Contents

1 Introduction **1**

1.1 Slow and fast light propagation 2

1.1.1 SFL physical principles 2

1.1.2 SFL device platforms 3

1.2 Tunable phase shifts and true time delays for MWP applications . . . 4

1.3 Thesis objectives 8

1.4 Structure of the thesis 9

2 SFL effects using stimulated Brillouin scattering for MWP applications **11**

2.1 Introduction 11

2.2 Principle of operation 13

2.3 Phase shifter based on double SBS generation 14

2.4 True time delay line based on SBS and separate carrier tuning 18

2.5 MWP filter using SBS effects 23

2.6 Dynamic Brillouin gratings 27

2.7 Basic MWP functionalities using DBGs 29

2.8 MWP filter implementations based on DBG reflections 33

2.8.1 MWP filter based on an hybrid configuration: DBG + delay line (1^{st} configuration) 35

2.8.2 MWP filter based on multiple DBGs (2^{nd} configuration) 36

2.8.3 MWP filter for high-frequency applications based on multiple spectrally detuned DBGs (3^{rd} configuration) 37

2.8.4 MWP filter based on DBGs generated by a pseudo-random sequence (4^{th} configuration) 40

2.9 Conclusions 41

3 Long fiber Bragg gratings: spectral analysis and applications 43
3.1 Introduction . . . 43
3.2 Principle of operation . . . 44
3.3 Distributed sensing system . . . 46
3.4 Tunable delay line . . . 50
3.5 MWP basic functionalities . . . 51
3.6 All-optical temporal integrator . . . 53
3.7 Conclusions . . . 55

4 SFL effects in semiconductor optical amplifiers for MWP applications 57
4.1 Introduction . . . 57
4.2 Principle of operation . . . 58
4.2.1 Coherent population oscillations in SOAs . . . 58
4.2.2 Enhancing the phase shifter performance by filtering . . . 59
4.2.3 360° by cascading several SOA-based phase shifter stages . . . 61
4.3 Propagation model for the SOA-based phase shifter . . . 62
4.4 Nonlinear distortion analysis in SOA-based phase shifters . . . 67
4.4.1 Nonlinear distortion influence on the filtering scheme . . . 68
4.4.2 Nonlinear distortion evaluation for cascading phase shifter stages 76
4.5 Figures of merit for cascaded SOA-based phase shifter structures . . . 84
4.5.1 RF net gain evaluation . . . 85
4.5.2 Noise figure evaluation . . . 87
4.5.3 Spurious free dynamic range evaluation . . . 90
4.6 Fully tunable MWP phase shifter based on a single SOA . . . 94
4.6.1 Principle of operation . . . 95
4.6.2 Computed results . . . 97
4.6.3 Experimental results . . . 99
4.6.4 FOMs evaluation . . . 102
4.7 Fully tunable MWP filter using the single SOA based phase shifter implementation . . . 105
4.8 True time delay line based on cross gain modulation in SOAs . . . 107
4.9 Conclusions . . . 109

5 SFL effects in photonic crystals for MWP applications 113
5.1 Introduction . . . 113
5.2 Principle and fabrication . . . 114
5.3 True time delay characterization . . . 116
5.4 MWP filter . . . 118
5.5 Figures of merit for PhC-based delay lines . . . 121
5.5.1 Numerical fitting . . . 121
5.5.2 FOM: Modulation scheme . . . 122
5.5.3 FOM: Non-uniform delay tunability . . . 123
5.5.4 FOM: Tunability resolution . . . 125
5.5.5 FOM: Loss per unit delay . . . 126
5.5.6 FOM: Power uniformity per unit bandwidth . . . 126
5.5.7 FOM: Size . . . 127
5.5.8 FOM: Power consumption . . . 127
5.6 Conclusions . . . 127

6 Conclusions and future perspectives 129
6.1 Summary and general conclusions . . . 129
6.2 Directions for future research . . . 133

A Publications 135
A.1 Journal . . . 135
A.2 Conference . . . 137