21st Annual Meeting of the IEEE Lasers & Electro-Optics Society (LEOS 2008), WB2, pp.421-422, Newport Beach (Nov. 2008)

Highly Pure 160-GHz Two-Tone Lightwave Generation using High Extinction-Ratio Optical Intensity Modulator and Delay Interferometer

Hiroyuki Toda (1), Junichi Miyashita (1), Akito Chiba (2), Takahide Sakamoto (2), Tetsuya Kawanishi (2), Masahiro Tsuchiya (2), and Masayuki Izutsu (3)
1 : Faculty of Engineering, Doshisha University, 1-3 Tatara-Miyakodani, Kyotanabe, Kyoto 610-0321 Japan
e-mail: htoda@mail.doshisha.ac.jp
2 : National Institute of Information and Communications Technology (NICT),
4-2-1 Nukui-kitamachi, Koganei, Tokyo, 184-8795 Japan e-mail: kawanish@nict.go.jp
3 : Tokyo Institute of Technology, Nagatsuta, Midori-ku, Yokohama 226-8503 Japan

Abstract

We demonstrate highly pure 160-GHz two-tone lightwave generation using a high extinction-ratio optical intensity modulator and a delay interferometer. The undesired sideband suppression ratio was more than 39 dB.

.

Introduction

Two-tone lightwave generation using an Mach-Zehnder modulator (MZM) is a very attractive technique for clock distribution in radio astronomy, CS-RZ optical clock generation for ultra high speed transmission systems, radio-over-fiber links, etc [1-3]. 2nd order optical sidebands are effectively obtained when DC bias of an MZM is set to maximum transmission point and an optical band-rejection filter is used [4]. In [4], a high extinction-ratio MZM (HER-MZM) [5] was used in order to suppress odd order optical sidebands. Recently, the use of a delay interferometer (DI) has been proposed in RZ and/or CS-RZ optical clock generation with such a bias condition of the MZM where the output clock rate is four times of the RF driving frequency [6, 7]. The delay of the DI is adjusted to the output clock period. When the DI is considered in frequency domain for CS-RZ clock generation, it acts as optical notch filters where the free spectral range is four times of the driving frequency in order to suppress input optical frequency component and n x 4th order optical sidebands (n: integer). Therefore, if a HER-MZM is used in conjunction with the DI, highly pure optical two-tone signal generation can be expected. In this paper, we demonstrate 160-GHz two-tone lightwave generation using a HER-MZM and DI. In order to suppress odd order sidebands more effectively, we use the so-called dual parallel MZM (DPMZM) as a HER-MZM, and highly balanced operation of the DPMZM both optically and electrically was performed [8].

Experimental setup

Figure 1 shows a schematic view of the DPMZM and the driving circuit. A CW laser light, with the optical frequency f_0, is fed to the DPMZM. The highly balanced operation was completed in the following way. Two sub Mach-Zehnder modulators MZ_A and MZ_B, driven by DC voltages, are used for balancing the optical intensities of the two arms of the main Mach-Zehnder modulator MZ_C. The optical phase difference between the two arms of the MZ_C was adjusted to be 0 for maximum bias condition. This is made by changing the DC voltages V_{A1} and V_{A2} simultaneously in the same direction. The individual electrodes of the MZ_C are driven by 40GHz (=f_{RF}) RF carriers. The driving RF powers were adjusted to obtain the same phase modulation indices for both arms. The RF phase difference was adjusted to be p by electrical delay lines. In this way, odd order optical sidebands in the DPMZM output are, in principle, eliminated.

Figure 2 shows the experimental setup. The wavelength of the laser light source was 1549.9 nm. DC and 40-GHz RF voltages drive the DPMZM in the way described above. The output power of the RF amplifier for each electrode was + 24 dBm. The DI was constructed by polarization-maintaining fiber couplers and a collimator pair on a mechanical stage. Since the delay can be adjusted by the mechanical stage, f_{RF} can be tunable. A piece of fiber in one arm of the DI was wound on a piezo cylinder to perform phase stabilization electronically. The phase stabilization of the DI was made with a phase-locked loop by monitoring interference of another CW light source which was not shown in the figure. The

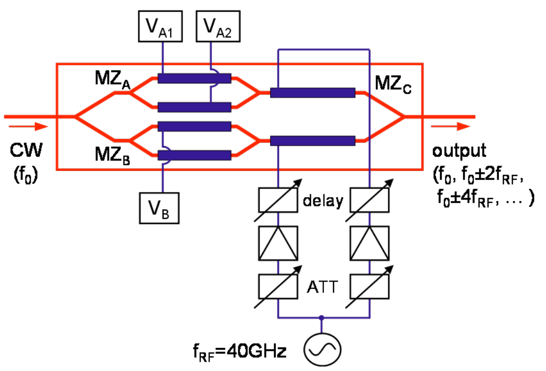

Figure 1: Schematic of DPMZM and driving circuit for highly balanced operation. V_{A1}, V_{A2} and V_B are DC bias voltages

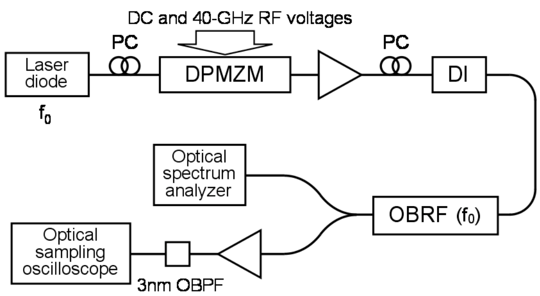

Figure 2: Experimental setup.

extinction ratio of the DI was 21 dB. Since the extinction ratio was not enough to remove the f_0 component, we used an optical band-rejection filter (OBRF). Finally, optical spectrum and intensity waveform were observed by an optical spectrum analyzer and an optical sampling oscilloscope (Picosolve PSO101).

Results

Figures 3 show optical spectra observed when (a) without DI and OBRF, and (b) with DI and OBRF, respectively. From Figure 3 (a), we can see that the odd order sidebands are effectively suppressed because of the highly balanced operation of the DPMZM, and the 4th order sidebands are dominant excluding the optical carrier component (f_0). The 4th order and the odd order sidebands were suppressed by 29 dB and more than 35 dB of the desired 2nd order sidebands, respectively. We can also estimate the RF driving voltage for each electrode to be 0.4 Vp, where Vp is the half-wave voltage. From Figure 3 (b), we can see that the optical carrier component is eliminated by the DI and the OBRF. The 4th order sidebands are also suppressed by the filtering of the DI. The dominant spurious is now 1st and 3rd order sidebands which are suppressed by more than 39 dB of the desired components.

Figures 4 show observed waveforms of the 160 GHz two-tone signal when (a) DPMZM was in the balanced operation, and (b) RF phase difference was slightly detuned from p where the suppression ratio was about 20 dB. Clear signal is observed in (a), whereas the amplitude of the signal is fluctuated in (b) which is because of the undesired optical sidebands.

Conclusions

We demonstrated highly pure two-tone lightwave generation using a high extinction-ratio optical intensity modulator and a delay interferometer. 160-GHz optical two-tone signal was successfully obtained with the undesired sideband suppression ratio of more than 39 dB.

References

[1] J. J. O'Reilly, P. M. Lane, R. Heidemann and R. Hofstetter, Electron. Lett., vol. 28, no. 25, pp. 2309-2311 (1992).

[2] T. Kawanishi, T. Sakamoto, M. Izutsu, IEEE J. Sel. Top. Quantum Electron., vol. 13, no. 1, pp. 79-91 (2007).

[3] H. Kiuchi, T. Kawanishi, M. Yamada, T. Sakamoto, M. Tsuchiya, J. Amagai, and M. Izutsu, IEEE Trans. Microwave Theory Tech., vol. 55, no. 9, pp. 1964-1972 (2007).

[4] T. Kawanishi, T. Sakamoto, M. Tsuchiya, and M. Izutsu, LEOS 2006, TuE2, Montreal (Oct. 2006).

[5] T. Kawanishi, T. Sakamoto, M. Tsuchiya, M. Izutsu, S. Mori and K. Higuma, OFC 2006 OWC4, Anahaim (2006).

[6] A. J. Torregrosa, H. Maestre, J. Capmany, and C. R. Fernández-Pousa, IEEE Photon. Tech. Lett., vol. 19, no. 22, pp. 1837-1839 (2007).

[7] X. Wu, L. Christen, J.-Y. Yang, S. R. Nuccio, A. Willner, and L. Paraschis, LEOS 2007, ThX3, Lake Buena Vista (Oct. 2007).

[8] T. Kawanishi, T. Sakamoto, A. Chiba, M. Tsuchiya, and H. Toda, CLEO/QELS 2008), CFA1, San Jose (May 2008).

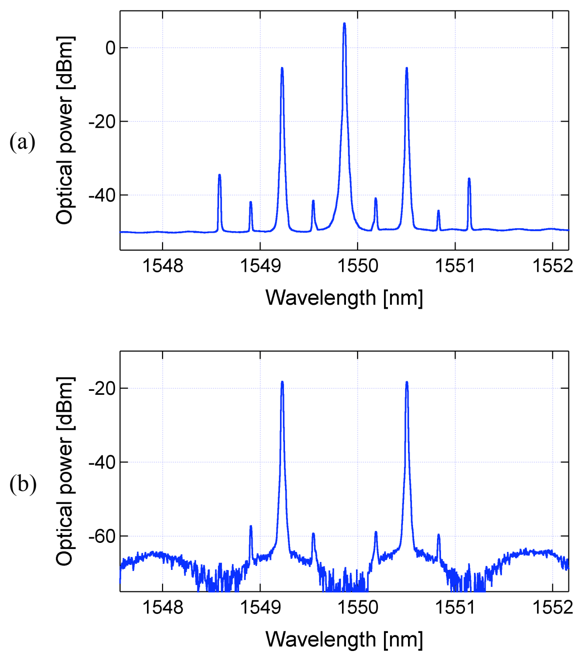

Figure 3: Observed optical spectra (a) without DI and OBRF, and (b) with DI and OBRF.

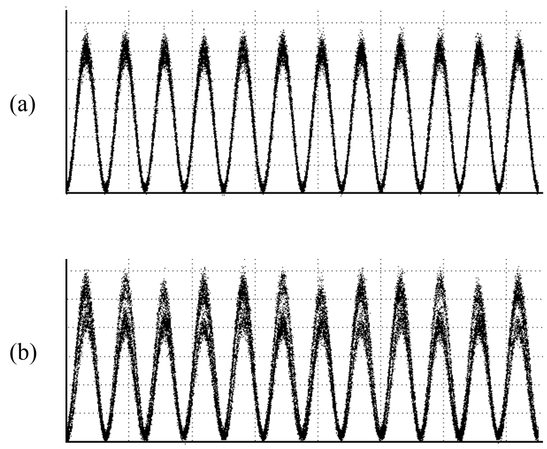

Figure 4: Observed 160 GHz waveforms when (a) balanced operation of the DPMZM was performed, and (b) RF signal was slightly off balanced.