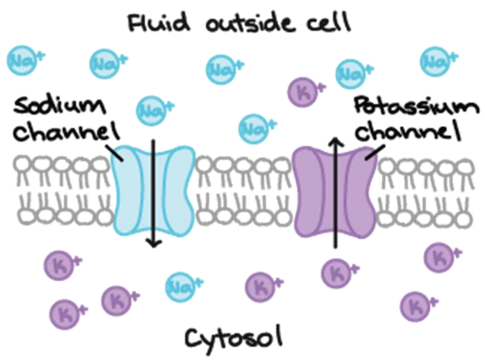
Exploring Ion transport through 2D Nanochannels

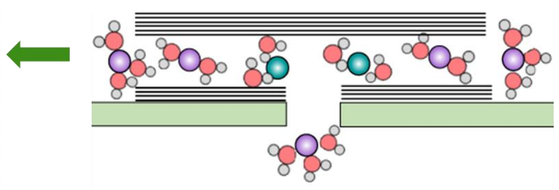
Joshua Foxton, V. Kalangi
School of Mathematics, Statistics and Physics

Motivation and Key Questions

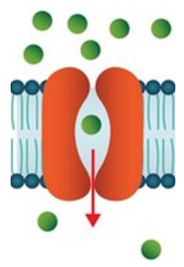
How do Neurons fire?



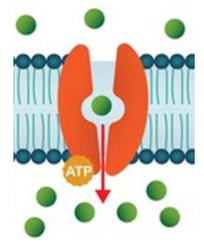
- Ion channels and ion pumps control the flow of potassium and sodium ions, enabling action potentials[1,2].



Why is Fluidic Transport at the smallest scales less explored than Electronic Transport[3]?



Passive transport with ultra-high selectivity



Active transport: Moving against the gradient

What unforeseen discoveries await as we explore fluidic transport inspired from biological pathways[3]?

Aims and Main Concepts

Aims

- Find the slipperiness of ions transported through 2D Nanochannels
- Develop in-house Python image analysis analogous to Fiji or ImageJ

Diffusion-Convection-Reaction Equation

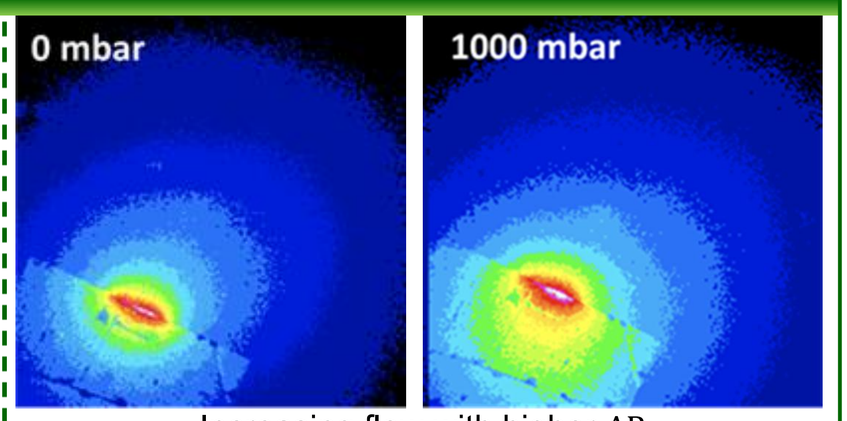
$$\frac{\partial[\mathrm{Ca}]}{\partial t} = D_p\nabla^2[\mathrm{Ca}] - \mathbf{v}\cdot\nabla[\mathrm{Ca}] - k_+[\mathrm{Ca}][\mathrm{F}] + k_-[\mathrm{CaF}]$$

Diffusion Convection Reaction

Flux Ratio – Data Analysis Equation

$$\frac{\bar{J}(\mathrm{Pe})}{\bar{J}(\mathrm{Pe}=0)} = 1 + \frac{\Delta P h^2}{24\eta D_{\mathrm{Ca}}}\left(1+\frac{6b}{h}\right)$$

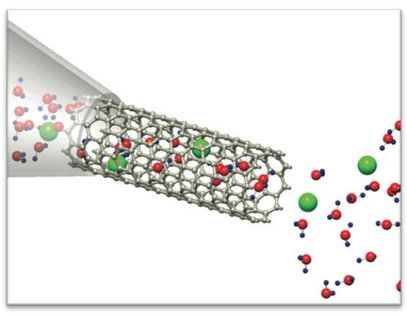
with Slip length **b**



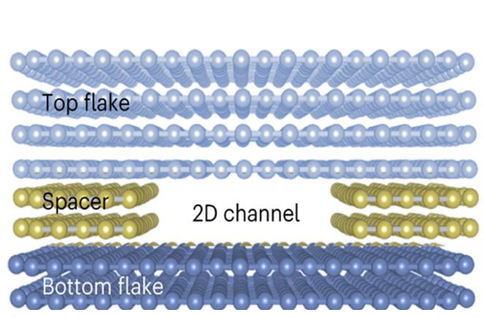
Increasing flow with higher ΔP

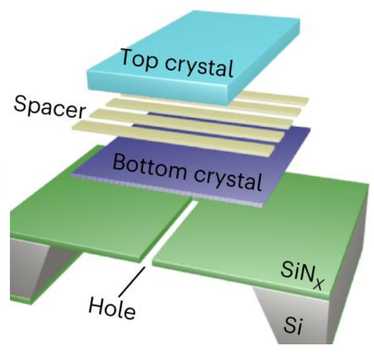
Our Approach and Findings

Visualizing Nanoscale Permeation Kinetics

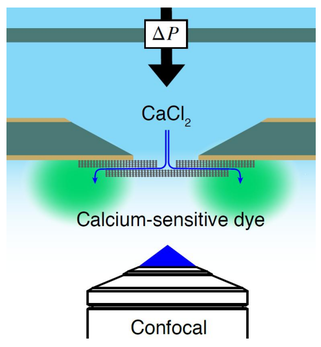


Depiction of fluid flow from Garden hose and Nanotube

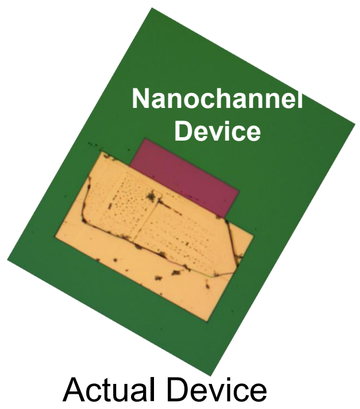




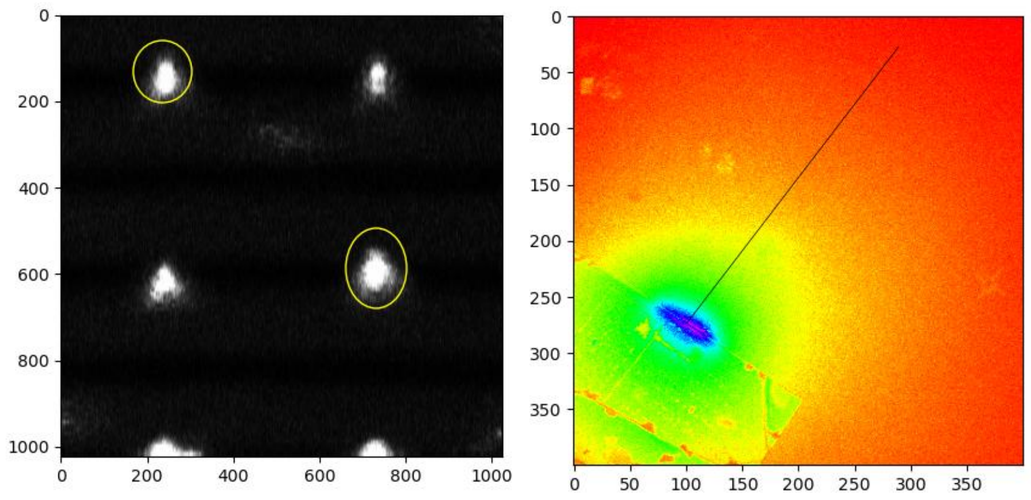
LEGO of Nanocrystals



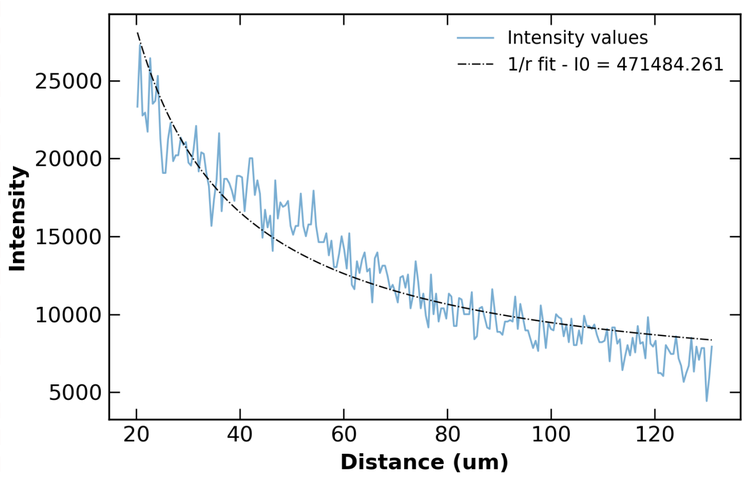
Imaging Setup



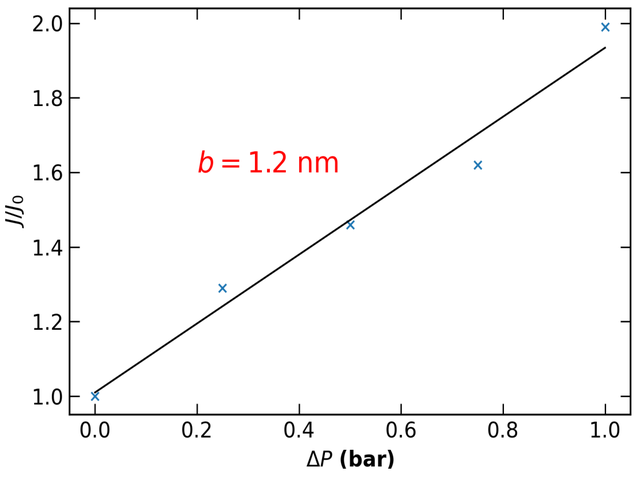
Actual Device



Developed Python analogues to Image analysis software like Fiji

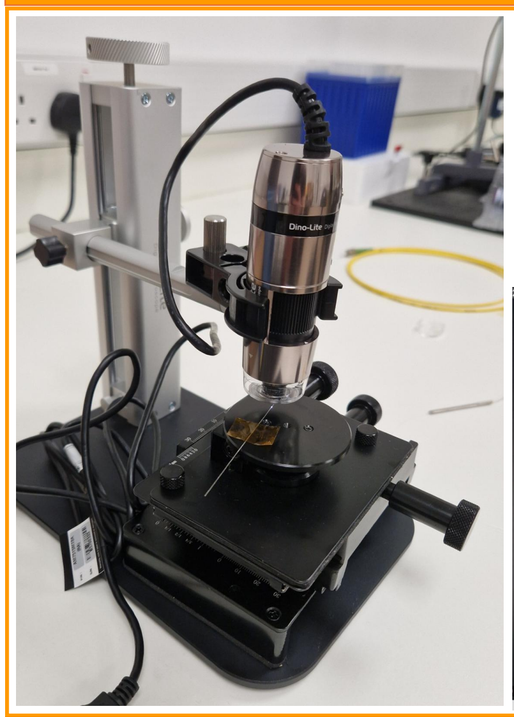


Intensity Profile



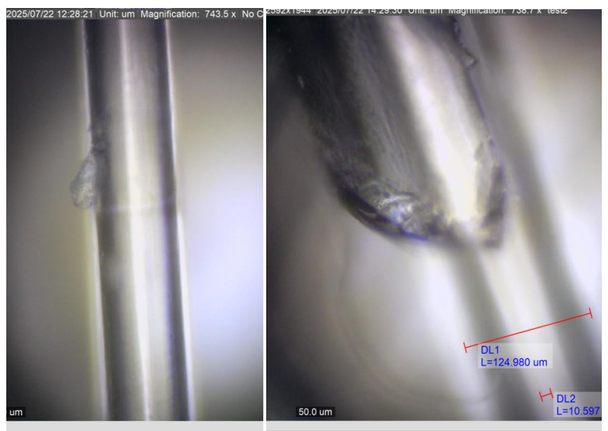
Flux Ratio with pressure

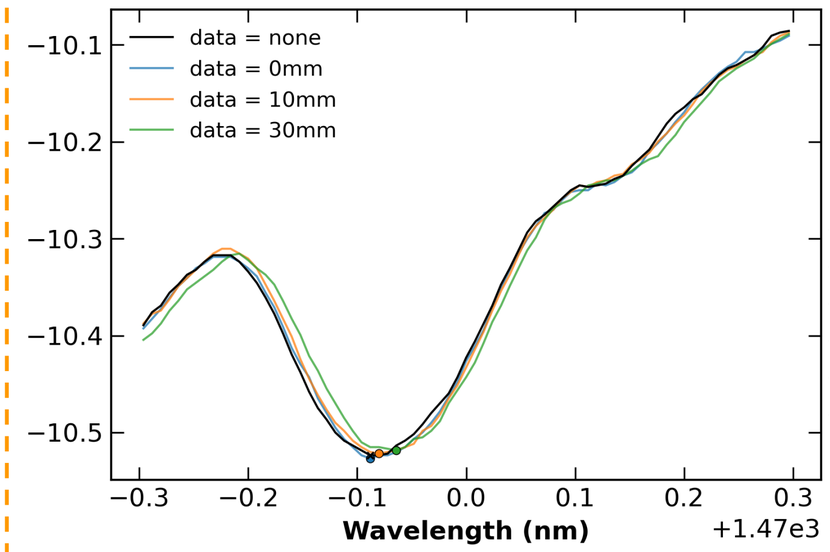
Photo-detection using Optical Fibres J. Foxton, S. Siddarama, R.Abouglila



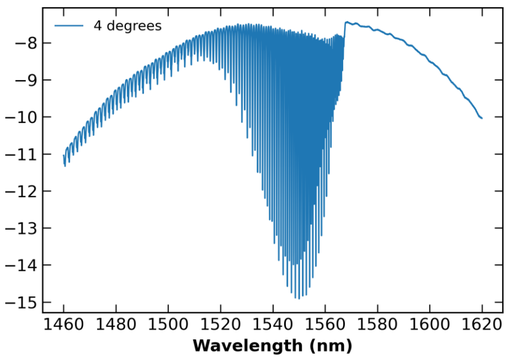
Aims

- Could optical fibres, 80 – 200 microns thick, be used as accurate light sensors?





- Applying laser to fibre sensor produced wavelength shifts on order of single- to double-digit picometres (10^{-12} m).



- At this level of sensitivity, the interrogators resolution of 8 picometres became an issue.

[1] https://neurosciencenews.com/wire-fire-neurons-19835/; [2] https://www.khanacademy.org/science/biology/human-biology/neuron-nervous-system/a/the-membrane-potential; [3] https://gtr.ukri.org/projects?ref=MR%2FX03660X%2F1;