

AN OPTICALLY CONTROLLED WAVELENGTH SELECTIVE SWITCH USING A FABRY-PEROT LASER DIODE

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Abstract: A fast optically controlled wavelength selective filter/switch (less than 0.08nm bandwidth) was demonstrated by using the higher order transverse modes of a Fabry-Perot laser diode. Wavelength tuning within 500ps can be controlled by optical-injection.

Introduction

To meet the expanding demand in Internet, it is very desirable to employ packet-based WDM networks, in which a fast wavelength switch is needed. Several wavelength switching and filtering schemes were proposed in the past. They included current injection of an InGaAsP/InP waveguide [1] or $\lambda/4$ -shifted DFB laser diode [2], voltage controlled FP filter using nematic liquid crystal [3], acousto-optically tunable filter [4] and tunable injection-locking filter [5]. Here, we report a new wavelength selective switching scheme that is based on the absorption characteristic of the higher-order transverse modes (subsidiary modes) of an FP laser diode [6]. A narrow band rejection filter ($\delta\lambda \sim 0.08\text{nm}$) was demonstrated with a band rejection ratio over 15dB. A wavelength switching time of less than 500ps was measured by the red shift of the FP mode comb through injection locking of the FP diode by a control wavelength.

Wavelength selection by of the FP laser diode

The FP laser diode used in the experiment [Fig. 1(a)] exhibits subsidiary modes (due to its broad active waveguide region), which appear as side modes located on the longer wavelength side from the main longitudinal modes. We first study the absorption characteristics of the FP laser at the subsidiary modes. The TL2, modulator, 50km SMF, BPF, and EDFA in Fig. 1(a) were not used for this measurement. Fig. 1(b) shows the absorption spectra obtained through feeding a cw source from a scanning tunable laser with its emission's polarization aligned with that of the subsidiary mode, showing an absorption null at these modes. The 10-dB absorption width was found to be 0.3nm. A red shift through injection locking (by another optical signal, DFB) causes a shift of up to 0.4nm towards the longer wavelength side in the absorption spectra. Such feature can be used to switch/select two uncorrelated signals separated by the same spectral shift generated by the injection locking.

To show the wavelength selection effect, two 10Gb/s signals, uncorrelated through 50km SMF, at 1548.8 nm and 1549.1nm were fed into the FP laser diode as shown in Fig. 1(a). The 1548.8nm signal, coincided spectrally with the subsidiary mode, experienced a 10dB attenuation [Fig. 2(b)] in the transmission. Fig. 2(a) and 2(b) show the eyediagrams for the wavelength selected at 1549.1nm by two cascaded FP filter (with a compound passband 0.6nm)

and by this FP laser, respectively. The FP laser is thus demonstrating as a narrow band band-reject filter.

Figure 1: (a) Experimental Setup: TL – tunable laser, PC – polarization controller, MOD – intensity modulator, BPF – bandpass filter, Att – attenuator, SMF – standard single mode fiber, FP – Fabry-Perot laser diode, PD – photodetector and OSA – optical spectrum analyzer and (b) The absorption spectrum for the higher order transverse mode of the FP laser diode with and without optical pumping. (Note the red shift of the absorption null due to pumping.)

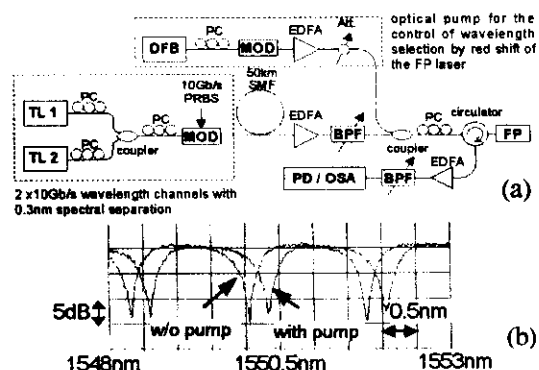


Fig.3 depicts the band rejection ratio and the filtering bandwidth centered at the subsidiary mode of the FP laser diode as a function of bias current. When the FP laser was biased between $0.8I_{th}$ (I_{th} = threshold current) and $1.4I_{th}$, rejection ratio over 15dB and 3dB-bandwidth less than 0.08nm can be achieved for an input optical signal power between -10dBm and -20dBm.

Fast wavelength switching

Fig.4 demonstrates wavelength switching between two equal intensity signals with wavelengths at 1553.95nm and 1554.15nm (0.2nm separation) by the FP laser diode. The 1553.95nm signal was initially situated at the one of the subsidiary mode with a 10dB of power suppression (Fig.4a). After injection-locking the FP laser by a third signal at 1547.3nm (generated from a DFB laser as shown in Fig.1a) with optical power 10dB (adjust by the variable attenuator) higher than the two signals, the subsidiary mode comb exhibited a 0.2nm red shift [7] thus coincided with the 1554.15nm and demonstrated a power suppression of 6dB to this signal (Fig.4b).

Figure 2: (a) (left) The spectrum of the two 10Gb/s wavelength signals with 0.3nm separation, (right) eyediagram of signal after passing through two cascaded FP filter. (b) (left) The spectrum of the signals after passing through the FP laser, (right) eyediagram of the signal after filter by the subsidiary mode.

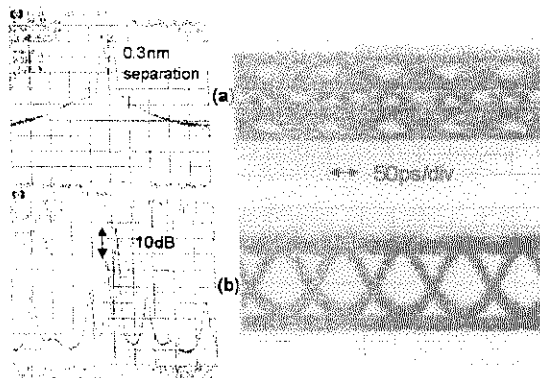


Figure 3: The band rejection ratio and the filtering bandwidth of the subsidiary mode of the FP laser diode with different biasing current. (injected optical power: solid line for -10dBm and dotted line for -20dBm)

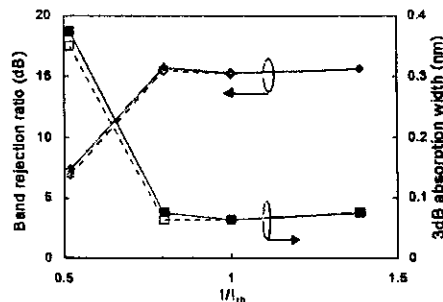
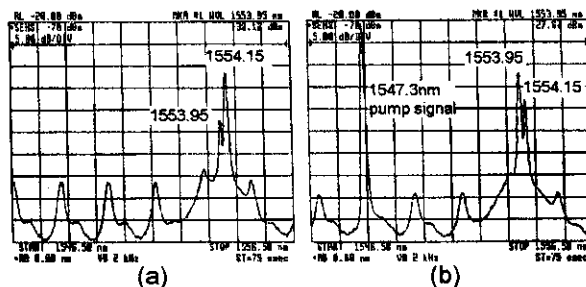


Figure 4: The spectrum for two wavelength signals 1553.95nm and 1554.15nm after passing through the FP laser, (a) the 1553.95nm being suppressed by the higher order transverse mode of the FP laser and (b) the absorption null switched to the 1554.15nm position due to the red-shifted of mode comb by optical injection.

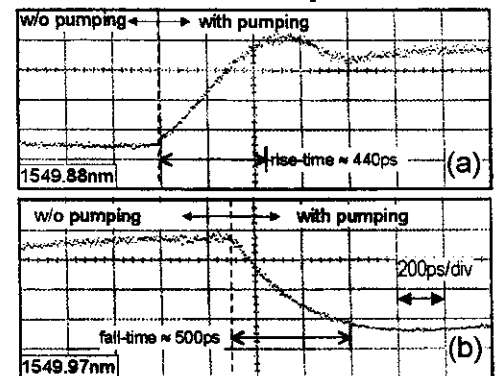


The difference in suppression ratios of the two signals was mainly due to the variation in polarization between the two signals.

The wavelength-switching dynamic of the proposed scheme was investigated by modulating the pumping DFB laser with a short transient step. A 1549.88nm signal was initially injected to one of the subsidiary mode position of the FP laser diode. After injection locking the FP laser by the DFB pump signal, the 1549.88nm signal rose to a steady intensity level within 440ps (Fig.5a). For the fall-time measurement, a 1549.97nm was initially situated at about 0.1nm from the longer wavelength side of the

subsidiary mode. After injecting the pump, the 1549.97nm signal fell to its "low" intensity level within 500ps (Fig.5b). From the above results, the switch-on and switch-off times between two wavelength signals can be achieved within 500ps. Degree of red shift can be controlled by the wavelength detune and optical power of the pumping signals. In our experiment a 0.4nm red shift of mode comb can be demonstrated, i.e. suitable for 50GHz spectrally-separated WDM systems. For this scheme, wavelength separation between the two signals should be equal to $\Delta\lambda_{rs} + m\Delta\lambda_{FP}$, $\Delta\lambda_{rs}$ is the degree of red-shift by injection-locking and $\Delta\lambda_{FP}$ is the separation between the FP modes, where m is any integer provided that $m\Delta\lambda_{FP}$ falls in the gain bandwidth of the FP laser diode.

Figure 5: Step response for (a) the 1549.88nm signal with a rise time of 440ps and (b) the 1549.97nm with a fall time of 500ps



Summary

A fast wavelength switch/filter with 500ps switching time controlled by optical injection-locking is demonstrated. Continuous wavelength tuning can be achieved by thermal control of the FP laser diode, thus signals with wavelength fall within the gain bandwidth of the FP laser can be switched by this device. This scheme is suitable for packet demultiplexing in packet-based WDM networks. Further improvement is needed to enhance the band rejection ratio, for example by cascading two stages of FP lasers.

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