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Simple Multi-wavelength Stabilization Technique Using a Periodic Optical Filter for WDM Access Networks

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Abstract

This paper proposes a multi-wavelength stabilization technique based on a periodic optical filter and maximum power searching. The operating principle is described and the performance is experimentally estimated for four 100-GHz spaced transmitters.

Introduction

The rapid growth of the Internet has drastically increased the total number of data packets being transferred and has necessitated the emergence of broadband access networks. To meet this demand, several wavelength division multiplexed (WDM) access networks employing dense-WDM (DWDM) technology were reported [1-2]. In these systems, wavelength stabilization is required to provide stable services to users. The conventional approach is to incorporate a Fabry-Perot (F-P) Etalon filter into each transmitter to stabilize the output wavelength [3]. However, in this approach the cost increases in proportion to the number of wavelengths.

In this paper, we propose a simple multi-wavelength stabilization technique that is suited to WDM access networks. Each wavelength is stabilized in the desired ITU-grid one-by-one using a single optical filter with a periodic peak profile. We conduct an experiment to confirm the feasibility of this technique.

WDM Transmitter Configuration

Figure 1 shows the WDM transmitter configuration employing the proposed multi-wavelength stabilization technique. This configuration includes N transmitters, an optical multiplexer (MUX), an optical coupler, a periodic optical filter, an optical power monitor, and a wavelength stabilization circuit. Each transmitter consists of a laser diode (LD) with an auto power control (APC) circuit and a temperature controller. The wavelength stabilization circuit determines the LD temperature from the optical power obtained through the filter. The transmission spectrum of the optical filter is a periodic peak profile that has minimum losses at the desired ITU-grid. Optical filters such as a Mach-Zehnder interferometer (MZI) filter and a F-P Etalon filter can also be applied. Each wavelength is stabilized one-by-one by searching for the LD temperature at which the optical power obtained through the filter is the maximum within the spectral range involving the target spectral peak.

Wavelength stabilization is achieved by varying the LD temperature and searching for the local maximum. Figure 2 shows the operation scheme when searching for the local maximum. The optical power through the filter is measured each time while changing the LD temperature. The LD temperature is varied in steps based on arbitrary units as indicated in Fig. 2. Initially, the optical power is measured at the initial LD temperature and then compared to the measurements at temperatures above and below that point. Thus, the direction that the LD temperature changes when the optical power increases is determined. Next, the LD temperature is varied until the optical power decreases. Thus, three points surrounding the local maximum are selected. Finally, the LD temperature corresponding to the local maximum is determined by interpolating a parabola against the three points.

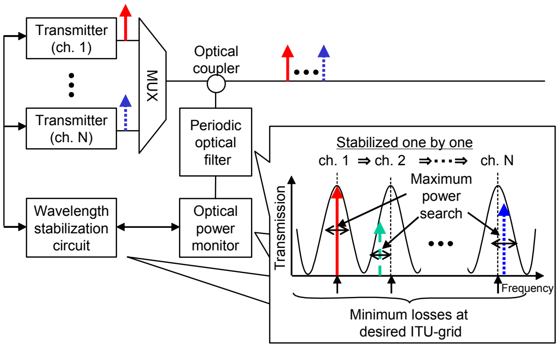

Fig. 1: WDM transmitter configuration employing proposed multi-wavelength stabilization technique

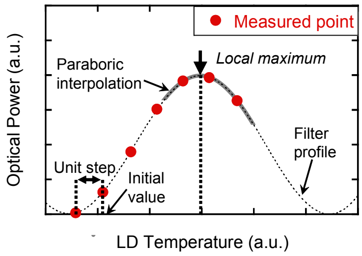

Fig. 2: Operation scheme for local maximum search

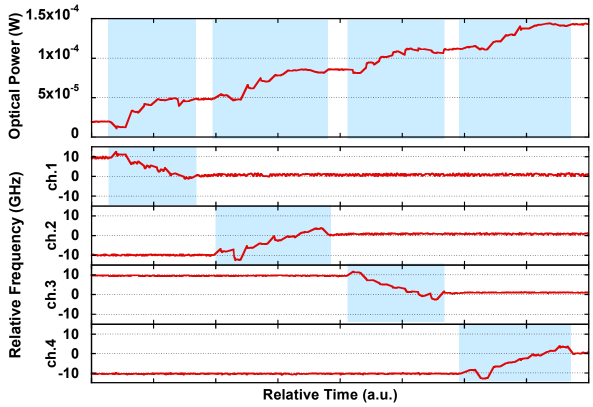

Fig. 3: Experimental results

Experiments

To confirm the feasibility of this technique, we conducted an experiment. Four Distributed-Feedback LDs (DFB-LDs) are connected to a 100-GHz spaced MUX with a flat profile. The multiplexed WDM signal is tapped using a 3-dB optical coupler, and input to a 25-GHz spaced MZI filter. The optical power input to the filter is –12 dBm/ch. The optical power through the filter is measured using an optical power meter. The one-by-one local maximum search operation program is fabricated on a PC.

Figure 4 shows the experimental results for the case where the initial frequency deviations are set to +10 GHz for ch. 1, -10 GHz for ch. 2, +10 GHz for ch. 3, and –10 GHz for ch. 4. The frequency deviation of each channel is expressed by the relative frequency against the desired ITU-grid. Based on the one-by-one local maximum searching operation, the frequency deviation of each channel is suppressed to +0.8 GHz for ch. 1, +1.2 GHz for ch. 2, +1.2 GHz for ch. 3, and +0.6 GHz for ch. 4. Regardless of the sign of the initial frequency deviation, we find that the frequency deviation after the stabilization is suppressed to 1.2 GHz for the four transmitters.

Discussion on Effect of Modulation

In the proposed technique, the wavelength is stabilized in the wavelength corresponding to the local maximum. In the case of a symmetric optical spectrum such as a continuous wave (CW) and externally modulated signal, the wavelength corresponding to the local maximum corresponds to the desired ITU-grid. On the other hand, in the case of an asymmetric optical spectrum such as a directly modulated DFB-LD signal, which is caused by an adiabatic chirp, there is the possibility that the wavelength corresponding to the local maximum is somewhat far from the desired ITU-grid.

Therefore, we investigated the effect of a directly modulated DFB-LD signal on the proposed technique. Figure 4(a) shows the output spectrum of the 1.25-Gbit/s directly modulated DFB-LD used in this investigation. As shown in the figure, the directly modulated signal exhibited adiabatic chirp dominant behavior [4], i.e., strong and weak peak powers in the optical spectra. For simplicity, we define the frequency with the strongest peak power as the relative frequency of zero. Figure 4(b) shows the relationship between the optical power through a 25-GHz spaced MZI filter and the relative frequency against the peak frequency of the filter. The peak frequency in the case of the CW (dashed line) corresponds to the peak frequency of the filter. In the case of the directly modulated signal (solid line), the peak frequency deviates by approximately -0.4 GHz from that of the CW. This is because the weighted center of the output optical spectrum lies on the frequency between the two spectral peak powers. Considering the modulation effect, we conclude that the frequency deviation after the stabilization in the case of a directly modulated DFB-LD signal is expected to be less than approximately 2 GHz.

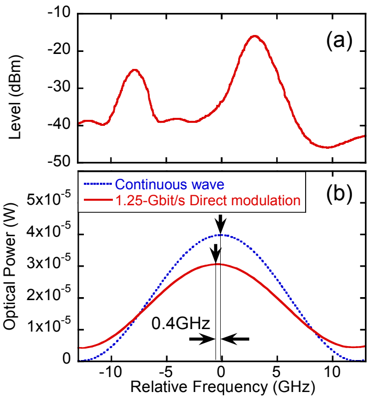

Fig. 4: Effect of directly modulated signal

(a) Output spectrum of directly modulated DFB-LD

(b) Optical power through 25-GHz spaced MZI filter

Conclusion

We proposed a simple multi-wavelength stabilization technique for WDM access networks. This technique reduces the number of optical filters used for wavelength stabilization compared to the conventional method. Each wavelength is stabilized in the ITU-grid one-by-one by searching for the LD temperature at which the optical power obtained through a periodic optical filter is the maximum within the spectral range involving the target spectral peak. We experimentally confirmed that regardless of the sign of the initial frequency deviation the frequency deviation against the desired ITU-grid is suppressed to 1.2 GHz using four 100-GHz spaced CW lights. We quantitatively estimated the effect of the asymmetric profile due to direct modulation and concluded that the proposed technique stabilizes the frequencies of directly modulated signals within approximately 2 GHz.

References

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