DFB 레이저 FWM conjugate Injection-Locking 을 이용한 30 GHz 밀리미터파 생성과 100 Mbps Pulse 전송

30 GHz Optical Millimeter-Wave Generation and 100 Mbps NRZ Pulse Delivery by Injection-Locking FWM Conjugates in DFB Lasers

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Abstract

The 30 GHz optical millimeter-wave (MMW) generation and 100 Mbit/s NRZ pulse delivery are demonstrated. The pure and stable MMW signals can be obtained by injection-locking the FWM conjugate modes in a DFB laser under the external light injection. Using the produced millimeter-waves, the 100 Mbit/s NRZ pulses are delivered over the fiber-optic link.

The optical generation and fiber-optic transmission of MMW signals have been attracting much interest in many applications, such as broadband mobile communication, intelligent transport system, and wireless indoor LAN. In the mobile communication, particularly, the optical MMW signal generation and transmission in the control station (CS) has several advantages. The system implementation cost can be reduced since MMWs are remotely generated and each base station (BS) does not need the millimeter-wave components. The compact BSs can be expected when the complex electrical signal processing units are centralized in CS.

One of the optical MMW generation techniques is the optical sideband injection-locking. It is a promising technique because of its capability of generating pure and high frequency signals with low phase noise and good stability. To obtain these signals, the frequency modulation (FM) sideband injection-locking scheme has been demonstrated [1]. It is necessary for the master laser (ML) to be electrically modulated to produce many FM sidebands. Two slave lasers (SLs) have two target FM sidebands selected and beat each other in the photodiode (PD) to generate the microwave signals. The achievable beat frequency is, however, limited to within the several tens of GHz owing to the ML modulation frequency response.

As another technique for the optical MMW signals, the four-wave mixing in a DFB laser can be used. When the ML lasing frequency is set sufficiently higher than the SL lasing wavelength outside the locking region, the non-degenerate four-wave mixing (NDFWM) occurs [2, 3]. The beat signal is observed due to the SL cavity photon density oscillation at a frequency roughly same as the lasing frequency difference between ML and SL. The high frequency beat signals can be easily generated by the control of the laisng frequencies. These signals, however, are not stable and have poor phase noise characteristics [3]. In order for these signals to be of any use, the NDFWM beat signals should be stabilized.

In this paper, we propose a novel FWM beat signal stabilization scheme for the low phase-noise by using the FM sidebands of ML and SL under the electrical rf-modulation. We also demonstrate the NRZ pulse delivery at the MMW bands over the fiber-optic link.

Fig.1 shows the fiber-optic experimental setup. The FWM beat signal is set at around 14 GHz as shown in Fig. 2. When we rf-modulate both ML and SL electrically, the ML FM sideband is injected into the SL cavity and makes the SL FM sideband partially overlapped. The overlapping and overlapped sidebands will get coupled and behave like MLs and SL, respectively. When the locking condition is met, the SL FM sidebands are locked to ML FM sidebands as shown in Fig. 3. Consequently, beat signals at much higher frequencies are observed. In our experimental setup, the highest beat signal observed was 45 GHz, which was limited by the PD used. The generated beat signal is very stable and has the low phase-noise of −81 dBc/Hz at 100 kHz from 30 GHz.

The 100 Mbit/s NRZ pulse is delivered at the MMW band over the fiber-optic link. The NRZ pulse (100 Mbit/s) combined with the rf-signal (3 GHz) modulates SL electrically and is detected in PD. Fig. 4 shows the rf-spectra of the photo-detected and amplified SL power before and after 30 GHz down-conversion. The electrical filters are not yet employed in the experiment, here. The 30 GHz down-converted and detected pulse in the oscilloscope is shown in Fig. 5. It clearly shows that the digital signals at the MMW bands can be delivered through the fiber-optic link.

In summary, we demonstrated the fiber-optic experiment on the FWM beat signal stabilization in a new master-slave configuration, using the FM sidebands of the directly modulated master and slave laser. Since the produced MMW signal frequency is determined by the conjugate mode separation, which can be very large, we believe that this is quite useful for producing very high-frequency optical MMW signals. It is also found that the 100 Mbit/s NRZ pulses at 30 GHz can be transmitted with little difficulties. Moreover, the injection-locked FWM beat signals are very stable with low phase noise, unlike the unlocked ones having the frequency fluctuation and broad line-width.

References

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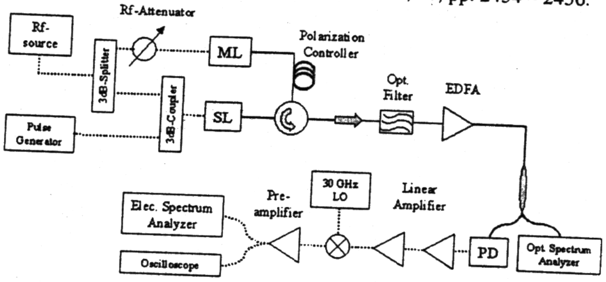

Fig. 1 Experimental Setup

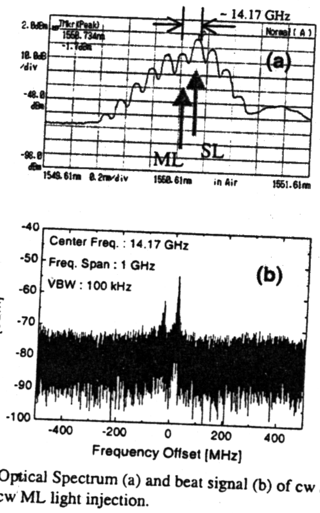

Fig. 2 Optical Spectrum (a) and beat signal (b) of cw SL under cw ML light injection.

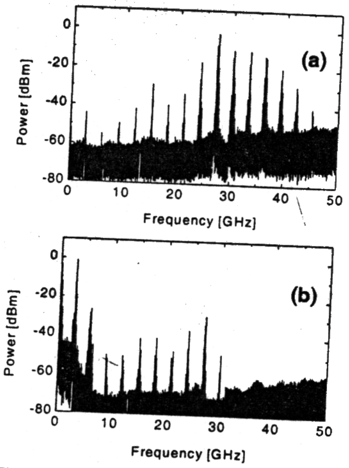

Fig. 4 Rf-spectrum of the sideband injection-locked SL (a) before and (b) after 30 GHz down-conversion, when the 100 Mbit/s pulses are employed.

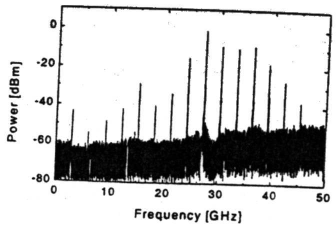

Fig. 3 Rf-spectrum of the photo-detected and amplified SL power, once the SL FM sidebands are injection-locked to ML FM sidebands.

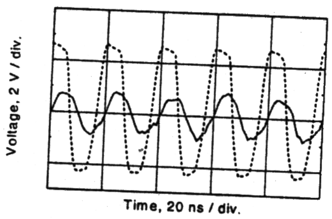

Fig. 5 The measured NRZ pulse patterns. The dotted line is the applied electrical NRZ pattern, and the solid line the down-converted pulse pattern at 30 GHz MMW band.