An 8x8 Array of Resonant Cavity Enhanced Light Emitting Diodes Integrated Onto Silicon Grayscale (32 Level) Driver Circuitry

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Arrays of emitters integrated with driver circuitry are useful in a variety of applications including massively parallel communications and image display. An array of slower channels can pass the same amount of aggregate data as a single fast channel. Since faster optoelectronics devices can be significantly more expensive than slower optoelectronics devices, array integration offers the opportunity for fast aggregate data transfer at low cost. However, the established base for VLSI circuitry is in silicon, which does not efficiently emit light and cannot detect at wavelengths greater than approximately 950 nm. Compound semiconductor systems such as GaAs and InP can be used to fabricate optoelectronic devices than emit and detect well, but are more expensive than silicon circuitry. One solution is to combine the best of both materials systems into a multi-material integrated optoelectronic system. In this paper, we report the integration of an 8x8 array of GaAs-based resonant cavity enhanced light emitting diodes with grayscale silicon drive circuitry.

Grayscale controllability of RCELEDs is desirable to balance individual array elements' output power, as well as for display applications. Toward this end, a driver circuit with an 8x8 array of grayscale controllable drivers was designed. Each cell of the array had five bits of resolution (32 grayscale levels), was matrix addressable, and could be latched into RAM cells to hold a particular output level. The entire addressing and grayscale level control circuitry was underneath each pixel of the array (Figure 1). The circuit was planarized with DuPont PI 2611 polyimide, and metallized vias connected each emitter to the driver circuitry underneath the emitter. An 8x8 array of 100 μm square GaAs P-i-N RCELEDs [1] was separated from the substrate and bonded to the polyimide planarized circuit using epitaxial liftoff (ELO).[2] A thin linking layer of semiconductor was left between the devices to provide rigid registration during the transfer and bonding stages.[3] A fully integrated optoelectronic circuit is shown in Figure 2.

The integrated 8x8 grayscale circuit was initially tested to determine if the circuitry was functioning as expected, independent of the integrated RCELEDs. Once correct operation of the circuit was determined, the pixels were all turned on with all address bits on (maximum grayscale level). The input current to the circuit was slowly raised until emission was observed from all 64 pixels. There was some nonuniformity between pixels, but this discrepancy can be assuaged by varying the grayscale drive current levels of the individual pixels to achieve uniform output. Next, the individual addresses of the pixels were tested by turning off rows and columns in succession. This test was performed to ensure that the RCELEDs were being correctly addressed by the silicon circuitry. Finally, the independent grayscale controllability of the optoelectronic integrated circuit was verified by changing the values in the bit register for each pixel and

observing the change in emission strength. Note that each pixel in the array can be independently set to any of the 32 levels of grayscale emission.

In conclusion, we have demonstrated a fully operational 8x8 array of GaAs RCELEDs integrated directly on top of a silicon grayscale array silicon driver circuit. This integrated optoelectronic circuit allowed 32-level grayscale emission from each individually addressable pixel. A yield of 100% was achieved from the array, with full circuit functionality demonstrated.

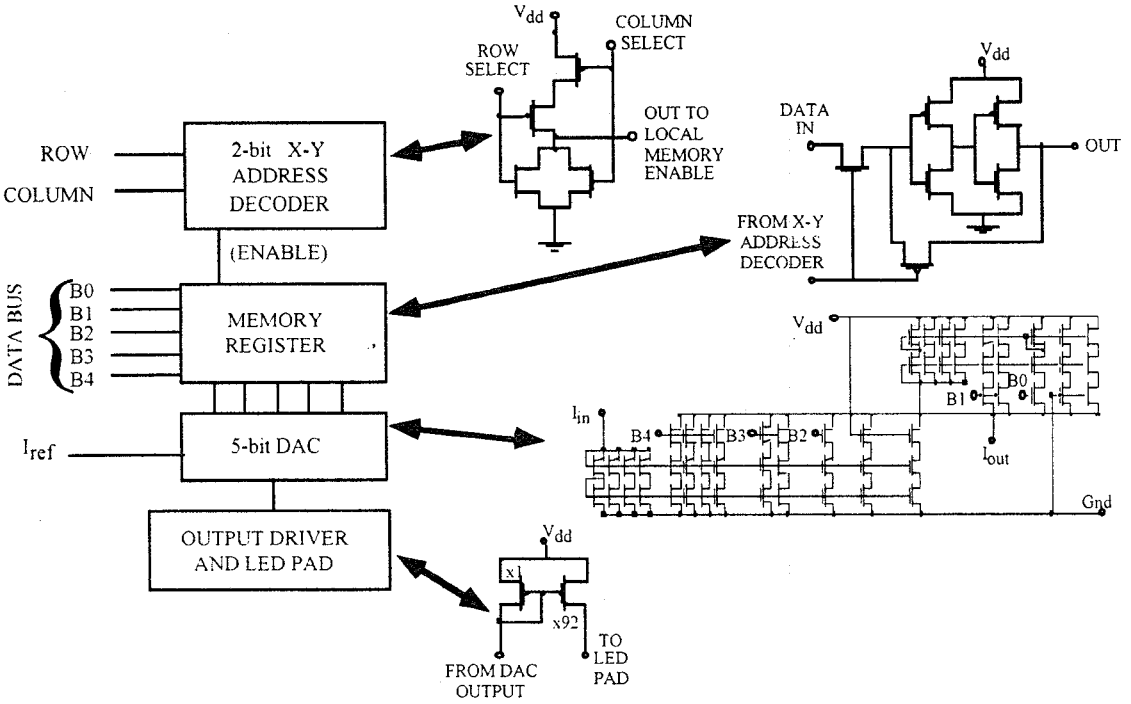

Figure 1 : Block diagram and schematics of the circuitry beneath each pixel of the 8x8 array.

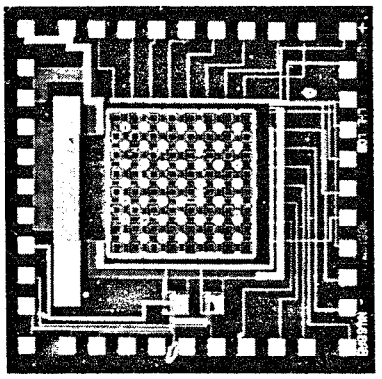

Figure 2 : Grayscale circuit integrated with an 8x8 array of RCELEDs.

1 S. T. Wilkinson, N. M. Jokerst, and R. P. Leavitt "Resonant Cavity Enhanced Thin Film AlGaAs/GaAs/AlGaAs LEDs with Metal Mirrors." *Applied Optics*, vol. 34, no. 3, pp. 8298-8302, 20 December 1995.

2 C. Camperi-Ginestet, M. Hargis, N.M. Jokerst, and M. Allen, "Alignable Epitaxial Liftoff of GaAs Materials with Selective Deposition Using Polyimide Diaphragms," *IEEE Photon. Techn. Lett.*, vol. 3, pp. 1123-1126, 1991.

3 S. M. Fike, B. Buchanan, N. M. Jokerst, M. A. Brooke, T. G. Morris, S. DeWeerth,"8*8 array of thin-film photodetectors vertically electrically interconnected to silicon circuitry," *IEEE Photonics Technology Letters*, vol.7, no.10, p.1168-70, Oct. 1995.