Characterization of Directed Fluid Flow in Flexible Microchannels for Possible Tissue Engineering Applications

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Background

- Tissue engineering seeks to repair, replace, or regenerate specific tissues in order to improve biological function
- 3D scaffolds to initiate regeneration
- Currently, scaffolds are inadequate for long term survival of implanted cells, depend on diffusion
- Tesla valve scaffold structure seeks to encourage the flow of oxygen and nutrients
- Tesla valves are microchannel structures that may provide enhanced scaffold capabilities

Project Objectives

- Fabricate elastic Tesla valve microchannel arrangements
- Characterize directional fluid flow through the mechanically loaded microchannels by applying a newly developed particle image velocimetry (PIV) instrument
- Integrated PIV and optical tweezers instrument

Tesla Valves

- Patented in 1920 by Nikola Tesla
- Work on the premise of rectification of fluid flow
  - Forward flow is greater than reverse flow creating a net flow in the forward direction
- Currently used in micropumps for moving fluid in micro fluid systems and are rigid structures
- Development of a flexible valve is a new concept, valves induce pumping

Tesla Valves

- Structure
  - T intersection and Y intersection
  - Manipulate angle of Y intersection for optimum fluid flow

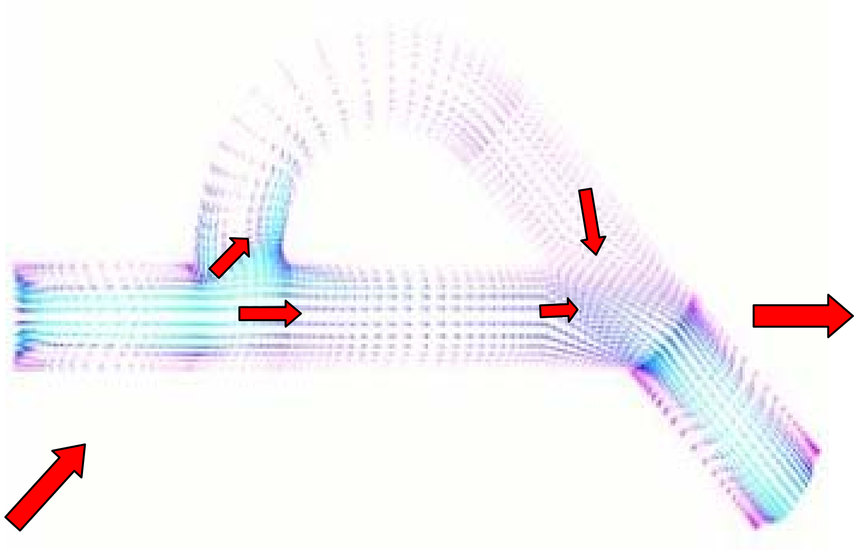


Photo taken from: http://lettuce.me.washington.edu/micropump/

Designing the Tesla Valves

- Used solid works to create a 3D drawing of Tesla valve and molds
- Cut mold from Teflon (5mm) and Polyethylene (3mm)
- Used Dow Corning Sylgard 527 A&B Silicone Dielectric Gel

Designing the Tesla Valves

- Tested various ratios of parts A&B
  - 1:1 ratio was not firm enough
  - 1:2 was firmer
  - 2:1 did not set completely
- Used 1:2 ratio to create large (5mm channels) and small (3mm channels) Tesla Valves

Designing The Tesla Valves

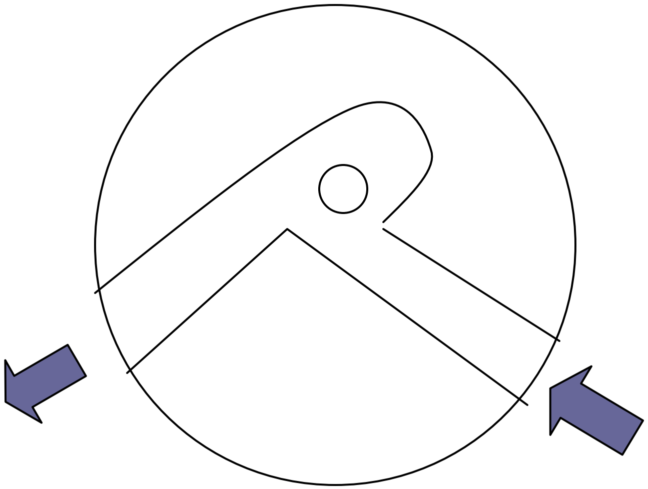
- Experimented with different materials and different sizes
- Polydimethylsiloxane (PDMS) will allow for better control of the material properties desired

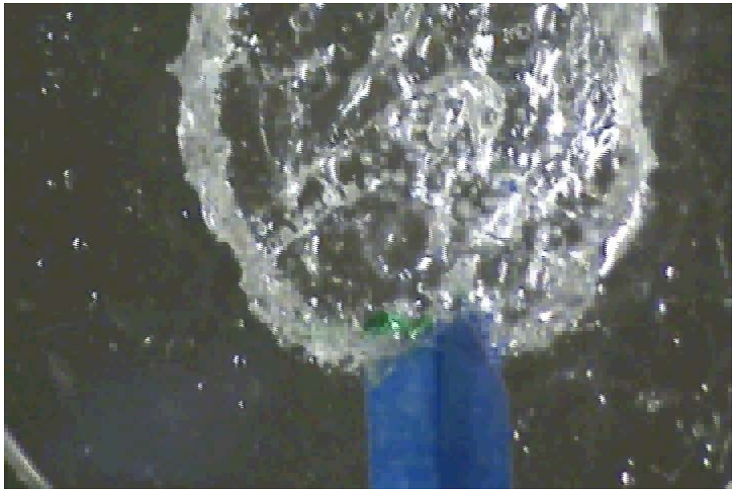
Testing the Tesla Valves

- Placed gel in Petri dish and created a barrier to establish two reservoirs
- Placed drop of dye at opening of channel
- Manually created a load at approximately 0.5 Hz
- Digital video camera to record experiment

Sylgard Tesla Valve

- Experiment on Sylgard material
- Completing path time: 1 minute
- Frequency: 0.5 Hz





Integration of Optical Tweezers and Micro PIV

- Purpose of two techniques-instrument to study single cell biomechanics
- Response of cells
- Novel instrumentation
- Assisted in acquisition, assembly, and development of optical components
- Laser alignment

Particle Image Velocimetry
What is PIV?

- Optical method used to measure velocities and related properties in fluids
- May be used on the microscale
- Fluid is seeded with fluorescent particles which follow flow dynamics
- Movement of particles determines velocity of fluid

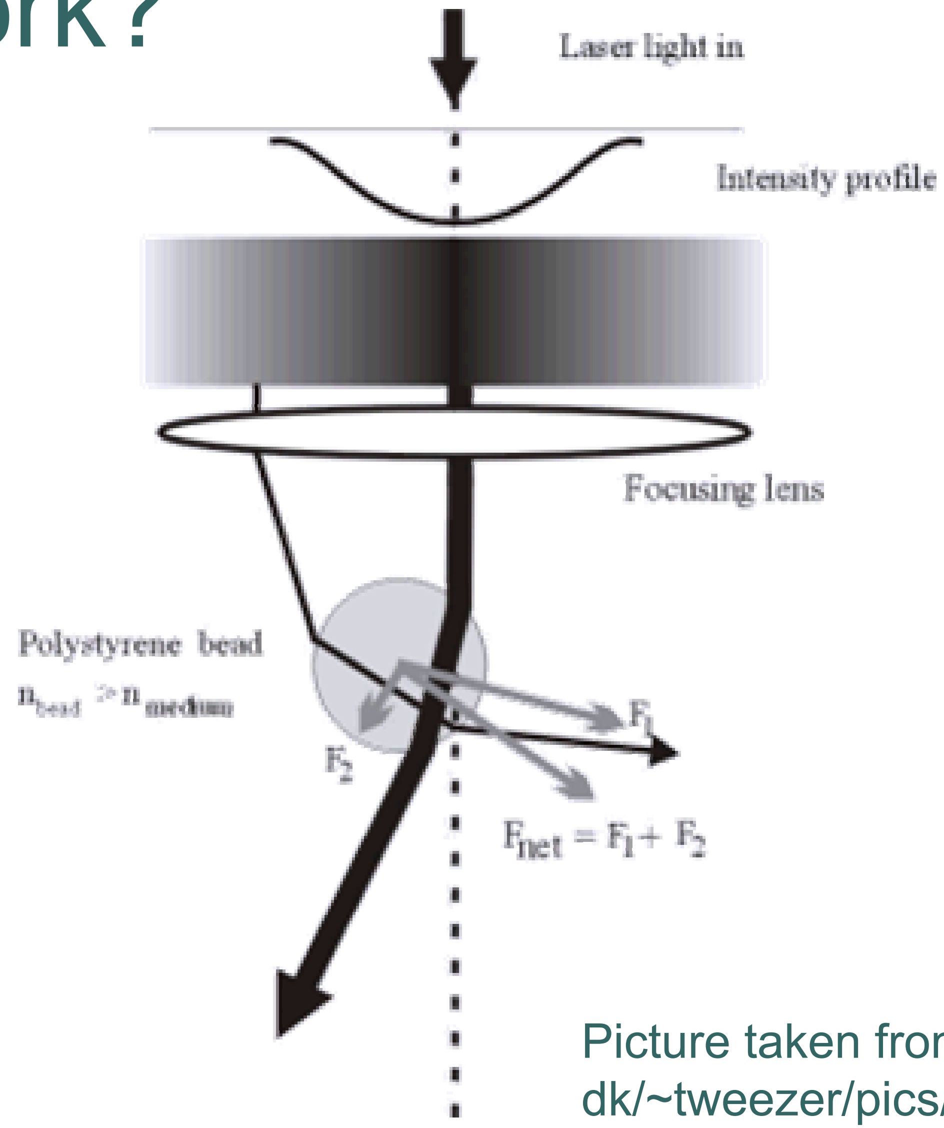
Particle Image Velocimetry How does PIV work?

- Camera and high power laser (532nm)
- Velocity of particles determined by measuring the movement of particles between two light pulses
- Average distance determined by statistical methods
- Velocity is average displacement over time between pulses
- Full field velocity measurements with velocity vectors every 436nm

Dual Trap Optical Tweezers

- "Tweeze" microscale particles and hold stable in three dimensions
  - Dielectric (non conducting) sphere interacts with electric field created by laser beam, creating an induced dipole about the sphere
  - Sphere drawn along electric field gradient to the point of highest intensity of light
  - Scattering force less than dipole force to allow trapping

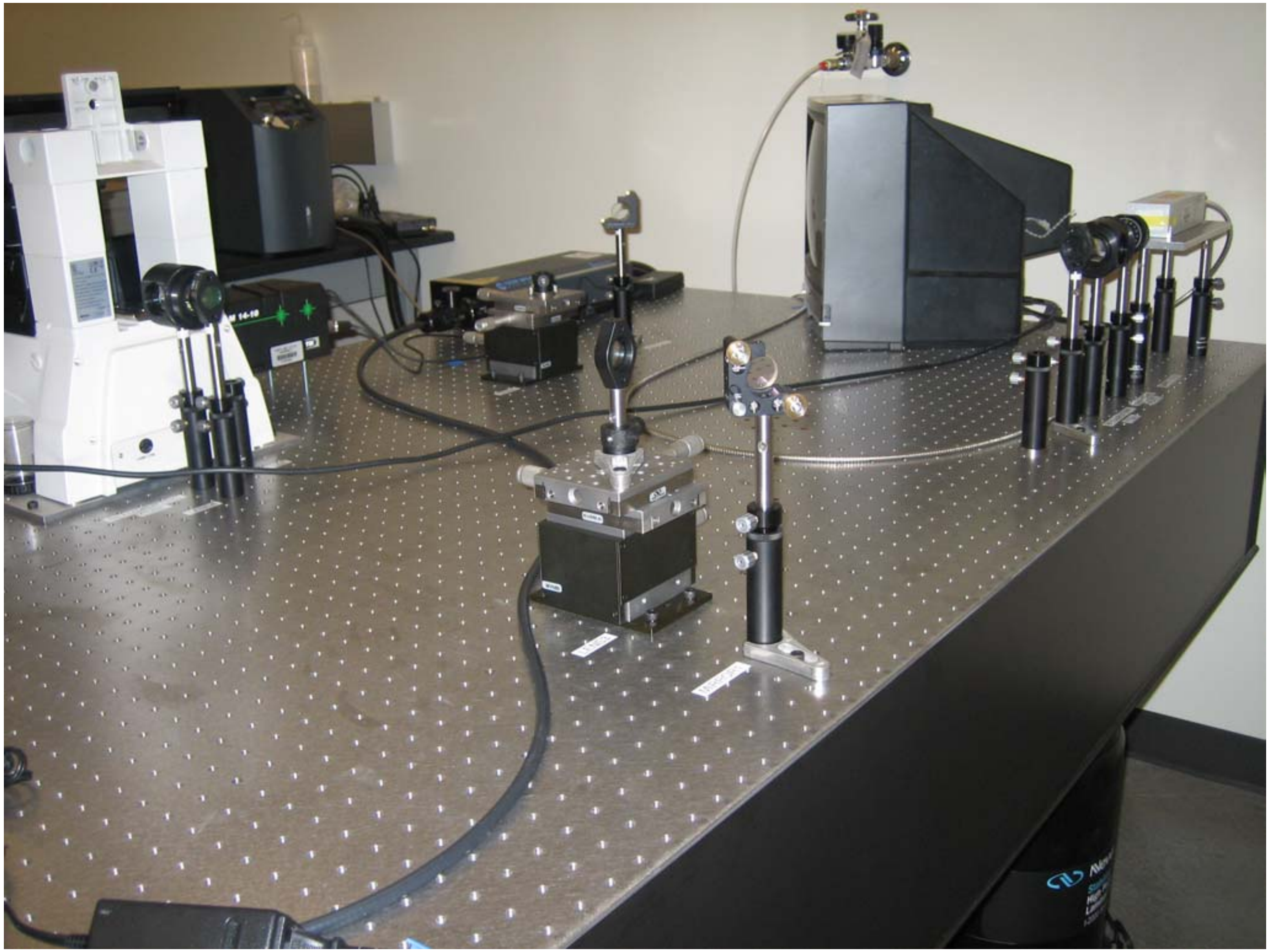
How Do Optical Tweezers Work?



Picture taken from http://www.nbi.dk/~tweezer/pics/laser-beam3.gif

Dual Trap Optical Tweezers

- Integrated system of PIV and Optical Tweezers



Results

- Experiments demonstrated that a flexible microchannel works
- Applying a manual load, we observed fluid flowing through the small (3mm) Sylgard valve

Summary

- Able to characterize directional fluid flow through flexible Tesla valves
- Unable to observe flow using PIV instrument
- Progress in assembly and development of optical trap

Future Work

- Create a more precise mold
- Design a automated mechanical loading device to place on microscope stage
- Optimize fluid path design
- Quantitative PIV measurements

Ultimate goal is to create micro- manufactured scaffold designs

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