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FAST SWITCHING TUNABLE LASER SOURCES FOR WAVELENGTH DIVISION MULTIPLEXING IN PASSIVE OPTICAL ACCESS NETWORKS

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Abstract

Tunable laser structures with nanosecond switching time between wavelength channels and low-power injection locking are demonstrated on a low-cost platform. These lasers are suitable as source or slave lasers in WDM passive optical access networks.

I. Introduction

Telecoms lasers are typically fabricated with DFB technology for single frequency, or use Sampled Grating-DBR lasers for tunability. Both technologies require overgrown, lithographically defined gratings. However, single frequency operation can be more simply achieved by introducing a small number of modal perturbations (slots) in a ridge laser [1-3]. We have termed this laser the slotted Fabry-Perot (SFP) laser. Here we present a tunable SFP laser, where we have controlled the spectral modes by varying the etch depth, the number of slots present in the laser and the number of contacts to the laser. As is the case for slotted single frequency lasers, this allows for a dramatic cost reduction and so, such tunable lasers may become applicable to a wide range of applications including Wavelength Division Multiplexed passive optical access networks (WDM-PON). We discuss applications in a tunable WDM-PON system, where the lasers can play two roles – firstly as the initial single-frequency downstream laser located at the head end requiring a high side mode suppression ratio and fast switching time for rapid provisioning, and secondly as injection locked lasers in the remote optical network unit [4,5] which will require low injection powers. Slotted lasers fulfil the requirements both for the tunable single mode laser and for the injection locked laser.

II. Device structure

Laser material was grown as a standard *p-i-n* heterostructure with lattice matched AlInGaAsP on an InP substrate. It had a standard laser layer structure, with five QWs emitting at 1550 nm, embedded in a 540 nm waveguide, and a 1.75 μm p-type InP cladding layer, capped with a 0.2 μm p+ InGaAs layer. Using standard optical lithography a 3 μm wide slotted ridge was etched down 1.95 μm to a buried etch stop layer. The slots were nominally 0.85 μm long. The etch depth went to the top of the waveguide layers, and did not go through the active region in order to avoid leakage currents and excessive losses in the waveguide. To produce a multichannel laser, we cleaved a 1.1 mm long laser with a slot configuration of three slots spaced at 89.5 μm from each other and from the facet at one end of the laser, and three slots spaced 107.4 μm from each other and from the facet at the other end of the laser. These slots give reflectivity spectra that implement the Vernier effect with a periodicity of about 400 GHz. The laser used two electrical contacts, and one of the slots also electrically isolated the contacts from each other. For injection locking, we used a single contact SFP laser that was 607 μm long with eight slots equally spaced at 37 μm separation from each other and 237 μm from the cleave. The lasers were mounted p-side up without facet coatings on a ceramic test board.

III. Experiment

The 1.1 mm long SFP laser was temperature controlled by a Peltier stage, and was first characterised in DC operation with combined currents in the range 40 – 150 mA. The laser output was fibre coupled and the emission measured on an optical spectrum analyser. Selected spectra are shown in Fig. 1, which show the single mode spectra on the designed channel spacing of 3.2 nm, which corresponds to a frequency of 400 GHz.

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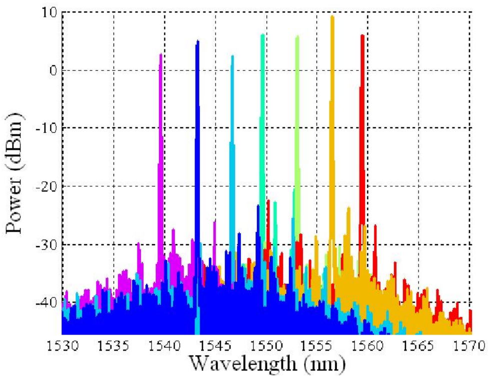

Fig. 1: Overlay of selected single mode spectra with SMSR > 28 dB showing 7 wavelength channels spaced by 3.2 nm

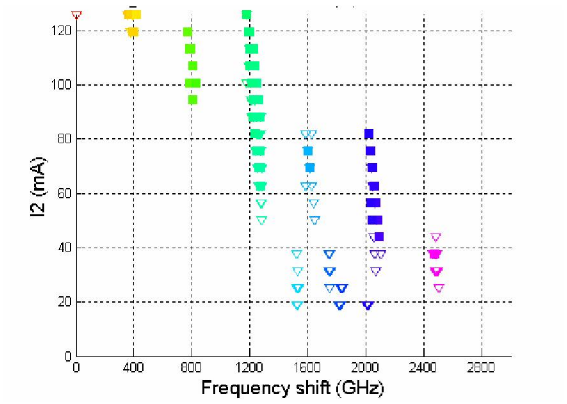

Fig. 2 : Full 2D map of single mode spectra as a function of the two bias currents. Triangles represent spectra with SMSR between 20 and 30 dB, while squares represent SMSR greater than 30 dB. A clear tendency for hopping at 400 GHz is shown. Frequency values are taken relative to the lasing peak at 1559 nm.

While selected spectra are plotted in Fig. 1, all single mode data is summarised in Fig 2. The current in section 1 was varied from 0 to 60 mA and the current in section 2 was varied from 0 to 125 mA. The current ranges are proportional to the length of each section, which had a ratio of about 2 to 1. A clear tendency to hop at a frequency spacing of 400 GHz is presented, showing good agreement between the model and experiment.

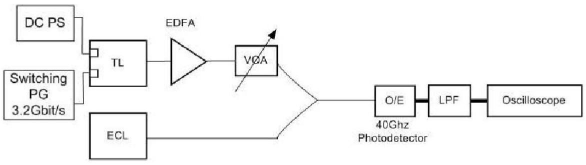

Fig. 3 : Experimental configuration used to determine switching time of tunable laser module. DCPS=DC power supply, TL=tunable laser, ECL=External cavity laser, EDFA=erbium doped fibre amplifier, VOA=variable optical amplifier, O/E=opto to electronic photodetector, LPF= low pass filter

To determine the switching speeds of these lasers, we use a heterodyne technique [6] that involves the use of an external cavity laser (ECL) set to a frequency 1 GHz away from channel 1 emitted from the tunable laser, Fig. 3. A 770 μm long multi-channel SFP laser was used for this experiment. One section was biased using a bias tee and a high speed pulse pattern generator while the second section was driven DC. With a peak-to-peak tuning current of 20 mA, the laser switched between two single mode channels which were separated in wavelength by 33.4 nm (a frequency separation of 4.24 THz). The output was combined with the output of a separate tunable external cavity laser (ECL) which was detuned from the SFP laser by approximately 1 GHz and detected using a high speed detector, a low pass filter with a 1.87 GHz cut-off frequency and an oscilloscope. An EDFA and Variable Optical Attenuator are used to ensure that the power from the Tunable Laser and the power from the ECL are equalised to give a strong beat signal. When the SFP laser and the ECL laser are less than 1.87 GHz apart in frequency, the beat signal appears as a high frequency oscillation on the oscilloscope, and when the SFP was far from the ECL frequency the beat signal is beyond the bandwidth of the detection electronics, so only the DC power component is displayed. These measurements demonstrated a typical switching time between channels of 1.5 ns as shown in Fig. 4.

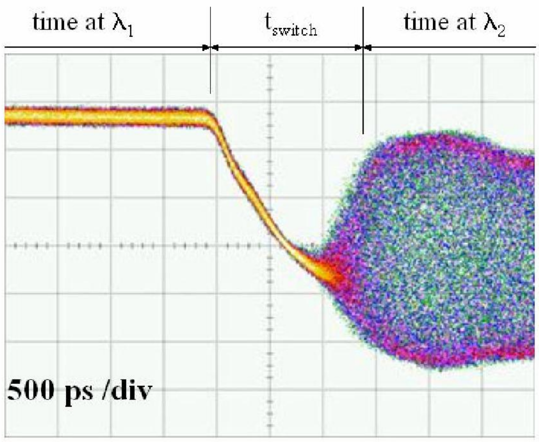

Fig. 4 : Switching time of 1.5 ns demonstrated between two wavelength channels

A further set of experiments characterised the laser as a slave laser as may be required in a remote optical network unit (ONU). In our implementation of this function, the laser needs to lock to the injection wavelength and to amplify the injected signal. The 607 μm long SFP laser was pumped with an Ando tunable laser source in the configuration shown in Fig. 5.

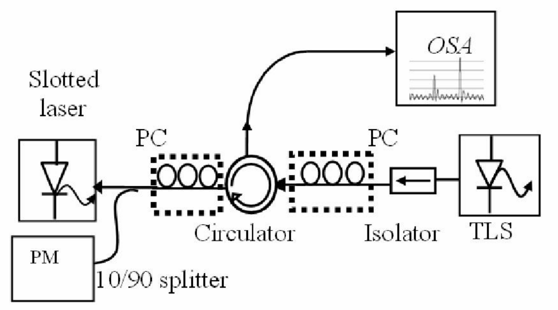

Fig. 5 : Experimental setup for injection locking. PM=power monitor, PC=polarisation controller, OSA=optical spectrum analyser, TLS=tunable laser source.

The laser has a threshold current of 37 mA, and was biased at a fixed current of 45 mA. The free-running wavelength in this case is 1536.82 nm, as shown in Fig. 6(a) and has an output power of about +4 dBm. At an estimated injection power of -16 dBm, it was found that when the injection was at any frequency in a band of 25 GHz around the natural frequencies of the SFP laser the free-running emission was suppressed, and the injected wavelength became the dominant wavelength without adjustment of the SFP bias current, Fig. 3(b-f). The laser required only –25 dBm of co-polarized injected power to lock with 25 dB SMSR to any of these channels, which is very low compared with previously reported systems using FP lasers which typically required between –6 to –14 dBm injected power for significant locking [4-5].

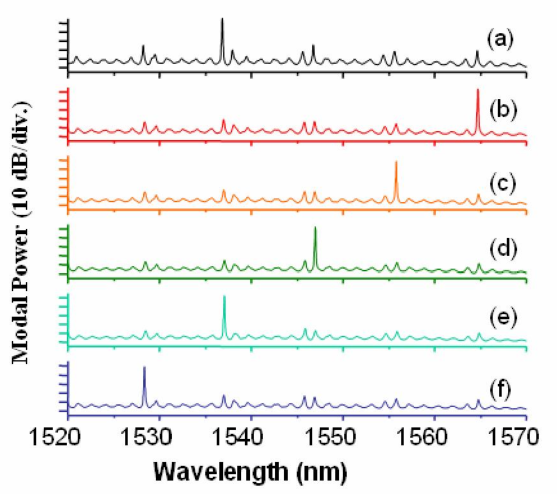

Fig. 6 : Injection locking of different channels. (a) free-running spectrum, (b-f) locked spectra with injected power of –20 dBm at the dominant wavelength.

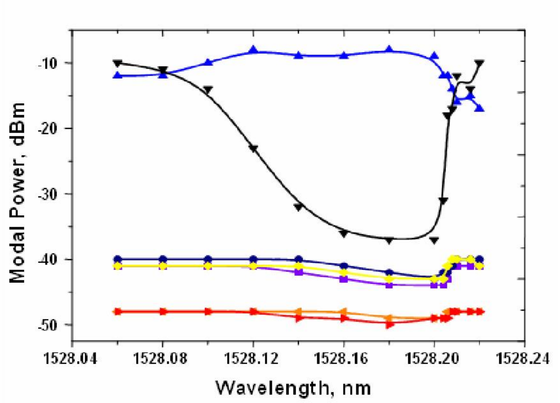

Fig. 7 : Power in each channel as the injected wavelength is varied from 1528.06 to 1528.22 nm. Suppression of the free-running peak (black, down triangles) is shown, while the power of the locked mode (blue upwards triangles) increases slightly. Powers in all other modes stay low, and even decreases slightly during locking.

Finally, in Fig. 7 we show how the peak power in the free running peak is suppressed as the injected wavelength is varied across one of the channel wavelengths. In this case, the channel at 1528.18 nm is chosen for locking. The injecting tunable laser wavelength is detuned from this wavelength, and is swept from 1528.06 nm to 1528.22 nm. The injected power is estimated at -20 dBm inside the slotted laser for this set of data. As the injection wavelength approaches the channel wavelength, the free-running peak denoted by the black downward triangles drops in power. As the injecting wavelength sweeps through 1528.18 ±0.02 nm, the power in the other channels also drops slightly, showing that the injected power is contributing to the stimulated emission. The best SMSR in this case is 29 dBm. Locking width is taken at an SMSR of 25 dBm, and for the -20 dBm injected power used in this example a locking width of 9.0 GHz is measured.

IV. Conclusions

We have shown that monolithic, single-stage epitaxy lasers based on the SFP platform can have several functions: wavelength-selection of channels separated by 400 GHz, rapid switching between different channels in the nanosecond regime, and these lasers can be designed to be easily injection locked. These functions should be useful in passive optical network access applications.

Acknowledgments

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