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WA8

**CMOS Optical Receiver with Integrated InGaAs Thin-Film Inverted MSM Detector
Operating up to 250 Mbps**

Myunghee Lee, Olivier Vendier, Martin A. Brooke, Nan Marie Jokerst,
and Richard P. Leavitt*

School of Electrical and Computer Engineering
Microelectronics Research Center
Georgia Institute of Technology
Atlanta, GA 30332

* Army Research Laboratories
AMSRL-EP-EE
2800 Powder Mill Road
Adelphi, MD 20783-1197

Standard digital CMOS receivers are desirable for their low-cost and low-power dissipation. In addition, tele-communication applications require long-wavelength ($1.3\ \mu\text{m}$ / $1.55\ \mu\text{m}$) optoelectronic devices, which is possible only with compound materials. Because of material mismatch, implementing a monolithic optical receiver requires exotic process technologies [1] or hybrid integration. Digital CMOS amplifiers with external photodetectors have been reported [2,3]. We have previously demonstrated an optical receiver in which GaAs photodetectors are integrated onto standard digital CMOS amplifiers [4-7] by using a thin-film epilayer device separation and bonding technology [6]. We now report that an amplifier has been fabricated in a $0.6\ \mu\text{m}$ digital CMOS foundry, and integrated with an InGaAs inverted Metal-Semiconductor-Metal (I-MSM) photodetector sensitive to $1.3\ \mu\text{m}/1.5\ \mu\text{m}$ light, and characterized up to 250 Mbps.

Fig. 1 shows a single-stage amplifier circuit. The overall amplifier consists of 5 identical stages and is fabricated through a $0.6\ \mu\text{m}$ standard digital CMOS process through MOSIS foundry. Each stage has a current gain of 3. The total transimpedance gain is about $12\ \text{K}\Omega$ with a $50\ \Omega$ load. To get a wide bandwidth, a multi-stage, low-gain-per-stage configuration is employed. Detailed operation of circuit in Fig. 1 has been reported [5,6]. To achieve stability, an open-loop approach over feedback-type is selected since an open-loop usually provides stability. Another important feature is the current-mode design. It gives wide-bandwidth capability due to low impedance nodes on the signal path. In addition, a diode-connected transistor at the front of an optical receiver replaces a bias resistor and minimizes parasitics.

A metal-semiconductor-metal (MSM) photodetector was selected since low capacitance per unit area is of vital importance in the design of high speed, low power and alignment tolerant optical receivers. The I-MSM detector, with the electrodes defined on the bottom of the device, overcomes the low responsivity problem of conventional MSM detectors with fingers on the top by eliminating the shadowing effect of the electrodes. The I-MSMs demonstrated up to $0.7\ \text{A/W}$ responsivity and the leakage current is less than $10\ \text{nA}$ at $10\ \text{V}$ bias [7]. The bandwidth is up to $6\ \text{GHz}$. Because the I-MSM photodetector is fabricated separately, it is not compromised by CMOS process constraints. The detector structure has $3\ \mu\text{m}$ metal finger width with $3\ \mu\text{m}$ spacing between fingers. The detector size is $50\ \mu\text{m} \times 50\ \mu\text{m}$, resulting in $70\ \text{fF}$ of capacitance. The detector is integrated onto the CMOS amplifier by using a thin-film epilayer device separation and bonding technology [6].

Fig. 2 shows a microphotograph of the completed receiver front-end after integration of the I-MSM photodetector. Two small pads at left side of the figure have overglass cuts for integration of the thin film detector in post processing.

The eye diagrams and pulse waveform at 250 Mbps has been measured for 2^7-1 NRZ pseudorandom bit stream (PRBS) and are shown in Fig. 3. ± 2.5 V power supplies are used for the amplifier. Total power dissipation is less than 20 mW. However, more than half of the power consumption is used for the offset control. Therefore, the 5-stage amplifier itself dissipates less than 10 mW and its size is about $150\text{ }\mu\text{m} \times 50\text{ }\mu\text{m}$. $50\text{ }\Omega$ output impedance is used to measure the data in Fig. 3.

In conclusion, a quasi-monolithic digital CMOS amplifier integrated with $1.3\text{ }\mu\text{m}$ wavelength, InGaAs I-MSM is reported. The power dissipation is less than 20 mW. The sensitivity for 10^{-10} BER measured at 2^7-1 , 155 Mbps PRBS is about $8\text{ }\mu\text{A}$. To our knowledge, we have demonstrated a quasi-monolithic digital CMOS amplifier with $1.3\text{ }\mu\text{m}$ photodetector for the first time. This integration shows the possibility to make low-cost, low-power, and small-size digital CMOS amplifiers for tele-communication applications such as SONET and FDDI.

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References

- [1] C. G. Fonstad, Jr. and K. V. Shenoy, "Application specific OEICs fabricated using GaAs IC foundry services," *Tech. Dig. IEEE/LEOS '94 Sum. Top.*, pp. 25-26, July 1994.
- [2] D. M. Pietruszynski, J. M. Steininger, and E. J. Swanson, "A 50-Mbit/s CMOS monolithic optical receiver," *IEEE J. Solid-State Circuits*, vol. SC-23, pp. 1426-1433, Dec. 1988.
- [3] M. Ingels, G. V. der Plas, J. Crols, and M. Steyaert, "A CMOS $18\text{ THz}\Omega$ 240 Mb/s transimpedance amplifier and 155 Mb/s LED-driver for low cost optical fiber links," *IEEE J. Solid-State Circuits*, vol. SC-29, pp. 1552-1559, Dec. 1994.
- [4] M. Lee, C. Camperi-Ginestat, M. A. Brooke, and N. M. Jokerst, "Silicon CMOS optical receiver circuit with integrated compound semiconductor thin-film P-i-N detector," *Tech. Dig. IEEE/LEOS '94 Sum. Top.*, pp. 58-59, July 1994.
- [5] M. Lee, O. Vendier, M. A. Brooke, and N. M. Jokerst, "CMOS optical receiver with integrated compound semiconductor thin-film inverted MSM detector Operating at 155Mbps," *Tech. Dig. LEOS '95*, October 1995.
- [6] N. M. Jokerst, M. A. Brooke, O. Vendier, S. T. Wilkinson, S. M. Fike, M. Lee, E. Twyford, J. Cross, B. Buchanan, and D. S. Wills, "Thin-film multmaterial optoelectronic integrated circuits," *IEEE Trans. Comp., Pack., Manufac. Technol. Part B*, vol. 19, no. 1, pp.97-106, Feb. 1996.
- [7] Olivier Vendier, Nan Marie Jokerst, Richard P. Leavitt, "High efficiency inverted MSM photodetector", *Technical Digest CLEO '95*, vol 15, pp. 177-178, May 1995.

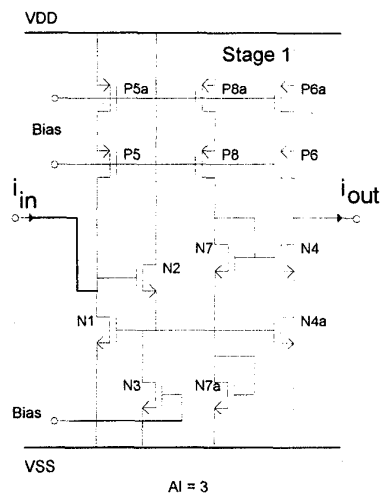


Figure 1. A single-stage circuit diagram of the standard digital CMOS amplifier.

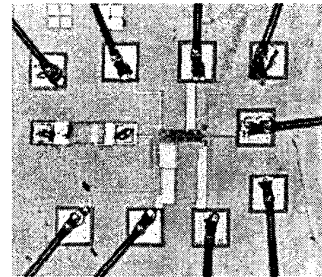


Figure 2. The microphotograph of the integrated amplifier.

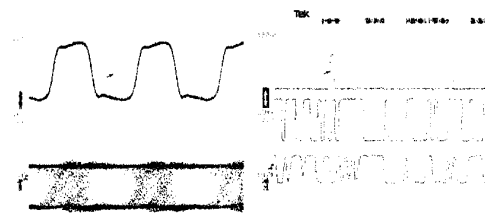


Figure 3. The eye diagram and pulse waveform of the integrated optical receiver at 250 Mbps.