Microfluidic Cell Sorter

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ABSTRACT

- Current microfluidic chips move cells too fast past the detector
  - Goal is to design a microfluidic plate that will sufficiently slow cells down
  - Need to consistently hold an x, y, z location for cells
- Two designs selected for additional testing
  - Funnel Design
  - Inertial Ordering (AKA Snake Design)
- Flow simulations utilizing SolidWorks
- Results:
  - Funnel shows promise, further experimentation needed
  - Snake design hiccups, little control over centering cells
- Future:
  - Alterations to designs
  - Prototyping

BACKGROUND

Skala Lab

- Run by Dr Melissa Skala
- Research focuses on studying cancer via photonics-based technology
- Developed new cell sorting tech with aid of the Morgridge Institute

Cell Sorting

- Process of separating cells by size or type for further analysis
- Usually accomplished via an innate system of size identification or via labelling/tagging
- Often important as a source of cell identification and for stem cell research

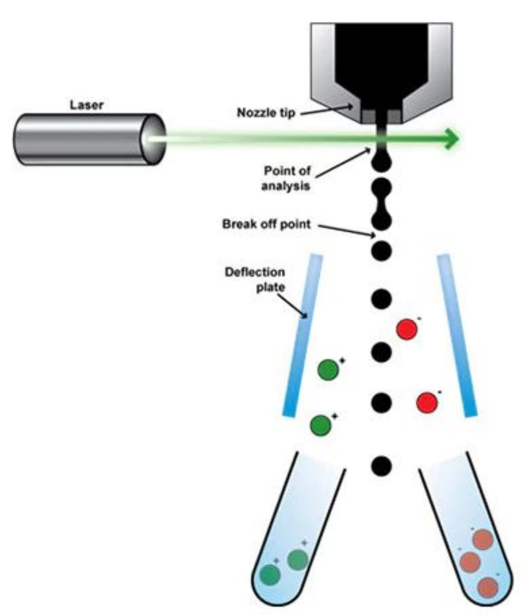

Figure 1. Fluorescence Activated Cell Sorting (FACS)[1].

DESIGN CRITERIA

- Sufficiently slow cells down (Flow speed of ~1 mm/s)
- Should allow for 100's of ms integration time on the detector
- Single-file cell flow through interrogation window
- Flow in PBS (Phosphate-Buffered Saline)
- Cells held in a fixed x, y, z location
- Flow cell has to fit the microscope stage insert
- Bottom side of the flow cell would need to have ~150 micron glass thickness and accommodate the ~1 inch wide objective lens with a working distance of 0.2 mm.

FINAL DESIGNS

Funnel Design

- Based on previous in-lab designs
- 3D cone-shaped cellular inlet
- Allows sheath flow to surround cell injection site
- Cell centering is more consistent

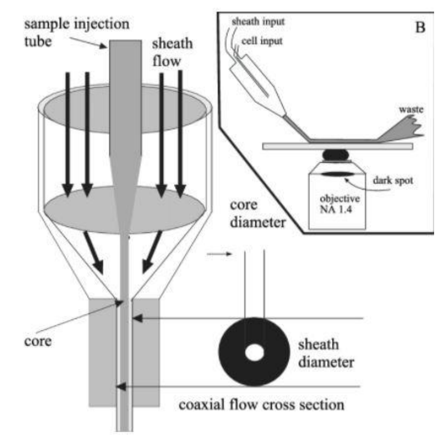

***Figure 2.** A sample prototype for a Funnel Design with Sheath Flow.*

Inertial Focusing

- Cells laterally focus themselves
- Potential to reduce flow via outlets
- The sum of inertial lift forces encourages cells to line up as they take the path of least resistance

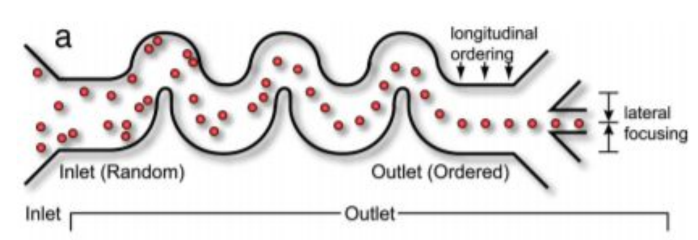

***Figure 3.** A sample prototype for an inertial channel.*[2]

TESTING AND RESULTS

Flow Simulation

- Models generated via SolidWorks
- Basic flow simulation with static pressure at the outlet

- Results in faster fluid velocity as fluid gets confined in funnel
- Radius of fluid stream containing cells is reduced

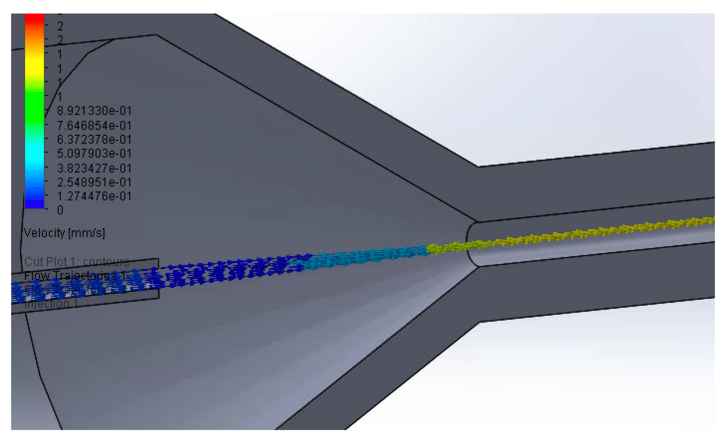

***Figure 4.** Flow simulation of Flow Trajectories for Funnel design.*

- Inlet speed of snake run at 0.05m/s
- Results in more speed near the center of the channel
- Appears to work well asymmetrically

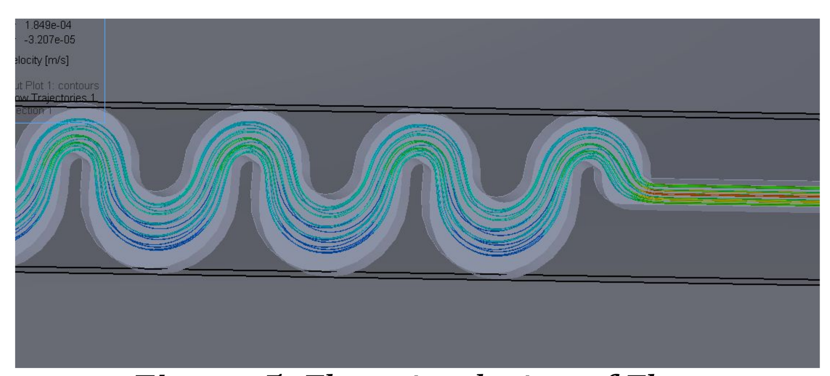

***Figure 5.** Flow simulation of Flow Trajectories for Snake design.*

Particle Tracing

- Particle simulation utilizing particle size of 10 μm
- Results in centering within channel

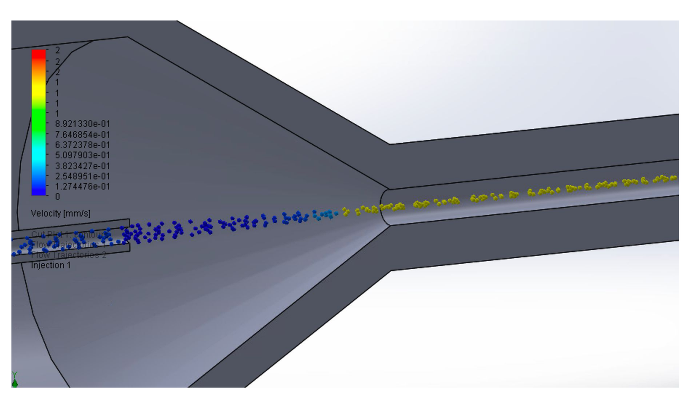

***Figure 6.** Flow simulation of Particle Tracker for Funnel design.*

- Particle simulation utilizing particle size of 10 μm in 50 μm channel
- Does not seem to result in obvious centering

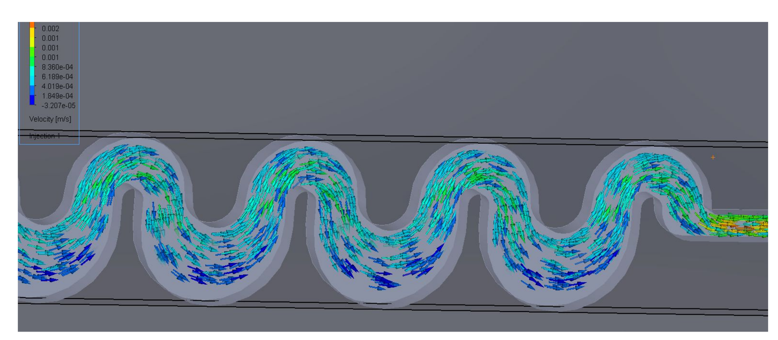

***Figure 7.** Flow simulation of Particle Tracker for Snake design.*

RESULTS CONT'D

Mathematical Considerations

- **Dean Number**

$$De = Re(D_h/2r)^{1/2}$$

***Figure 8.** Dean Number describes the ratio of viscous and centrifugal forces in a curved channel.*

- **Reynolds Number**

$$R_c = \frac{U_m D_h}{\nu} \qquad R_p = R_c \frac{a^2}{D_h^2} = \frac{U_m a^2}{\nu D_h}.$$

***Figure 9.** Channel and Particle Reynolds number. These values predict if particles move by inertial lift or viscous forces.*

Velocity Profiles for Funnel

- Velocity of the fluid in the channel at different Sheath Flow speeds
- During testing it was found that the inlet velocity of the cells had no significant effect on the velocity of fluid in channel

Velocity (Cells) [mm/s]	0.1	0.1	0.1	0.1	0.1
Velocity (Sheath Flow) [mm/s]	0.001	0.005	0.01	0.015	0.02
Velocity in the channel [mm/s]	0.148	0.656	1	2	3

***Figure 10:** Table of final velocities in the channel that correspond to the variety of inlet velocities*

Velocity (Cells) [mm/s]	0.1	1	0.1	1	0.1	1
Velocity (Sheath Flow) [mm/s]	0.01	0.01	0.055	0.055	0.1	0.1
Velocity in the channel [mm/s]	1	1	7	7	13	13

FUTURE WORK

- Optimize dimensions
- Create turbulence-free connection
- Fabricate prototypes in the Morgridge Center Fab Lab
- Test the designs with polystyrene beads
- Decide on one final design
- Conduct thorough efficacy testing with cells

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- Emmanuel Contreras
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- Dr. Justin Williams

REFERENCES

[1] D. D. Carlo, D. Irimia, R. G. Tompkins, and M. Toner, "Continuous inertial focusing, ordering, and separation of particles in microchannels," *PNAS*, vol. 104, no. 48, pp. 18892–18897, Nov. 2007, doi: 10.1073/pnas.0704958104.

[2] "facs-live-cells1.jpg 472×500 pixels." https://a.static-abcam.com/CmsMedia/Media/facs-live-cells1.jpg (accessed Dec. 04, 2020).