A 10 Gb/s OPTICAL HETERODYNE DETECTION EXPERIMENT USING A 23GHz BANDWIDTH BALANCED RECEIVER

Noboru Takachio, Katsushi Iwashita, Susumu Hata, Kohsuke Katsura,
Kiyomitsu Onodera, and Hiroyuki Kikuchi

NTT Laboratories
1-2356, Take, Yokosuka, Kanagawa, 238-03, Japan

ABSTRACT

A 0.5-30GHz GaAs MESFET monolithic distributed amplifier using coplanar waveguides and an wideband InGaAs twin pin photodiode are fabricated. A wideband balanced optical receiver is fabricated by connecting these devices using the solder bump flip-chip technique to reduce parasitic inductance and capacitance. A 10 Gb/s optical CPFSK heterodyne detection experiment is conducted using the receiver.

INTRODUCTION

Recently, the bit rate in optical heterodyne detection has increased and a bit rate of 8 Gb/s can be now achieved using discrete pin photodiodes and an amplifier[1]. However, it is difficult to realize a wideband optical heterodyne receiver because the IF center frequency and IF bandwidth must be about twice the bit rate.

For fabricating a wideband optical heterodyne receiver, a wideband preamplifier and a wideband twin pin photodiode are needed. Although, a distributed amplifier has a wide frequency bandwidth over 30GHz, the performance of a wideband optical receiver is strongly affected by stray capacitance and inductance effect at high frequencies region. Flip-chip interconnection techniques can be used to reduce these parasitic effect.

In this paper, flip-chip interconnection technique using solder bumps[2] is applied to the connection between a wideband monolithic distributed amplifier and a twin pin photodiode. The optical receiver has a 23 GHz frequency bandwidth and a 10 Gb/s optical CPFSK heterodyne detection experiment was conducted using the receiver. This receiver shows the possibility of future high-speed optical heterodyne transmission systems.

PREAMPLIFIER

The circuit configuration of the new optical receiver is shown in Fig.1. The distributed amplifier was fabricated using four WSiN gate self-aligned GaAs MESFETs with a gate width and gate length of 75 μm and 0.3 μm, respectively[3]. The FET gate width used realizes a cut off frequency over 25GHz. Their f_T and f_{max} are 43 GHz and 103 GHz, respectively. The transconductance is 37 mS for all MESFETs.

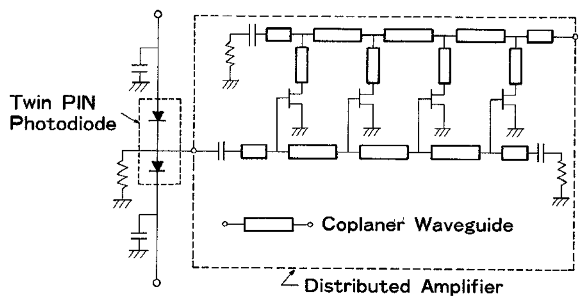


Fig.1 Circuit configuration of the fabricated optical receiver.

Coplanar waveguides were used as the transmission lines. Considering the MMIC fabrication process, coplanar waveguides are more advantageous than microstrip lines[4]. This is because via holes are not needed and the fabrication process can be simplified.

Circuit simulations were performed on TOUCHSTONE. The impedance of the coplanar waveguides was identical(76.5Ω). The input/output lines of the distributed amplifier were designed as constant-K low pass filters. The Cgs value used in the circuit design is 0.1pF. The circuit parameters were optimized to realize a 30GHz frequency bandwidth and flat gain over 7dB. The designed and measured frequency characteristics are shown in Fig.2. Measurement were made using an on-wafer RF test station. The measured gain and 3dB frequency bandwidth were 7.3 dB and 0.5-30 GHz, respectively.

CH2848-0/90/0000-0149$01.00 © 1990 IEEE

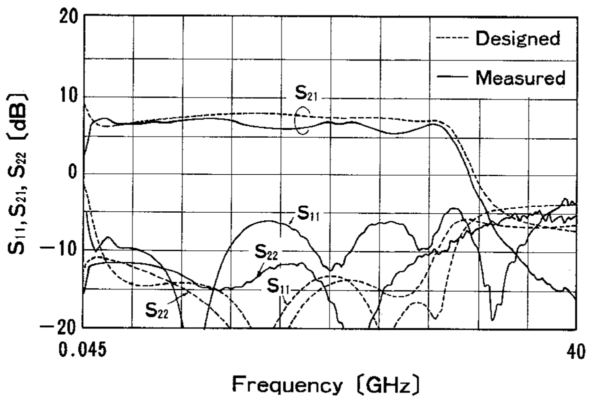


Fig.2 Distributed amplifier frequency characteristics.

OPTICAL RECEIVER

A balanced optical receiver(BOR) can suppress the local oscillator(LO) intensity noise under optical heterodyne detection. Moreover, it can make efficient use of LO power and achieve good sensitivity, i.e. close to the shot noise limit.

An InGaAs twin pin photodiode was used in the optical receiver. The receiver diameter of the pin-PD is 20 μm and its quantum efficiency is 38%. The measured capacitance of each photodiode is 60 fF. The frequency bandwidth calculated from the parameters is 27 GHz.

The preamplifier used for the optical receiver was developed by integrating the pattern for biasing the twin pin-PD and connecting it to the distributed amplifier. The preamplifier was co-located on the same wafer with the distributed amplifier shown in Fig.1. In case of a MMIC using coplanar waveguides, a ground plane is made on the top substrate surface. Therefore, the bias capacitances for photodiodes can be formed in the preamplifier IC chip and parasitic inductance can be reduced.

When bonding wire is used for the connection between the pin-PD and the preamplifier, the frequency response is degraded due to the wires' inductance. The frequency response dependence on wire length is shown in Fig.3. The wire diameters are 25μm. When the flip-chip interconnection technique is used, the simulated response is shown by a solid line. The 3dB frequency bandwidth is degraded from 12GHz to 7.7GHz by a 500μm long bonding wire.

The optical receiver shown in Fig.1 was fabricated by bonding the twin pin-PD on the preamplifier using the solder bump technique. A photograph of the fabricated BOR is shown in Fig.4. Its chip size is 2mm×4mm. The simulated frequency response is shown by a dotted line in Fig.5. The frequency response measured by the optical heterodyne method is shown by a solid line in Fig.5. Its frequency bandwidth is 23 GHz. Dips in the frequency response were due to the optical receiver packaging.

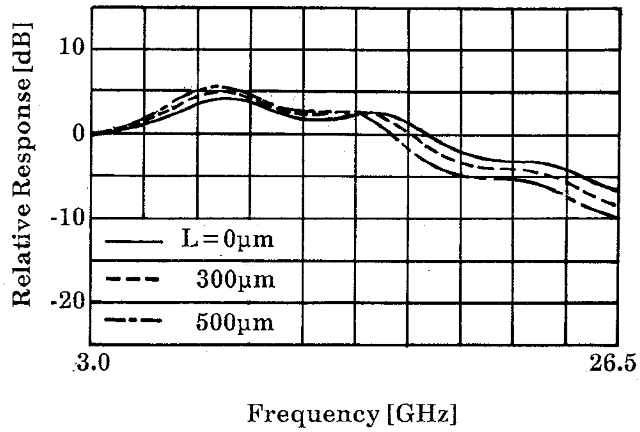


Fig.3 Frequency response dependence on bonding wire length between twin pin-PD and preamplifier.

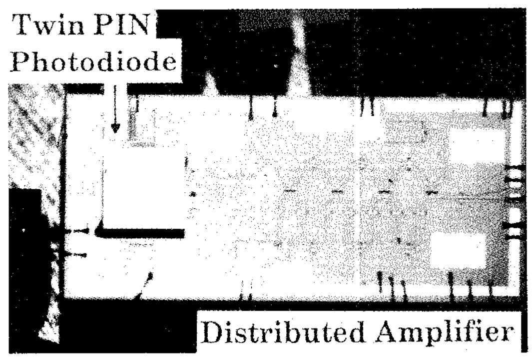


Fig.4 Double balanced optical receiver.

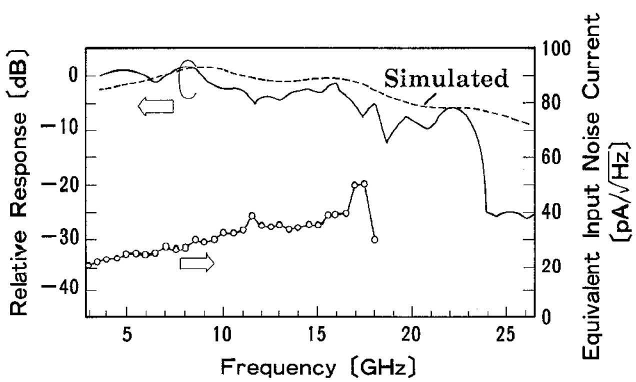


Fig.5 Frequency response and noise characteristics of fabricated optical receiver.

The measured minimum input noise current was 19.4 pA/√Hz at 2GHz. This value is due to the gate and drain line termination resistance. At frequencies over 10GHz, the noise current is increased by the photodiode capacitance, front-end stray capacitance and noise from transistor devices.

OPTICAL HETERODYNE DETECTION EXPERIMENT

A 10 Gb/s optical CPFSK heterodyne detection experiment was conducted using the fabricated BOR. The experimental set up is shown in Fig.6. A multi-electrode 1.55 µm DFB-LD was directly modulated with a 10 Gb/s NRZ signal. The 10 Gb/s modulation signal was multiplexed with a 5 Gb/s RZ fixed pattern having a delay of several bits. The LD frequency modulation bandwidth was 12GHz and modulation index was 0.52.

The modulation signal was combined with a local oscillator light and the combined signals were detected with the BOR. The IF center frequency was 13 GHz. The IF signal was demodulated by a differential detector .

The demodulated eye pattern is shown in Fig.7. 10Gb/s is the highest bit rate in optical CPFSK heterodyne detection to our knowledge. The eye degradation is caused by the frequency bandwidth limitation of the mixer used in this experiment and the optical receiver frequency response. A wideband mixer and the improvement of the optical receiver packaging technique are needed.

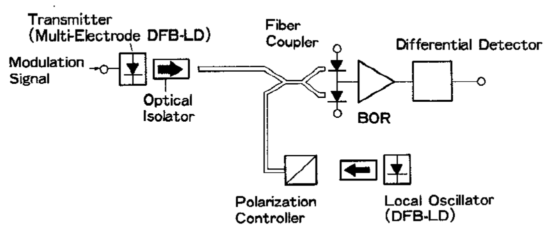
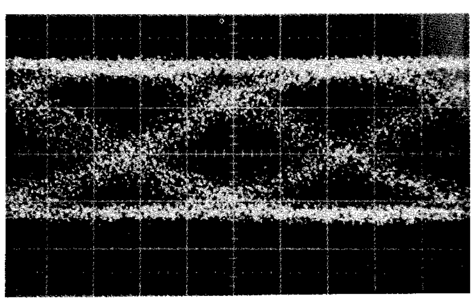


Fig.6 Experimental set up for 10 Gb/s optical CPFSK heterodyne detection experiment.



20ps/div

Fig.7 10Gb/s optical CPFSK demodulated eye pattern.

CONCLUSION

A wideband balanced optical receiver with a 23 GHz frequency bandwidth was fabricated with a wideband twin pin photodiode and a distributed amplifier using coplanar waveguides. The photodiode and amplifier were successfully bonded using a solder bump technique. A 10 Gb/s optical CPFSK heterodyne detection experiment was demonstrated using the receiver.

ACKNOWLEDGEMENT

We wish to thank Kiyoshi Nosu for his guidance and encouragement. We also thank Kazuyuki Yamamoto, Kazuo Kiuchi, Tadakatsu Kimura, Zyun-ichi Yoshida and Takaaki Ohsaki for their encouragement. We thank Fumikazu Ohira for his advice on fabricating optical receivers.

REFERENCE

(1)N. Takachio and K. Iwashita, "Chromatic dispersion equalization in an 8Gbit/s 202km optical CPFSK transmission experiment," IOOC'90, postdeadline pap. 31.

(2)K.Katsura et al., "A novel interconnection technique using solder bumps for high-speed photodetectors," OFC'90, WM-21.

(3)K.Onodera et al., "A 630-mS/mm GaAs MESFET with Au/WSiN refractory metal gate," IEEE Electron Device Lett. vol.9,No.8, pp.417-418,1988

(4)M.Riaziat et al., "Coplanar waveguides used in 2-18GHz distributed amplifier," IEEE MTT-S International Microwave Symposium Digest, June, 1986.