A TUNABLE-OUTPUT WAVELENGTH CONVERTER BASED ON A SELF-SEEDED FABRY-PEROT LASER DIODE WITH A CHIRPED FIBER GRATING

Kwang-Hyun Lee,[1] Yong-Sang Cho,[1] Sangin Kim,[2] and Woo-Young Choi[1]
[1] Department of Electrical and Electronic Engineering
Yonsei University
134, Shinchon-Dong
Sudaemun-Ku, Seoul, Korea
[2] Access Network Laboratory
Korea Telecom
62-1 Whaam-dong
Yusung-gu, Taejeon, Korea

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ABSTRACT: *We report a new all-optical wavelength conversion scheme based on a self-seeded Fabry–Perot laser diode with a chirped fiber grating as the external cavity. This converter can convert the wavelength of input optical signals into 14 discrete wavelengths with external RF modulation. We successfully demonstrate all-optical wavelength conversion at 10 Mbps.* Microwave Opt Technol Lett 37: 35–36, 2003; DOI 10.1002/mop.10817

Key words: *wavelength converter; self-seeded gain-switched FP-LD; injection locking*

INTRODUCTION

The wavelength division multiplexing (WDM) technique is very useful in broadband networks, because the network's capacity can be easily increased by adding a new wavelength that determines the signal destination in WDM networks. The wavelength-blocking problem in large networks can be overcome by using wavelength converters. Moreover, converters are also needed for flexible wavelength management with fixed wavelengths systems [1–2].

A tunable optical source is the key component in the wavelength converter. Until now, several types of tunable sources have been demonstrated, such as micro-electro mechanical external Cavity diode lasers (MEM-ECL) [3], MEM-VCSEL [4], and multi-section DFB or DBR lasers [5]. However, it is difficult to utilize the tunable sources constructed by MEM-ECL or MEM-VCSEL as all-optical wavelength converters because external optical injection is not possible. The multi-section DFB or DBR lasers can be used as all-optical wavelength converters, however, complex electrical control for stable wavelength tuning is needed.

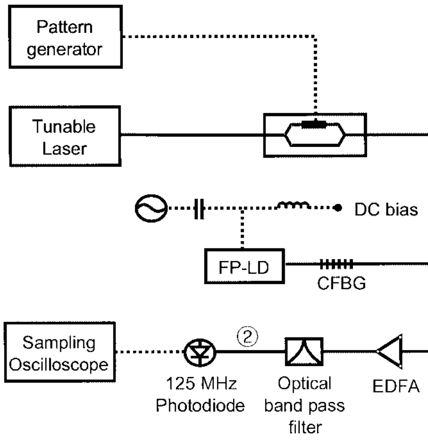

Figure 1 Experimental setup for wavelength conversion

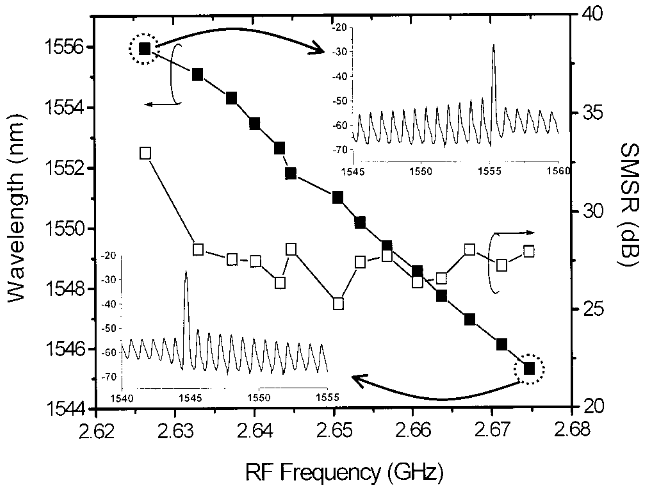

Figure 2 Wavelength switching characteristics of self-seeded FP-LD with LCFBG

In this paper, we demonstrate a new all-optical wavelength converter that can provide tunable output wavelength with a wide tuning range by simple control of RF modulation frequency. In this scheme, the tunable source is based on the self-seeded Fabry–Perot laser diode (FP-LD) with a linearly chirped fiber-Bragg grating (LCFBG) [6], and the injection-lock technique is used for all-optical wavelength conversion.

EXPERIMENT AND RESULTS

Figure 1 shows the experimental setup for an all-optical wavelength conversion scheme. The tunable source is composed of an FP-LD with 100-GHz mode spacing and an LCFBG with 12.14-nm spectral bandwidth (BW) from 1544.05 nm–1556.20 nm, with 68% reflectivity. The FP-LD is used as a multi-mode optical source and LCFBG as an external mirror with wide BW, which provides a wavelength-dependent external cavity length. As a consequence, each FP mode has its own cavity resonance frequency. With external RF modulation, only the FP mode whose cavity resonance frequency or its harmonics match the applied

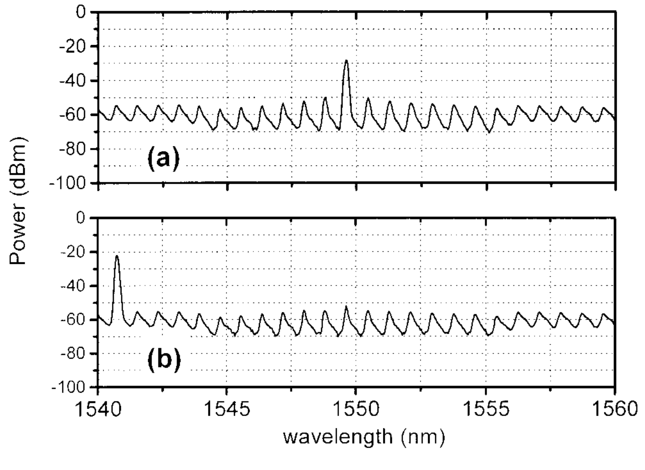

Figure 3 On/off switching of FP-LD with LCFBG (a) before and (b) after external optical injection

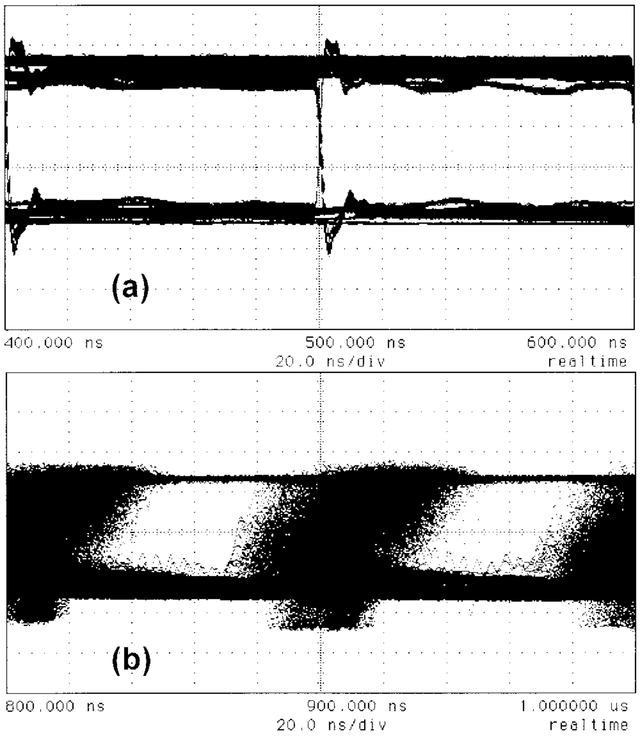

Figure 4 Eye diagrams (a) before and (b) after conversion

external RF modulation frequency can be excited. Therefore, by changing the external RF modulation frequency, wavelength switching between FP modes can be achieved.

Figure 2 shows the wavelength switching and the side-mode suppression ratio (SMSR) as a function of the applied RF modulation frequency. The RF frequencies in the range of 2.65 GHz are used, which correspond to the 12th harmonic of the cavity resonance frequencies. The applied RF power is 11 dBm, measured at the output of the RF source. The FP-LD is biased slightly above the threshold current. As can be seen from the figure, a change in RF modulation frequency produces a different excited wavelength. The longest wavelength within LCFBG BW is selected by an RF modulation of 2.626 GHz and the shortest wavelength is by 2.675 GHz. The optical spectra for these two cases are shown in the figure. The RF frequency shift required for switching from one FP mode to the next adjacent mode is about 3.715 MHz. In our experiment, 14 FP modes can be excited with larger than 25-dB SMSR. The total number of the excited FP modes is limited by the spectral BW of the LCFBG.

In order to directly transfer the input optical data to the switched wavelength without O/E conversion, we used an injection-lock technique. If the power of the incoming optical signal (whose wavelength lies outside the LCFBG pass band), is sufficiently large so that one of the FP modes can be injection-locked, the FP-LD lases dominantly at the mode into which external light is injected. Lasing due to self-seeding occurs only when there is no external light injection and, consequently, inverted wavelength conversion can be achieved. Although the wavelength of the input signal should lie outside the grating BW, this problem can be resolved by utilizing two facets of FP-LD for input and output, respectively.

Figure 3(a) and (b) show the output spectra of the FP-LD with and without external light injection, respectively. The optical power ratio between on and off states is larger than 20 dB. The converted signal is detected by a low-speed photodiode so that high frequency components of self-seeded lasing pulses can be filtered out. The optical band pass filter in front of the photodiode is used to filter out side modes of FP-LD for good conversion performance. Figure 4(a) and (b) show eye patterns of input and wavelength-converted signals detected at points 1 and 2 in Figure 1, respectively. The input signal is produced by externally modulated light signal at 1540.565 nm with 10 Mbps PRBS. The output has wavelength of 1550.16 nm. Due to the relatively large external cavity length of the self-seeded FP-LD used in our initial investigation, the data rate is limited to 10 Mbps. This data rate corresponds to about one-twentieth of the external cavity resonance frequency. It is expected that with a shorter cavity, a much higher data conversion rate can be achieved. For example, 155 Mbps of conversion speed is possible with about a 3.2-cm-long cavity. Although wavelength conversion at a single wavelength is shown, wavelength conversion into 14 discrete wavelengths can be easily achieved.

Asymmetry in eye patterns, shown in Fig 4(b), is due to the difference in the turn-on and turn-off transients of the self-seeded FP-LD. Schell, et al. reported that it takes about 10 times of cavity round-trip time for the external cavity laser to be turned on [7]. For turn-off, however, no significant transient effect exists. It is expected that with proper control of the bias level and the amount of optical feedback, reduction in turn-on delay time is possible.

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