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Demonstration of Multi-Wavelength Monitoring in WDM Systems Using Injection-Locked Fabry-Perot Laser Diode

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Abstract: *Fast multiwavelength monitoring was realized by injection-locking an Fabry-Perot laser diode, simultaneous wavelength monitoring of two WDM channels with resolution of 0.005nm was demonstrated with a response time of 3ns.*

As the channel spacing in WDM systems becomes denser to cater for the deployment of high spectral-efficiency wavelength routed networks, accurate wavelength monitoring with resolution of less than 0.01nm is a must. Wavelength deviation in WDM systems can be arising from aging and unstable thermal control of transmitters, wavelength mismatch in add-drop multiplexer and wavelength conversion in optical cross-connect, this small wavelength drift will cause signal distortion, power penalty, crosstalk and even signal loss after spectrally demultiplexing [1]. As a result, many schemes for multiwavelength monitoring have been proposed and even put into service. The most common type of multiwavelength monitoring can be implemented by using high-resolution CCD array or photo-diode array combine with a free-space grating [2]. Other methods such as using arrayed waveguide grating [3], tunable Fabry-Perot filter [4], cascaded fiber gratings [5] and interferometer with a reference laser [6] have also been reported. In this paper, a simple and cost effective multiwavelength monitoring scheme is proposed and demonstrated by injection-locking a Fabry-Perot laser diode (FP-LD), the FP-LD can act as a wavelength selective photodetector that replacing the photosensitive array in most detection schemes. In addition, FP-LD is more compact in size and easy for stocking compare to the interferometer. The injection-locking scheme can perform multiwavelength monitoring of wavelengths that fall within the gain-bandwidth of the laser with a resolution of 0.005nm.

The proposed multiwavelength-monitoring scheme is depicted in Fig.1a. Take the case for wavelength monitoring at central office as an example, all the WDM channels are partially being trapped off by an coupler and then being modulated into a pulse chain of small duty cycle (the larger the number of wavelengths to be measured, the lower the duty cycle). Each wavelength pulses will be separated into its consecutive time slot after passing through a spool of fiber with high dispersion (Fig.1a) value, therefore only one wavelength channel is being detect by the FP-LD at each time. The wavelength detection mechanism is based on injection

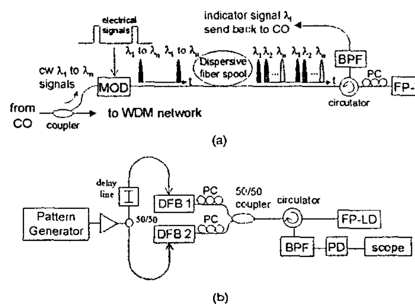

FIG. 1 (a) The proposed multiwavelength monitoring scheme; (b) the experimental setup. Note: CO – central office, MOD – modulator, BPF – band pass filter, PC – polarization controller, FP-LD – Fabry-Perot laser diode, PD – photodiode and DFB – distributed-feedback laser

locking of the FP-LD. By injecting the FP-LD a signal with wavelength close to one of the FP longitudinal modes, injection locking will occur and resulting an intensity suppression of the whole FP mode comb (see Fig. 4). This intensity suppression is precisely related to the wavelength detune between the signal and the FP mode. While one of the FP modes is assigned as indicator wavelength, all the other FP mode can be used as wavelength detection. Fig.2a shows the suppression of one of the FP mode while the other FP mode (at around 1547nm) is being injection-locked by a wavelength tunable signal (input power of –10dBm) with wavelength step of 0.005nm, thus this indicator signal can give response for this small spectral change. The indicator wavelength gives an asymmetric locking curve due to the red shift of FP mode comb after injection

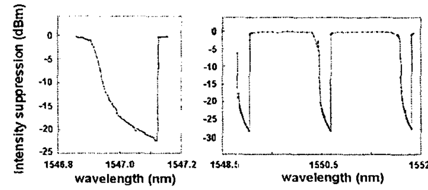

FIG. 2 (left) The intensity suppression of the indicator wavelength by injecting the FP-LD with a tunable source (power of –10dBm); (right) equal intensity suppression of the indicator wavelength for injection-locking of three different FP mode.

locking. Fig. 2b depicts equal intensity suppression of the indicator wavelength for injection locking of three different FP modes, thus the FP-LD can be capable of multiwavelength monitoring. Impulse response shows that the indicator wavelength can recover to its original intensity level after injection locking for about 3ns (Fig.3), therefore, in order to monitor different WDM channels by one FP-LD, the time different between each channels should be more than 3ns for each consecutive measurement (this can be done by the modulation pattern and the fiber). The experiment proceeded further for demonstrating multiwavelength monitoring. For the sack of simplicity, we used two DFB lasers that were directly modulated by two equal electrical signals with appropriate delay to generate a pulse train with alternating wavelengths (1545.2nm and 1546.9nm) in time domain (Fig. 5a). The electrical delay line simulated the dispersion effect of the fiber spool such that the delay between two wavelength pulses can be tuned easily. The two wavelength signals were then injected into the FP-LD with equal power of –12.4dBm, the FP mode at 1540.48nm was selected as an indicator wavelength. As shown by the spectra in Fig. 4, the intensity suppression of the indicator wavelength was due to the injection-locking of the FP-LD by the two wavelength channels. When the two wavelength channels are aligned exactly with their respective FP modes, the output from the photodiode that measured the indicator wavelength showed two equal troughs in time domain (Fig.5b). Then we tuned the wavelength of one of the monitoring channel (λ_1) by 0.087nm towards the shorter wavelength side, the intensity of the indicator at the trough rose for about 2mV. We done similar with the λ_2 channel and kept λ_1 aligned exactly with the FP mode, similar result obtained.

In summary, a simple and cost effective multiwavelength wavelength monitoring scheme with resolution of 0.005nm was successfully demonstrated by using injection-locked FP laser diode. As the response time for each measurement is only 3ns, number of channels can be increase by adjusting the modulation pattern with low duty cycle with a long zero level. The laser chip should be designed such that the ITU grid for WDM channel separation can be met, also, stability circuit should be implemented for the FP-LD before putting the scheme into practical.

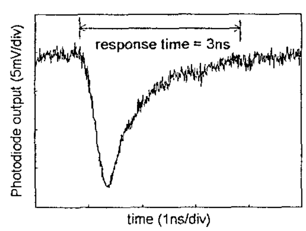

FIG. 3 Impulse response shows that the indicator signal can be recovered to its original intensity level after injection-locking for about 3ns.

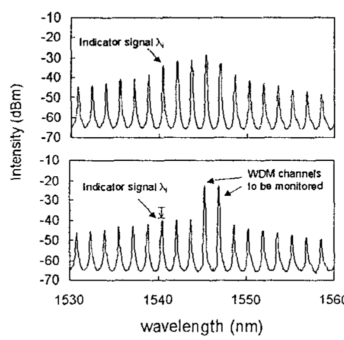

FIG. 4 Optical spectra of (above) free running FP-LD with indicator wavelength of 1540.48nm; and (below) the injection-locked FP-LD caused by two WDM channels (1545.2nm and 1546.9nm)

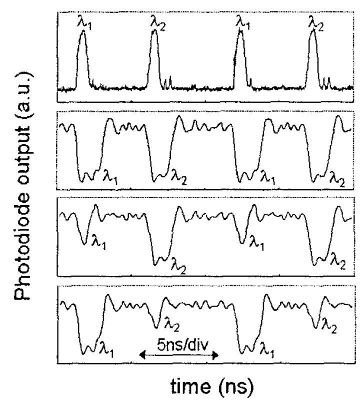

FIG. 5 Temporal profiles for (a) the input pulse train with alternative wavelength for wavelength measurement; (b) the output of the indicator wavelength with both wavelength aligned with its respective FP modes; (c) λ_2 channel has a 0.087nm wavelength detune; and (d) λ_1 channel has a 0.087nm detune

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