AN ANALOG AND DIGITAL REPRESENTATION OF POLARIZATION USING CMOS IMAGE SENSOR

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***Abstract*— A CMOS image sensor with an integrated wire grid polarizer to sense the polarization of light is presented. The chip consists of an array of 128 by 128 pixels, and it has been designed and fabricated in a CMOS 180nm process. The sensed polarization information is represented and analyzed in both the analog and the digital domain. Extinction ratios of 6.3 and 7.7 were achieved in analog representation.**

I. SENSOR DESCRIPTION

The three basic characteristics of light are intensity, color and polarization. The polarization can be detected using either with external polarization filters or with micropolarizers directly integrated on top of the photodetector. Micropolarizers can be made from organic materials [1] or using a metallic wire grid [2], [3]. The metallic wire grid micropolarizer can be made using the metal layers available with the standard CMOS technology.

Our polarization sensing sensor has an embedded linear wire grid polarizer in each pixel. The linear wire grid polarizer was implemented using thin metal strips with a wire grid pitch of 480nm, as shown in figure 1.

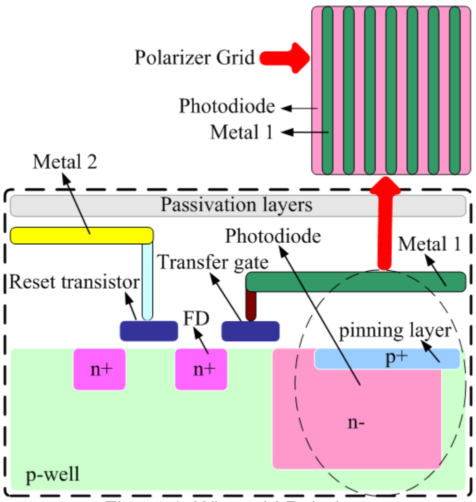

Figure 1: Wire grid Polarizer

Figure 2 shows the sensor die photograph along with the implemented polarization regions. The array of 128 by 128 pixels was split into three regions: 1) a 64x128 array without a metal grid used for normal imaging applications, 2) a 64x64 array (sense region 1) consisting of 2 by 2 pixel arrays where two pixels (A and B) measure the intensity while the other two measure the 0º (D), and 90º (C) degree polarized intensity respectively and 3) a 64x64 array (sense region 2) consisting of 2 by 2 pixel arrays where one pixel records the intensity of the light (A) while the other 3 record the 0º (B), 45º (C) and 90º (D) polarized intensity. Each pixel contains a pinned photodiode, an analog comparator, two banks of analog memories and two SRAMs. The image sensor provides both analog and digital readout of each pixel.

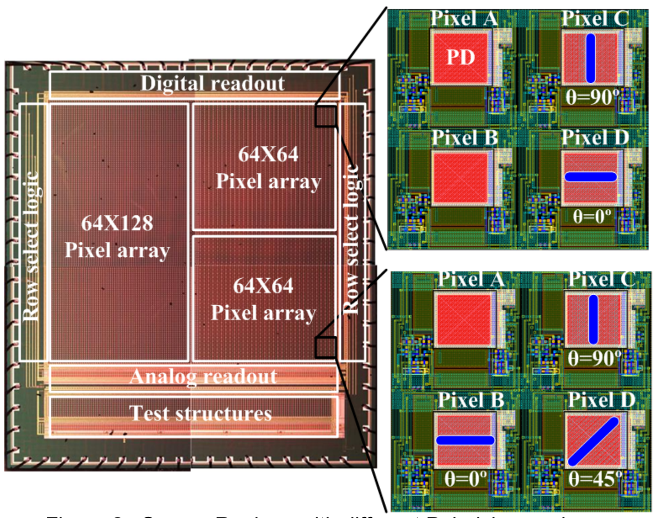

Figure 2: Sensor Regions with different Polarizing angles.

The analog readout consists of a column level double differential sampling circuit (DDS), an output amplifier, a buffer and the column shift registers. The digital readout circuit consists of a 7-bit counter which counts the number of active high pixels row wise during the column progressive scan readout, and a column shift register.

II. Analysis

A. Polarization (Analog representation)

Unpolarized light passes through a linear polarizer with its axis set to 90º and is incident on the image sensor. The transmittance measured in sense regions 1 and 2 is shown in figure 3(a). The extinction ratios[1] (ER) for the polarization sense regions 1 and 2 are calculated to be 6.3 and 7.7 respectively.

B. Polarization (Digital representation)

The digital polarization sensing principle is that of computing and analyzing the 1D-correlational optical flow from the intensity variations generated by a moving object on the sensor focal plane. The 1D binary optical flow is represented by the percentage of active pixels in a pixel array at a fixed time.

The theoretical and obtained polarized optical flow is shown in figure 3(b). As the light intensity reaches the threshold level, we should see subsequent step rises in the % of active high pixels first for the intensity sensitive pixels and then for the 45º and 90º pixels. In our experiments, the optical flow is obtained by increasing the light spot gradually from the center to the periphery of the polarization sense regions, using a linear polarizer. This results in a linear increase in the % of active high pixels with the variations in the linear polarizer angle, instead of the expected step rise.

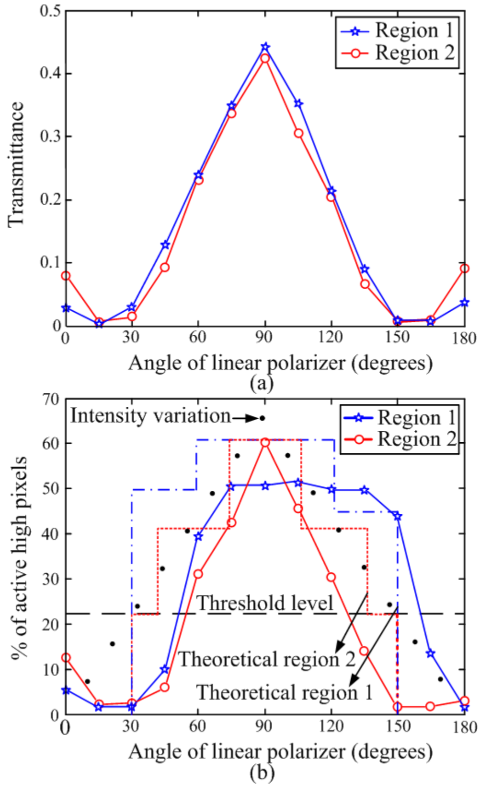

Figure 3: 90º polarization in sense regions 1 and 2: (a) analog (b) digital (optical flow variation)

Conclusions

The measured extinction ratios of 6.3 and 7.7 are higher than those presented at [1] and [2] (6 and 2.3, respectively). The linear polarization of the transmitted wave through a wire grid is a function of the pitch of the wire grid. The 1D binary optical flow was shown to have an angular dependence on the angle of the linear polarizer. It is further observed that by increasing the number of wire grid orientations, a digital representation of the polarization very similar to the analog can be obtained.

References

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[1] The extinction ratio is defined as the ratio of maximum to minimum transmittance.