Q1: Engineering Problem & Objectives

Problem:

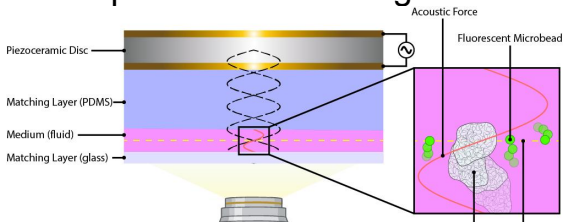
- Granular hydrogel models are unstable and are randomly arranged after creation

Objectives:

- Design and fabricate an acoustic force trap capable of generating stable bulk acoustic standing waves to manipulate hydrogel granules
- Validate results via simulation

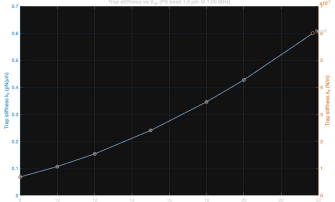
Q2: Project Design + Methodology

1. Design acoustic trapping device
2. Simulate pressure fields
3. Fabricate microfluidic chip
4. Manipulate microbeads
5. Test hydrogel granule trapping
6. Measure trap stiffness vs voltage

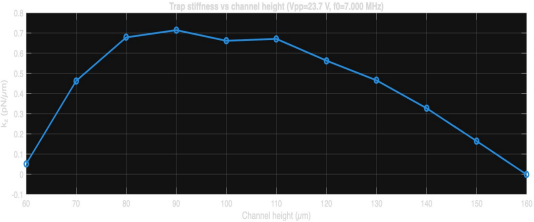


Q3: Data Analysis & Results

Trap Stiffness vs Voltage Peak to Peak



Trap Stiffness vs Channel Height



- Simulation allowed for comparisons and found optimal heights for trapping

Q4: Interpretation & Conclusion

- Trap stiffness scales with voltage
- Channel height controls Z trapping plane
- System meets theoretical force requirements
- Trapping strength is tunable
- Design supports hydrogel granule trapping
- Foundation for controlled in vitro stabilization and patterned LLS with cells

Engineering Problem

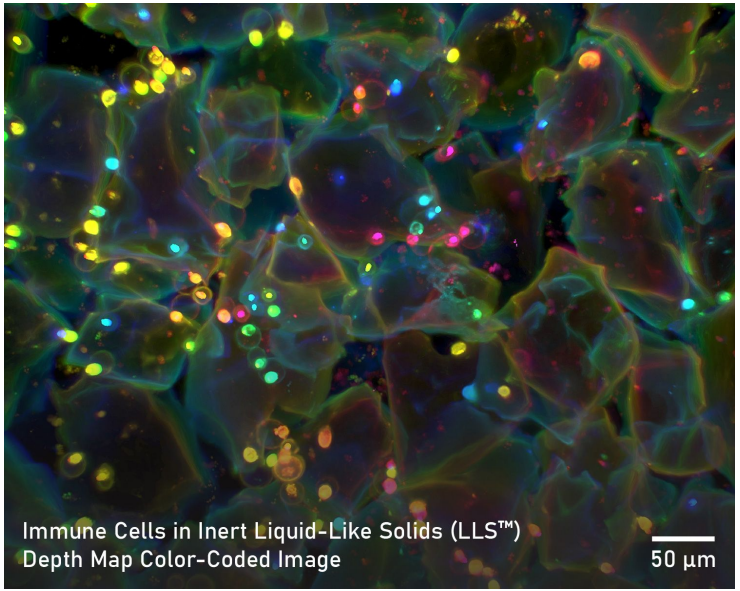
- Granular hydrogel models are unstable
  - No control of hydrogels after fabrication
  - Random granule arrangement

Engineering Goal

- Design a tunable acoustic trapping device capable of XY positioning of hydrogel granules

Current Research

- Acoustic trapping of microbeads (8µm)
- Static standing wave systems

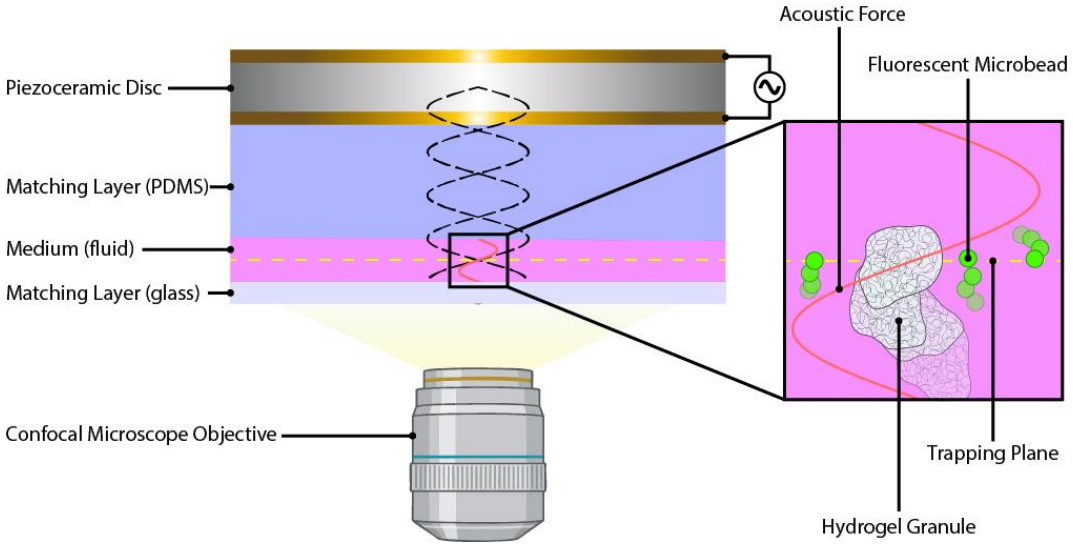


Methods

Acoustic Force Trapping

Standing waves create pressure nodes and antinodes leading to particle migration

- The transducer creates alternating regions of high and low pressure.
- Particles experience acoustic radiation forces that drive them towards stable pressure nodes, where they are trapped.



Methods - Testing Procedures

1. Design acoustic trapping device
2. Simulate pressure fields
3. Fabricate microfluidic chip
4. Manipulate microbeads
5. Test hydrogel granule trapping
6. Measure trap stiffness vs voltage

Simulation: Data collection

1) Acoustic pressure field in the channel
   a) To validate trapping stability
2) Particle trapping plane location
   a) To find for imaging
3) Trap Stiffness
   a) To analyze strength of trap
4) Voltage sweep
   a) To improve trap stiffness
5) Channel height sweep
   a) To locate optimal channel heights

Simulation

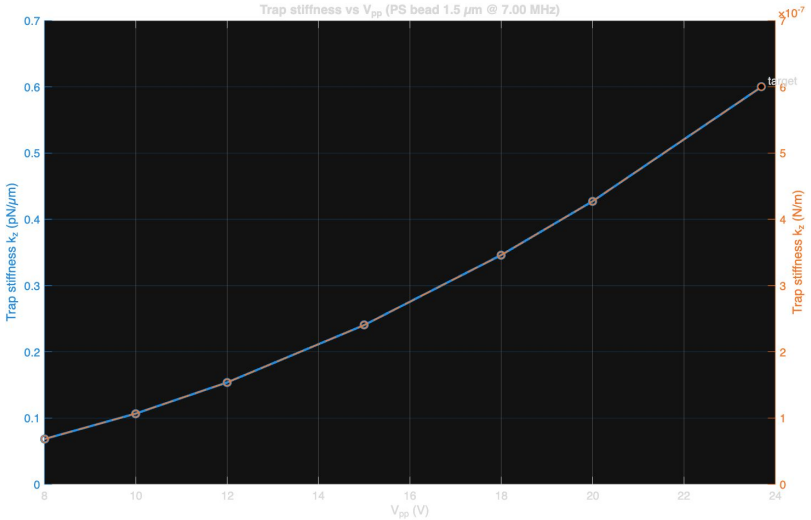
Trap Stiffness

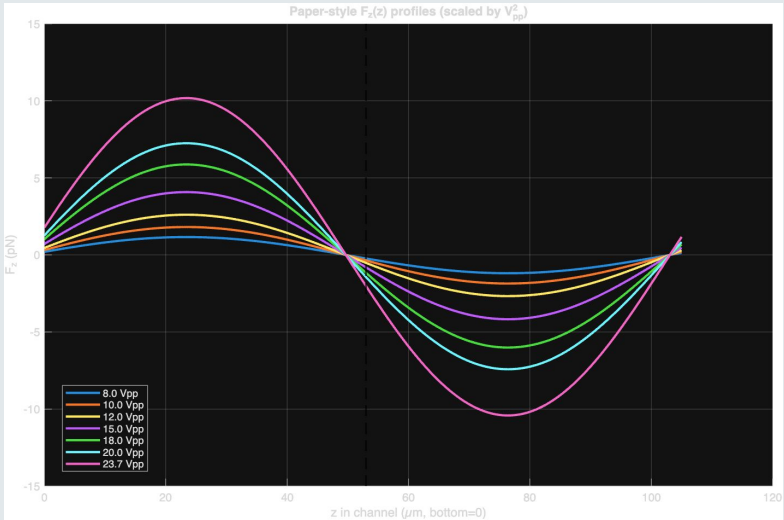
- ❏ Increased voltage leads to stronger acoustic radiation force
- ❏ Enables trapping of larger hydrogel granules
- ❏ Tunable trapping strength

Voltage Peak to Peak (VPP)

↓

Higher VPP
Greater Pressure Amplitude
Stronger Radiation Force
Increased trap stiffness



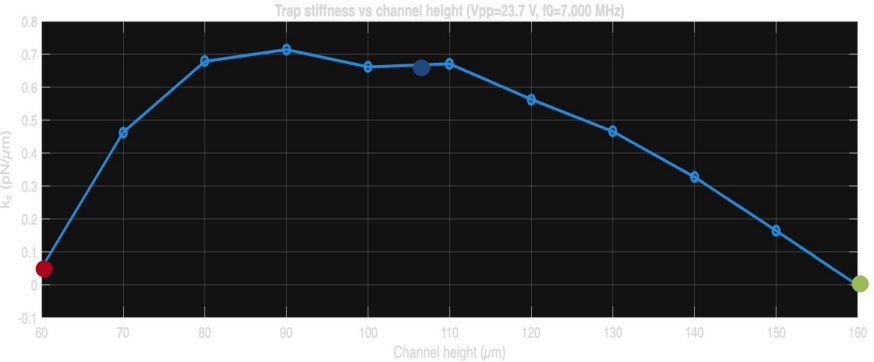


Simulation Results

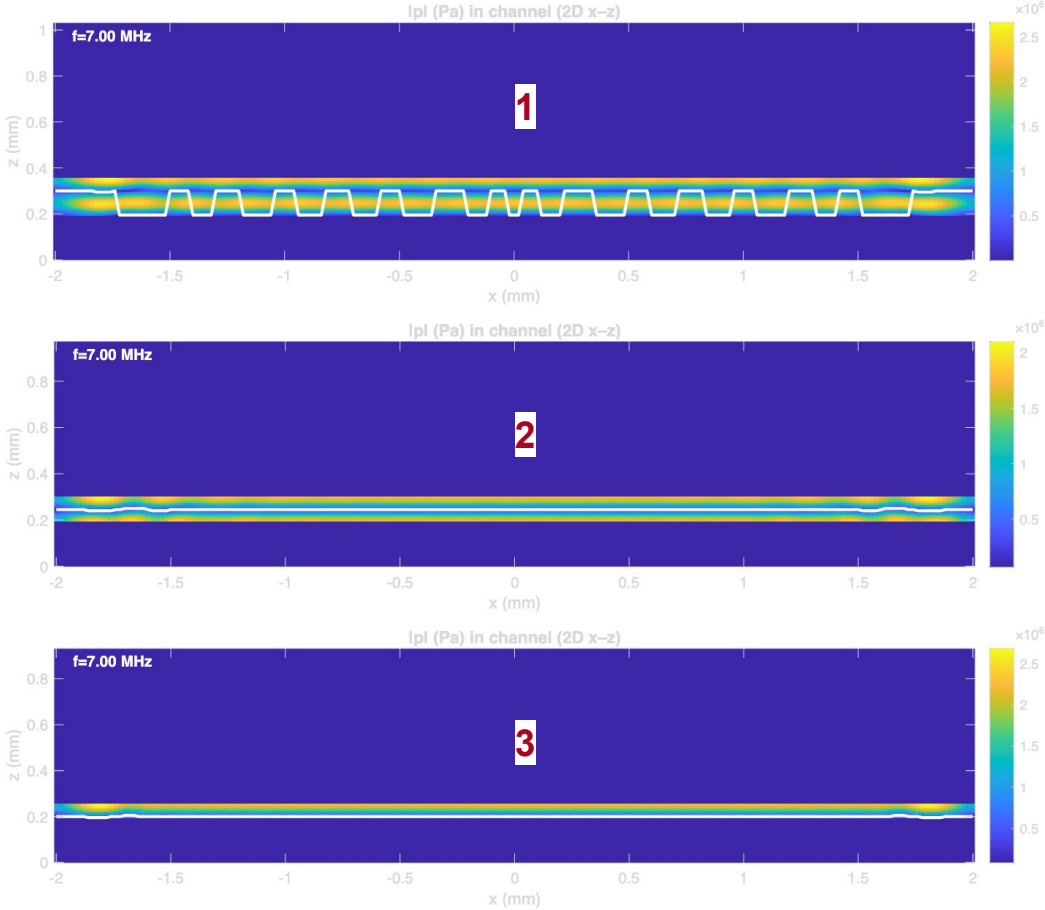
Trap Stiffness Comparison

- Finds optimal channel height for highest trap stiffness

Red: Graph 3 → Suboptimal (60µm)
Blue: Graph 2 → Optimal (106µm)
Green: Graph 1 → Suboptimal (160µm)



Trap Stiffness vs Channel Height (Vpp=23.7 V, Piezo: 7.00MHz)



Discussion & Conclusion

Results:

- Standing wave trapping behavior is reproduced in simulation
- Trapping plane can be predicted
- Scalable voltages support larger particles

Challenges:

Physical testing could not be completed

- Used simulation and design validation

No experimental validation of trapping stability

- Ran voltage sweeps and channel height sweeps to identify optimal trapping conditions

Risk of mismatch between simulation and real damping

- Included material damping in simulation model

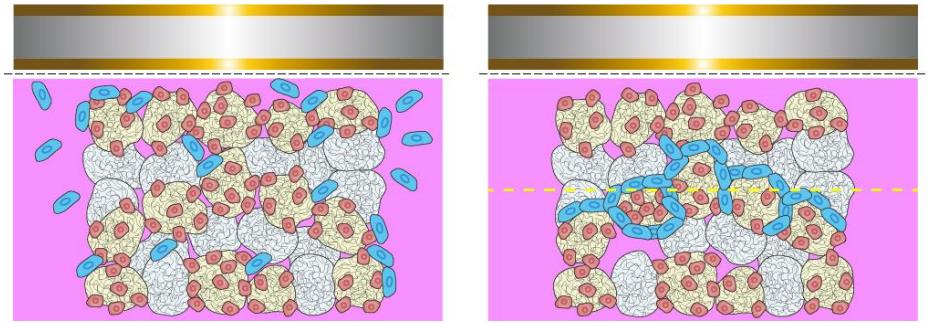
Improvement Over Current Research

- Extends acoustic trapping from beads to LLS
- Predicts trapping plane location before fabrication
- Supports future work towards stabilized and controlled granular in vitro scaffolds

Discussion & Conclusion

A) Did the project turn out as expected?
- The simulation worked properly and showed standing wave trapping behavior
- Trap stiffness scaled with Vpp consistent with other research papers and theory
- Experimental results were not achieved due to hardware delay

B) What are future applications for this project?
   a) 3D (x, y, and z) particle positioning control
   b) Acoustic trapping assisted bioprinting
   c) Patterned LLS with embedded cells



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