc-biased passively mode-locked QD-FP laser. To carry out this study in these domains, a frequency-resolved optical gating (FROG) system is used. This analysis is carried out in terms of the optical modes passing through a tunable band-pass filter at the laser output. Furthermore, owing to the initial chirp exhibited by the generated pulses and the group velocity dispersion of a single mode fibre (SMF), pulses are passively compressed after its propagation through such a given piece of fibre. Thus, we experimentally demonstrate the generation of pulses as short as 720fs by a 39.8 GHz dc-biased passively mode-locked QD-FP.

Experiment

Our device under test is a ~1 mm-long, dc-biased, multi-mode Fabry-Pérot quantum-dash MLL. Further information on this type of device can be found in Reference 5. This device presents a bias threshold of 18mA and a total collected power of 4mW when operating at 400mA and temperature controlled at 25°C. Its optical spectrum exhibits 31 longitudinal modes, with a 0.31nm free-spectral range, resulting in an optical FWHM-bandwidth of 12nm centred at 1526nm. The average optical linewidth of each longitudinal mode is measured at 120MHz.

The output of the FP QD-MLL is coupled to a 1m-long SMF followed by an isolator (ISO), a variable band-pass optical filter and an erbium doped fibre amplifier (EDFA). The ISO is placed at the laser output to suppress back-reflections, whilst the EDFA is used to enhance the power of the optical modes passing through the band-pass filter. In order to analyse pulse shape and chirp, the collected light from the EDFA is coupled to a FROG system. Thus, the experiment is performed by measuring the temporal width of the optically-generated pulses in terms of the band-pass filter bandwidth.

Owing to the initial chirp exhibited by the generated pulses and the group velocity dispersion effect, a piece of SMF (450m maximum length) lying in between the EDFA and FROG was added. Thus, it was possible to compensate for the initial pulse chirp and therefore to perform a passive pulse compression. In this sense, all the measurements were acquired by using, besides the 1m-SMF patch cord interconnecting the EDFA output and the FROG input, a given piece of SMF.

Results

The width of the retrieved pulses from the FROG system is depicted in Fig. 1 in terms of the filter bandwidth before and after its propagation through a piece of SMF lying in between the EDFA and the FROG system. The band-pass filter bandwidth was tuned from 1 to 6 nm. It is important to mention that the pulse width was also retrieved for an unfiltered optical spectrum, where the full optical bandwidth (12nm) of the device was injected into the FROG system. From these experimental results it is observed that the width of the generated pulses decreases as the filter bandwidth increases. The wider pulse (~6ps) is obtained when the filter suppresses most of the optical modes (1nm filter bandwidth), passing through only three longitudinal modes. Conversely, a 720fs pulse is obtained when the unfiltered optical signal (full bandwidth) propagates through the 450m-SMF.

For a filter bandwidth of 6 nm, detailed pulse shape and chirp retrieved from the FROG system (before their propagation through the SMF) are

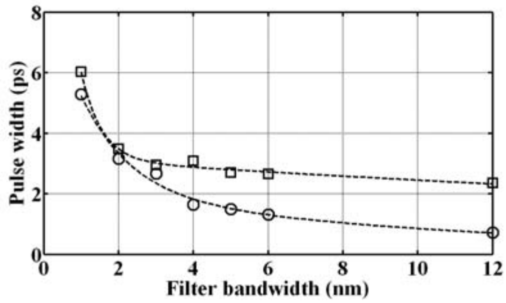

Fig. 1: Pulse width in terms of the filter bandwidth before (squares) and after (circles) its propagation through a piece of SMF (QD-MLL is dc-biased at 350 mA)

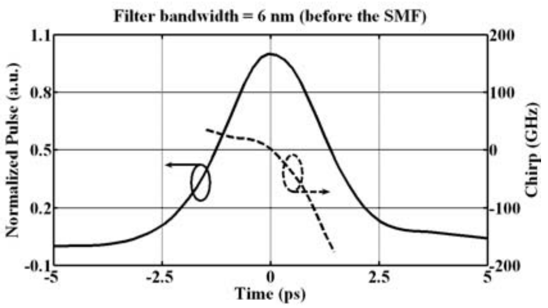

Fig. 2: Retrieved pulse shape and chirp (before its propagation through the SMF) from the QD-MLL for a filter bandwidth of 6nm

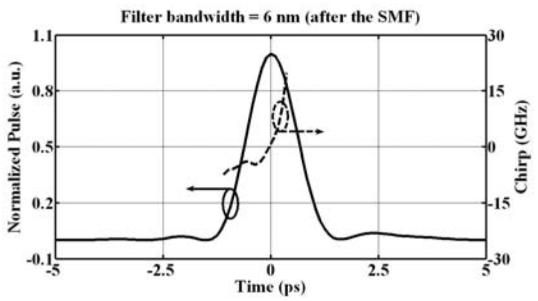

Fig. 3: Retrieved pulse shape and chirp (after its propagation through the SMF) from the QD-MLL for a filter bandwidth of 6nm

depicted in Fig. 2. Pulses have a FWHM-width of 2.6ps, respectively. Furthermore, at the FWHM-leading and -trailing edges, pulses exhibit a negative chirp ranging from +30GHz to -170GHz, respectively. The retrieved pulses after their propagation through a piece of SMF are depicted in Fig. 3. Despite the initial chirp is not completely cancelled out, compressed pulses are obtained after the 450m-SMF. In this case, the chirp is reduced to a value of -7 GHz at the FWHM-leading edge of the compressed pulse. At these conditions (6nm filter bandwidth), the pulse width is 1.25ps. This provides a pulse compression ratio approximately equal to 2. It should be noticed that chirp compensation and passive pulse compression can be further improved by using a piece of SMF with an optimum length[6]. For uncompressed pulses of 6 to 2 ps obtained at the output of the QD-MLL, we estimate SMF optimum lengths ranging from 50 to 500 m, respectively.

Conclusions

Pulse generation in the sub-picosecond regime and at a repetition rate of 39.8 GHz has been experimentally demonstrated by using a dc-biased passively mode-locked QD-FP. From these results, it can be envisaged the generation of even shorter pulses by using this type of lasers exhibiting a wider optical spectrum. Similarly, by designing QD-FP lasers with a specific free spectral range, sub-picosecond pulse generation can be obtained at different repetition rates with applications such as all-optical clock recovery functionalities.

Acknowledgements

Authors would like to thank Enterprise Ireland for its support under the Proof of Concept Program, project referenced PC/2007/042, and the INSPIRE Programme, funded by the Irish Government's Programme for Research in Third Level Institutions, Cycle 4, National Development Plan 2007-2013.

References

1 E.U. Rafailov et al., Appl. Phys. Lett., 87(8), 081107 (2005).
2 Y.-C. Xin et al., Elect. Lett., 44(21) (2008).
3 C. Gosset et al., Elect. Lett., 42(2) (2006).
4 G.-H. Duan, Proc. CLEO'08, CMG3 (2008).
5 A. Shen, et al., Proc. OFC'08, OThK1 (2008).
6 G. P. Agrawal, Nonlinear fiber optics, (1995)