Th4-6

00-7

All-Optical Mm-Wave Photonic Carrier Generation Using Fabry-Perrot Etalon

S.H. Lee, N.M. Kwak, and K. Cho
Department of Physics, Sogang University
1 Sinsoo-Dong, Mapo-Ku, Seoul, 121-742, Korea

W.-Y. Choi
Department of Electrical & Computer Engineering, Yonsei University
134 Shinchon-Dong, Sudaemun-Ku, Seoul, Korea

Tel +82-2-705-8435 ; Fax : +82-2-703-7229 ; Email : kcho@ccs.sogang.ac.kr

Abstract

Two laser sources were frequency locked independently to the corresponding full-width half-maximum frequencies of the characteristic transmission curve of a Fabry-Perrot etalon. Variable frequency mm-wave signal was generated by the use of heterodyne mixing technique. Side modes and mode hopping characteristics in commercial, high-power, narrow linewidth DFB LD's are discussed.

Keywords: frequency stabilization, heterodyne mixing, full-width half-maximum frequency of Fabry-Perrot etalon, mode hopping, high power DFB LD

I. Introduction

Various techniques for generating mm-wave photonic carrier have been discussed by many authors. Heterodyne mixing scheme is one of the commonly used technique in these applications, because harmonic distortions in the carrier are inherently small and any modulation format used in microwave wireless communications (ASK, FSK, PSK, QPSK, MPSK, etc.) can be employed easily [1-6]. In this scheme, wireless communication carrier wave is generated by mixing two, narrow linewidth, frequency stabilized lasers in a wideband photodiode. Depending on the data modulation format, either one of the lasers or both lasers can be amplitude, phase, or frequency modulated. These two beams are sent to an antenna through an optical fiber link and mixed at the high-speed photodiode. Therefore, data carried by the optical carrier could be down converted to the desired intermediate frequency photoelectric signal and used for wireless communications.

Frequency stability of the lasers are very important in the heterodyne scheme. However, absolute frequency stabilization of each laser is not necessary because the wireless communication frequency is given by the frequency difference between the two lasers. Therefore, it is essential to maintain the frequency difference at the constant value. Optical phase-locked-loop (OPLL) technique has been used extensively for locking the relative frequency between the two lasers at the desired value. Although OPLL can provide an excellent frequency stability and it can be integrated into a small size hybrid component [1], this technique has the following drawbacks: 1) It requires high frequency microwave components such as oscillators, mixers, amplifiers, and so forth. 2) It requires very narrow linewidth laser source and/or very short PLL loop length. 3) Manufacturing cost is expensive.

We present here a new all-optical mm-wave photonic carrier generation scheme using two full-width half-maximum (FWHM) frequencies of the Fabry-Perrot (FP) etalon as the references for frequency stabilization. The intermediate frequency between two lasers is given by the FWHM bandwidth of the FP etalon.

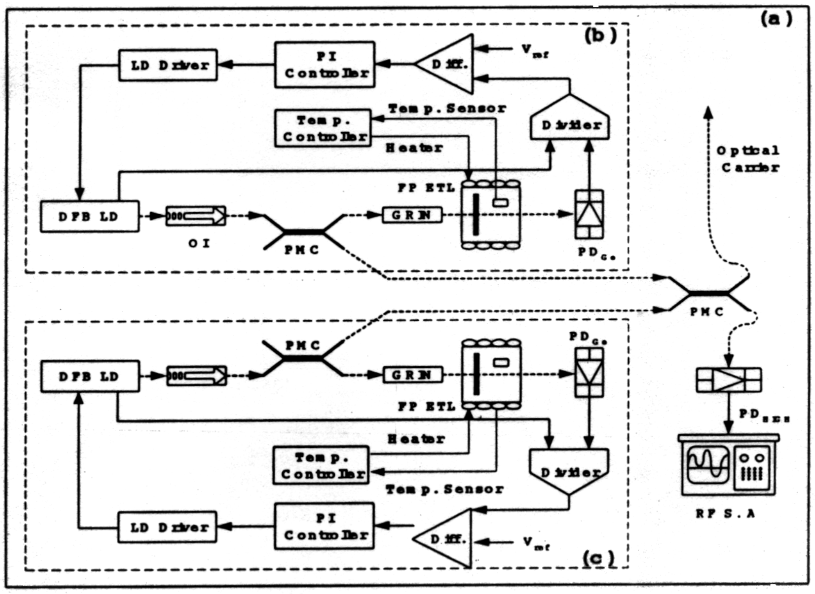

Fig. 1. Experimental arrangement.

II. Experimental Arrangement

Experimental arrangement is shown in Fig. 1. We used commercial, high power, narrow linewidth DFB LD's (Lucent, D2525P34 and 246 PF) for the light sources. Output light from the DFB LD is divided into two fibers by the use of 3dB coupler. One of the beams was sent to the communication system and used for the optical mm-wave carrier, while the other beam was sent to the FP etalon. The beam was collimated and transmitting through the FP etalon. Intensity of the transmitted beam is monitored by a Ge photodiode. The transmission characteristics of the FP etalon used in our experiment are shown in Fig. 2. The free spectral range and FWHM bandwidth of the FP etalon was 337 GHz and 21.7 GHz, respectively. In the vicinity of FWHM frequency, the transmitted beam intensity changes approximately linearly with the lasing frequency change. Intensity change with respect to the corresponding FWHM intensity was used for an error signal for the active feedback control of lasing frequency. One of the two lasers, say the one in the dotted region (b) in Fig. 1, was frequency locked to the lower frequency FWHM point while the other was locked to the higher frequency FWHM point.

FP etalon was placed in the temperature controlled environment. The temperature was maintained at slightly above the room temperature within ±.1 K. Since the coefficient of thermal frequency change in a fused silica etalon is about 7.7×10^{-6} K^{-1}, in principle, we expected better than PPM frequency stability.

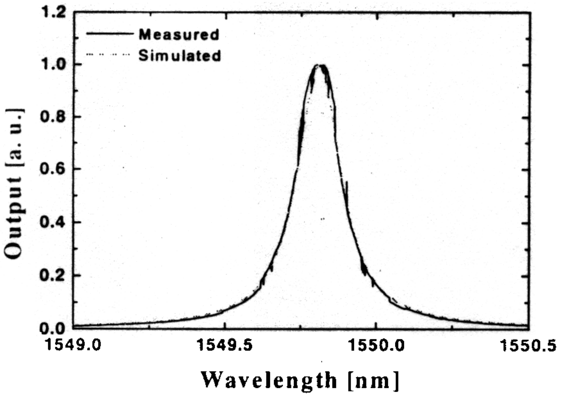

Fig. 2. Transmission characteristics of the FP etalon.

III. Experimental Results and Discussions

The frequency spectrum of the heterodyne beat signal is shown in Fig. 3, which shows that two DFB LD's were frequency locked to the corresponding FWHM frequencies of the FP etalon. At the present momment, however, we were not able to obtain long term stability for mm-wave optical carrier generation. As shown in Fig. 4, DFB LD's lost their locking conditions after 30 minutes running time. We found from the beat measurements between DFB LD and a tunable

LD that there were sidemodes in the high power DFB LD's, whose mode spacing was approximately 40 MHz and the lasing mode was hopping to the neighboring sidemode as the lasing condition varied. We could not explain the reasons why these side modes were presented in the high power DFB LD's. We believe, however, that the sidemodes and mode hopping characteristics are fundamental phenomena originated from the spatial inhomogenity caused by nonlinear optical Kerr effect in the high power DFB LD gain region.

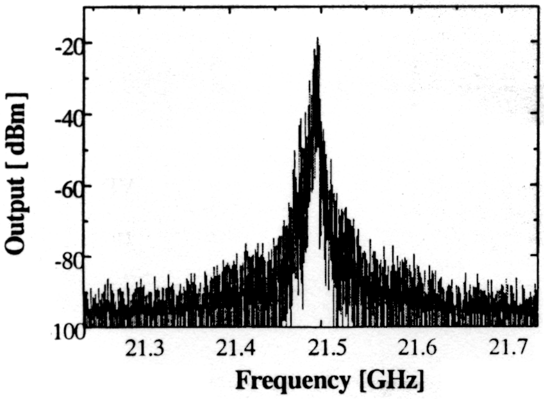

Fig. 3. 21.5 GHz mm-wave carrier generated by heterodyne mixing of two frquency stabilized DFB LD's.

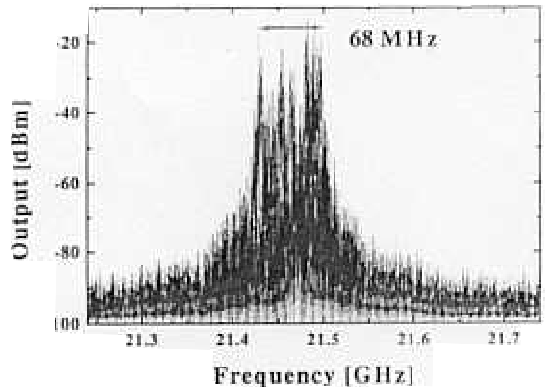

Fig. 4. Heterodyne mixing signal after approximately 30 minutes stabilization period. The DFB LD's lost their locking conditions because of the mode hopping occurred in the laser.

IV. Summary and Conclusions

We have proposed new heterodyne scheme that can be used for generation of mm-wave optical carrier. This technique is truly all-optical, because any microwave or mm-wave components were not used for generating the carrier. Therefore, our all-optical scheme can reduce the manufacturing cost significantly, and we believe that the entire system shown in Fig. 1 can be integrated into a small size component. We also found that commercial, high power DFB LD's are not appropriate light sources for our applications because of side modes and mode hopping characteristics.

References

[1] L.N. Langley, M.D. Elkin, C. Edge, M.J. Wale, U. Gliese, X. Huang, and A.J. Seed, "Optical Phse Locked Loop Module for Use as a 9 GHz Source in Phased Array Communications Antenna," Tech Dig. MWP'98, 141-142 (1998).

[2] U. Gliese, "Coherent Fiber-Optic Links for Transmission and Signal Processing in Microwave and Millimeter-Wave Systems" Conf. Proceed., MWP '98, 211-214 (1998).

[3] U. Gliese, Nielsen TN, Norskov S, Stubkjaer KE, "Multifunctional fiber-optic microwave links based on remote heterodyne detection" IEEE Trans. Microwave Theory Tech., **46**, 458-468 (1998).

[4] R.C. Steele, "Optical phase-locked loop using semiconductor laser diodes", Electron.Lett., **19**, 69-70 (1983).

[5] L. G. Kazovsky, "Balanced phase-locked loops for optical homodyne receivers : performance analysis, design considerations, and laser linewidth requirements," IEEE J. Lightwave Technol., **4**, 182-195 (1986).

[6] U.Gliese, et. al., "A wideband heterodyne optical phase locked loop for generation of 3-18 GHz microwave carriers," IEEE Phot. Tech. Lett., **4**, 936-938 (1992)