Compact and low-cost module for power, wavelength, and channel control of DWDM tunable lasers

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Abstract: Simultaneous monitoring of power, wavelength, and channel for a DWDM tunable laser is demonstrated by using a built-in isolator, etalon, polarizer, and photodiodes. The module is tunable and can detect mode hopping and incomplete tuning.

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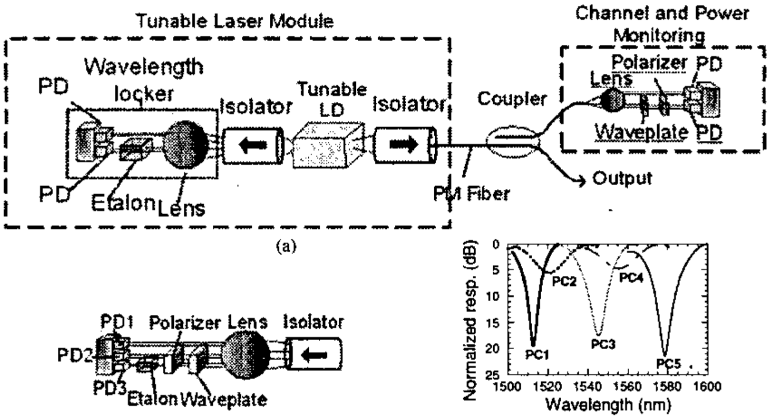
1. Introduction

A tunable laser module is usually packaged with an optical isolator to prevent the laser from external optical feedback as well as a FP etalon to stabilize its wavelength. We propose here to utilize the built-in optical isolator and a linear polarizer to monitor the channel number of a tunable laser. The channel monitoring function can be integrated with the power and wavelength stabilization parts into a compact module. This scheme is very advantageous over the existing methods in terms of cost and module size. For example, the commonly-used Fabry-Perot (FP) etalon for wavelength control of DWDM lasers can not distinguish among different channels since it has periodic wavelength characteristic. Etalons with special tuning mechanism or array waveguide gratings were proposed to monitor the mode-hopping and incomplete tuning problems that might happen in tuning a tunable laser [1-3], but they usually require expensive components or sophisticated tuning control.

2. Operation principles

Fig. 1 illustrates the concept of adding a channel-monitoring (CM) path to a tunable laser that uses a FP etalon for wavelength stabilization. If the optical isolator is designed to be polarization independent, the input light is separated by a polarization beam splitter (PBS) into two rays of orthogonal polarizations and passes through a Faraday rotator to achieve isolation for both polarizations [4]. The birefringence caused by the PBS and the output polarization combiner enhances the rotation of the polarization state. This causes the output polarization to be very sensitive to wavelength change. Thus, applying a polarizer after the isolator causes the output to be wavelength dependent.



(a)

(b)

(c)

Fig.1 Tunable laser with a wavelength locker and an add-on channel monitor (a), schematic of a compact module having multiple functions (b), and spectral characteristics of the isolator plus a polarizer for different input polarization states (c).

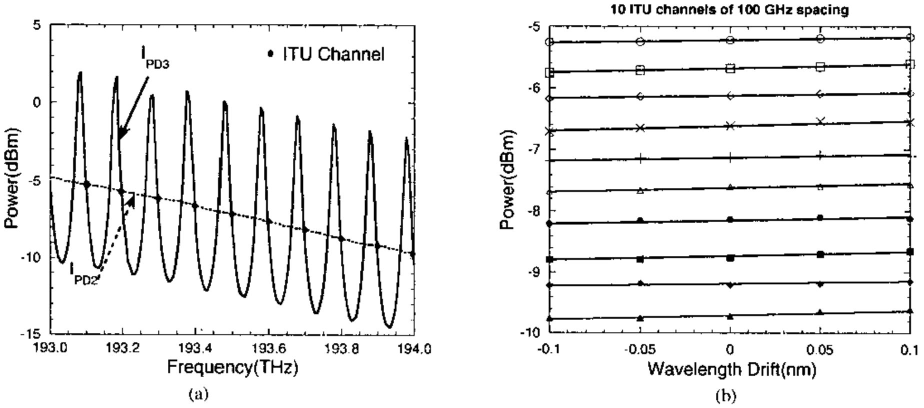
In packaging the isolator with a tunable laser, the optical axis of the input PBS must be adjusted to obtain the best spectral response. This can also be achieved by adding a waveplate after the isolator. This scheme is ideal for monitoring edge-emitting lasers since they typically emit linearly polarized light. The waveplate and polarizer can also be packaged with the laser. Adjusting the orientation of the waveplate causes a relative shift in the spectral response as well as a change in the slope of the curves. Thus, the monotonic spectral range can be tuned to match the laser tuning range. The waveplate can also be properly designed to compensate the thermal drift of the isolator response. Similar schemes based on birefringent crystals have been proposed for making wavelength filters [5].

The CM function can be integrated with the power monitoring (PM) and wavelength stabilization (WS) functions into a very compact module, as shown in Fig. 1(b). This module can be placed at one side of the tunable laser such that all the parameters can be monitored using the light output from the same laser facet. This is especially important for monitoring tunable lasers since the powers from two end facets may not follow each other. In addition to the power monitoring using PD1, wavelength locking is performed using the signal ratio of PD3 over PD2, while channel recognition is performed by using the signal ratio of PD2 over PD1. After wavelength switching, channel recognition is performed after the wavelength is locked to an ITU grid.

3. Experimental demonstration

In order to demonstrate the feasibility of the proposed approach, we investigated the monitoring characteristics with discrete components, including an external-cavity tunable laser, a polarization independent isolator (ETEK model PIFIA1AP55222), a polarization controller (PC), a linear polarizer, and a FP etalon. The PC is used to tune the spectral response. Fig. 1(c) shows the response for cascading the isolator, PC, and polarizer. The monitored wavelength window and slope of the curves changes with polarization states. In the figure, PC1 to PC5 refer to different polarization states by adjusting the polarization controller. The results prove the versatility of the proposed approach. The PC can be adjusted to generate a steeper spectral response if only a few channels are to be monitored. The channel monitoring is tunable but has a stable spectral response as the PC (or waveplate) is fixed.

Fig. 2(a) shows the spectral responses of PD2 and PD3. The wavelength is locked to the crossover point of the two curves. The frequency spacing between the adjacent crossover points is determined by the FSR of the FP etalon, which is designed to match the DWDM channel spacing. The spectral response of PD3 signal is ideal for monitoring tunable lasers since it has very sharp variation around the locking point while can differentiate the responses among the channels. Fig. 2(b) shows the stable and monotonic responses of PD2 around ten channels of 100 GHz spacing. The monotonic response can help to locate the wavelength position when the wavelength falls outside of the wavelength locking range of the etalon (±20GHz in our experiments). This is essential for a tunable laser to monitor the potential mode hopping or incomplete tuning problems.



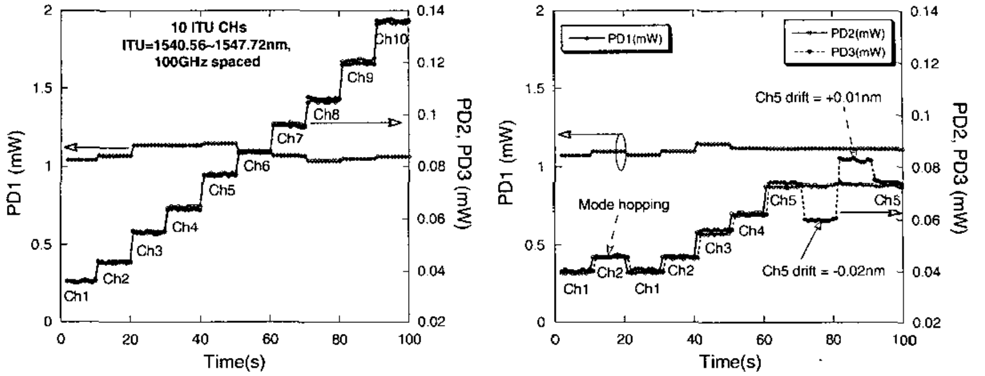
(a)

(b)

Fig. 2 Measured channel monitoring characteristics: (a) spectral responses of PD2 and PD3, and (b) PD2 response versus wavelength drift.

Fig. 3 demonstrates the feasibility of simultaneous monitoring of power, wavelength, and channel. In Fig. 3(a), the tunable lasers are tuned to ten ITU wavelengths. Since the wavelengths are correct, the detected signals of PD2 and PD3 are almost the same. The ratio of PD3 signal over PD2 signal is close to 1 for all channels. Under this condition, the ratio of PD2 over PD1 can indicate the channel number. We emulate the scenario of monitoring mode hopping and wavelength drift in Fig. 3 (b). The laser is to be tuned from CH1 to CH5 but stays at CH1 and CH5 for

3 and 4 time slots, respectively. The laser encounters mode hopping to CH2 on the second time slot and wavelength drift on slots 8 to 9. By coincidence, the mode hopping hits an ITU wavelength grid, so the ratio of PD3/PD2 remains at 1. From the PD2 response, one can discover the happening of wavelength hopping. On the other hand, for a tiny wavelength drift, it may not be sensitive enough to reveal the drift from the PD2 signal, but the signal on PD3 can definitely tell the difference.



(a) (b)

Fig.3 Demonstration of simultaneous power, wavelength, and channel monitoring for continuous tuning to (a) 10 ITU channels, and (b) channels with mode hopping and wavelength drift.

4. Discussion and summary

The CM path needs a monotonic wavelength response that covers the tuning range of the tunable laser. The wavelength range of the monotonic response is roughly equal to half the free-spectral range (FSR), which is in turn determined by the phase difference between the two orthogonal rays. Near 1550nm, the FSR of an optical isolator is approximated by $\Delta\lambda_{FSR} = 7.8/\Delta\tau$, where $\Delta\lambda_{FSR}$ is in *nm* and $\Delta\tau$ is in *ps* [6]. $\Delta\tau$ is the differential group delay (DGD) that is typically listed in the specification of an isolator. Thus, one can choose an isolator with an appropriate DGD value to match the monitored band. For instance, the isolator used in the experiments has a DGD value of 0.243 *ps*, so its FSR is 32 *nm*. Though the required filter characteristic can also be obtained by using other types of optical filters, like thin-film filters or fiber grating filters, the spectral response needs to be elaborately designed for different tunable lasers.

In summary, we proposed a novel approach for recognizing the channels of DWDM tunable lasers. We used the components that were usually built-in with the laser but provide additional functions. We demonstrated its versatility for monitoring different wavelength bands and feasibility for detecting mode hopping and wavelength drift. Simultaneous monitoring of power, wavelength, and channel number can be integrated into a very compact module.

5. References

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