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ISCAS 2020

2020 IEEE International Symposium on Circuits and Systems
Virtual, October 10-21, 2020

CAS

Weight Based Current Assisted Photonic Demodulator (WBCAPD) – Expansion Towards Neuromorphic Applications

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2020 IEEE International Symposium on Circuits and Systems
Virtual, October 10-21, 2020

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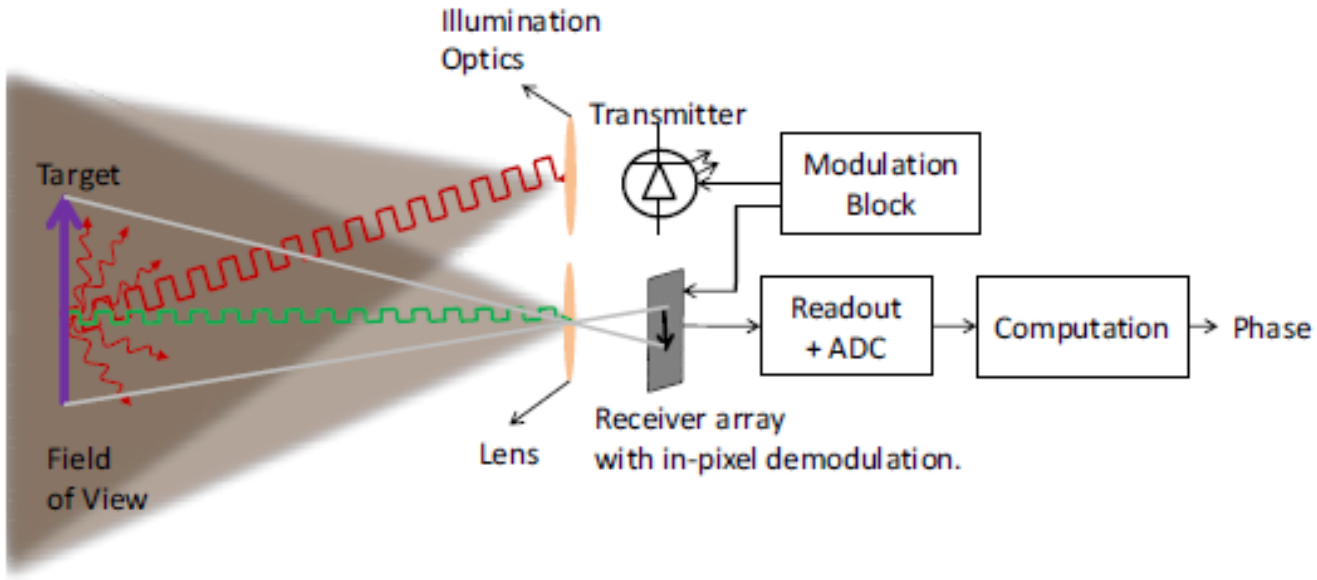
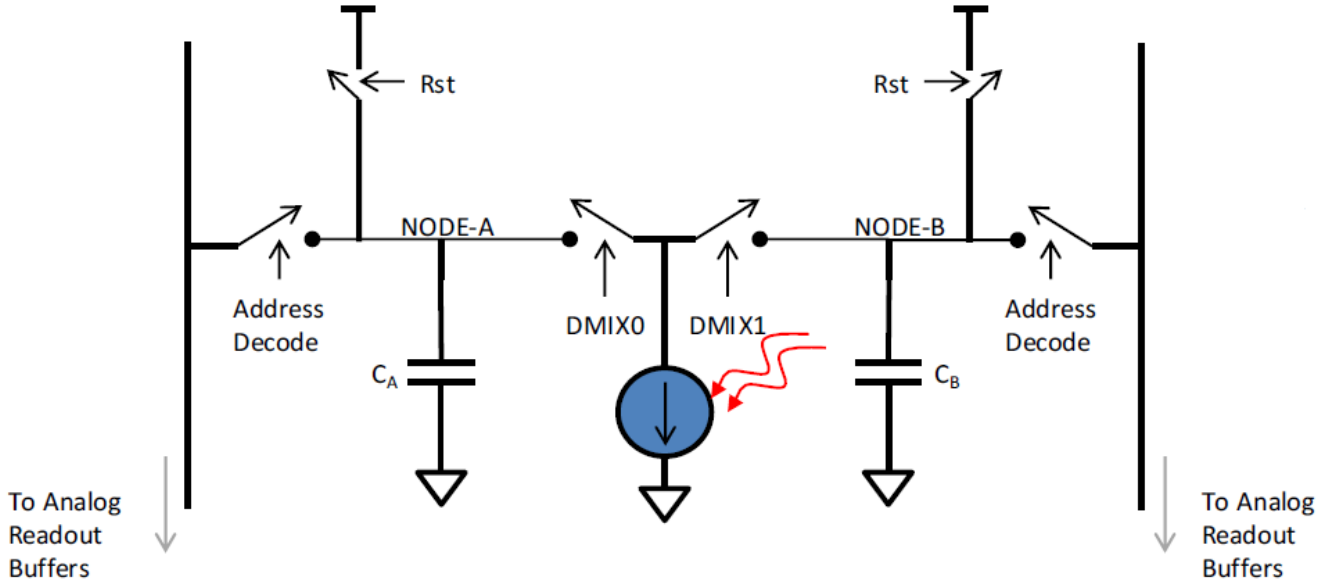
ToF and the CAPD

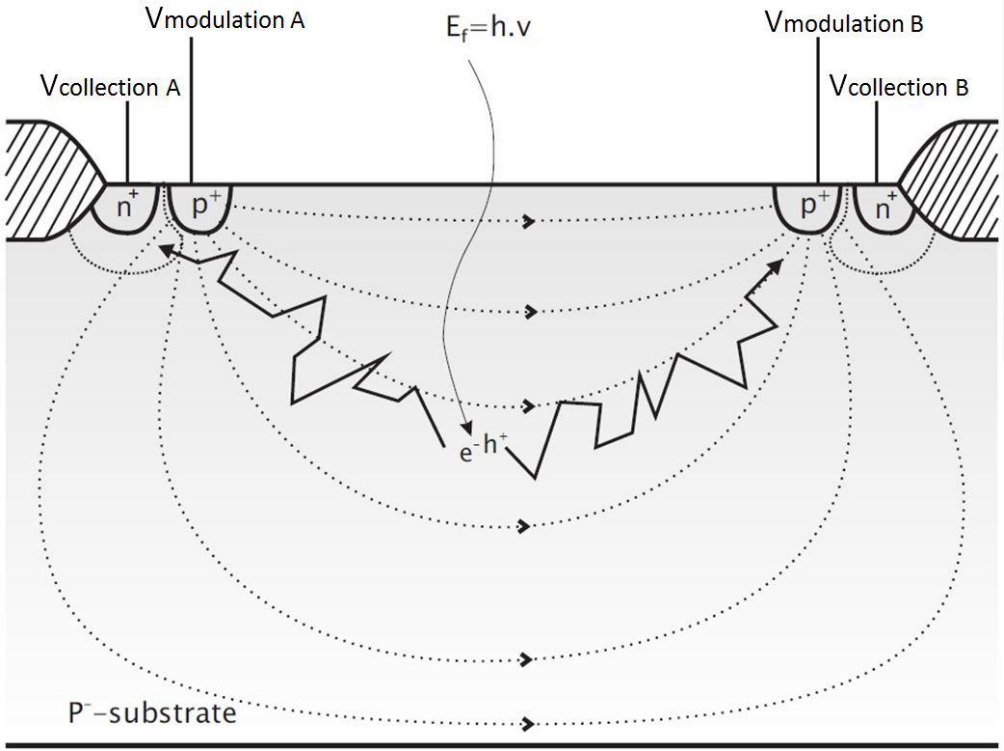
- The indirect ToF method utilizes a photonic mixer to find the phase of the incoming light pulse, using the phase difference the distance to an object is calculated
- The CAPD (Current Assisted Photonic Demodulator)is a photonic mixer which modulates the incoming light to one of two separate collection junctions

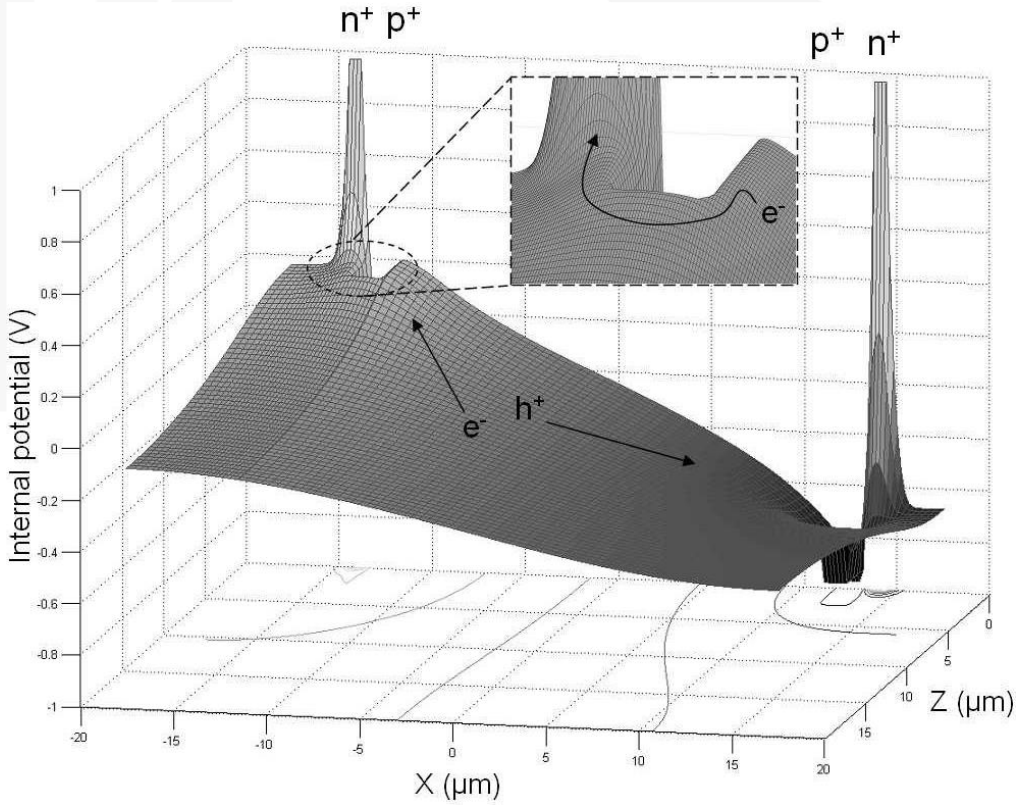




The CAPD

- Each terminal of the CAPD is made of one p+ diffusion (the modulator) and one n+ diffusion (the collection junction)
- The modulators voltage difference dictates the electric field direction and intensity through the bulk, the electric field produces a majority current flow which guides the minority current (electron current in the p-substrate case) to the modulator with the highest voltage bias
- The induced electric field also separates the electron-hole pairs before recombination occurs

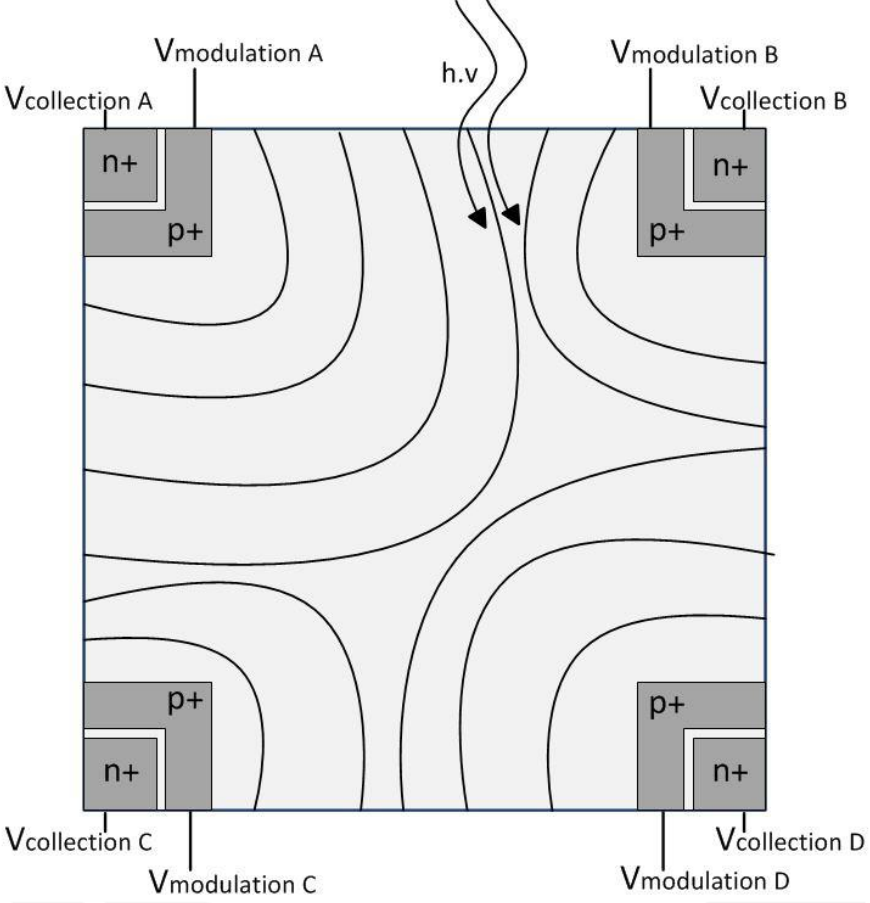


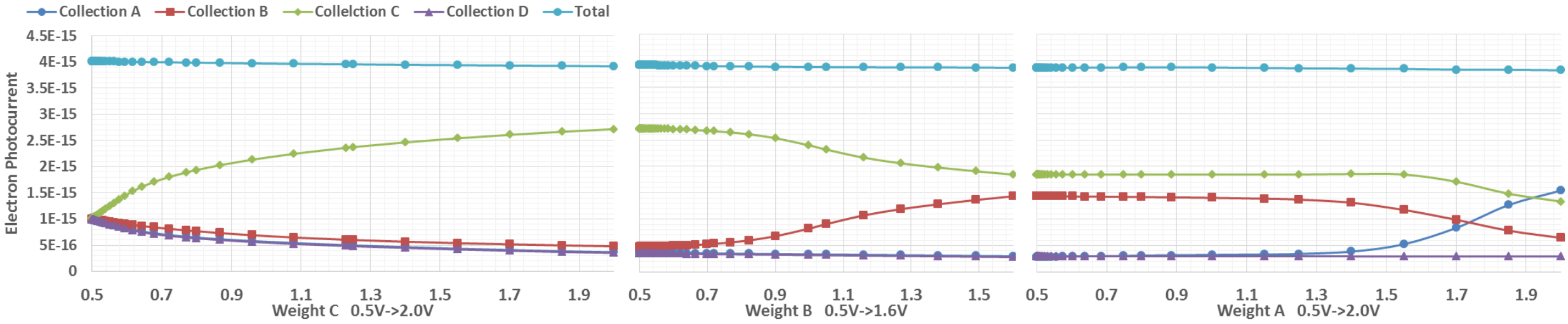


The WBCAPD

- The WBCAPD (Weight-Based CAPD) applies varying analog voltages on the modulators so that the photo-current flow to each junction is a function of that junction modulation voltage (or weight) and of the surrounding weights
- The WBCAPD is expended to 4-terminals, each one contains a n+ diffusion (a collection junction) and a p+ diffusion (a modulator)
- In equilibrium conditions the photo-current flow to each junction is given by –

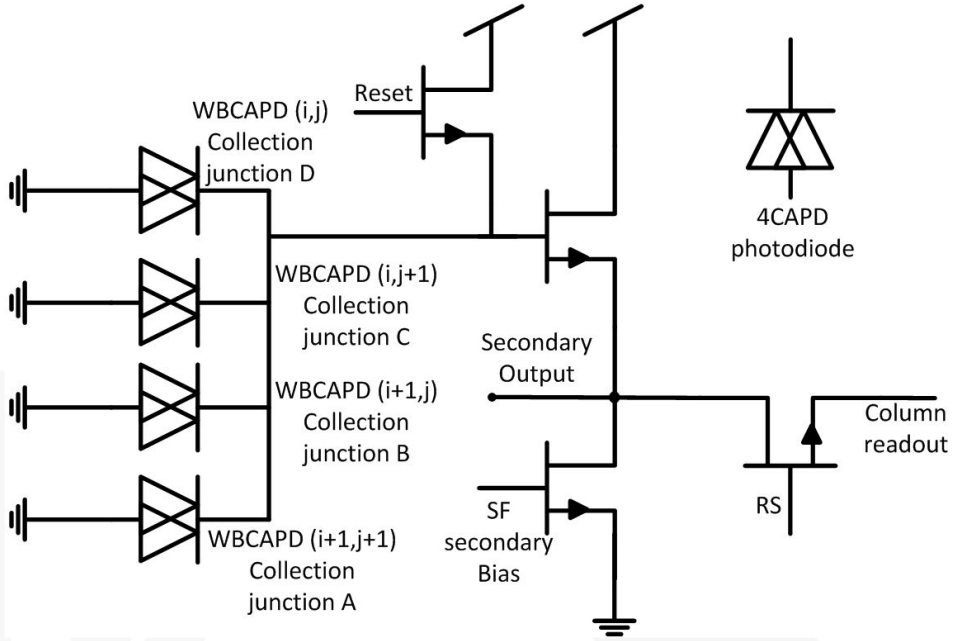
$$PhotoCurrent_i = \frac{Weight_i}{Weight_A + Weight_B + Weight_C + Weight_D} \cdot PhotoCurrent_{Total}$$

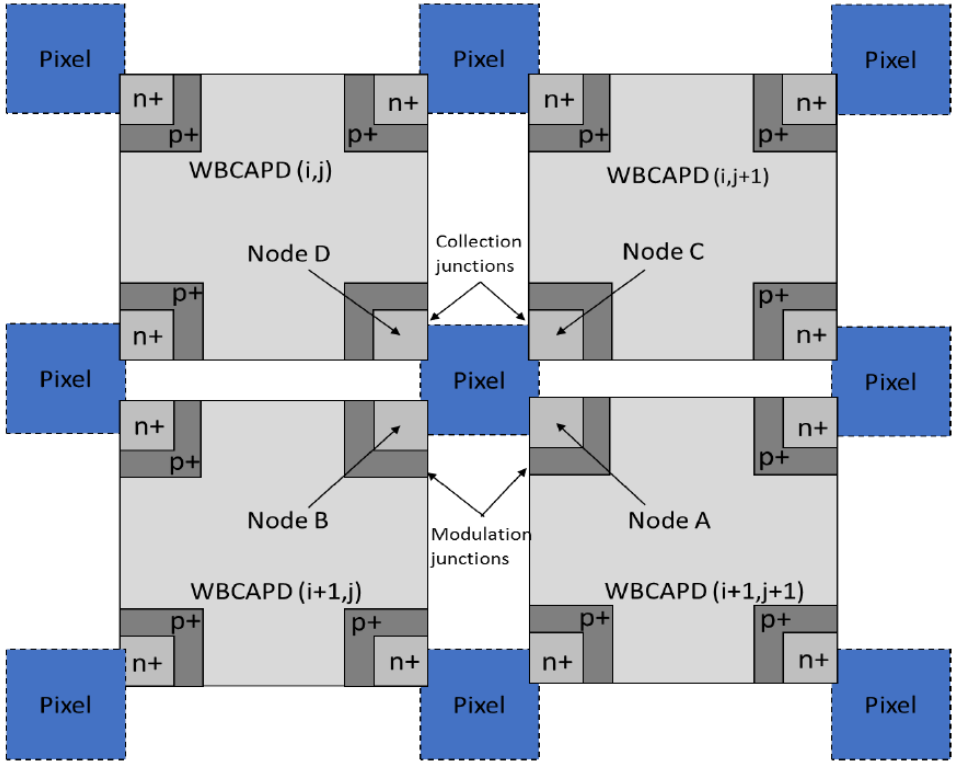




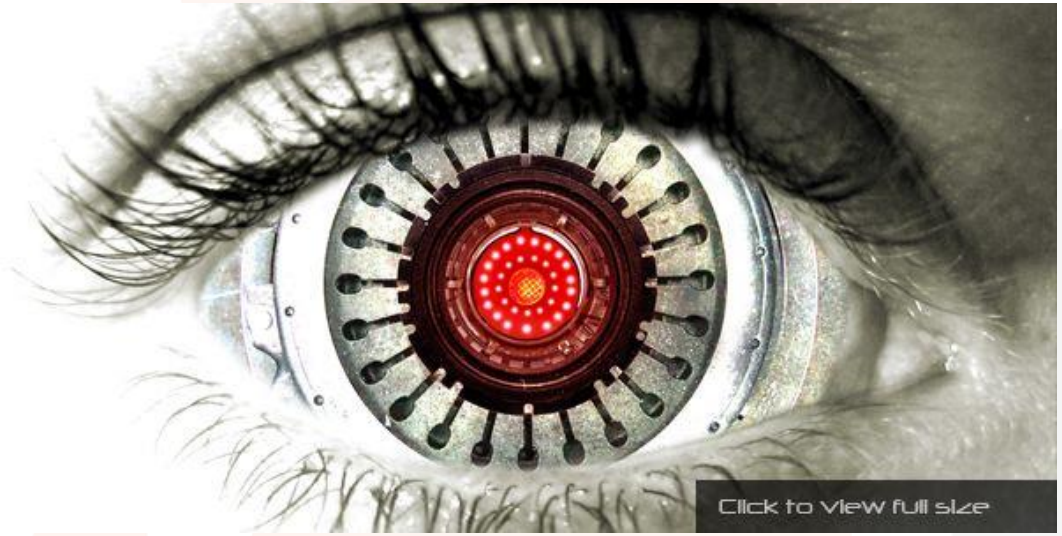
The WBCAPD pixel

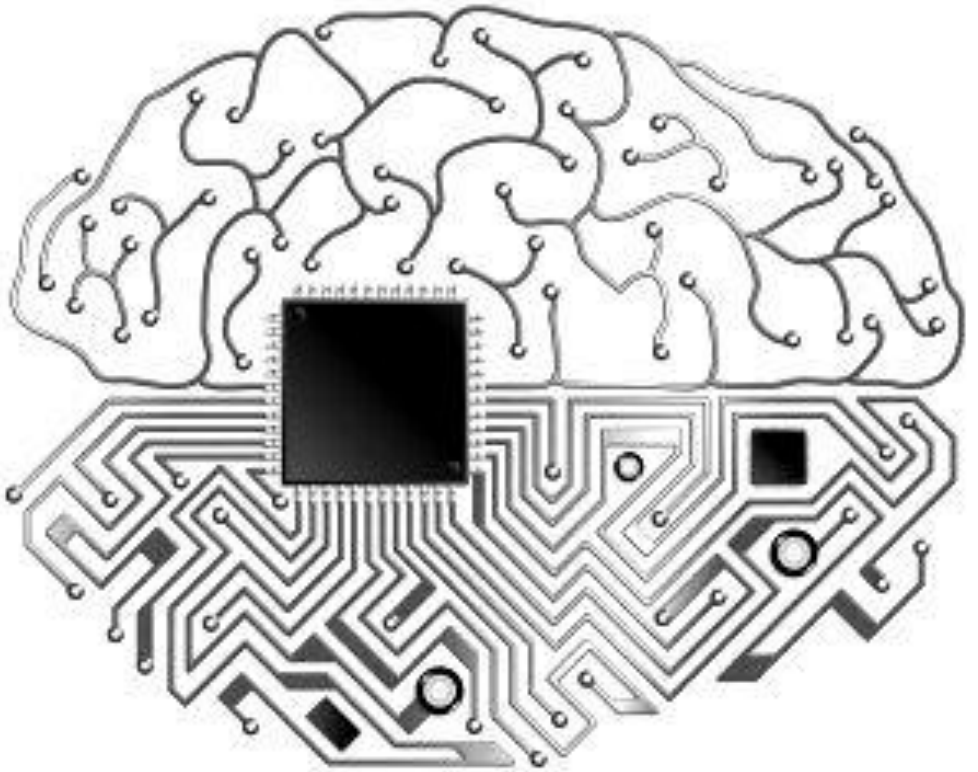
- The WBCAPD pixel connects to 4 different photodiodes and each photodiode connect to 4 pixels
- The photo-current flow to each pixel is the sum of the photo-current flow to its 4 collection junctions
- The WBCAPD pixel includes an additional transistor for real-time readout (secondary output at the top fig) which may be used to bias the weights of surrounding photodiodes





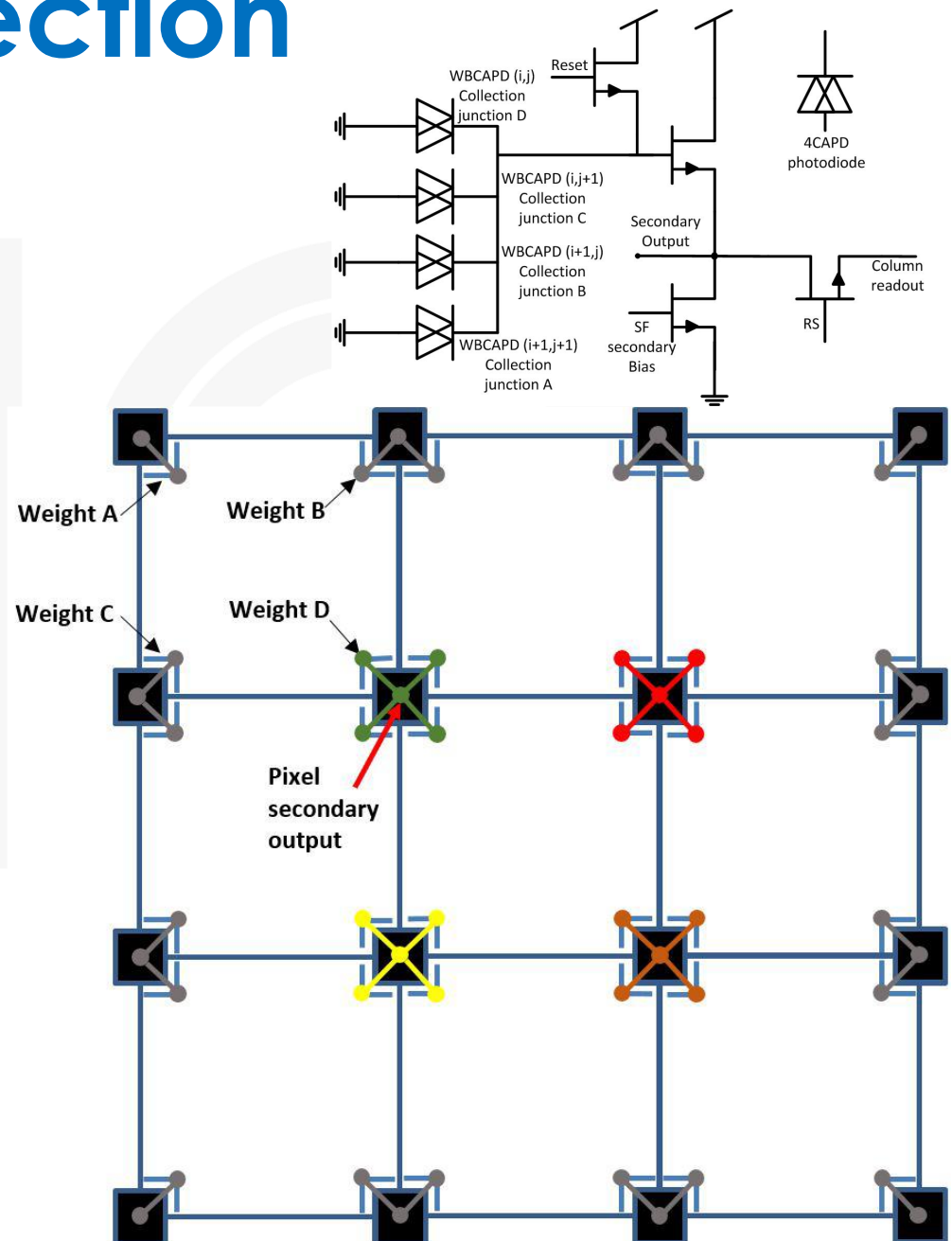
Neuromorphic applications





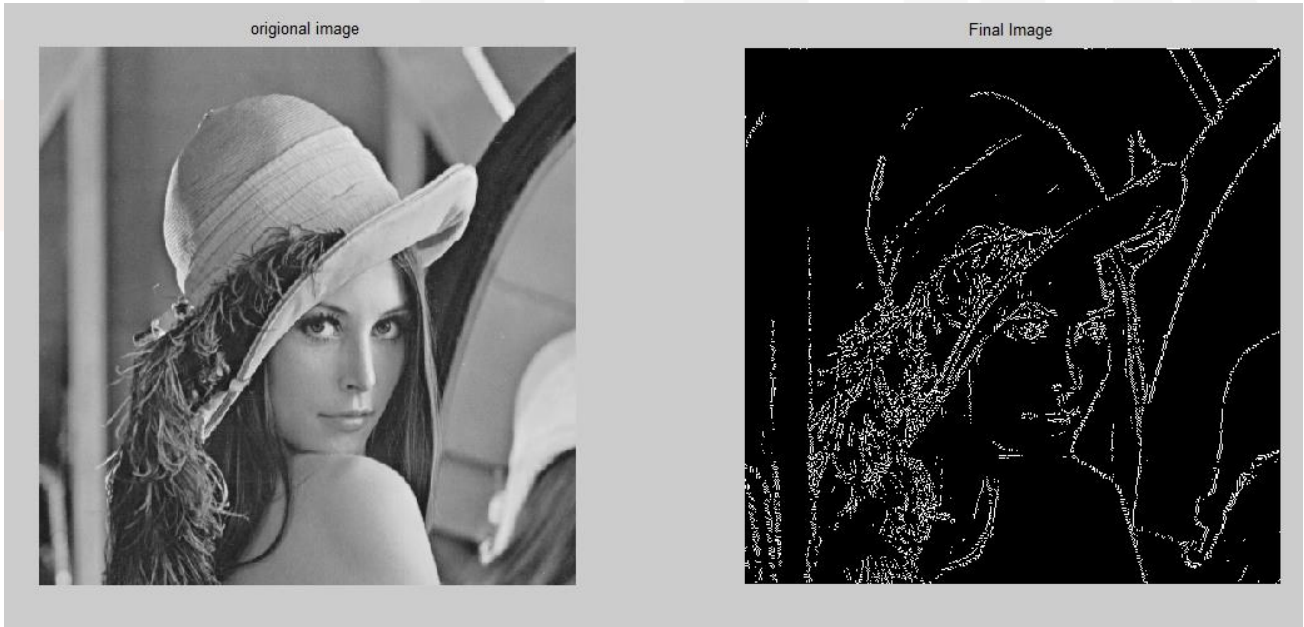
Averaging and edge detection

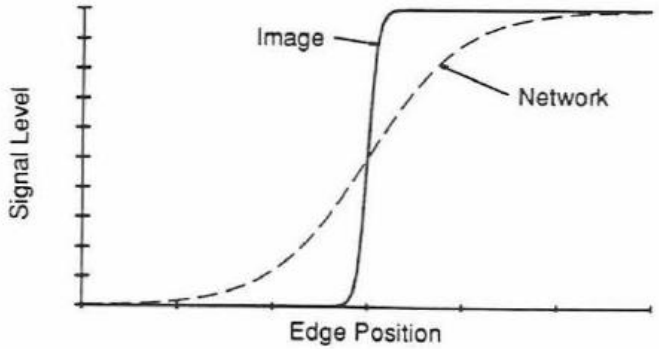
- Connecting the secondary real-time output of each pixel to its surrounding weights (see fig) creates a negative feedback between the photo-current flowing into the pixel and the weights values
- Strong illumination -> strong photo-current -> V_{PD} decreases fast -> secondary output decreases fast -> weights are biased low -> less photo-current flows to the pixel
- If one pixel receives more illumination (and photo-current) than its surrounding pixels, than its weights will be biased at a lower value allowing more photo-current to flow to the surrounding pixels. The result is spatial averaging

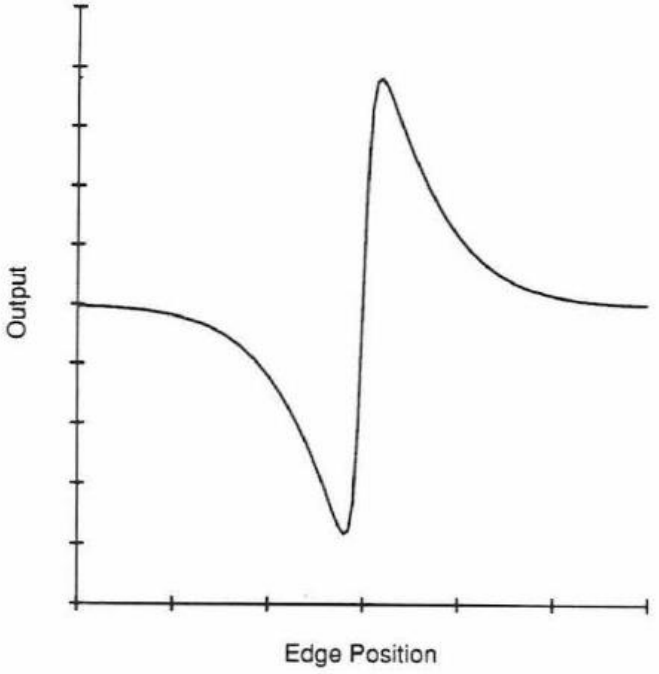


Averaging and edge detection

- The WBCAPD pixel can be operated in different manners, for normal image sensing the weights of all the photodiodes will be biased with the same voltage
- To achieve edge detection, a normal image sensing picture should be subtracted form the spatially-averaged picture to produce a picture of only edges

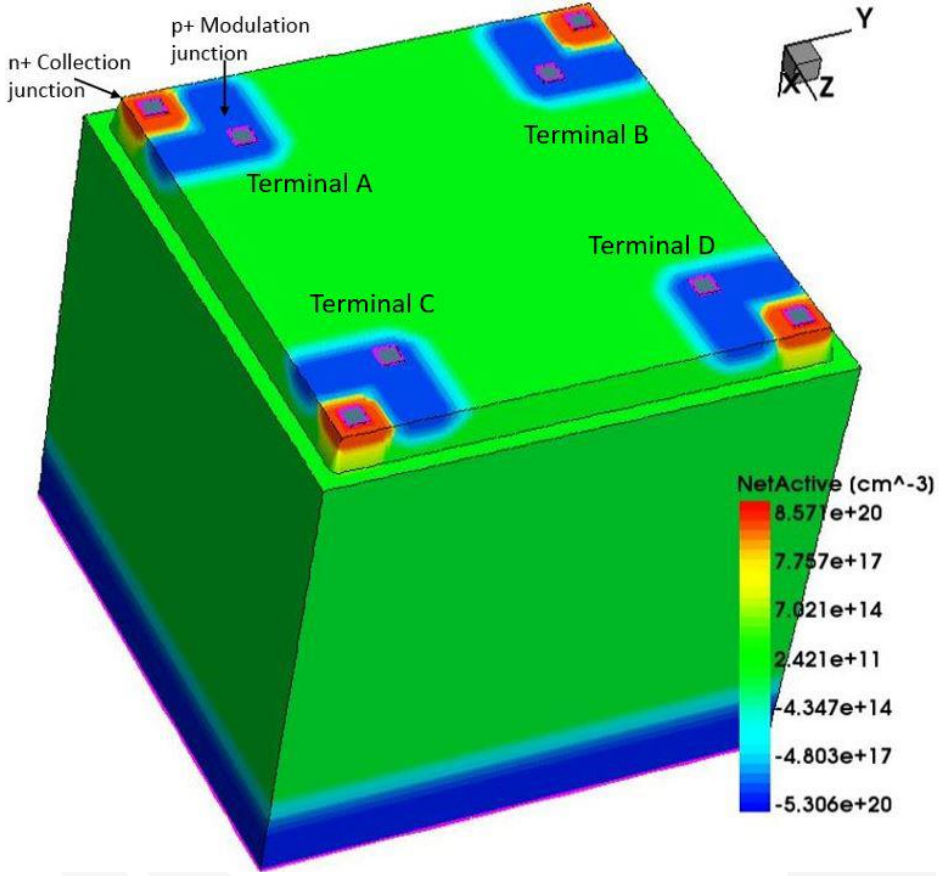


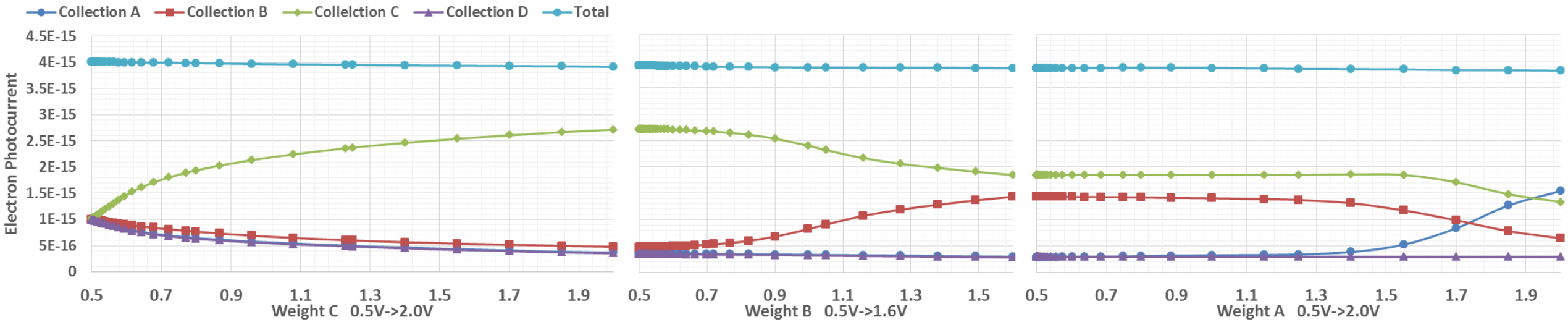




TCAD simulations

- The WBCAPD photodiode was simulated in synopsis TCAD using the sdevice simulator
- The fig below shows the electron current flow into each collection junction during the weights ramp-up
- The photo-current flowing into each collection junction is a function of the weight value of the specific junction as well as the weights of the surrounding junctions





Summary and future work

- In this paper we have shown a novel use of the CAPD photodiode, to be used as a smart neuromorphic sensor photodiode
- The WBCAPD responsivity control via weights make it possible to change the photo-current flow to each pixel in real time and thus to facilitate various neuromorphic functions
- Currently our research group is working on the tape-out of a sensor that will include the WBCAPD array

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