A Multi-wavelength Stabilization Technique Based on a Local Minimum Search Using a Shared Reflective Etalon Filter for Coexistence-type WDM-PON

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Abstract

A multi-wavelength stabilization technique is proposed based on a local minimum search. Experiments confirm that the estimated frequency stability is 3GHz even for 100 downstream wavelengths with 50GHz spacing.

Introduction

Passive optical networks (PONs) are being deployed in some countries. To provide a wider bandwidth, discussion is currently focused on coexistence-type next-generation access (NGA) systems, which are based on the same infrastructure as existing PONs /1/. A promising candidate NGA system is a wavelength division multiplexing (WDM)-PON, in which a dedicated wavelength is assigned to each optical network unit (ONU). Dense WDM (DWDM) technologies are essential if we are to accommodate many users in a limited wavelength bandwidth (see figure 1) /2/.

As key technologies, we have already reported a coexistence-type WDM-PON that employs wavelength-tunable DWDM small form factor pluggable (SFP) /2/ and a centralized wavelength stabilization technique /3/ for upstream signals. For downstream applications, we have also reported a simple multi-wavelength stabilization technique based on a one-by-one local maximum search using a periodic optical filter /4/. In ref [4], the feasibility was demonstrated using four channels. However, there is an issue in that a large frequency deviation may result when the number of wavelengths is increased.

This paper proposes a simple multi-wavelength stabilization technique based on a local minimum rather than a local maximum search, which is suitable for a large number of wavelengths. We use a shared reflective etalon filter and DWDM-SFPs to obtain experimental results that reveal improved performance and confirm the feasibility of this approach for up to 100 wavelengths.

Coexistence-type WDM-PON with MWSC

Figure 1 shows the configuration of the coexistence-type WDM-PON with a multi-wavelength stabilization circuit (MWSC) for downstream signals. The WDM-PON is overlaid on the existing power-splitter-based infrastructure. The WDM-PON optical line terminal (OLT) comprises arrayed waveguide gratings (AWGs), multiple WDM optical subscriber units (WDM-OSUs) and an MWSC. As the transceiver modules of the WDM-OSUs we use DWDM-SFPs with an interface for wavelength stabilization. The MWSC monitors the tapped DWDM signal and provides the interface of each DWDM-SFP with a frequency setting signal (FSS).

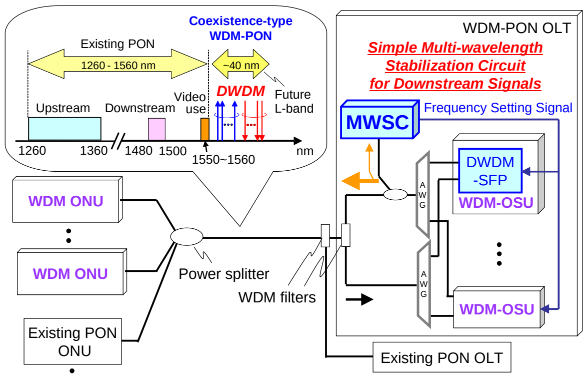

Fig. 1 Coexistence-type WDM-PON with MWSC for downstream signals

Proposed MWSC

Figure 2 shows the multi-wavelength stabilization of downstream signals with the proposed MWSC. The MWSC comprises an etalon filter, a circulator, a power monitor (PM) and a microprocessor unit (MPU). The loss spectrum of the etalon filter is periodic peak profiles that correspond to the desired ITU-T grids. Each wavelength is stabilized one-by-one by monitoring the total optical power reflected from the etalon filter and calculating the optimum FSS.

The previous MWSC stabilize each wavelength by employing a local maximum search with a periodic optical filter /4/. This corresponds to the use of the transmission port of the etalon filter. This paper proposes achieving wavelength stabilization by employing a local minimum search, not local maximum search, using the reflection port of the etalon filter and greatly improves the wavelength stabilization performance.

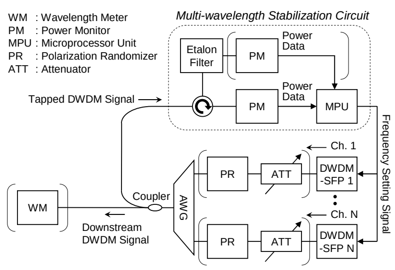

Fig. 2 Multi-wavelength stabilization technique with proposed MWSC

The MWSC first stabilizes the wavelength of channel 1. After that, the wavelength of other channel is stabilized in the same way. This operation continues to channel N and is repeated with a constant period. To stabilize each wavelength, the optical power data is measured with small unit frequency steps of δF and the FSS corresponding to the target peak is calculated by the numerical curve fitting /4/.

The number of wavelengths applicable to this technique is limited by the power fluctuation originating from wavelengths not involved in the peak search operation. Figure 3(a) and (b) show the impact of power fluctuation when using the transmission port (previous MWSC) and the reflection port (proposed MWSC) of the etalon filter, respectively. As shown, the performance is greatly improved when using the reflection port compared to when using the transmission port because the power fluctuation at the local minimum σ_R is much less than that at local maximum σ_T.

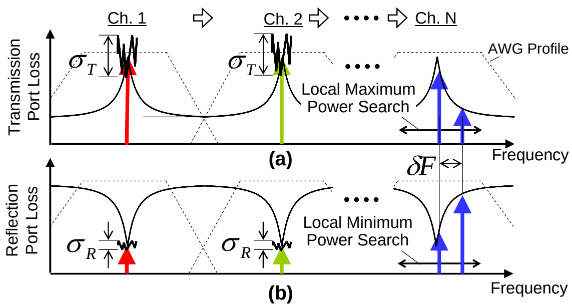

Fig. 3 Impact of power fluctuation
(a) Using transmission port (previous MWSC)
(b) Using reflection port (proposed MWSC)

Experiments and discussion

The experimental setup is shown in Fig. 2. We use two DWDM-SFPs for ch. 1 and ch. 2 and a 50 GHz spaced AWG with a flat profile. δF is set at 2 GHz. Variable attenuators and polarization randomizers (PRs) are used to simulate the power fluctuation originating from the PDL of plural wavelengths. The optical power input to the MWSC is –30 dBm/ch. The frequencies of the DWDM-SFPs are monitored with a wavelength meter. The free spectral range and finesse of the filter are 50 GHz and 6.5, respectively.

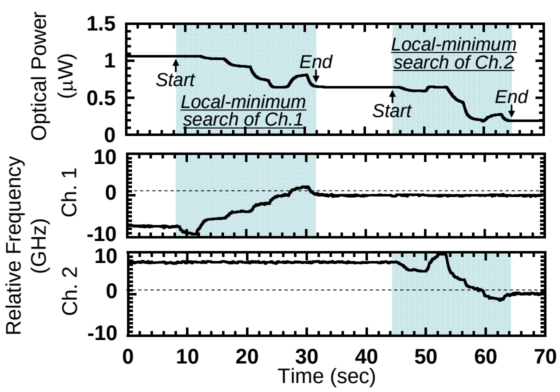

Fig. 4 Measured time transition of optical power

Figure 4 shows the measured time transition of the optical power and the relative frequency under wavelength stabilization when using the proposed MWSC. The initial frequencies are set at -7.5 GHz for ch. 1, and +7.5 GHz for ch. 2. The frequency of each channel is expressed by the relative frequency against the desired ITU-T grid. As shown, the frequency of each channel is suppressed to around zero GHz.

Figure 5 compares the performance of the previous and proposed MWSCs. Figure 5(a) shows an example frequency histogram when stabilization was conducted 100 times for 32 wavelengths. The mean values (MVs) of the measured frequencies when using the previous and proposed MWSCs are 0.38 and 0.36 GHz, respectively. These values are determined by the peak frequency accuracy of the filter. Figure 5(b) shows the dependence of the standard deviation (SD) of the measured frequency after stabilization on the number of wavelengths. As shown, the SD increases in proportion to the number of wavelengths when using the previous MWSC. In contrast, The SD remains below 0.21 GHz over 100 wavelengths when using the proposed MWSC. Considering MV (0.36 GHz), SD (0.21 GHz) and δF (2 GHz), we found that the proposed MWSC achieved a total frequency deviation of less than 3 GHz.

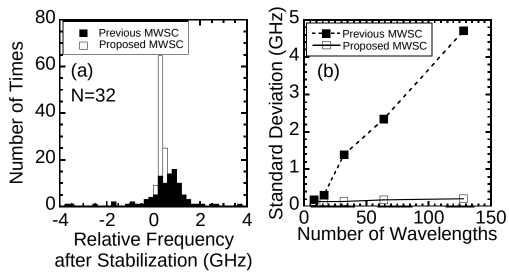

Fig. 5 Performance comparison of previous and proposed MWSCs
(a) Histogram of relative frequency after stabilization
(b) Standard deviation versus number of wavelengths

Conclusions

We proposed a simple and cost-effective multi-wavelength stabilization technique for coexistence-type WDM-PON. Each wavelength is stabilized one-by-one by searching for the local-minimum optical power reflected from an etalon filter whose peak profile corresponds to the desired ITU-T grid. We confirmed experimentally that the frequency deviation with respect to the desired ITU-T grid is suppressed to 3 GHz over one hundred wavelengths with 50 GHz spacing.

References

1. R. Davey et al., IEEE Commun. Mag., pp. 50-56, Oct., 2006
2. H. Suzuki et al., ECOC2007, PD3.4, 2007
3. M. Fujiwara et al, ECOC2007, 7.6.2, 2007
4. T. Suzuki et al., OECC2007, 11A2-3, 2007