Wavelength Switching of Semiconductor Tunable Lasers - How to Suppress Thermally Induced Wavelength Drift

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We discuss and compare two techniques that can be used to counteract the thermally induced wavelength drift associated with the switching of the tuning currents of semiconductor tunable lasers: RC-precompensation of the tuning currents and optical feedback from an external reference filter. For the RC-precompensation we show numerically and experimentally that the wavelength drift can be suppressed, but that it is difficult to optimise this technique for different values of the current steps. The optical feedback works regardless of the value of the current step and we show numerically that frequency drifts up to 15GHz can be suppressed.

Introduction

Due to the fact that in present (D)WDM networks most of the routing of the data in the crossconnects and add-drop multiplexers is done in an electronical way, a bottleneck is created. In order to avoid this bottleneck and to have a more flexible and efficient usage of the very high bandwidth capacities of the WDM technology, it is expected that future network technologies will move towards optical packet/burst switching [1].
Obviously, rapidly (order 10 ns) tunable transmitters will be one of the key components for such a technology. Some semiconductor tunable lasers allow such rapid, electronic tuning [2], but then one encounters problems on a larger timescale due to the thermally induced wavelength drift associated with the switching of the tuning currents [3-4]. In this paper we present two techniques that can be used to alleviate this problem.

RC-precompensation of tuning currents

Model

We developed a model based on the optical, electrical and thermal rate equations [5] to investigate the behaviour of the thermally induced wavelength drift. Fig. 1 shows the time evolution of the deviation of the (lasing and Bragg) wavelength from its steady state end value after a current step of 30 mA has been applied to the Bragg section of a three section tunable laser. It is clear that the wavelength drift is dominated by three time constants, associated with the heat transfer from waveguide-to-chip, chip-to-subcarrier and subcarrier-to-heatsink respectively. The total wavelength drift is about 0.04 nm or 5 GHz which may appear to be rather small, but higher current steps are possible and generally more than one tuning current has to be switched to switch the wavelength between two valid operation points. Also, the (static) frequency accuracy of a commercial tunable laser module is typically required to be 1 GHz or better. Fig. 2 shows the wavelength drift for increasing values of the current step. As can be seen, increasing step amplitudes lead to higher drifts, but the time constants are independent of the step amplitude.

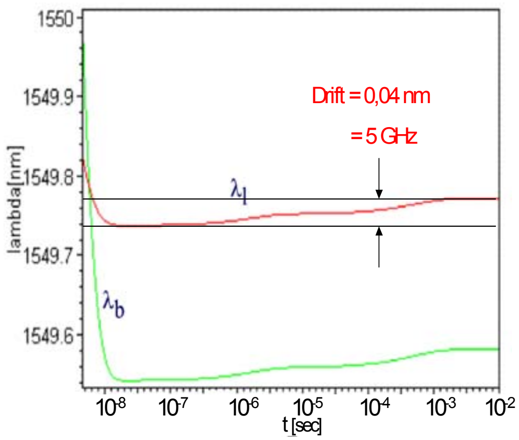

Fig. 1: Time evolution of wavelength drift

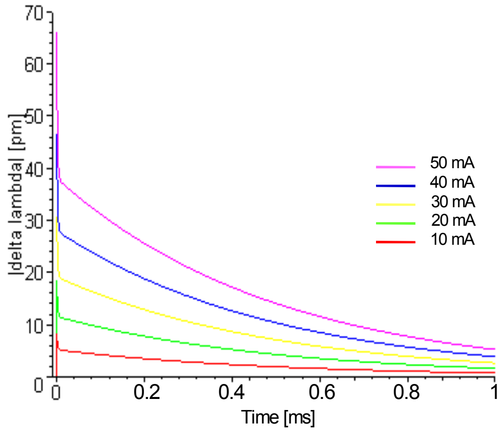

Fig. 2: Drift for increasing current step

Fig. 3 shows the measured (full lines) wavelength drift vs. the drift calculated using a three time constant model (symbols) for three different step amplitudes. Again, three time constants, independent of the step amplitude can be observed and there is good agreement between theory and experiment.

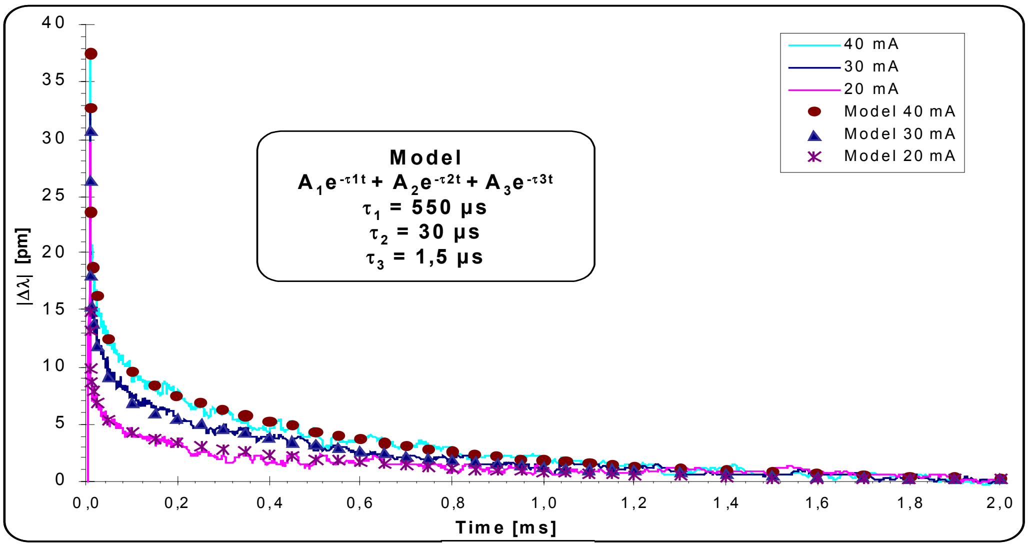

Fig. 3: Comparison theory vs. experiment

Compensation technique

Taking into account the previous results, one could think of counteracting the thermally induced wavelength drift by precompensating the tuning currents using simple first order RC filters [5]. Proof of this very simple principle is shown in Fig. 4. It can be seen that the drift is already strongly suppressed by only compensating two time constants. Unfortunately, due to the quadratical dependence of the heating on current ($\sim RI^2$), compensation for different current step values is difficult to obtain using only linear elements. For current steps bigger or smaller than the one the precompensation was optimised for, under respectively over compensation occurs, as is shown in Fig. 5. Alternatively a more complex (adaptive digital) filter could be used.

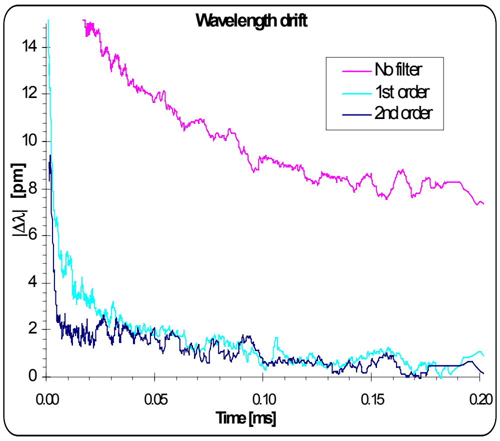

Fig. 4: Compensation of wavelength drift

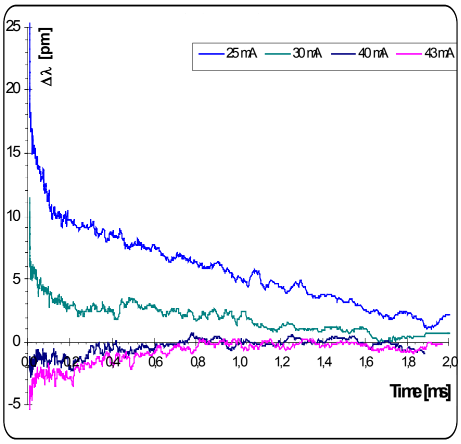

Fig. 5: Over and under compensation

Optical feedback from a stable reference filter

We developed a simple optical feedback scheme that can be used to suppress the wavelength drift, independent from the switching current amplitude.
The scheme is shown in fig. 6. It only contains two powers splitters and a comb filter (a simple Fabry Perot etalon can be used) that is physically -and thus thermally- separated from the laser, thus providing a stable frequency reference, independent of temperature changes in the laser sections.

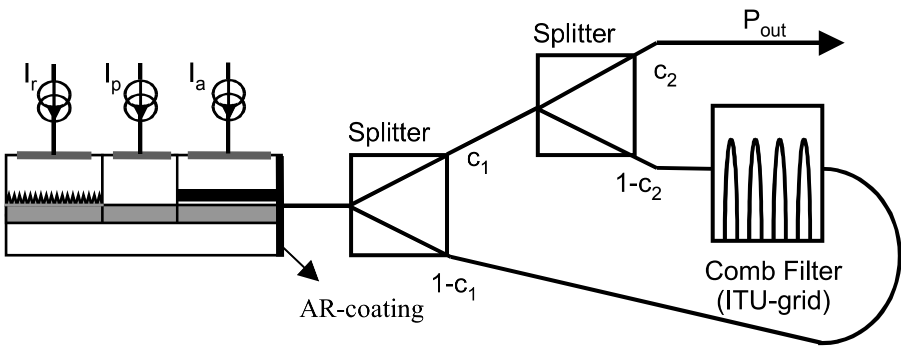

Fig. 6: Feedback scheme

The feedback ratio (f_{ext} = reflected power/emitted power) is determined by the splitting ratios c_1 and c_2. The right facet of the laser is AR-coated and the external cavity roundtrip time t_d should be kept sufficiently small to avoid coherence collapse [6].
We have investigated the feasibility of the above scheme numerically using commercially available software [7]. Separate transmission line-based models for the active, phase and Bragg section are incorporated in the software and can be combined to form a three-section DBR laser. The FWHM of the filter peaks was 3.3 GHz, FSR=100 GHz, the power reflection of the facet is R=0.01, f_{ext} was -10 dB and t_d=0.6 ns.
Figure 7 shows a simulated frequency switch, with and without feedback. Since thermal effects are not included in our simulation software, we simulated thermal drift by applying a linearly decreasing current to the Bragg section. Although the switching event is somewhat delayed by the feedback, it is clear that the frequency drift and

eventually the mode hop occur earlier when there is no feedback applied. Deviations up to 15GHz can be counteracted this way, which is sufficient for thermally induced drifts.

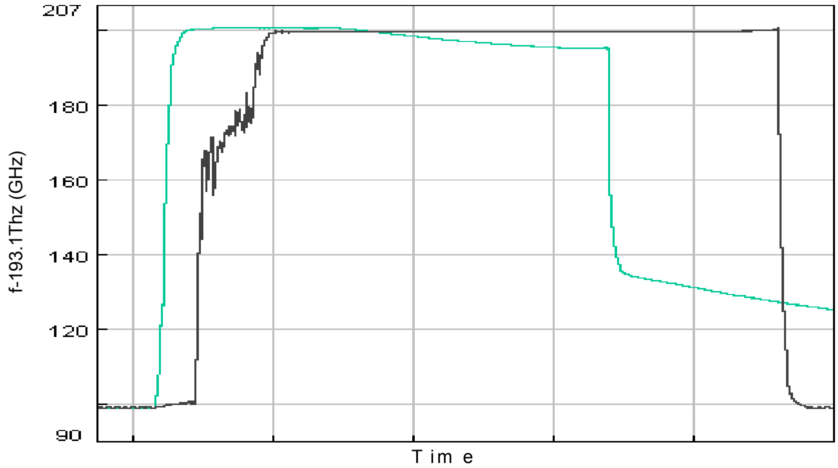

Fig. 7: Frequency switch for the laser with (—) and without (—) feedback

Conlusion

We discussed two techniques that can be used to enhance the wavelength switching behaviour of tunable lasers. The RC-precompensation technique is a very simple, straightforward technique, but unfortunately it is difficult to optimise it for different values of the current steps. The optical feedback works regardless of the value of the current step and thus independent from which channel the wavelength is being switched to and also independent from the switching history. We showed numerically that frequency drifts up to 15GHz can be suppressed. Furthermore, ageing effects or tuning table inaccuracies will have a reduced influence.

Acknowledgements

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