PHYS613 Final Project

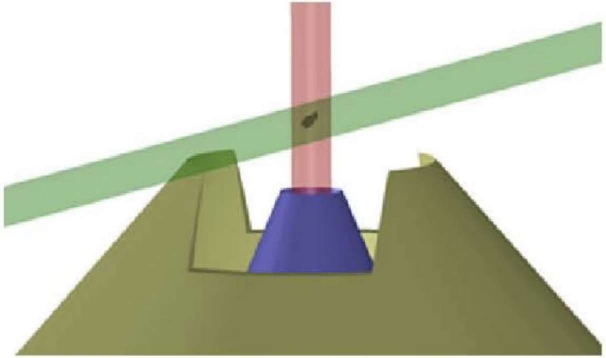
Modeling An Ion Trap

Robert Wolle

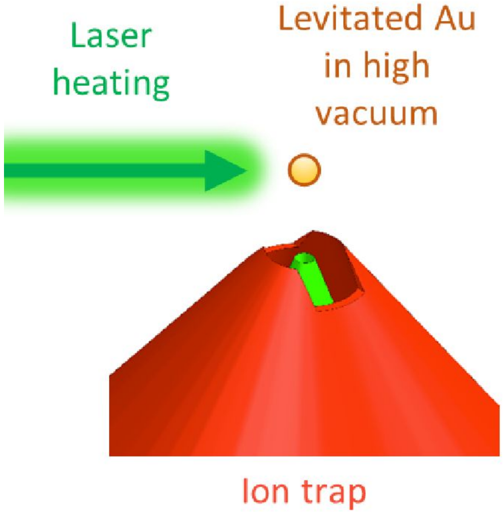
Motivation

Research at LPS:

Joyce E. Coppock, et al. *Dual-trap system to study charged graphene nanoplatelets in high vacuum* (2017)

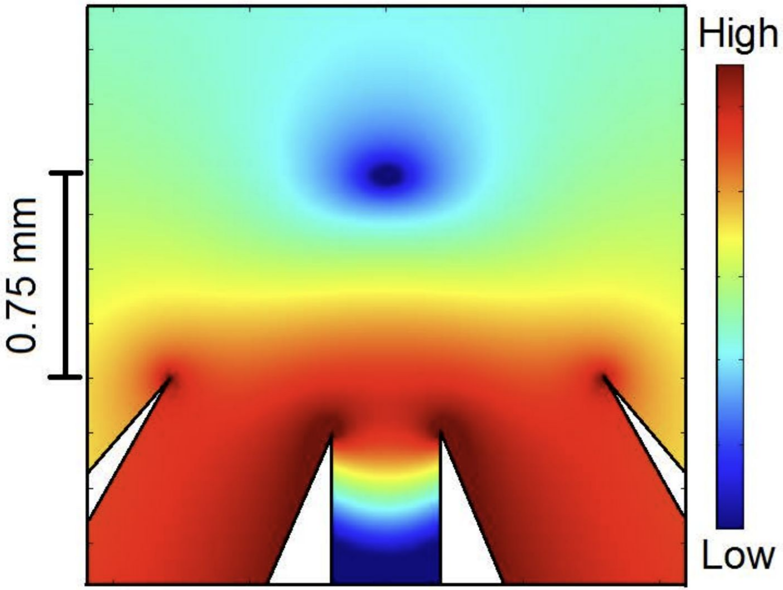


Joyce Coppock, Quinn Waxter, Robert Wolle, and B. E. Kane *Observation of Undercooling in a Levitated Nanoscale Liquid Au Droplet* (2022)



Solution

Plot of |**E**|, simulated with COMSOL



Joyce E. Coppock, et al. *Dual-trap system to study charged graphene nanoplatelets in high vacuum* (2017)

Algorithm

- 2D Laplace equation, Neumann boundaries dV/dn = 0

$$\nabla^2 V = \frac{1}{6h^2}\Big(20V_{i,j} + 4V_{i-1,j} + 4V_{i+1,j} + 4V_{i,j-1} + 4V_{i,j+1}$$

$$+V_{i-1,j-1} + V_{i+1,j-1} + V_{i-1,j+1} + V_{i+1,j+1}\Big), \quad h_x = h_y = h$$

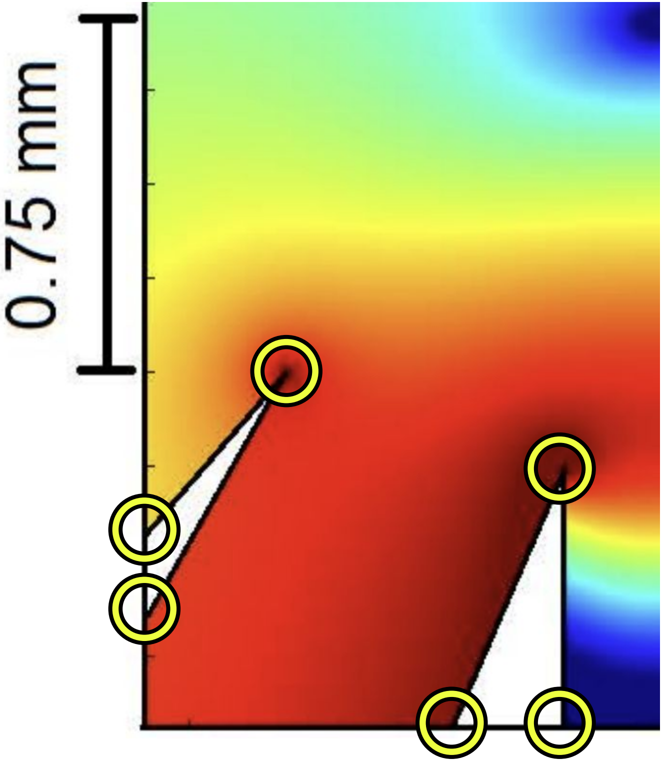
- Solved with system of linear equations **A**x = **U**

Geometry

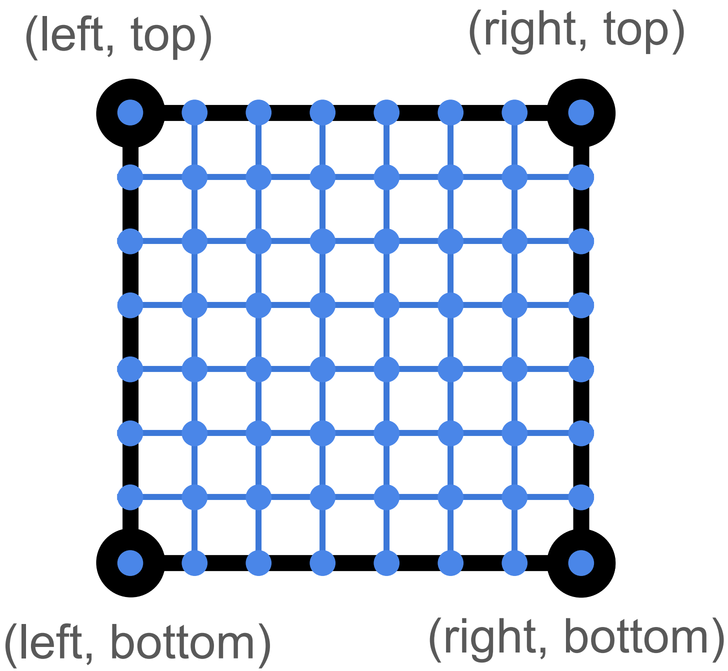
1. Define important vertices
2. Find all points inside shapes

vertex → boundaries

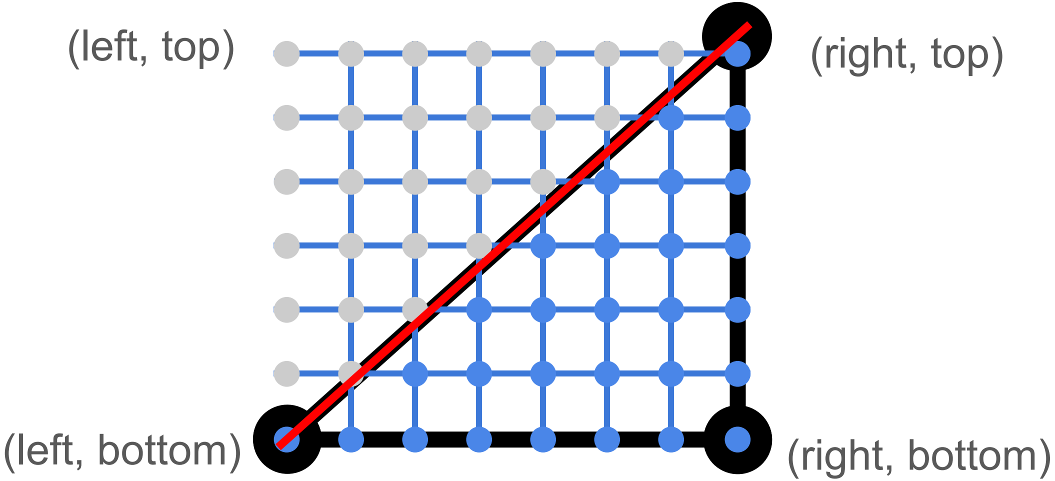
(x, y) → (i, j)



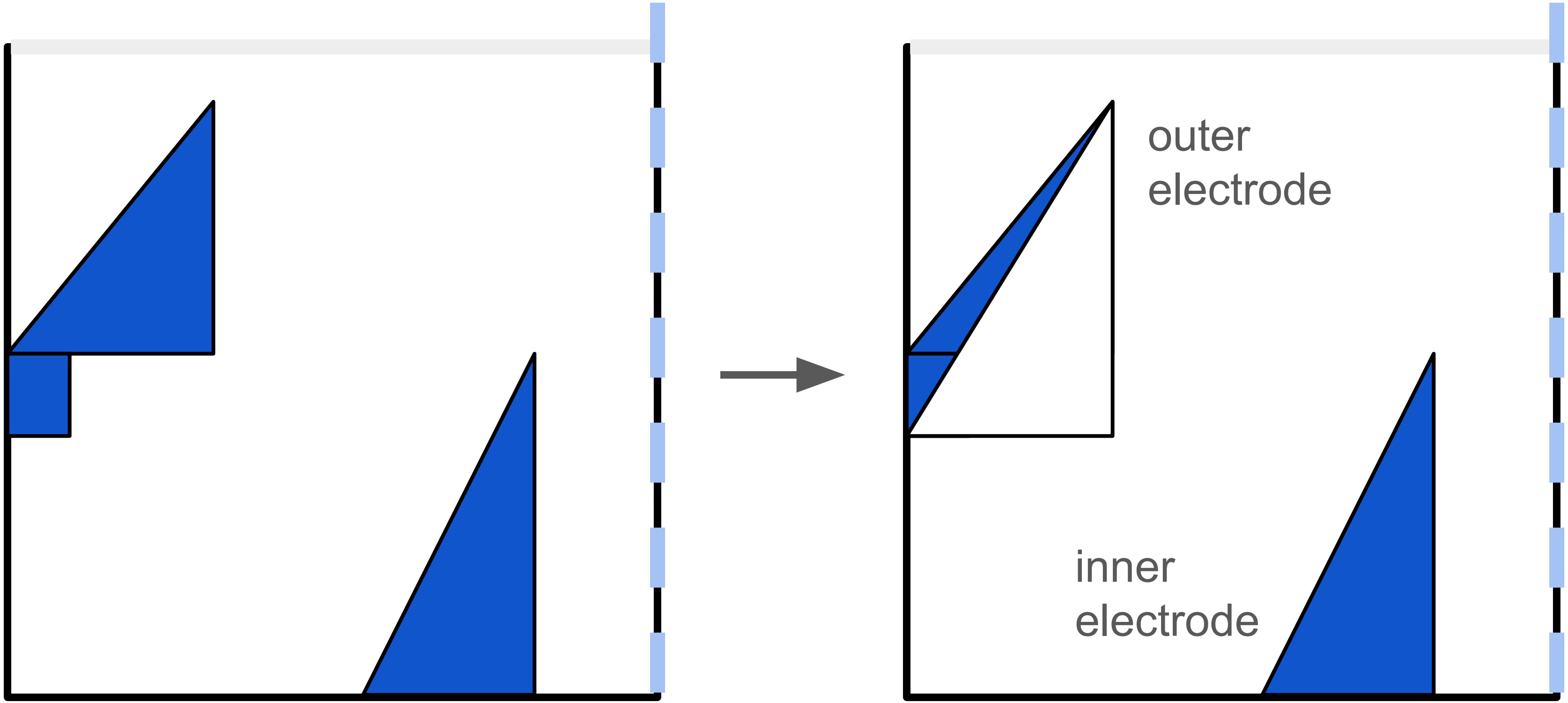
Building Shapes



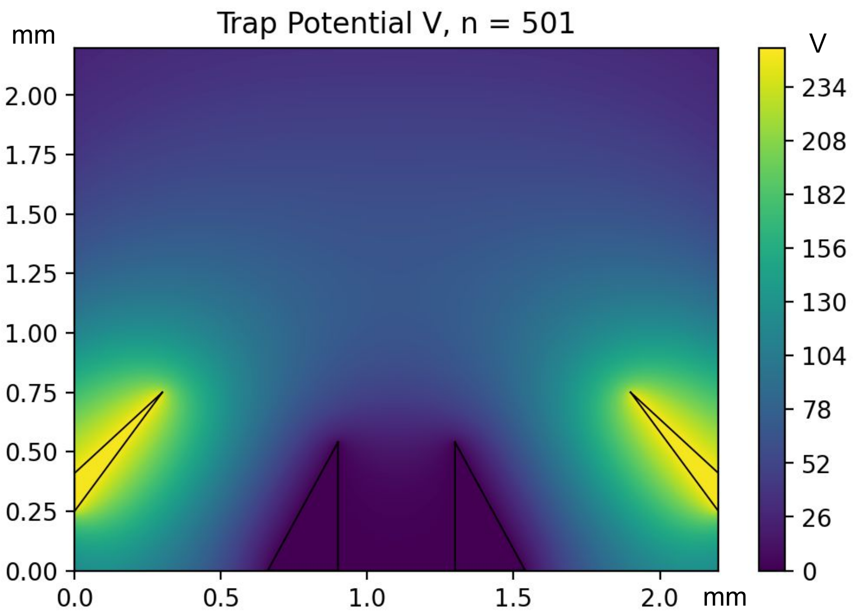
- Store all points **(i, j)** inside shapes
- Remove all points inside holes
- Exclude all stored points from **A** matrix

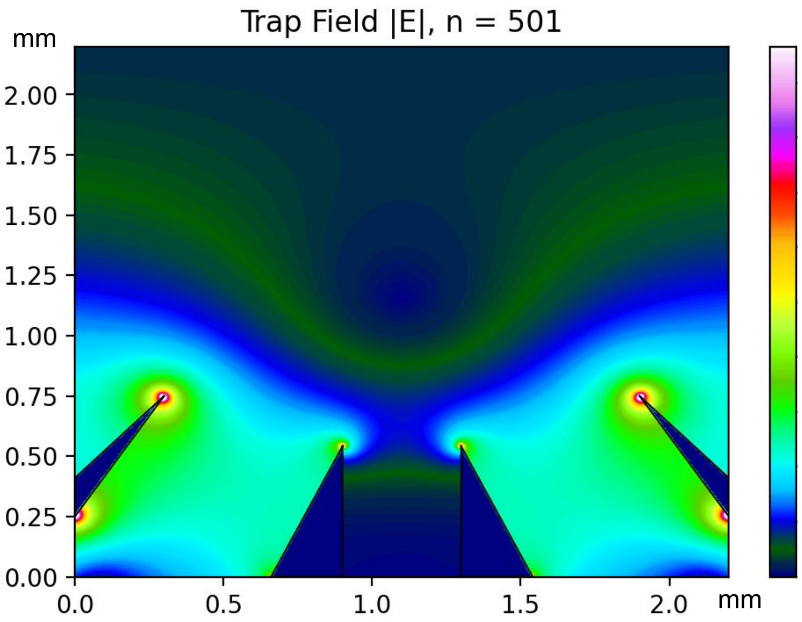


Geometry



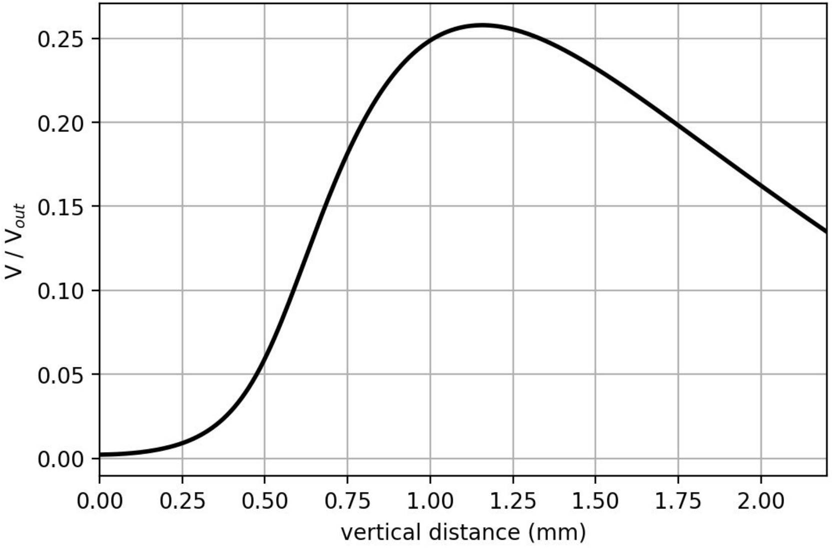
Results

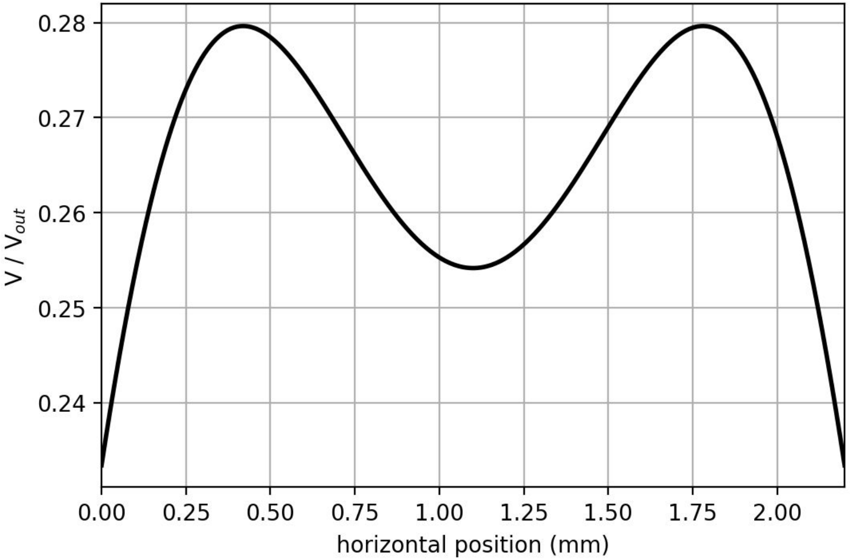




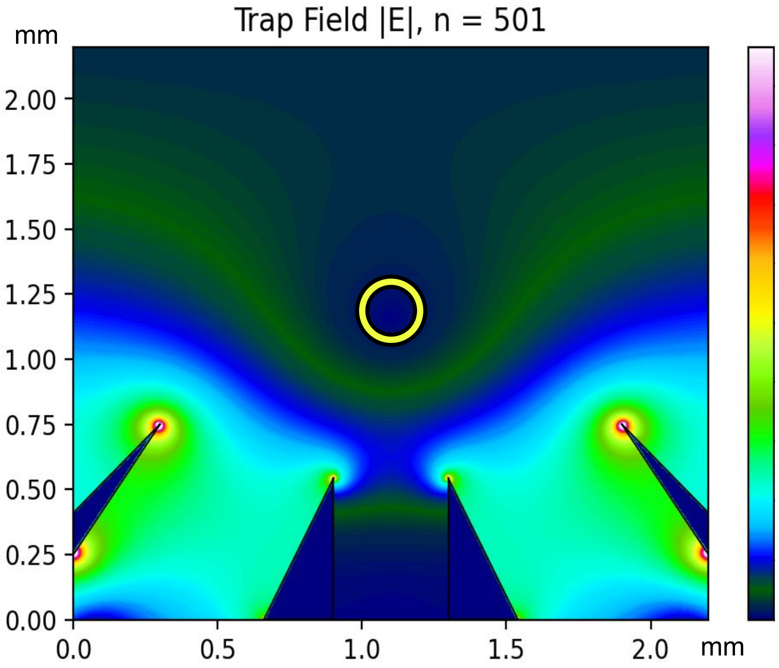
|E| = 0 at 1.16 mm, or 0.41 mm from the trap

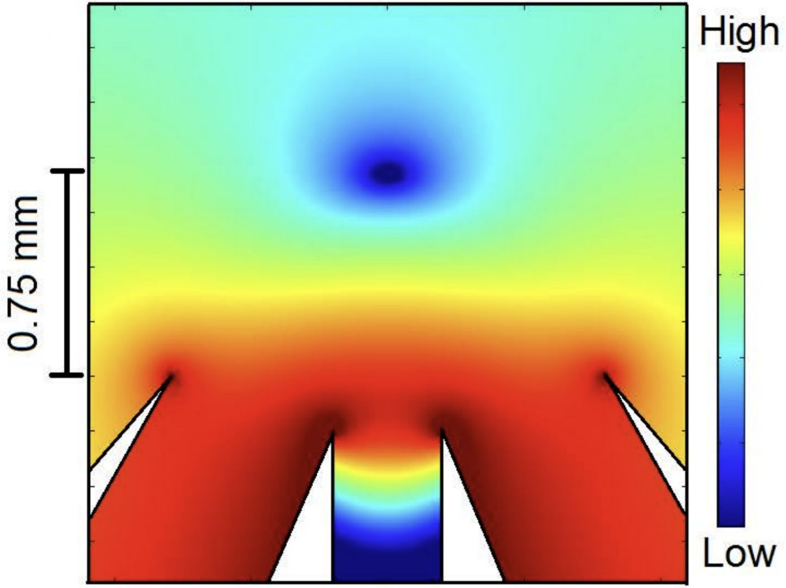
Results


V / V_{out}
0.25
0.20
0.15
0.10
0.05
0.00
0.00 0.25 0.50 0.75 1.00 1.25 1.50 1.75 2.00
vertical distance (mm)


V / V_{out}
0.28
0.27
0.26
0.25
0.24
0.00 0.25 0.50 0.75 1.00 1.25 1.50 1.75 2.00
horizontal position (mm)

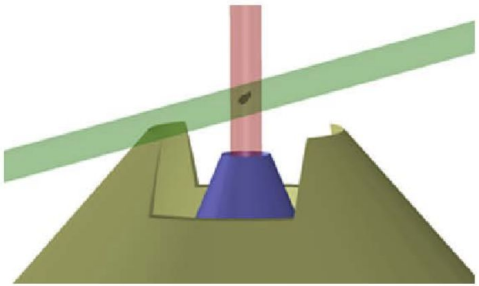
Results


Trap Field |E|, n = 501
mm
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
mm


0.75 mm
High
Low

Results

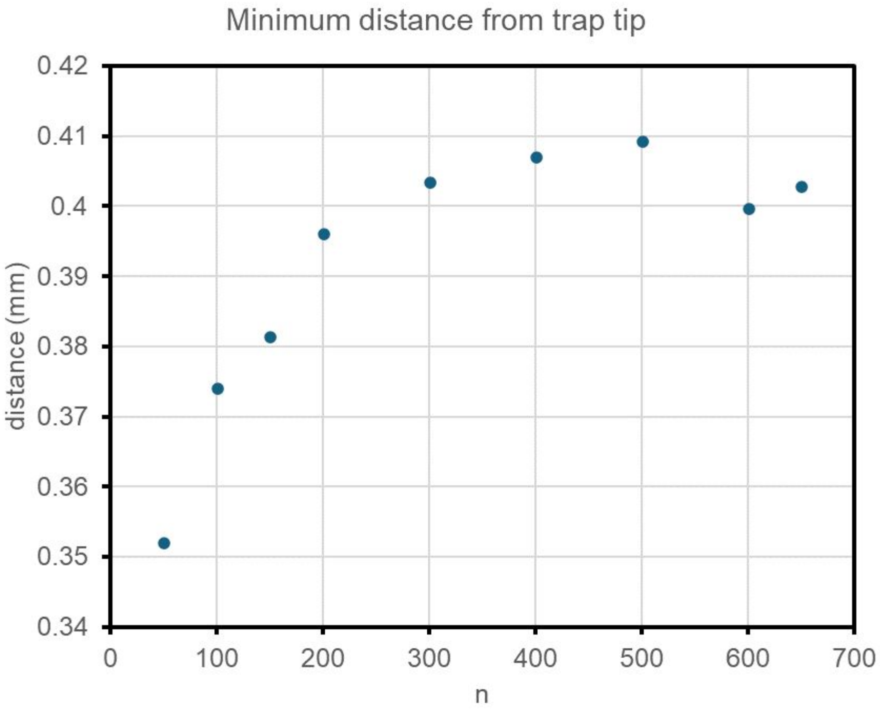
- Why don't they agree?
  - Not necessarily 2D $\longrightarrow$ 3D
  - cylindrical coordinates: $x \longrightarrow r$, $y \longrightarrow z$, $dV/d\phi = 0$
- Paper's display might be a cropped result

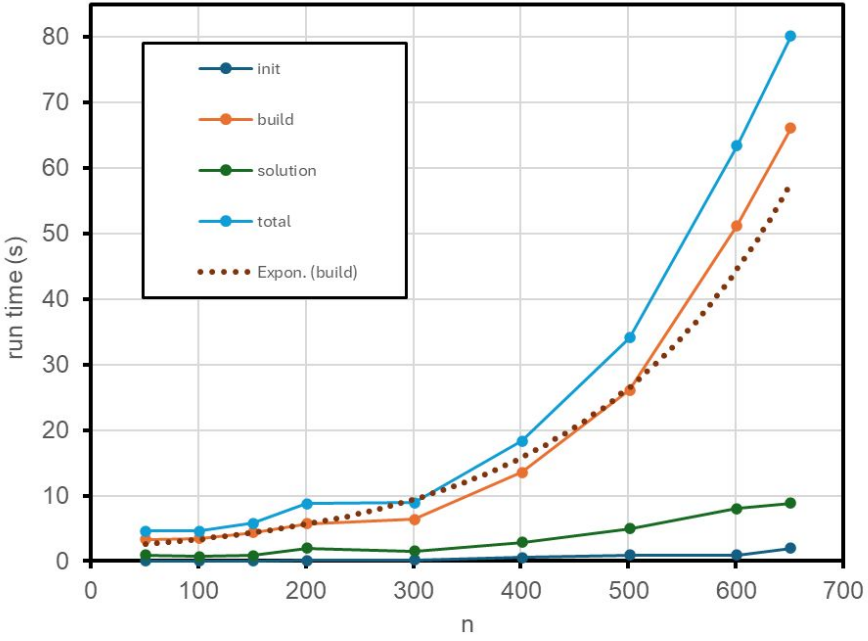


Performance

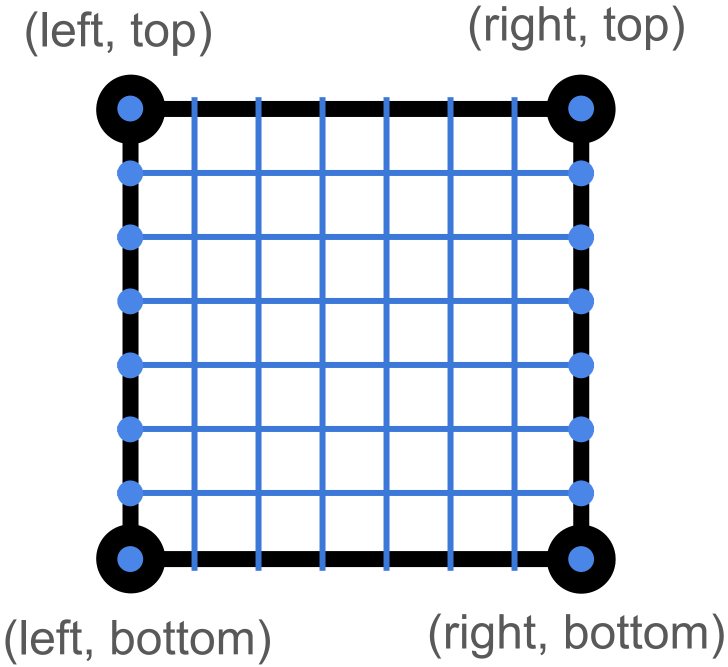
- Sparse matrices allow much higher resolution, much faster solving
  - e.g. n = 301 → **A** is 90,601 x 90,601
- Limiting factor is building time
  - Searching through even a small section of 90,000 points is expensive

Performance





Performance



- Store all rows **(i, j)** inside shapes
- Check only points near slope