A Wavelength Monitoring System Using Tunable MEMS Filter Calibrated by F-P Laser

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Abstract
We report a wavelength and power monitoring system based on a scanning MEMS filter as wavelength discriminator and a near-threshold-biased Fabry-Perot diode laser as wavelength reference. This system is capable of monitoring 250 channels of DWDM signal at 25 GHz ITU Grid with an error of less than ±8 pm.

1 Introduction
Recent phenomenal growth in dense-wavelength-division-multiplexing (DWDM) systems as a result of the explosion of Internet traffic called for more wavelength channels as well as narrower channel spacing to accommodate the large bandwidth. Wavelength and power monitoring of DFB lasers, and the subsequent control of these lasers becomes a critical issue in order to avoid unwanted channel crosstalks as the channel spacing is reduced.

Diffraction grating with photodetector array [1] and tunable fiber Fabry-Perot filter [2] are the two common approaches to realize a wavelength and optical power monitoring system. In the former approach, no mechanical part is involved and so they could operate at high-speed and has long lifetime. However, wavelength resolution is insufficient, mainly limited by the number of pixels of the photodetector array. On the other hand, the tunable filters approach could provide very high wavelength resolution as well as good power resolution for the evaluation of optical signal-to-noise ratios of DWDM signals but they consist of moving parts, mostly activated by piezoelectric element. Piezoelectric transducer suffered from serious hysteresis and drift, therefore constant calibration by a wavelength-referencing source is necessary when they are used for wavelength monitoring purposes. In this paper, a wavelength monitoring system that incorporates a tunable filter fabricated using the micro-electro-mechanical-system (MEMS) technology is described. MEMS filters are electrostatically actuated microstructures that exhibit small hysteresis and drift when operating at constant temperature. MEMS filters are very small and can be hermetically sealed and packed inside a small metal housing with thermal cooler as in commercial laser diode packages. The monitoring system is similar to the one we reported previously [3] and uses the peak wavelengths of the longitudinal modes of a near threshold-biased Fabry-Pérot laser diode (FP-LD) as wavelength referencing source to calibrate the scanning MEMS filter. The preliminary results show that this system is capable of measuring 250 channels, 25 GHz spacing DWDM signal simultaneously with a wavelength measurement accuracy of better than ±8 pm.

2 Experiment and result

Fig.1 (a) shows the schematic diagram of the proposed DWDM monitoring system used to measure both the wavelength and optical power of a DWDM signal.

![Diagram](image)

Fig. 1 DWDM signal monitoring system; (a) Schematic diagram, (b) FP-LD output spectrum, and (c) voltage waveforms to the optical switch and MEMS filter.

The optical switch has a switching time of 4 ms, is switched alternatively to scan the DWDM signal spectrum and the spectrum of the F-P LD, which was calibrated earlier using a multiwavelength meter. The multiple peak wavelengths of the F-P LD spectrum is
used to calibrate the scanning MEMS filter. The F-P LD was temperature stabilized at 22°C with a stability of ±0.01°C using a commercial TEC controller. The laser drive current was maintained at 10.3±0.01 mA, which is slightly below the lasing threshold current of the laser. The measured output spectrum of the F-P laser is depicted in Fig. 1 (b), the broad spectrum allows a broad wavelength range of the filter to be calibrated. The F-P laser was biased at a particular current that exhibits zero wavelength shift against drive current \(^3\) and thus wavelength drift due the current fluctuation of the drive electronics is minimized. The scanning MEMS filter has an optical bandwidth and FSR of 0.02 nm and 150 nm respectively. The optical power from the filter was measured with a photodiode detector capable of measuring optical power from –70 dBm to 0 dBm. The optical switch and MEMS filter were controlled using a computer via a D/A & A/D card. The signals sent to the optical switch, S1(t), and the MEMS filter, S2(t), are shown in Fig. 1 (c). The voltage and frequency of the MEMS filter were adjusted so that it scanned over 50 nm (1525 nm – 1575 nm) in 0.5 s.

The monitoring system was tested with a DWDM signal emulator which consisted of a broadband ASE source followed by an etalon filter. The etalon filter has peaks located at the 25 GHz ITU Grid with a channel accuracy of better than ±1.25 GHz. The filter has a contrast of better than 30 dB and wavelength temperature-dependent shift of better than 0.2 pm/°C. The broadband ASE source was a single stage configuration and is similar to the one we reported previously \(^4\). The output power of the source is +13 dBm and its bandwidth is larger than 80 nm. The light source can therefore emulate 400 DWDM channels. Part of the spectrum of the emulated DWDM signal is shown in Fig. 2.

The wavelength of the 250 DWDM channels (from 1525.11 nm to 1574.98 nm) was measured with the monitoring system for 1 hour. Figure 4 shows the measured wavelength deviation of the 250 channels. The wavelength stability of the 250 channels is expected to be better than 1 pm during the measurement period. These results demonstrate that the monitoring system is capable of measuring wavelength with an accuracy of better than ±8 pm. The results are in fact limited by the noise of the A/D and D/A card.

In conclusion, we have demonstrated a wavelength and power monitoring system that utilizes a tunable MEMS filter and a FP-LD as a reference source. Wavelength monitoring of 250 channels DWDM signal spaced 25 GHz apart was achieved with an accuracy of ±8 pm.

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References