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Fast Integrated Tunable Laser using Filtered Feedback

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Abstract— **A novel integrated tunable laser is presented which combines a simple tuning method with ns switching speed. The Photonic Integrated Circuit consists of a Fabry-Perot laser with deeply-etched DBR mirrors. The Fabry-Perot modes can be selected independently using an Arrayed Waveguide Grating and then re-injected into the laser cavity, forcing single mode operation at the wavelength of that mode. 4ns switching time as well as 15 dB SMSR is demonstrated on the prototype device.**

Keywords-tunable laser; fast switching; filtered feedback; DBR mirrors;AWG; active passive integration.

I. INTRODUCTION

Fast switching tunable lasers (TLs) are key components in the pursuit of all-optical reconfigurable telecom networks. Traditional solutions for TLs rely on complex and costly control schemes for selection of the desired wavelength and stabilization of the output signal. For instance, a continuously tunable, multi-section laser based on Distributed Bragg Reflector (DBR) mirrors has at least 4 analog control sections; a set of look-up tables is necessary to address each section with the proper control current and frequency drifts due to temperature effects need to be compensated in order to achieve the desired operation. Such lasers are available with high power (> 10 dBm), a wide tuning range (> 40 nm) and tuning speeds in the ms-range [1]. So far, attempts to simplify the control scheme have not yet led to competitive devices.

We have reported the invention, fabrication, modeling and characterization of a new Integrated Filtered-Feedback Tunable Laser (IFF-TL) [2,3,4]. The device is composed of two integrated cavities which are separated by high reflection DBR mirrors: a short lasing cavity allowing for very fast switching speed and a filtered-feedback cavity allowing for easier control. Improved chirp performance has been demonstrated in [5], where the filtered feedback cavity contained a coupled micro-ring filter. It was shown that with this approach the frequency drift can be reduced to less than 1 GHz. In this paper we report dynamic measurements on an IFF-TL laser with a discretely tunable feedback filter, consisting of an AWG with an SOA gate array, which demonstrate 4 ns switching speed.

II. DEVICE DETAILS, DESIGN AND FABRICATION

A schematic picture of the IFF-TL is shown in fig 1. A Fabry-Perot (FP) laser is formed by a Semiconductor Optical Amplifier (SOA) and two deeply etched Distributed Bragg Reflector (DBR) mirrors. The laser cavity length (L_{cav} = 822 µm) is chosen such that the mode spacing (given by $\Delta\lambda = \lambda^2 / 2N_g L_{cav}$) equals 50 GHz (0.4 nm) –the channel spacing in the standard ITU-grid used for telecom applications. N_g is the group index of the waveguide (3.65) and λ is the central wavelength (1.55 µm).

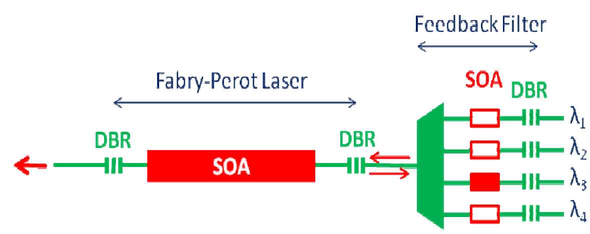

Figure 1. Schematic diagram of the Integrated Filtered-Feedback Tunable Laser.

The FP laser is coupled to an AWG filter, with a 400 GHz (3.2 nm) channel spacing, that routes the modes of the lasing cavity into several waveguide branches according to their wavelength –4 in the case of the device reported in this paper. Each branch contains a 100-µm-long SOA that works as an optical gate. The SOA length is chosen in such a way that an unbiased gate will absorb the light in the waveguide, and a forward biased one will amplify it. The light is then fed back into the lasing cavity reflected either by a cleaved chip facet, another DBR mirror or any other form of broadband mirror. The feedback light causes the laser mode with the largest feedback strength to dominate over the other modes and single-mode operation is achieved. The feedback strength and phase are controlled by the gates in the feedback branches. The output light leaves the chip through the opposite DBR mirror. The DBR mirrors, which have been deeply etched as shown in [6], can be used to obtain high reflectivity over a broad wavelength range and allow us to control the cavity length very accurately.

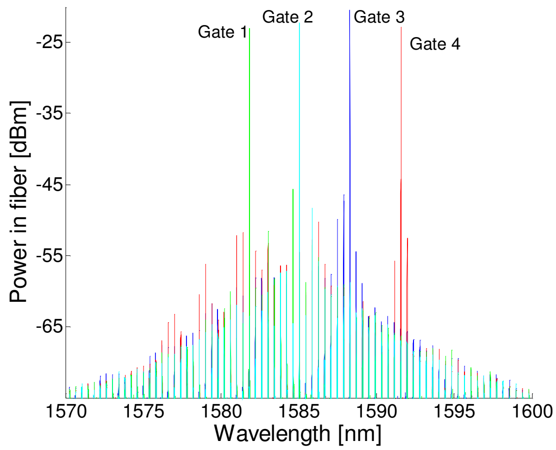

Figure 2. Optical spectra of the IFF-TL

III. CHARACTERIZATION

We measured a threshold current of 40 mA at 15 ^{0}C. For the characterization of the tunability, the device has been forward biased at 45 mA; at this operation point an output power of 20 μW has been collected using a lensed fiber. The performance of the device as a tunable laser is shown in fig. 2, where the 4 spectra, corresponding to each of the SOA gates operated in forward bias separately, are plotted. The separation between the 4 possible lasing wavelengths is equal to 3.2 nm, or 400 GHz corresponding to the channel spacing of the AWG. The sub-threshold peaks show the mode-spacing of the FP laser, which are positioned 50.5 GHz apart; only 1% mismatch with the designed 50 GHz. These sub-threshold peaks collide for all 4 lasing spectra, providing a good indication that the carrier density in the main laser cavity is the same, and the temperature does not vary much at all. This also confirms that the wavelength is tuned due to small feedback received from the gates, and the device does not operate as an extended cavity laser.

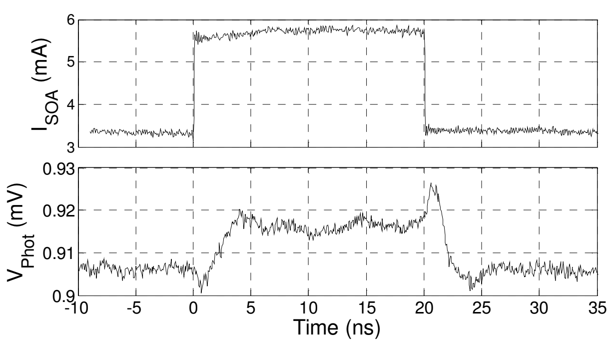

Figure 3. Characterization of the switching speed. (top) I_{SOA} is the signal applied to one of the SOA gates. (bottom) V_{PHOT} is the signal received from the laser by a photodiode at the wavelength corresponding to that gate.

In order to characterize the switching speed, a square signal like the one shown in fig. 3 (top) was applied to one of the SOA gates. The signal shows transitions of high and low values. The current values on the SOA are chosen such that the high value is sufficient to induce single mode operation, whereas at the low value the device operates in multimode regime. At the output of the laser a tunable filter was used to filter the wavelength of interest. The output of the filter is connected to a 10-GHz photodiode and electrical amplifier. The resulting RF signal is studied in a digital oscilloscope. A sample of the output signal is shown in fig. 3 (bottom), demonstrating a transition time of 4-5ns for both the rise and decay. The switching characteristics of the IFF-TL were investigated numerically using a multimode Lang-Kobayashi model with frequency selective feedback [4]. Simulations based on this model (not shown) predict a switching time of 0.8 ns. The difference between the modeled and experimental result is attributed to an impedance mismatch between the SOA and the signal generator.

IV. CONCLUSIONS

The new concept of the IFF-TL combines high switching speeds with simple wavelength control. While the latter promises a reduction in cost of the control electronics compared to continuously tunable lasers, we believe that the fast switching speed is the biggest advantage of this novel device. Together with the fact that the device can be integrated with other active and passive components, we expect that fast switching will enable new applications in packet routing techniques for all-optical telecommunication networks. This research was supported by the Dutch Technology foundation STW and the Belgian Science Policy Office under Grant No. IAP-VI10. I.V.E., S.B. and J.D. Acknowledge support from the Research Foundation-Flanders (FWO).

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