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Towards CMOS integrated Optically Controlled AlN Transducer

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Background, Motivation and Objective:

Previously, we proposed a framework for an ultrafast Sonic Fourier transform (SFT) physical computer leveraging the property that the Fourier transform of an image is its far-field pattern. To represent different input images requires actuating a 2D array of transducers with controllable magnitude and phase. In this work, we demonstrate a CMOS-based optically-controlled excitation approach for AlN transducers. This approach provides an optical pixel based amplitude modulation of electrically generated ultrasonic waves, providing a direct interface between an optical camera-like imager and ultrasonic waves. The monolithic integration of this CMOS-based control circuitry and the AlN transducer array would enable the proposed SFT to instantly respond to the light from the environment or from an image mask, achieving real-time image recognition in the Fourier domain.

Statement of Contribution/Methods:

Custom designed CMOS circuits, including a photodiode, transimpedance amplifier (TIA), and variable gain amplifier (VGA) were implemented (Fig 1a&b.). A 15 mW HeNe laser beam is focused on the photodiode through a polarizer and a lens (F=35.0 mm), producing a DC current with amplitude proportional to the incident power. Then, a TIA converts the DC current into a DC voltage which is used as the control voltage of the VGA. The VGA outputs a RF signal with controllable amplitude, which is further amplified by 38 dB by two off-chip power amplifiers. The amplified output is fed to an off-chip RF switch to create a pulsed RF signal which drives a 100 um square transducer as shown in Fig 1c.

Results/Discussion:

The TIA output changes from 1.51-0 V as the degree of polarization varies from 0-360 degree, as depicted in Fig 1d, controlling the amplitude of the RF signal in VGA. The actual incident power at the photodiode is smaller than the power after the polarizer due to beam misalignment and reflection. The VGA output varies with the control voltage as shown in Fig.1e. The 100 ns sonic pulse-packet from the transmit transducer travels through the silicon substrate, reflects off the backside and measured at the receive transducer (Fig 1f). The effective optical dynamic range control of the ultrasonic amplitude can be defined as $\gamma=(A_{max}-A_{min})/A_{min}$, and was measured to be 400%.

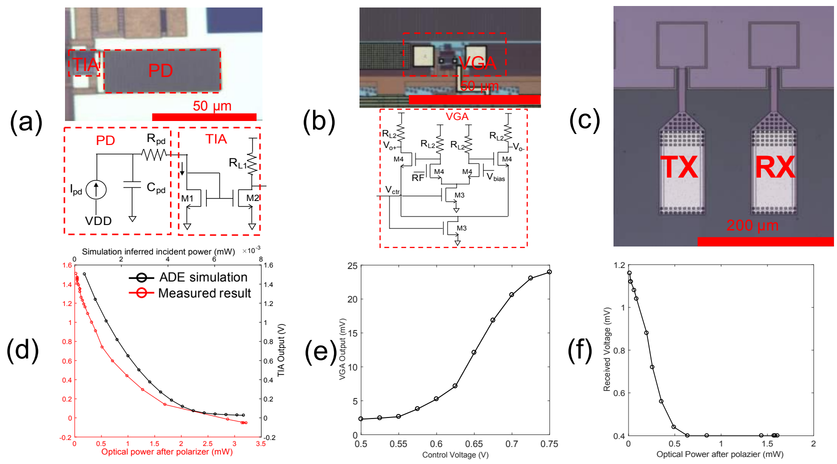

Fig 1 (a) is photodiode and TIA where R_{L2}=15kΩ, M1=410nm, M2=8.8µm (fabricated in GF 180nm). (b) is VGA where R_{L2}=290Ω, M3=64µm, M4=32µm (fabricated in TSMC 180nm). (c) is transmit and receive AlN transducer. (d) is the TIA output. (e) is the VGA peak-to-peak output. (f) is the voltage at receive transducer.