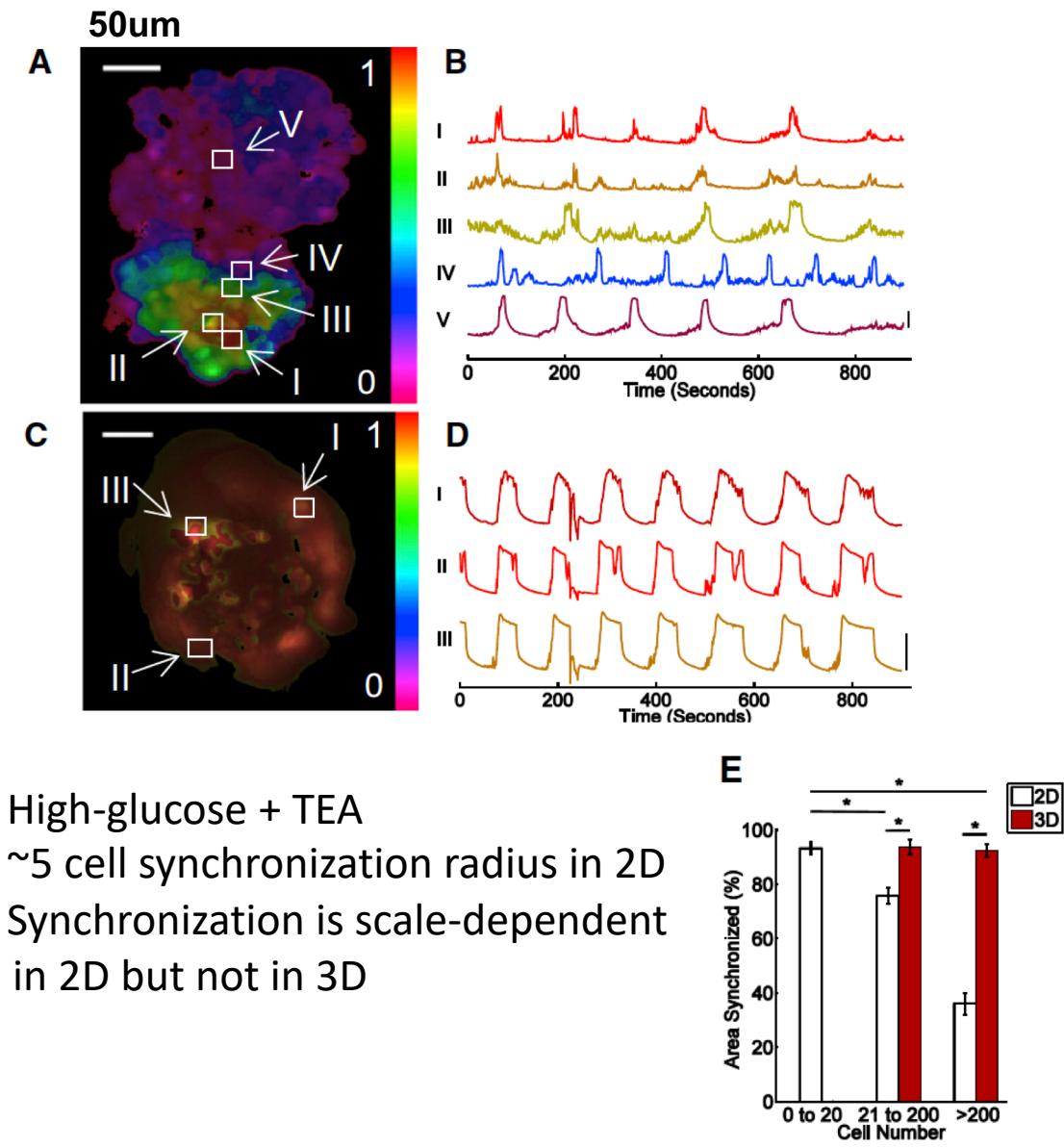
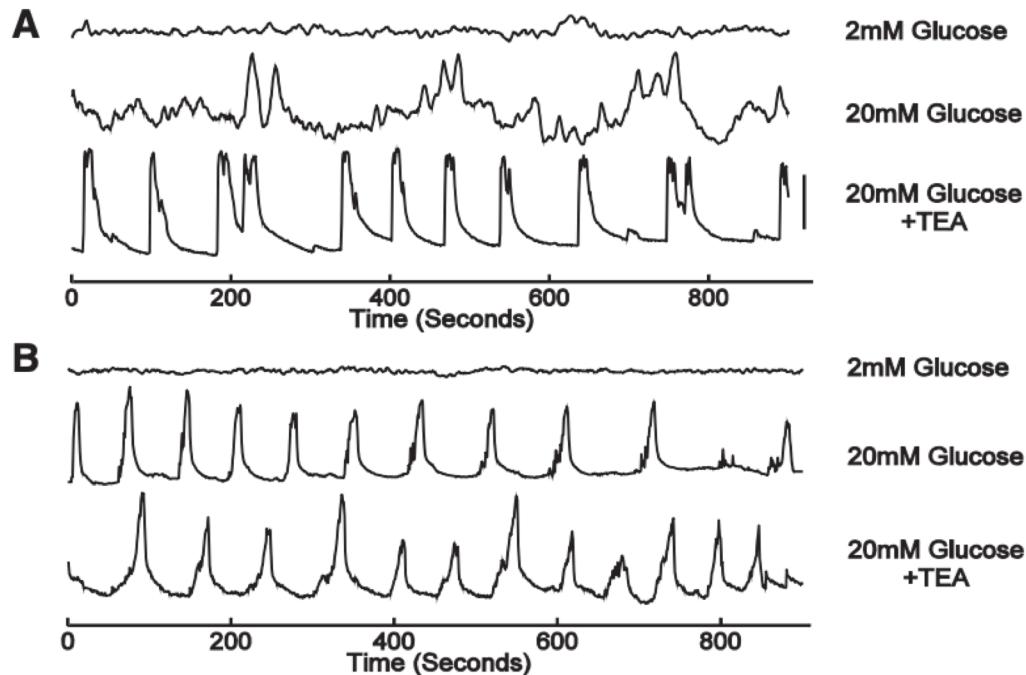


# Dimension and size dependence of [Ca<sup>2+</sup>] synchronization

2D: ~4000 cells/mm<sup>2</sup> (MIN6)

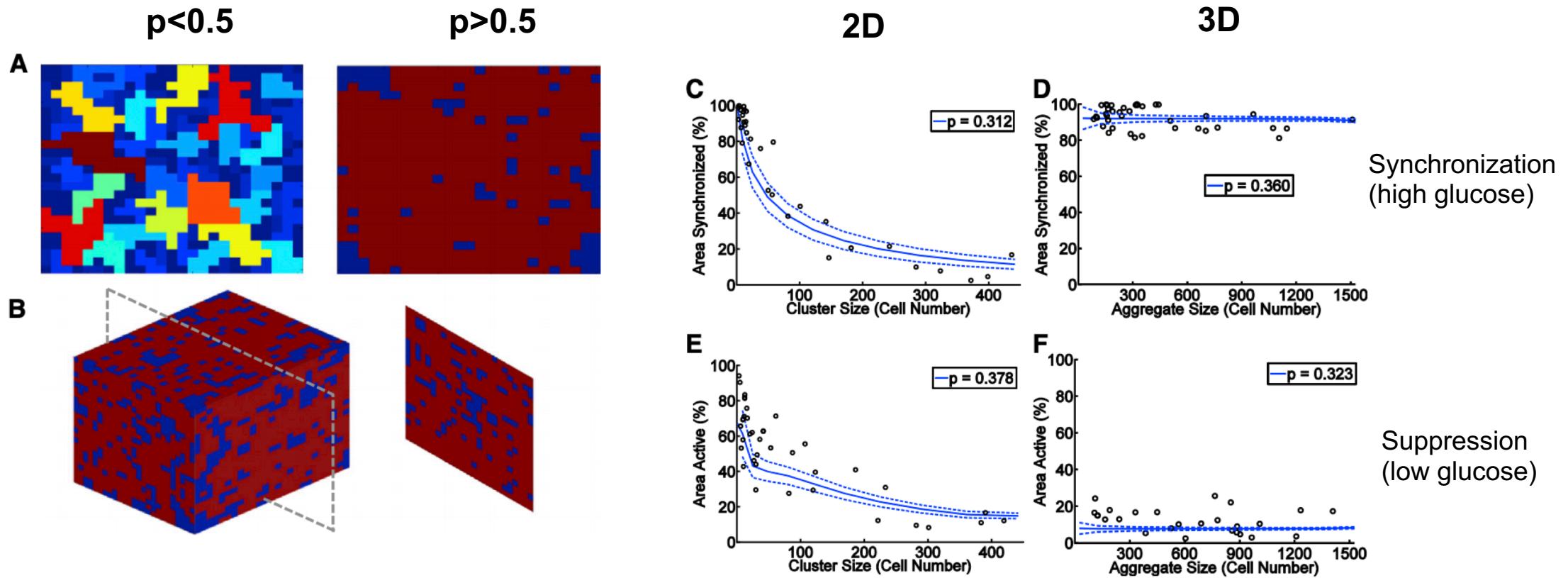
3D: ~520,000 cells/cm<sup>2</sup> in hydrogel microwell arrays

[Ca<sup>2+</sup>] readout using Fluor4

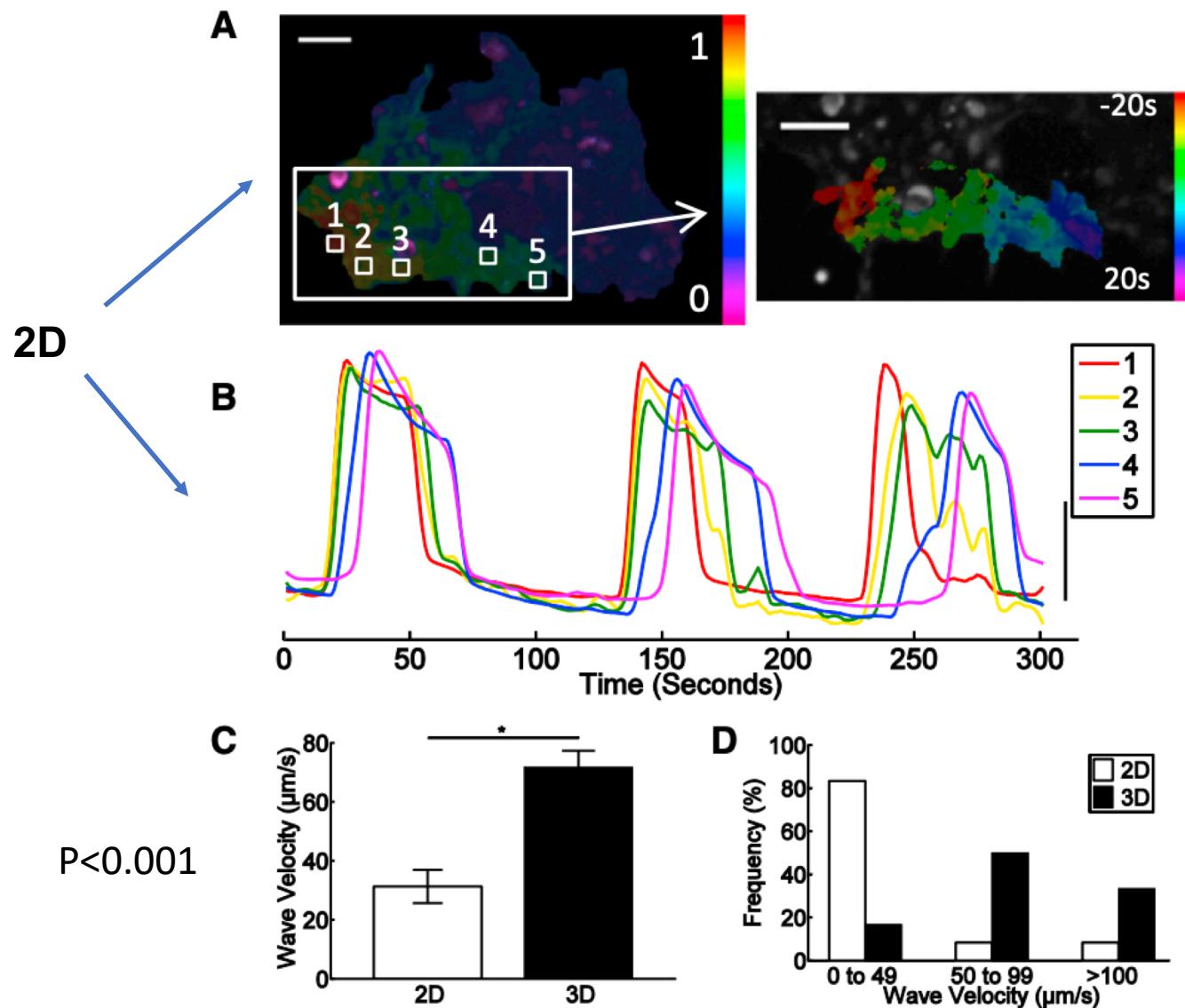


- High-glucose + TEA
- ~5 cell synchronization radius in 2D
- Synchronization is scale-dependent in 2D but not in 3D

# Coupled-resistor network model

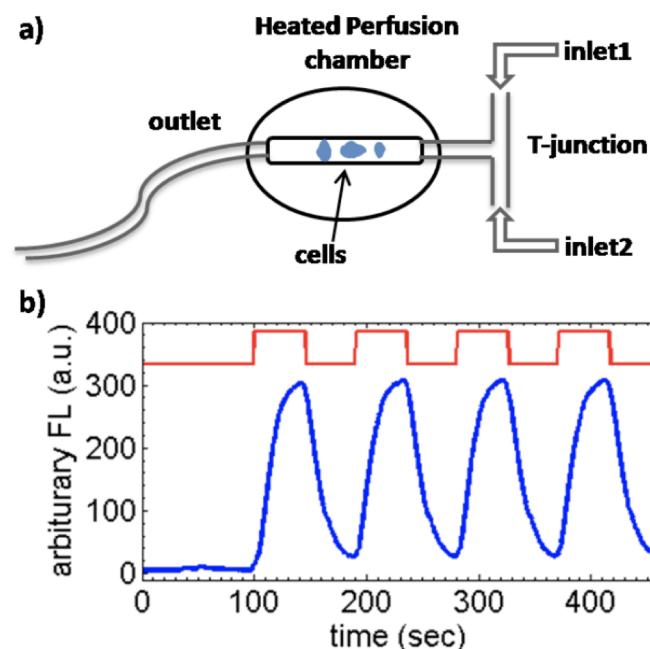
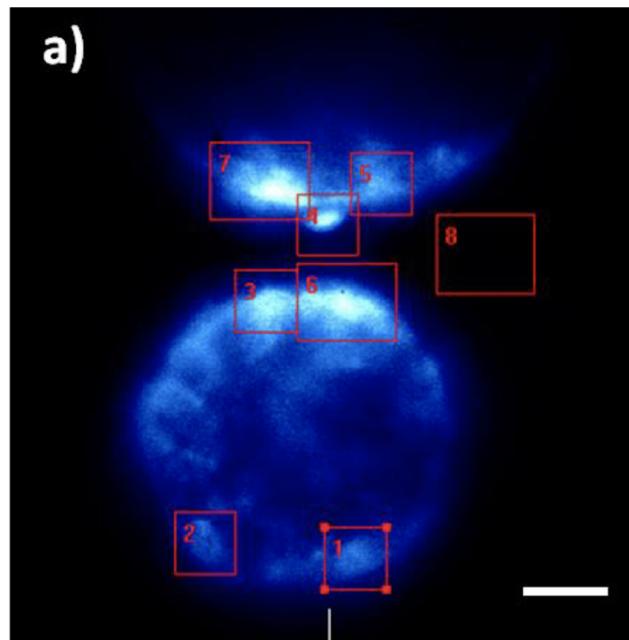


# Wave velocity under 2D/3D coupling



## Interesting points

1. Low-pass frequency response of beta cells
2. Only small populations of cells (pacemakers) sense glucose stimulus
3. Unknown degree of randomness and strength of coupling
4. Entrainment of cells to glucose stimulus



## Coupled phantom burster model

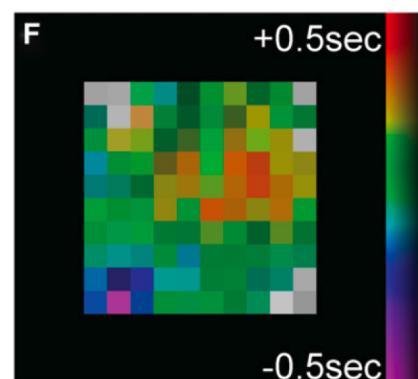
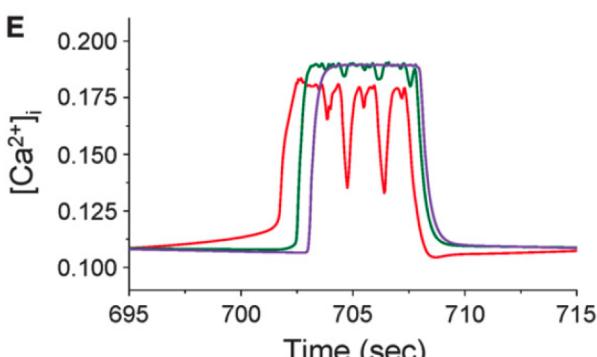
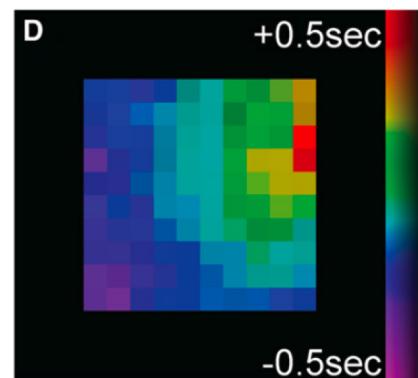
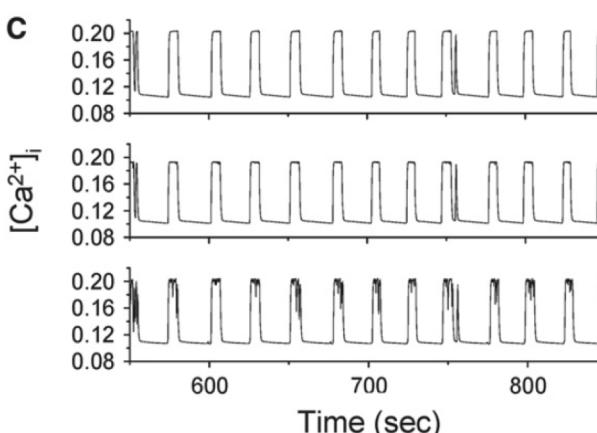
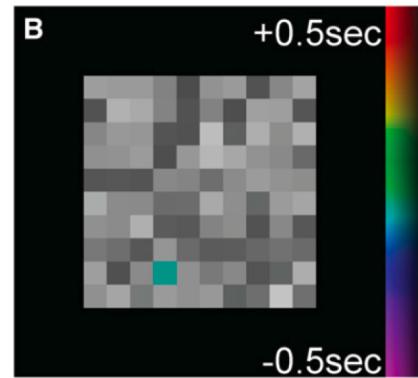
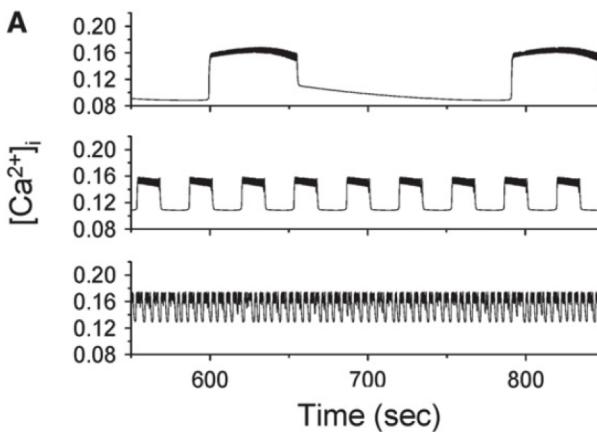
$$C_m \frac{dV_j}{dt} = -(I_{K(Ca)} + I_{K(ATP)} + I_{Ca} + I_K + I_{coupl,j})$$

$$I_{coupl,j} = g_c \sum_i^{\text{neighbor}_j} (V_j - V_i).$$

↑

How is this distributed?

5056

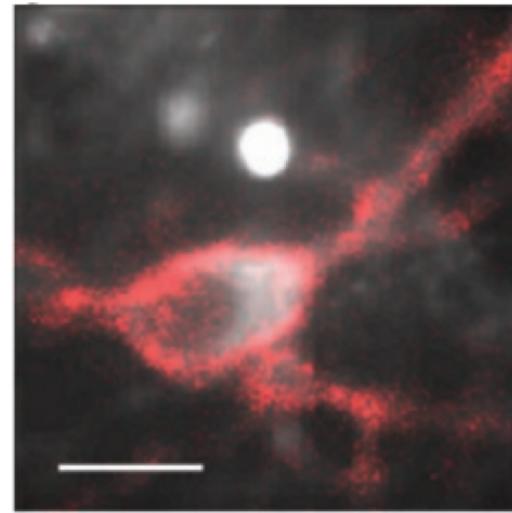


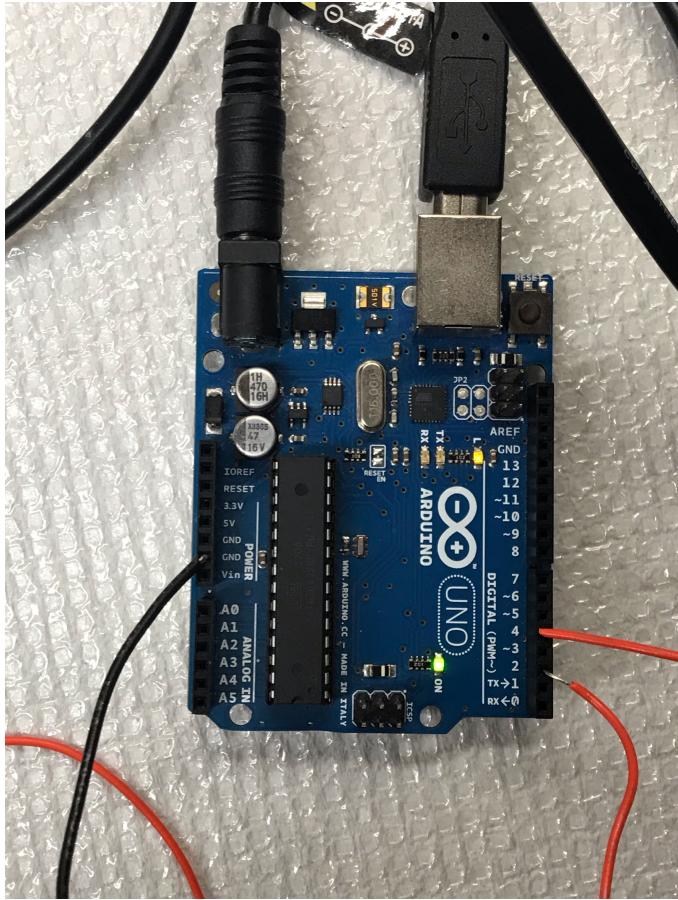
## Estimating membrane potentials

$$S_i(t) = a_i + b_i V(t) + \varepsilon_i(t)$$

$$\langle \varepsilon_i(t_1) \varepsilon_j(t_2) \rangle = \sigma_i^2 \delta_{i,j} \delta(t_1 - t_2)$$

$$\zeta_i^2 = \left\langle (\hat{V}_i(t) - V(t))^2 \right\rangle \quad w_i \equiv \frac{1/\zeta_i^2}{\sum_i 1/\zeta_i^2}$$





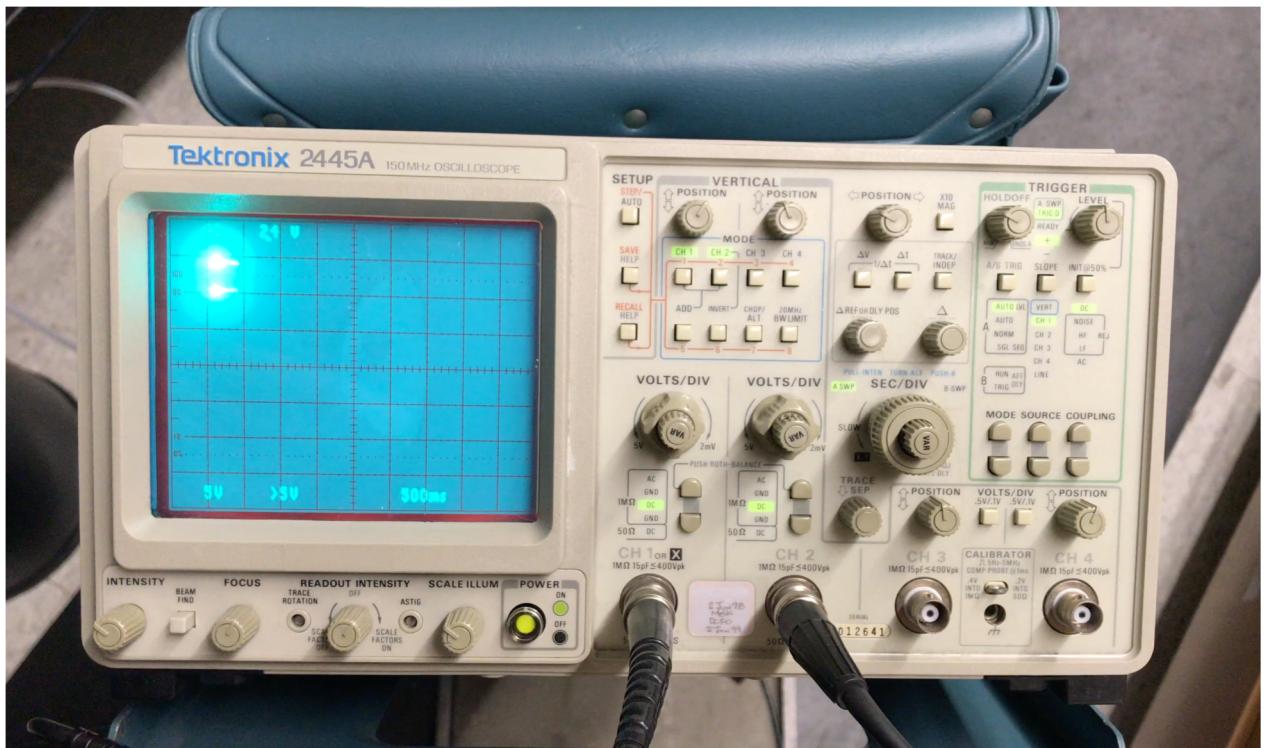
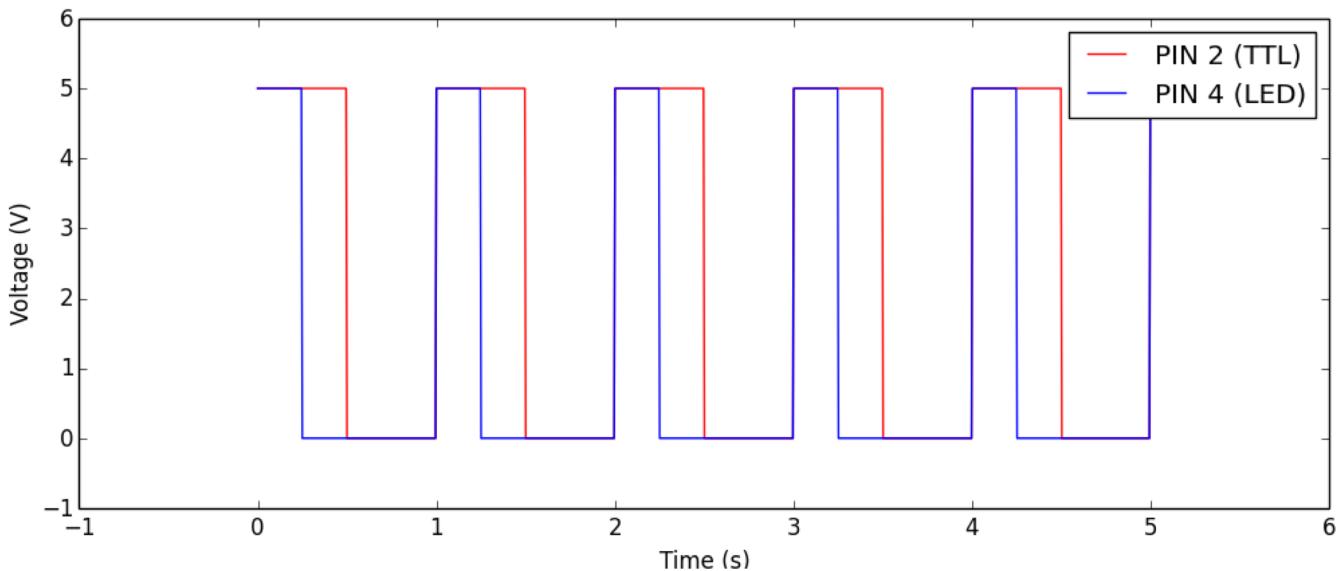
### Analog Input

Onboard 10-bit ADC (6 channels)

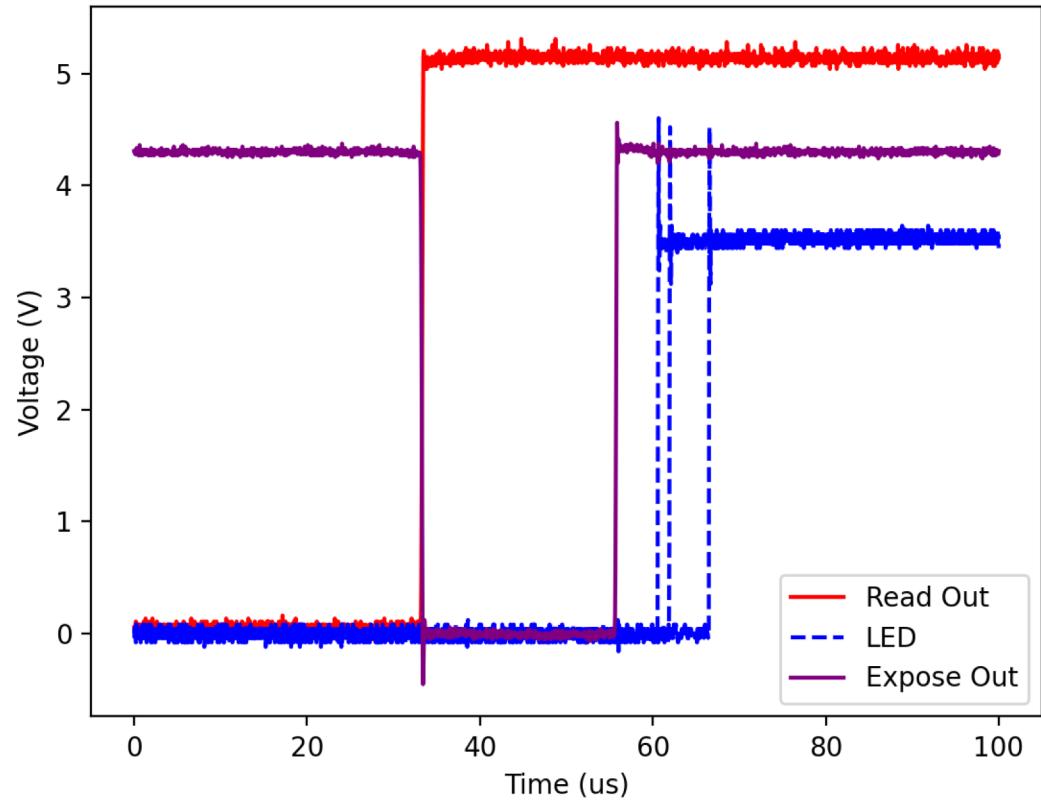
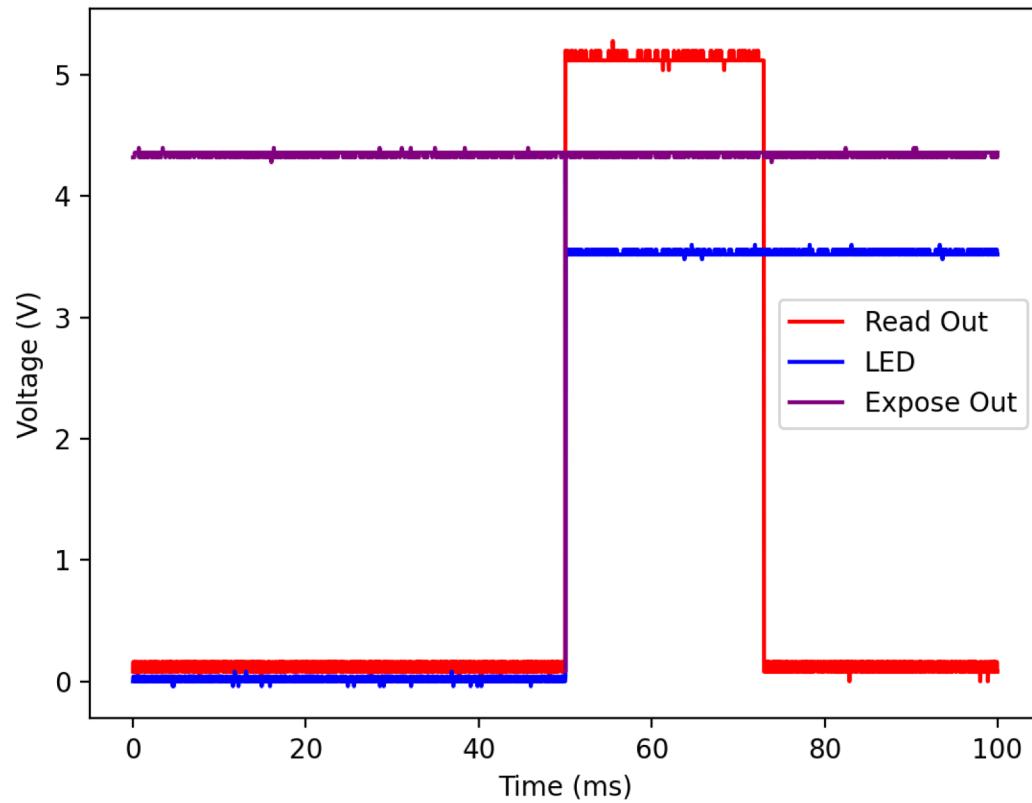
16 MHz Arduino has ADC clock set to 16 MHz/128  
= 125 kHz. Each conversion in AVR takes 13 ADC  
clocks so  $125 \text{ kHz}/13 \sim 10 \text{ kHz}$

### Digital Input

12 digital I/O pins. No analog to digital conversion  
but input has to be 0 or 5V



1s exposure

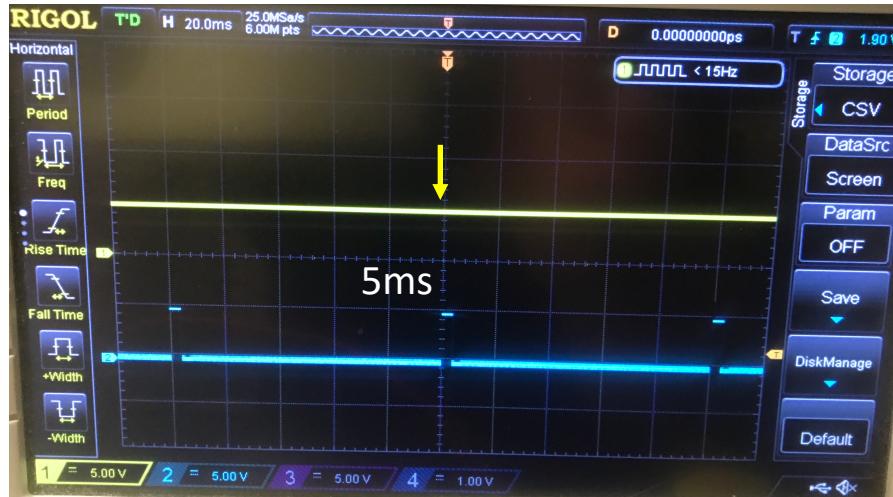


**Expose-Out** signal is high for each row the reset signal propagates past – **any row** that is exposing

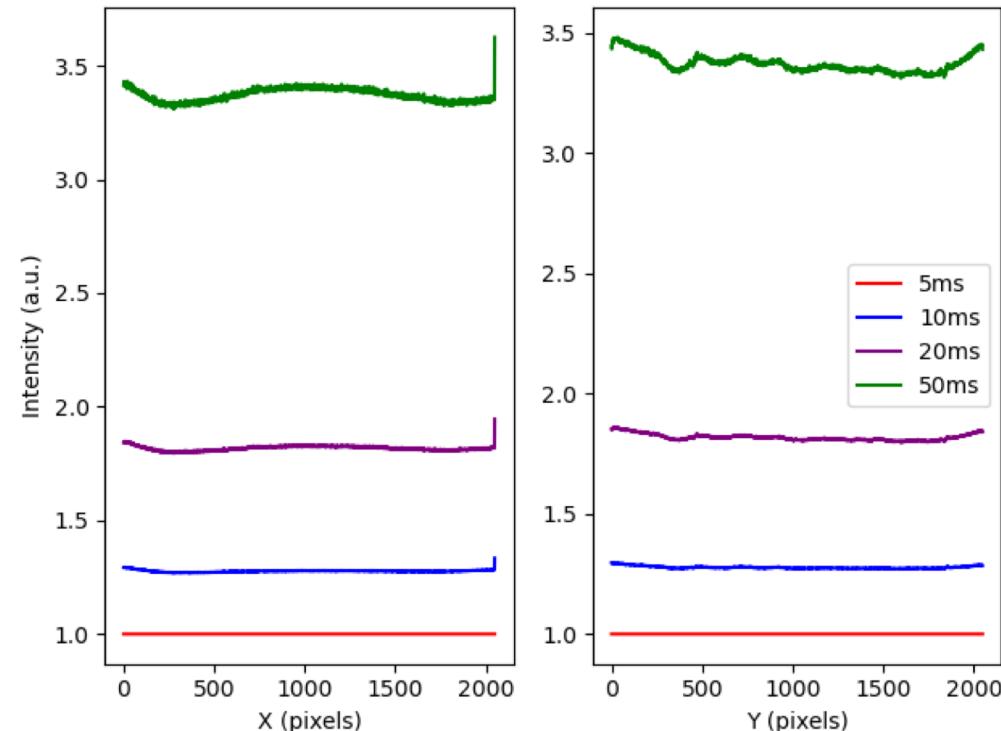
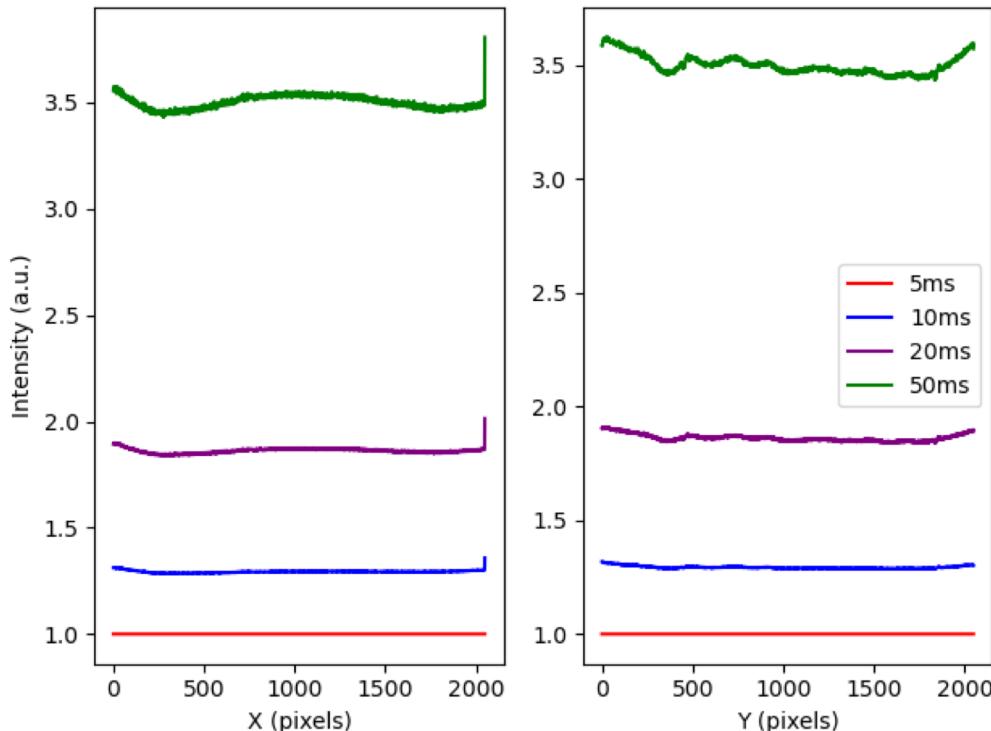
**Read-Out** signal is high when any row is digitizing (?)

1s exposure

## Immediate Pulse

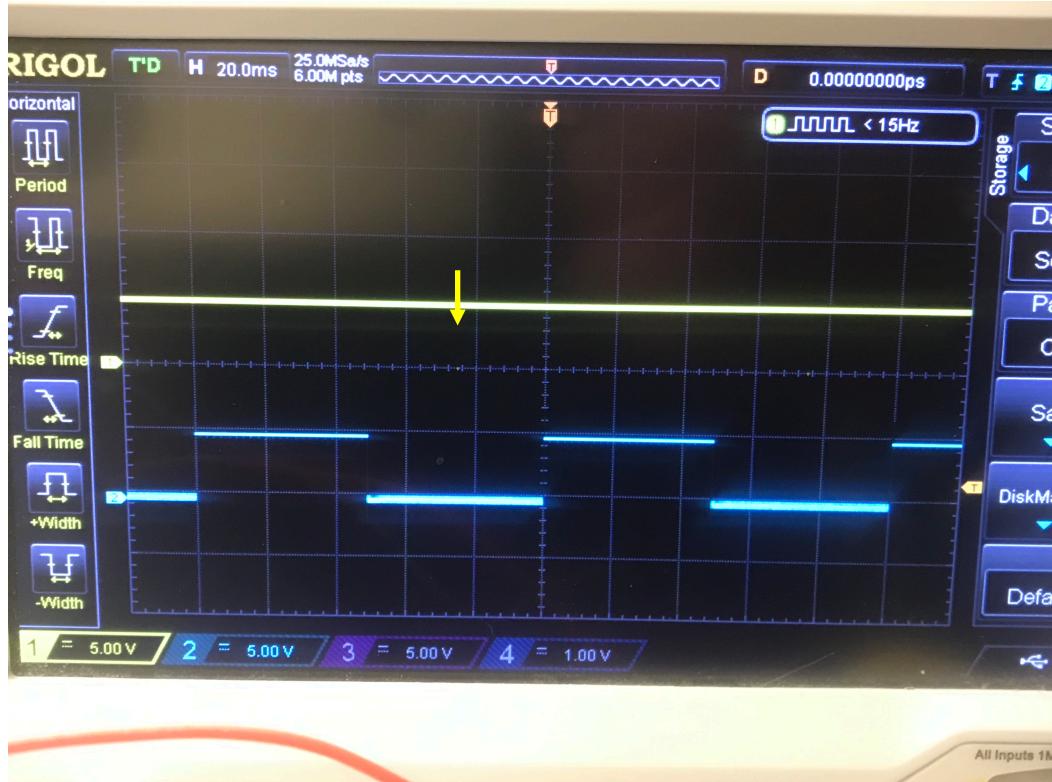


## Centered Pulse



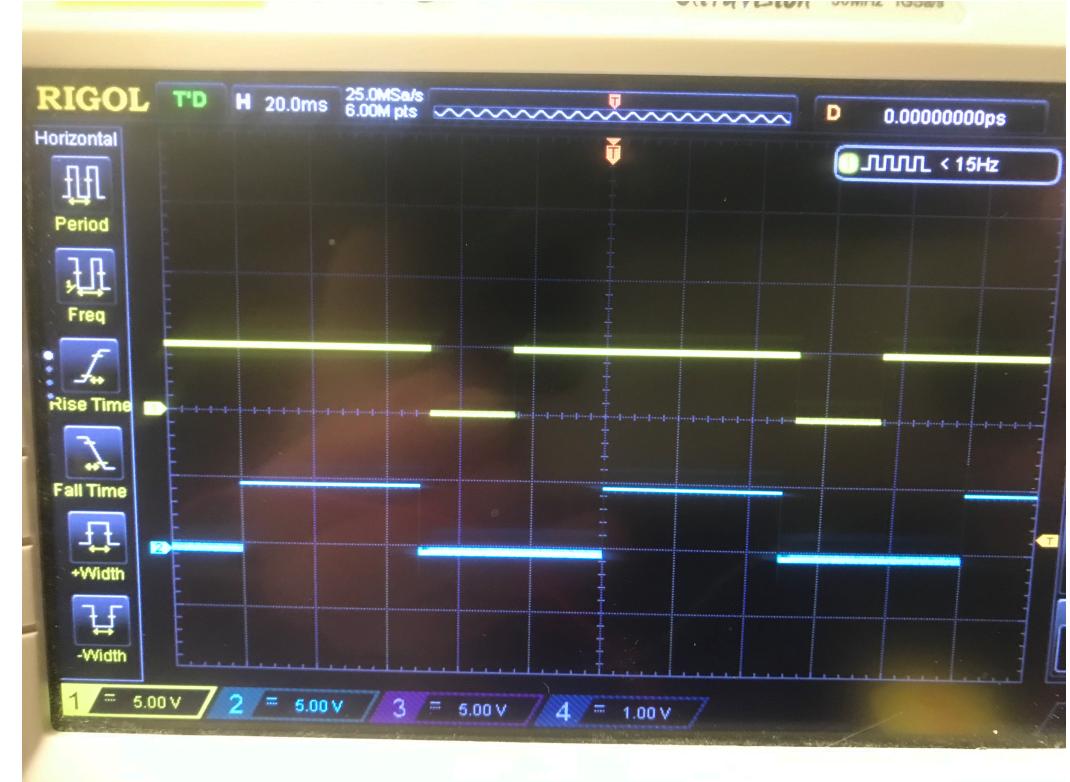
## Different Expose Out Modes

Any Row



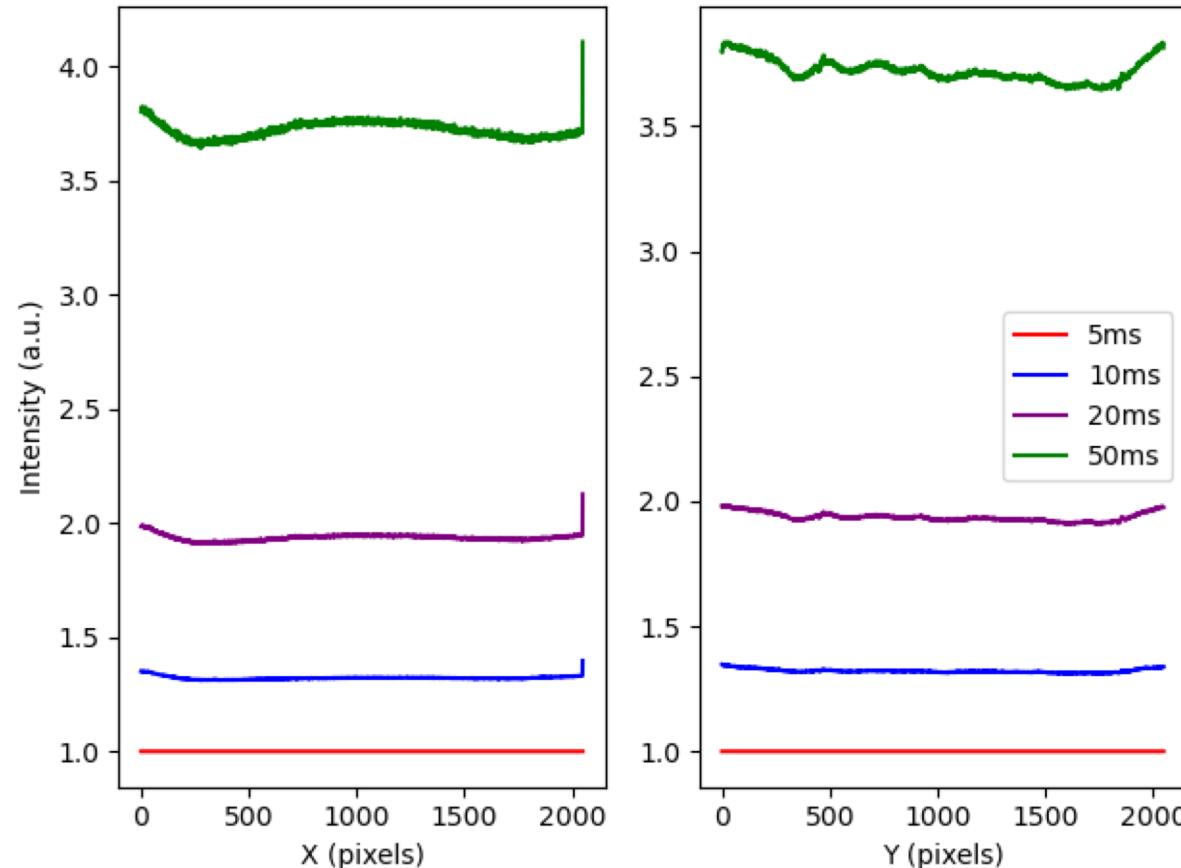
High when any row is exposing

Rolling Shutter



High when all rows are exposing and low during readout

## Rolling Shutter Expose Out Mode



Readout Mode

Rolling Shutter  
Effective Global Shutter  
Programmable Scan Mode (PCI-E only)

