One Drop: Lab on a Chip

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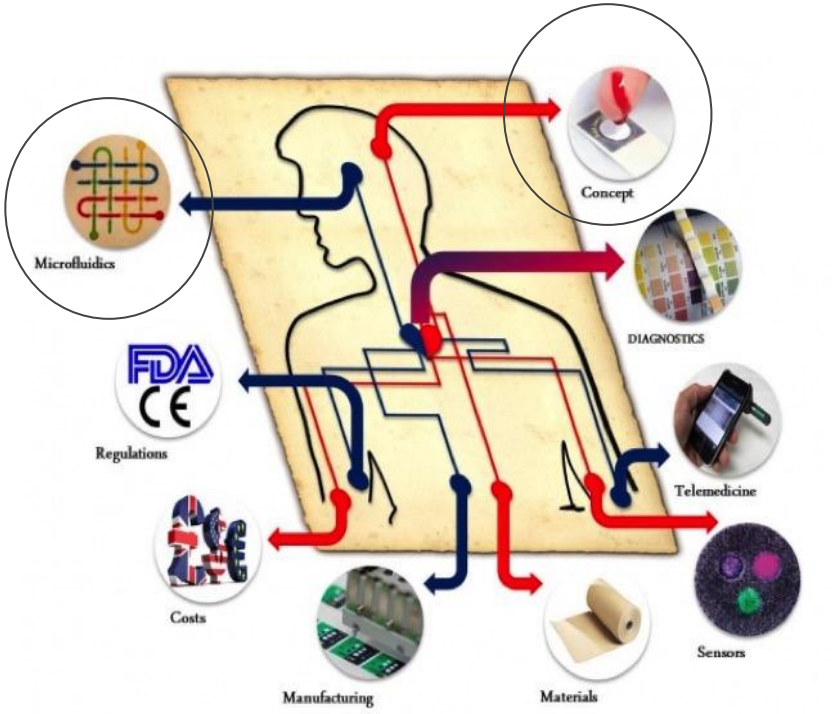
Disease Diagnostics


(5)

- Traditional Approach
  - Assay test: search for biomarkers in blood
    - Complex equipment
    - Lengthy test time
    - Expensive ~700 million dollars of testing[5]
  - Biopsy: remove tissue from body and perform extensive pathological tests
    - Invasive
    - Time consuming
- New Approach
  - Lab on a Chip

Project Objectives

- Design an assay that simplifies the diagnosis of breast and ovarian cancer
- Design a microfluidic ‘lab on a chip’ device that will mix blood and reagent streams to generate turbulent flows within a fluidic chamber
- Enable enough mixing for device to detect tumor biomarkers in blood
- 3D Print a Prototype of our most probable design



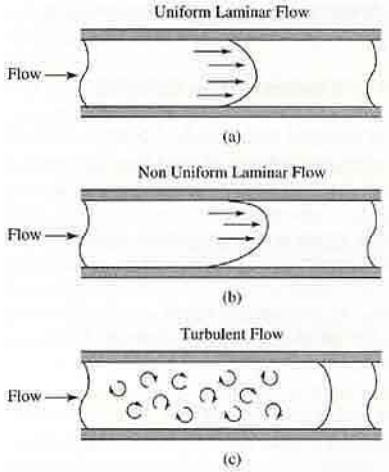
(6)

Technical Requirements

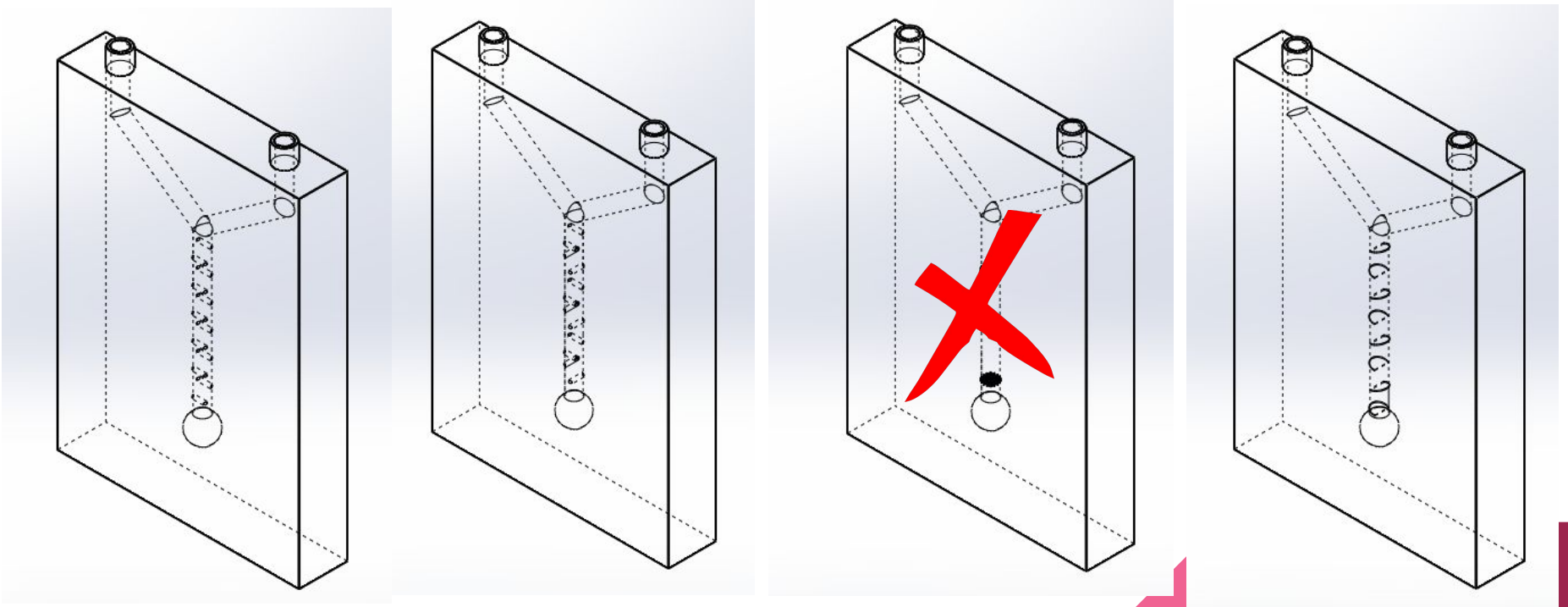
- Size needs to be smaller than a credit card
- Mixing of blood and reagent accomplished without any external forces
- Application to be single-use
- Low cost (<$1 in materials)
- We must generate turbulence on a small scale
    - Reynold's Number doesn't need to be >2000[5]

Creating Turbulence

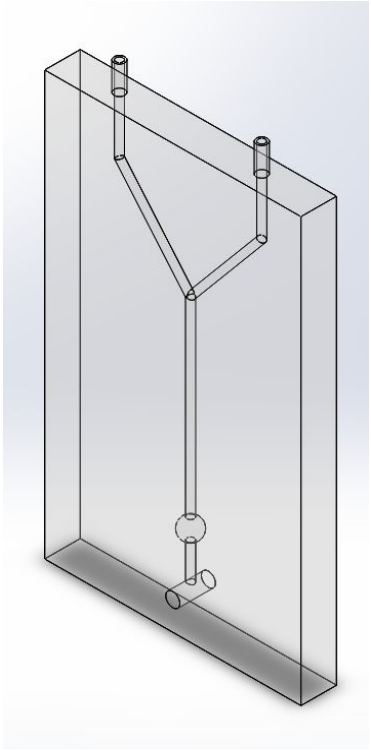
- Difficult to create turbulence in small microfluidic chambers[2,3,4] (microns in diameter)
  - Loops & turns
  - 3D geometries
- Surface tension (capillary force) and viscous forces (frictional drag) must be calculated[1].
- The best design will depend on channel length and capillary-driven flow rates for quick mixing



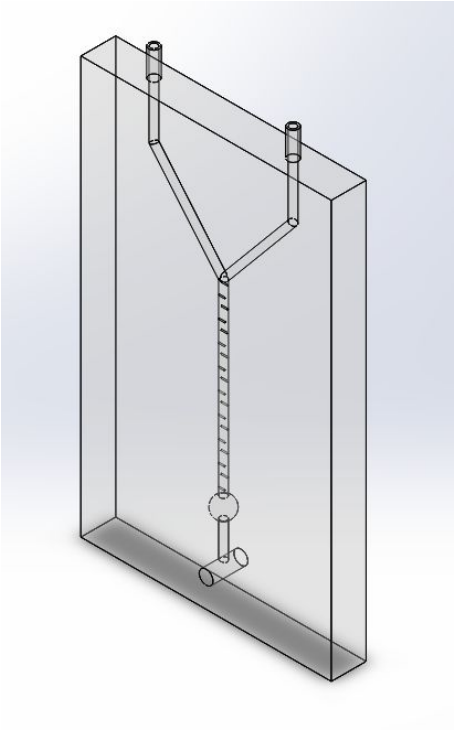
Original Four Designs

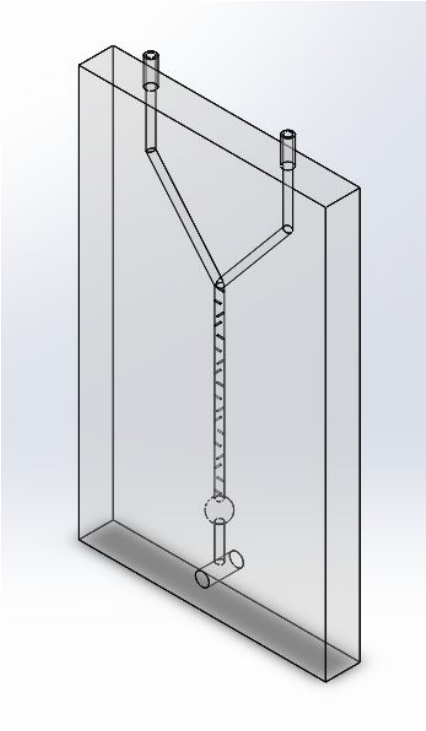


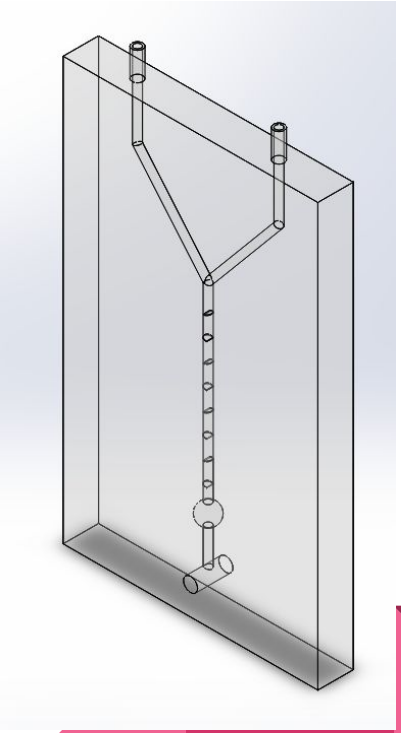
Redesign



Redesign with Obstructions

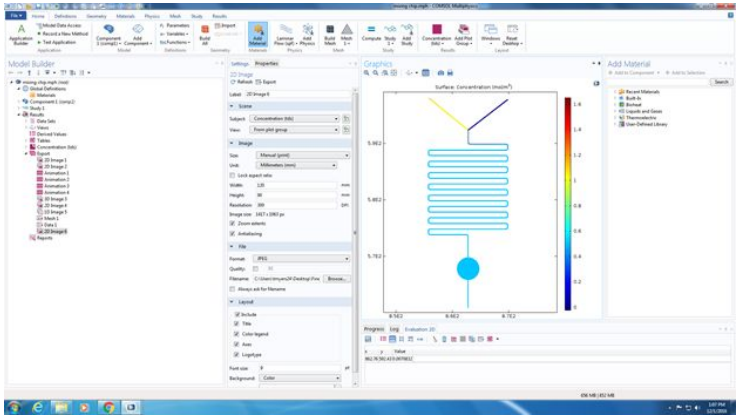


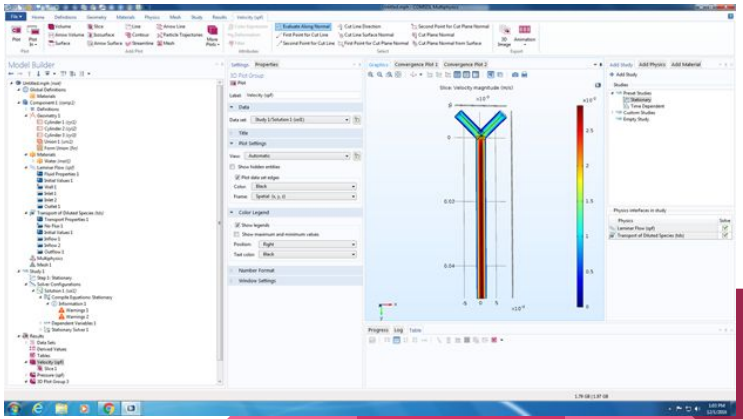




COMSOL Research

- Learn software from ground up
  - Help from Matt Campbell from AMI Manufacturing
  - Import SolidWorks & AutoCAD files and set parameters to study fluid profile within microchannels
- Used to determine which of our designs provides the best mixing
  - Simulations can give us numerical analyses of velocity and concentrations at inlets & outlets
- Mimic simulations from Dr. He's studies
  - Many simulations
  - One takes 96 hours



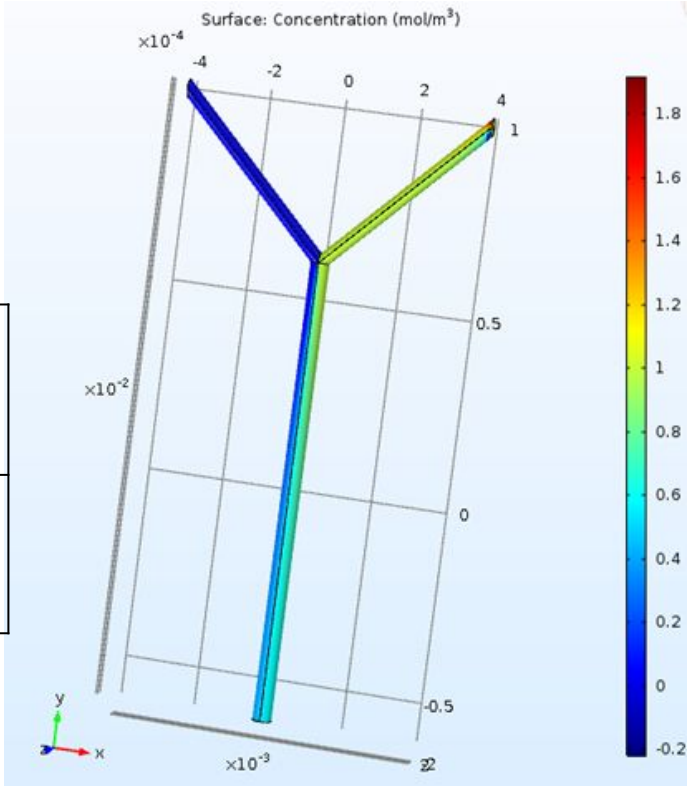


COMSOL Results- Generic Tube

- First successful COMSOL simulation
  - Nearly 3 hours to compute inlet & outlet velocities and concentrations
  - Set predetermined parameters
    - Laminar flow
      - We don't have the software to handle turbulent flows
    - Transport of diluted species
    - Water + Diluted Blood (consistency of water)
  - Post simulation, a 12 page report is produced by the software

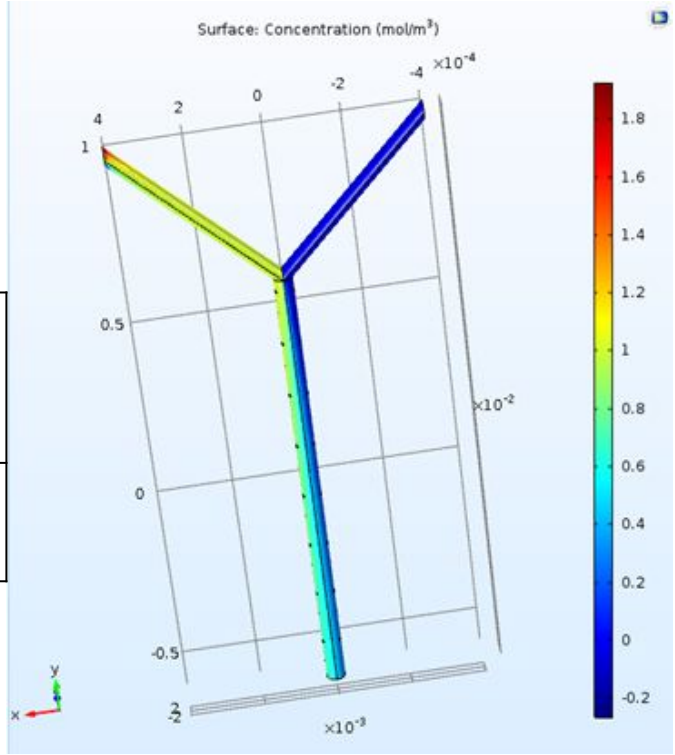
Generic Tube: Concentration Slice

Outlet Conditions	Maximum Concentration (mol/m^3)	Minimum Concentration (mol/m^3)	Range	Average Velocity (m/s)
No obstructions tube	.75404	.23639	.51765	.014670



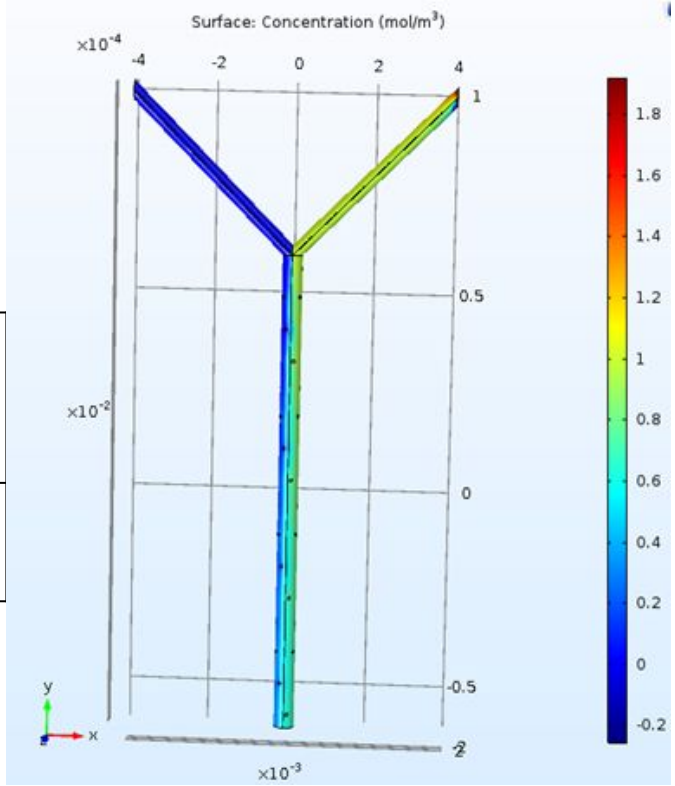
Ladder Tube: Concentration Slice

Outlet Conditions	Maximum Concentration (mol/m^3)	Minimum Concentration (mol/m^3)	Range	Average Velocity (m/s)
Ladder tube	.71882	.27538	.44344	.014521



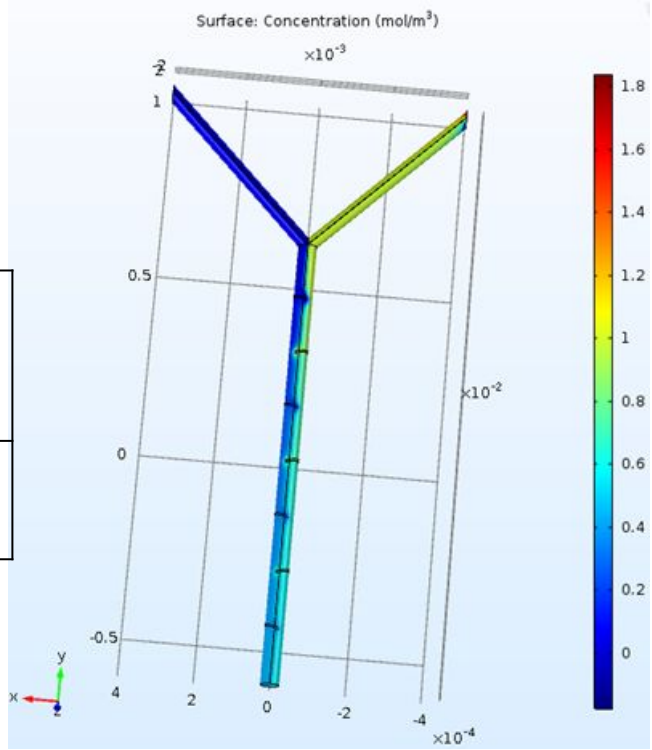
Crossed Ladder Tube: Concentration Slice

Outlet Conditions	Maximum Concentration (mol/m^3)	Minimum Concentration (mol/m^3)	Range	Average Velocity (m/s)
Crossed Ladder tube	.69840	.29406	.40434	.014526



Diagonal Planes Tube: Concentration Slice

Outlet Conditions	Maximum Concentration (mol/m^3)	Minimum Concentration (mol/m^3)	Range	Average Velocity (m/s)
Diagonal Planes tube	.57433	.42247	.15186	.014762



Results

Outlet Conditions	Maximum Concentration (mol/m^3)	Minimum Concentration (mol/m^3)	Range	Average Velocity (m/s)
No obstructions Tube	.75404	.23639	.51765	.014670
Ladder Tube	.71882	.27538	.44344	.014521
Crossed Ladder Tube	.69840	.29406	.40434	.014526
Diagonal Planes Tube	.57433	.42247	.15186	.014762

Inlet velocity .0074m/s

Inlet 1 concentration 0 mol/m^3

Inlet 2 concentration 1 mol/m^3

Results: Diagonal Planes Modifications

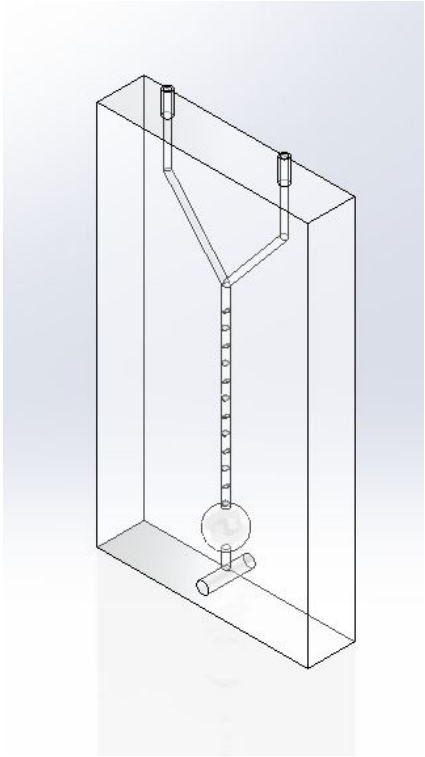
Outlet Conditions	Maximum Concentration (mol/m^3)	Minimum Concentration (mol/m^3)	Range	Average Velocity (m/s)
Same length, more obstructions	.55050	.44867	.10183	.017433
Longer length, same obstructions	.54857	.44780	.10077	.014759
Longer length and more obstructions	.52651	.46833	.05818	.014983

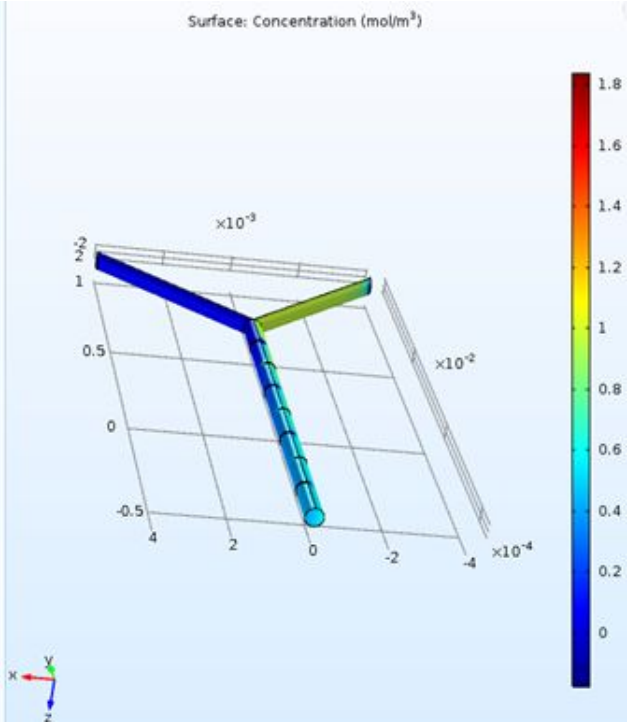
Inlet velocity .0074m/s

Inlet 1 concentration 0 mol/m^3

Inlet 2 concentration 1 mol/m^3

Final Recommendation





Diameter = 500 microns
Channel Height = 15 mm
Chip Dimensions = 3.3 x 1.8 cm

Average Concentration at outlet:
.49832mol/m^3

High Mixing Efficiency 99.6%

Future Work

- Modify the diagonal planes tube height and number of obstructions to facilitate an even higher mixing efficiency
- Wet lab research will be conducted with red and blue dyes to verify that the COMSOL results were accurate
- The team will create a cap that attaches to the inlets of the microfluidic chip
- Future Senior Design Teams
  - Design a reagent
  - Work with our advisor, Dr. He, to produce a cell phone application to read concentration from the chip

References

1. C. C. Lai and C. K. Chung, “Numerical simulation of the capillary flow in the meander microchannel,” Microsyst. Technol. 19(3), 379–386 (2013).
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3. Zheng, Z., Yang, Y., Zeng, Y., & He, M. (2016). A microfluidic ExoSearch chip for multiplexed exosome detection towards blood-based ovarian cancer diagnosis. *Lab Chip, 489*(16).
4. Lee, C., Chang, C., Wang, Y., & Fu, L. (2011). Microfluidic mixing: A review. *International Journal of Molecular Sciences, 12*. 3263-3287.
5. Plevniak, K., Campbell, M., Myers, T., Hodges, A., & He, M. (2016, October 5). *3D printed auto-mixing chip enables rapid smartphone diagnosis of anemia* [WORD]. AIP Publishing.
6. "CDC - Bloodborne Infectious Diseases - Preventing Needlesticks And Sharps Injuries - NIOSH Workplace Safety And Health Topic". *Cdc.gov*. N.p., 2017. Web. 13 Dec. 2016.

QUESTIONS?