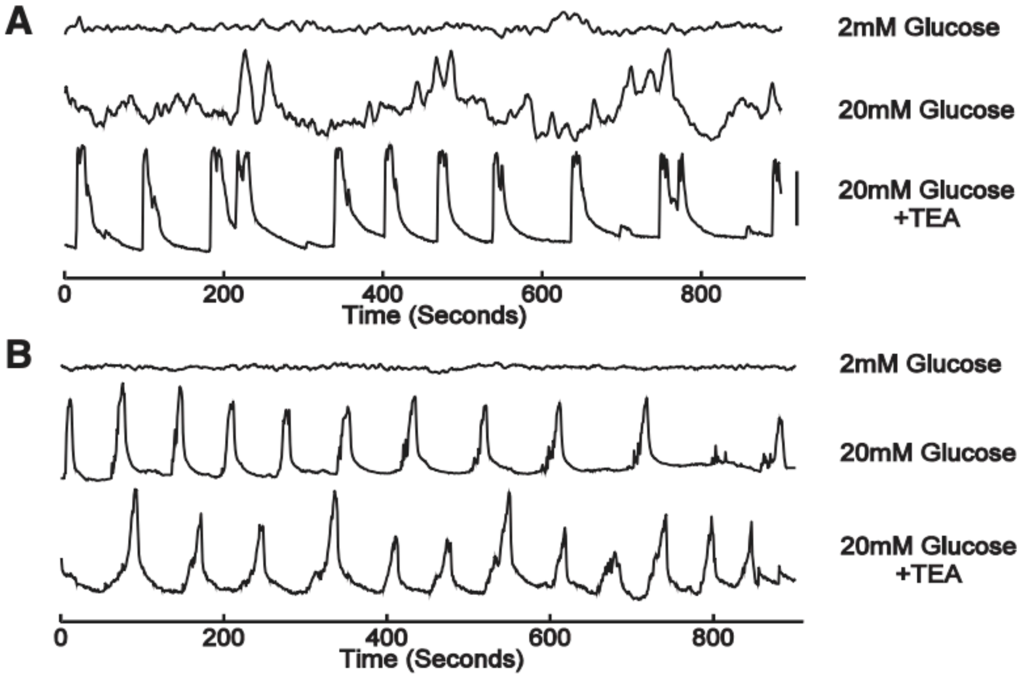
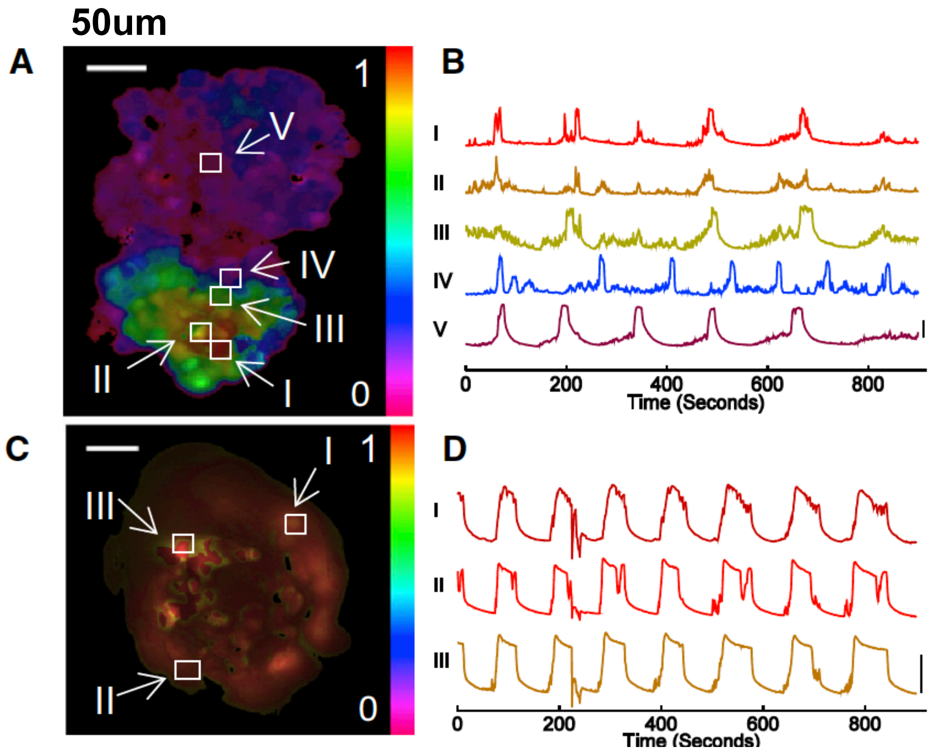
Dimension and size dependence of [Ca2+] synchronization

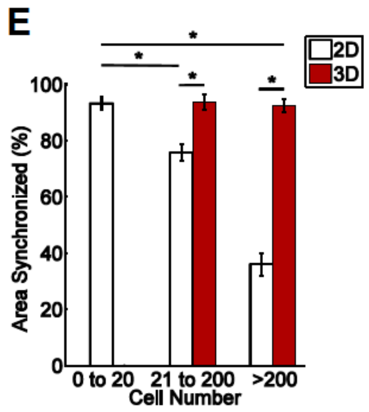
2D: ~4000 cells/mm^2 (MIN6)
3D: ~520,000 cells/cm^2 in hydrogel microwell arrays

[Ca2+] readout using Fluor4



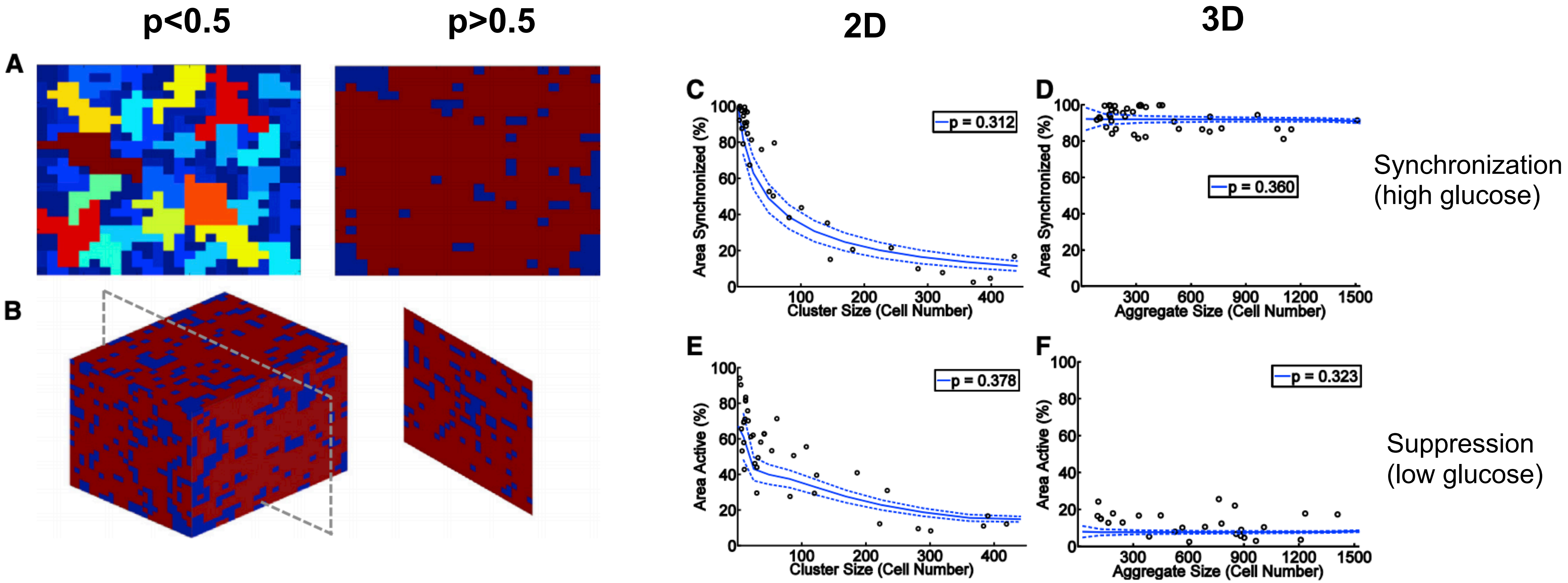


- High-glucose + TEA
- ~5 cell synchronization radius in 2D
- Synchronization is scale-dependent in 2D but not in 3D



Dimensionality and size scaling of coordinated Ca2+ dynamics in MIN6 beta-cell clusters. **Biophysical Journal. 2014**

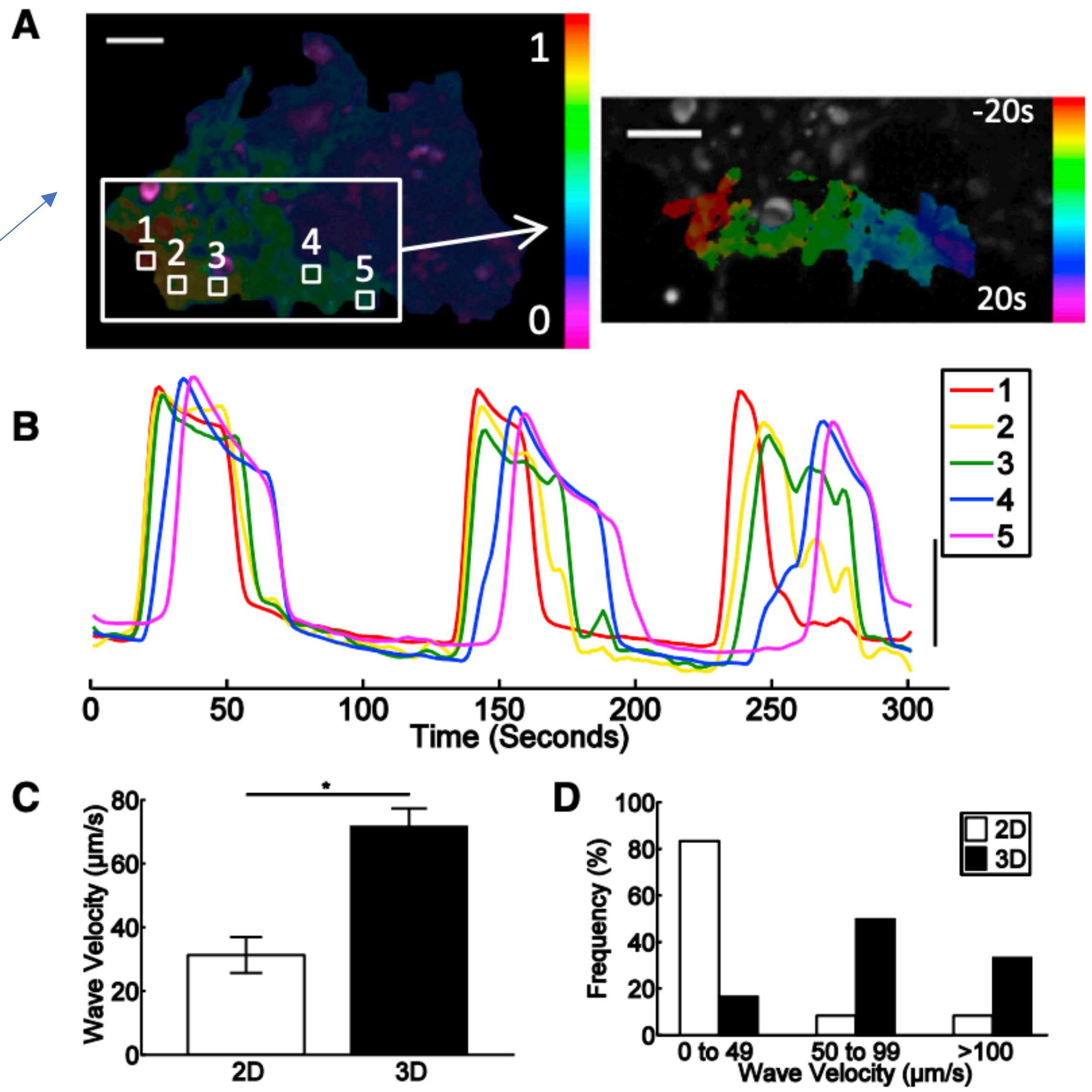
Coupled-resistor network model



Dimensionality and size scaling of coordinated Ca2+ dynamics in MIN6 beta-cell clusters. **Biophysical Journal. 2014**

Wave velocity under 2D/3D coupling

2D

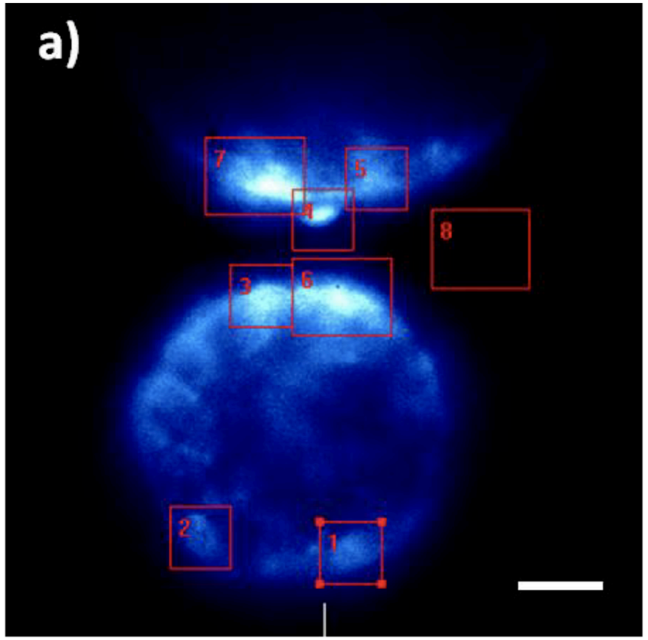


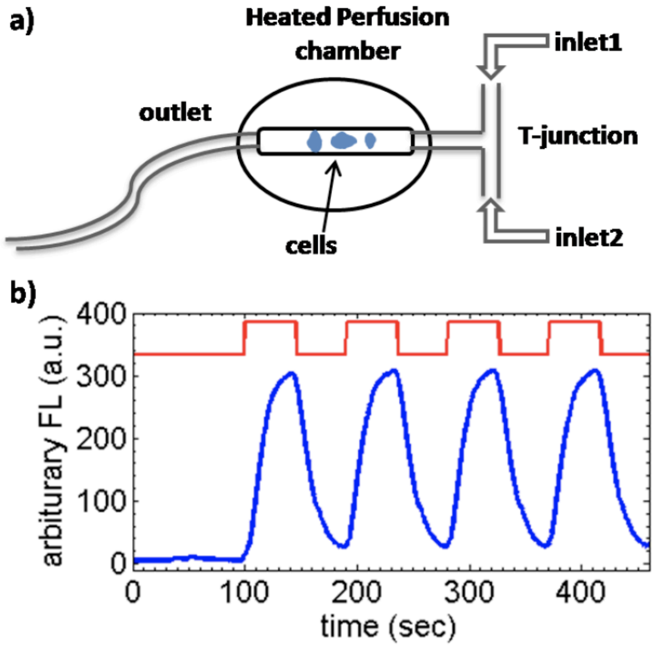
P<0.001

Dimensionality and size scaling of coordinated Ca2+ dynamics in MIN6 beta-cell clusters. **Biophysical Journal. 2014**

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





Quantifying granule transport and controlling calcium oscillations in insulin-secreting beta cells. **2010**

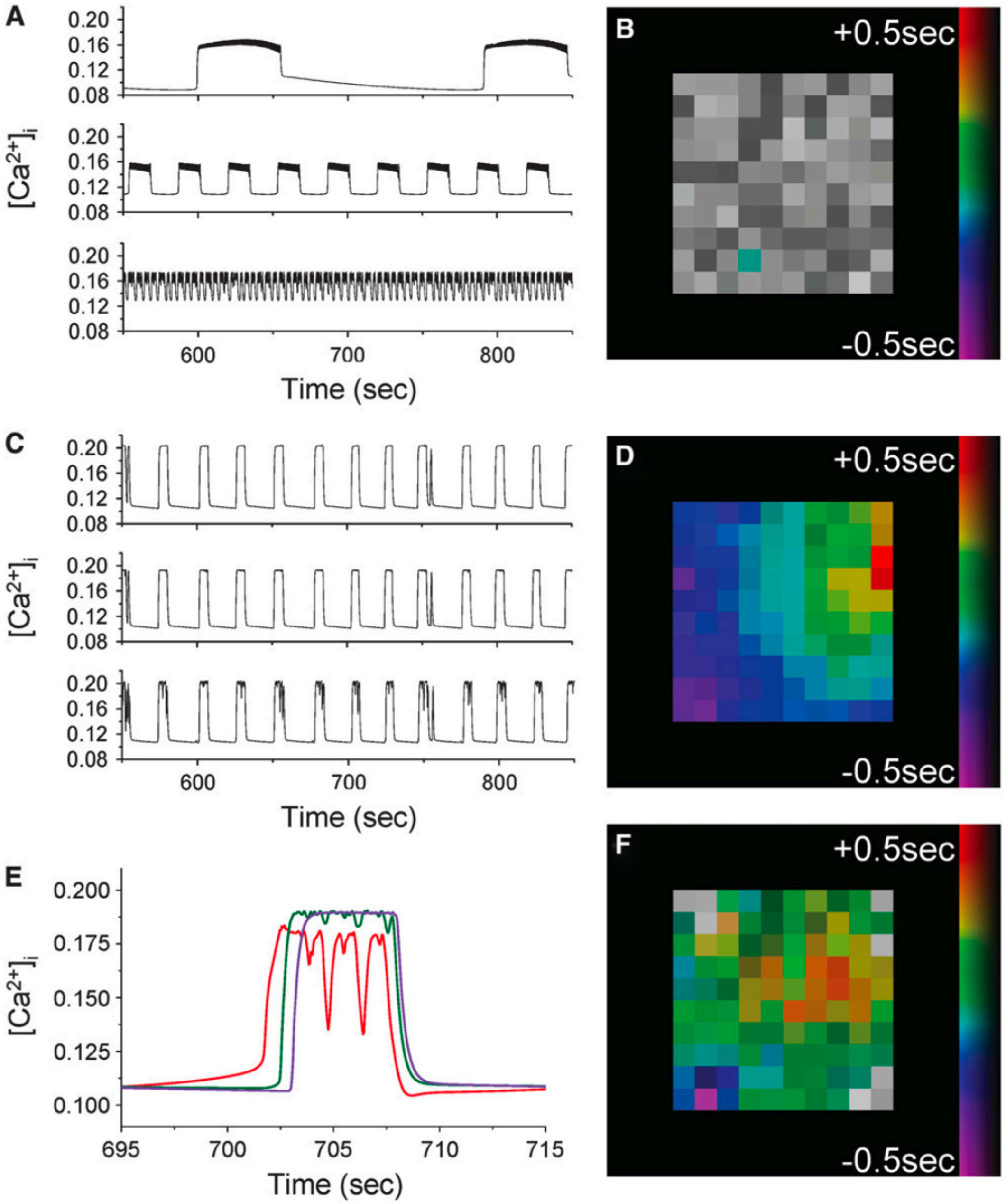
Coupled phantom burster model

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

$$I_{coupl,j} = g_c \sum_{i}^{neighbor_j} (V_j - V_i).$$

How is this distributed?

5056



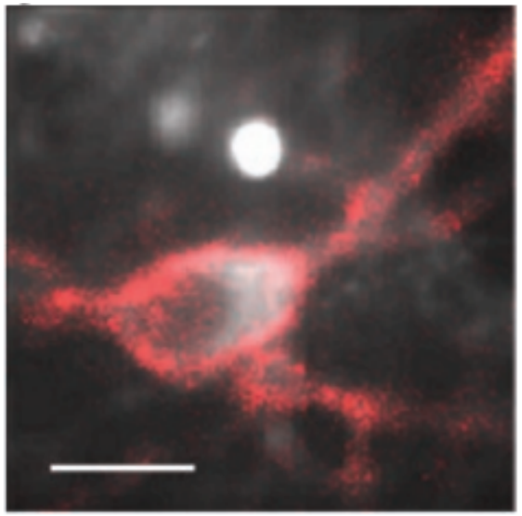
Gap junction coupling and calcium waves in the pancreatic islet. **Biophysical Journal**

Estimating membrane potentials

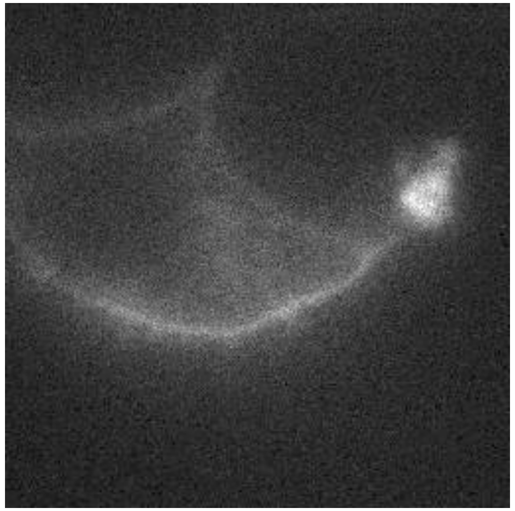
$$S_i(t) = a_i + b_i V(t) + \varepsilon_i(t)$$

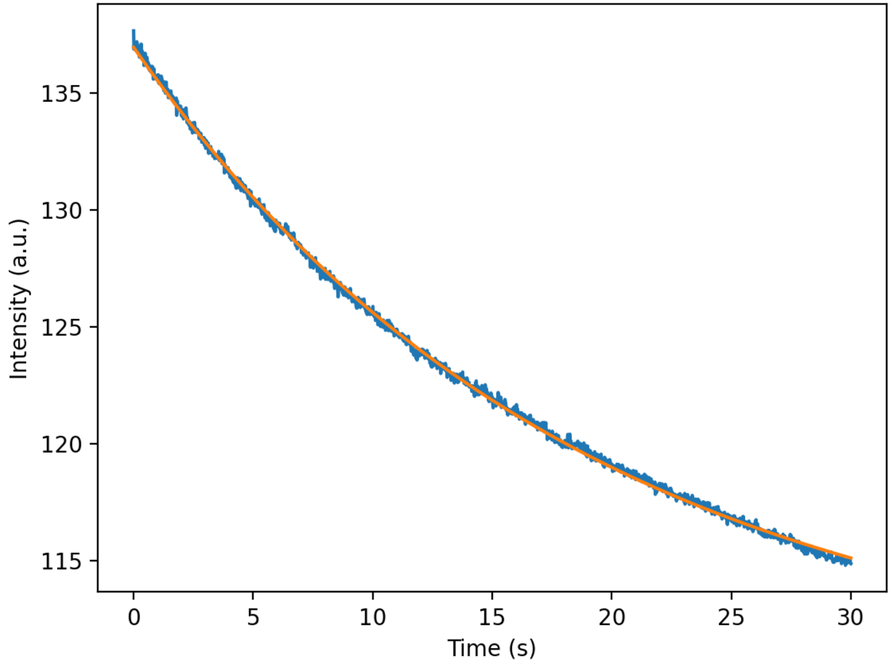
$$\left\langle \varepsilon_i(t_1)\varepsilon_j(t_2) \right\rangle = \sigma_i^2 \delta_{i,j} \delta(t_1 - t_2)$$

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

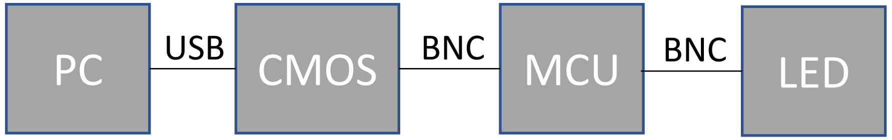


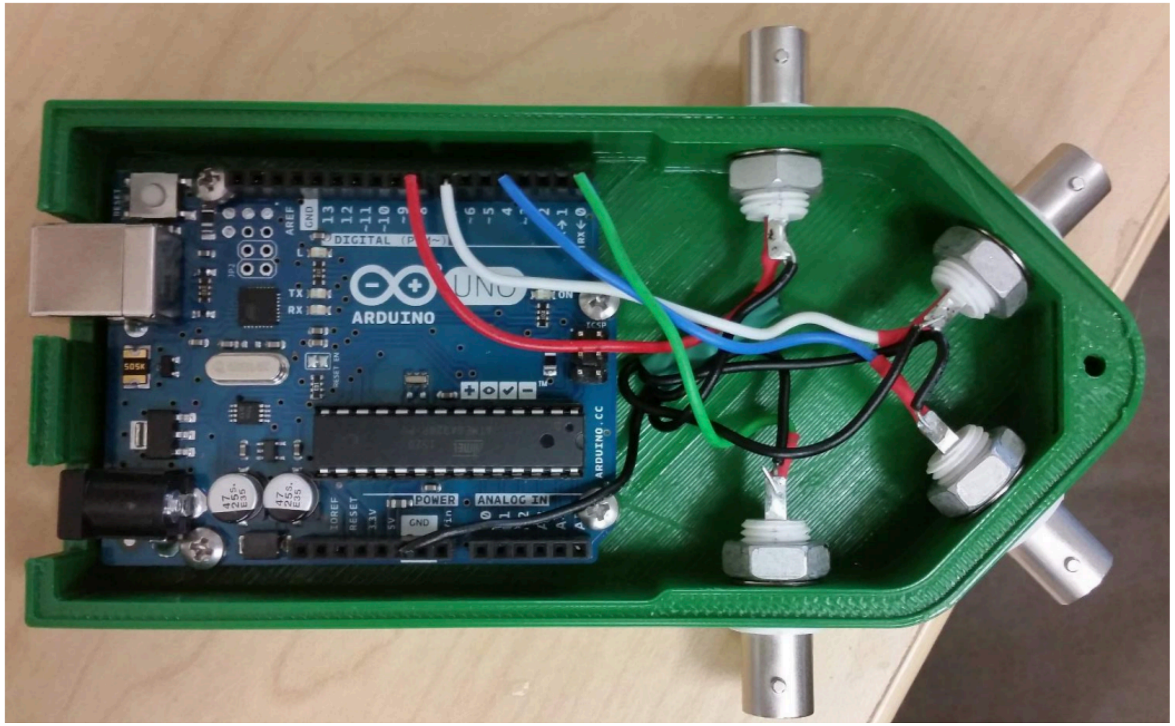
Photobleaching Correction





Optical recording of action potentials in mammalian neurons using a microbial rhodopsin. **Nature Methods**

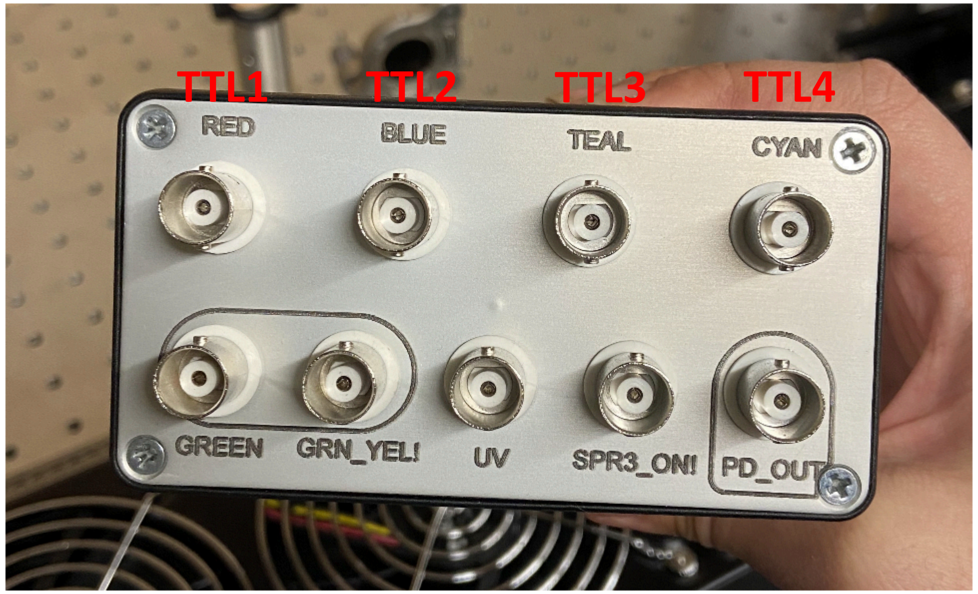


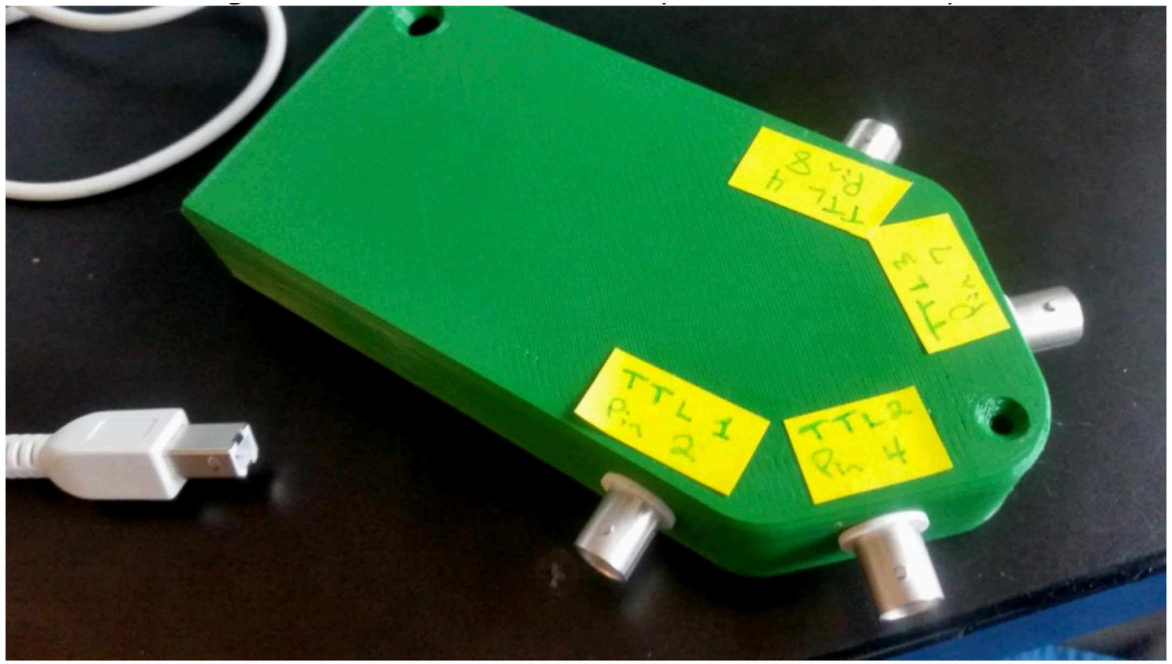


Onboard 10-bit ADC (6 channels)

16 MHz Arduino has ADC clock set to 16 MHz/128 = 125 KHz. Each conversion in AVR takes 13 ADC clocks so 125 KHz/13 = 9615 Hz

How to control intensity?





Equipment

Equipment	Supplier	PN	Cost	Unit	Comment
Arduino Uno R3	Adafruit	50	24.95	Each	
Arduino Cable	Adafruit	900	2.95	Each	
Arduino Power Supply	Adafruit	63	6.95	Each	
Female BNC Connectors	Mouser	5227726-1	3.41	Each	Need 4
Hookup Wire 22 AWG	Adafruit	3175	27.5	10x25ft	Need a very small amount
Silicone Caulk	mcmaster	63500334	9.51	Tube	Any caulk will do
Heat Shrink	Amazon	707470898884	10.29	Kit	Only need very small amount
Mineral Oil	Amazon	79567100386	4.59	Bottle	Optional, need very small amount
Solder	Mouser	601-46-502	3.86	Tube	Only need very small amount
3D Printed housing	Varies	NA	40-80		Optional
IR Beam	Adafruit	195	21.67		Optional, example 2
Male BNC Connectors	Mouser	565-4969	8.95		Optional, example 2
Total			164.24		Total
Recommended			108.49		Without general lab parts
Without housing			48.49		No 3D printed housing