A New Method for Microwave Generation and Data Transmission Using DFB Laser Based on Fiber Bragg Gratings

J. S. Leng, Y. C. Lai, W. Zhang, and J. A. R. Williams

***Abstract*—A novel architecture for microwave/millimeter-wave signal generation and data modulation using a fiber-grating-based distributed feedback laser has been proposed in this letter. For demonstration, a 155.52-Mb/s data stream on a 16.9-GHz subcarrier has been transmitted and recovered successfully. It has been proved that this technology would be of benefit to future microwave data transmission systems.**

***Index Terms*—Data transmission, microwave generation, optical fiber lasers.**

I. Introduction

THE OPTICAL generation of microwave/millimeter-wave subcarrier signals is of interest for many microwave-photonic systems with applications ranging from broadband wireless access networks (which is commercial reality now) to emerging potential applications in phased-array antennas, electronic warfare, and radio astronomy [1], [2]. A number of techniques for the generation of millimeter-wave modulated optical carriers for downstream data transmission in radio-on-fiber systems have been reported and demonstrated. These include the use of optical heterodyne, self-heterodyne, resonantly enhanced semiconductor lasers, and pulsed lasers [3]. Currently, an effective technique is the optical heterodyne, in which two lasers whose frequencies differ with the required microwave frequency are used and mixed at a photodetector to produce an electrical beat signal. In a particular fiber-radio application, this technique has obvious advantages in that it reduces base station hardware complexity and overcomes limitations in transmission imposed by fiber chromatic dispersion.

The major difficulty of this technique is achieving sufficient phase coherence between the two laser sources to produce a beat frequency with an adequately narrow linewidth. Successful implementations of the technique include using an external RF source for frequency locking [4], injection locking [5], and the optical phase-locked loop [6]. Previously, we have reported optical generation of very narrow linewidth (<1 kHz at 32.5 GHz) microwave carrier using a two-wavelength fiber-based distributed feedback (DFB) laser [7].

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In this letter, we exploit the orthogonal polarization of the two-wavelength components from DFB laser source to enable modulation of data on the microwave subcarrier (which is typically difficult to do with a two-wavelength source) and demonstrate the modulation and demodulation of a 155.52-Mb/s data stream at a generated microwave subcarrier frequency of 16.9 GHz.

II. Carrier Generation Using a Fiber-Bragg-Grating-Based DFB Laser

The fiber laser consists of two collocated phase-shifted gratings fabricated on an Er–Yb-doped fiber using UV inscription [7]. A second grating structure consisting of a pair of collocated uniform gratings inscribed on high-birefringence (Hi-Bi) fiber external to the laser cavity is used to provide polarization discriminating self-injection feedback. The experimental arrangement of a DFB fiber laser is shown in Fig. 1. The millimeter-wave signal can be generated with desired frequency range up to 3 THz by such fiber laser. As an example, a DFB laser with 16.9-GHz microwave generation has been fabricated in this letter. Fig. 2 shows the generated millimeter-wave beat signal electrical spectrum of the fiber laser, which has an optical mode spacing of 0.135 nm. A microwave signal frequency of 16.9 GHz, with a linewidth of <1 KHz (limited by the instrumentation used) has been reliably and stably achieved.

III. Data Modulation and Demodulation

Fig. 3 illustrates how the setup used to test the data modulation and demodulation of the generated subcarrier. The DFB fiber laser in Fig. 3 is made by using fiber gratings on a Er–Yb-doped fiber [7]. It is not a traditional semiconductor DFB laser. The optical signal from DFB laser is first split to two branches by a 3-dB coupler. One of them then passes a polarization beam splitter (PBS) to get two perpendicular polarization beams. A 2.5-GHz phase modulator from Sumitomo Osaka Cement Co. LTD is placed to modulate one polarization beam. One of the two perpendicular modes is phase-modulated using the data pattern from a pattern generator. Then the two perpendicular polarization beams are combined together through the polarization beam combiner (PBC).

At the receiver, the optical signal is polarized along an axis between the two transmitted states and then detected by a photodiode (PD) generating a phase-shift-keyed microwave signal. In our demonstration experiment, this has been electronically mixed with a microwave carrier down-converted directly from the fiber DFB laser to detect the modulated data pattern.

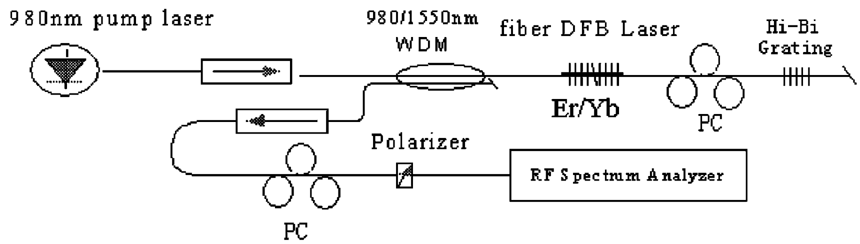

Fig. 1. Experimental arrangement of DFB fiber laser including Hi-Bi Bragg gratings.

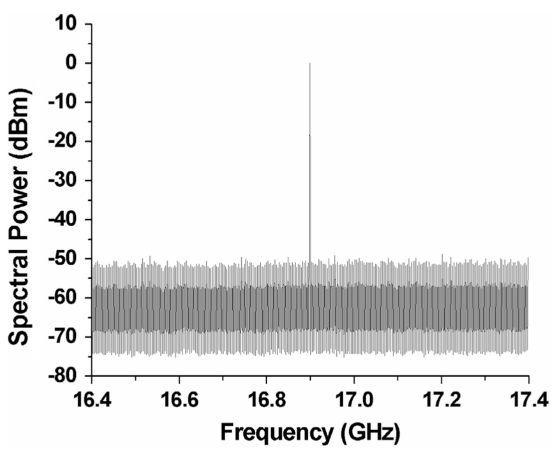

Fig. 2. Millimeter-wave beat signal.

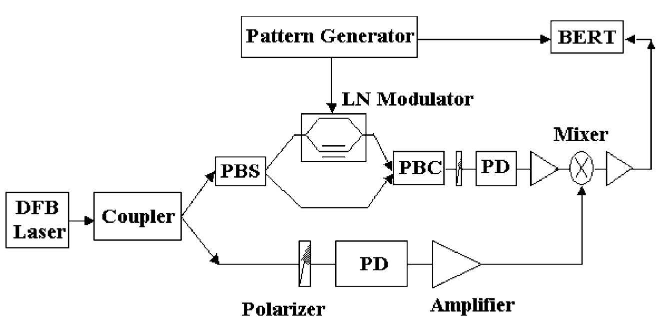

Fig. 3. Illustration of demodulation experiment.

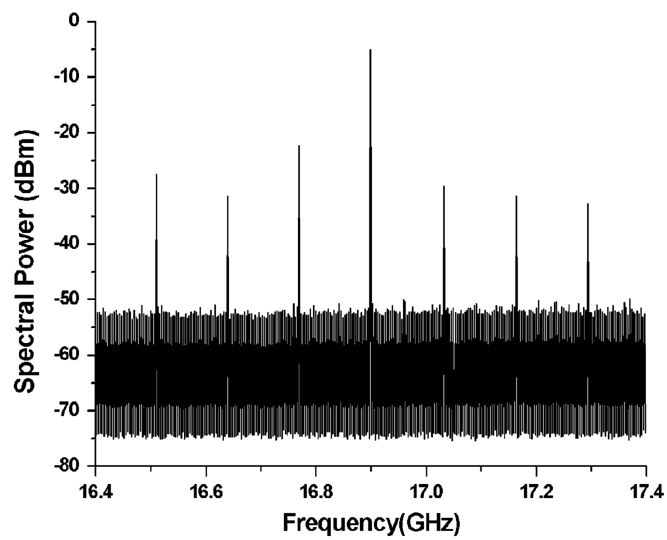

Fig. 4. Modulated millimeter-wave signal.

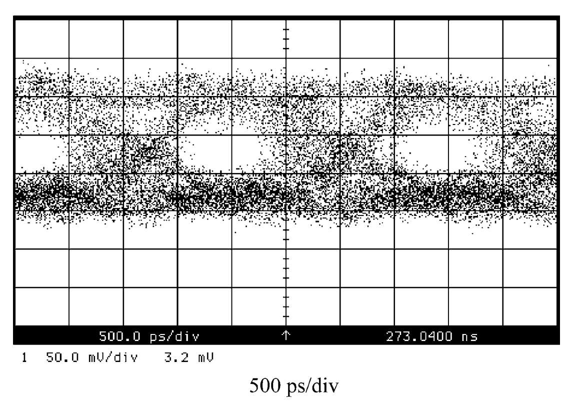

Fig. 5. Eye diagram of recovered signal.

For demonstration, a 500-MHz square-wave (00001111, 8-bit) is generated by an ANRITSU pattern generator and has been used to validate this data transmission system. The modulated microwave signal with 16.9-GHz microwave carrier and 500-MHz square-wave is shown in Fig. 4. It can be found clearly that the 500-MHz signal has been modulated successfully.

An eye diagram of recovered signal is shown in Fig. 5 to prove the demodulation capability of this novel technology. The Q-factor is around four, which is equivalent to a bit-error rate of 10^{-5} assuming Gaussian noise. This is limited due to the low optical power produced by the laser and the noise resulting from the subsequent large amount of RF amplification required at the receiver. In this letter, the power of DFB fiber laser is about 1 mW. Higher optical output should be achievable from the DFB laser by increasing the length of the Er–Yb gain medium in the cavity, and this would result in improved noise performance.

IV. Conclusion

A novel architecture for microwave/millimeter-wave signal generation and modulation using a fiber-grating-based dual-wavelength orthogonal polarization DFB laser has been demonstrated. Eye-diagram measurements show the successful transmission and demodulation of a 155.52-Mb/s data stream on an experimental 16.9-GHz microwave subcarrier. Therefore, this technology would be a benefit to the future microwave data transmission system with a high-frequency microwave subcarrier.

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