An Integrated 155 Mbps Digital Transmitter Using a 1.3μm Wavelength Thin Film LED

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As the interconnectivity of silicon becomes limited due to the high density of in-plane electrical interconnections, vertical parallel interconnections become attractive alternatives. Vertical optical interconnections between circuits can be achieved using either a hollow via,[1,2] or by using light of wavelengths to which silicon is transparent ($\lambda \geq 1.1\mu m$).[3] InGaAs emitters at wavelengths of 1.12μm have been grown directly on silicon wafers, but these emitters had short lifetimes and low efficiencies.[4] Alternately, InP-based lasers have been flip-chip bonded to silicon wafers, but emission was limited to the plane of integration, which does not lend itself easily to vertical communication.[5] Thin film based surface emitters, grown on InP, have been bonded directly to silicon wafers[3] and to silicon circuits[6], but demonstrated very limited speed operation (1kHz). This paper reports, for the first time, InP-based thin film surface emitters bonded directly to digital silicon CMOS circuits operating at 155Mbps with digital I/O for application in a three dimensional, through-silicon, communication system.

The digital CMOS driver circuitry consisted of a 2-stage tapered buffer, a current switch, and a constant bias current source. The current switch was used before the power transistor stage to avoid voltage spikes. The output stage included a current source to DC bias the LED for increased speed. Careful layout design of the power transistors was performed to minimize any series resistance and to improve the current carrying capability.

The emitter integrated onto this circuit was grown by MBE and consisted of a highly doped thin quaternary active region of InGaAlAs to facilitate high speed, low current density operation. Growth took place on an n-type <100> InP substrate and consisted of an InGaAs stop etch layer (1000Å, $n=2*10^{18}$ cm^{-3}), followed by InAlAs (1.9μm, $n=2*10^{18}$ cm^{-3})/InGaAlAs (0.45μm, $p+=1.2*10^{19}$ cm^{-3})/InAlAs (0.98μm, $p=3*10^{18}$ cm^{-3})/InGaAs (100Å, $p=1*10^{19}$ cm^{-3}).

Fabrication of the thin film LEDs was accomplished by selective mesa and substrate etching, followed by adhesion to a Mylar transfer diaphragm.[7] The thin film device was then bonded to a TiAu contact pad on the emitter driver circuit. The emitter was isolated using DuPont polyimide 2611, and contacted using a AuGe top contact. Individual LEDs were probed at this point to verify operation. Finally, a self aligned RIE plasma etch was used to remove the polyimide and expose the circuit pads for bonding.

The integrated circuit was packaged into a high speed flat pack and was tested in a noise free enclosure. A digital input was fed to the circuit from a Tektronix CSA907T pattern generator. Emitted light was collected using a dual lens collimation/collection system and was detected using a high sensitivity receiver (New Focus 1811). Pseudorandom input data at 155Mbps (2^{15}-1 NRZ), and output data from the New Focus receiver can be seen in Figure 1.

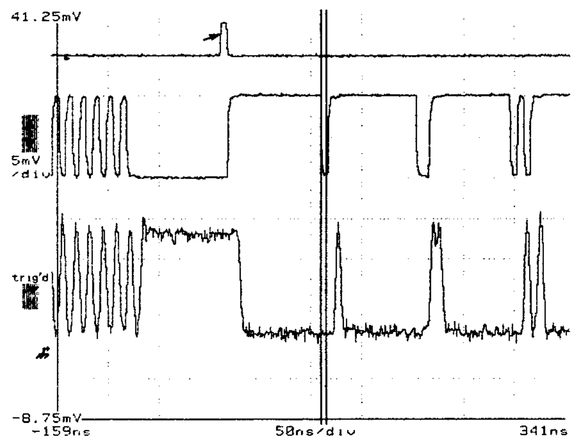

Figure 1. From Top to Bottom: Trigger, Input and Output Signals for Tested Integrated Circuit.

In conclusion, a high speed optical transmitter has been fabricated using the hybrid integration of an optoelectronic thin film emitter and silicon CMOS driver circuit. The integrated system functioned with digital-in/optical-out transmission exceeding 155Mbps. This transmitter is the first building block in a high speed, optically connected, three dimensional processing cube. The authors wish to acknowledge funding and support from Army Missile Command and the Manufacturing Research Center at Georgia Tech.

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