SAND2007-1336C

A Microfabricated Flow Cytometry System for Optical Detection of Cellular Parameters

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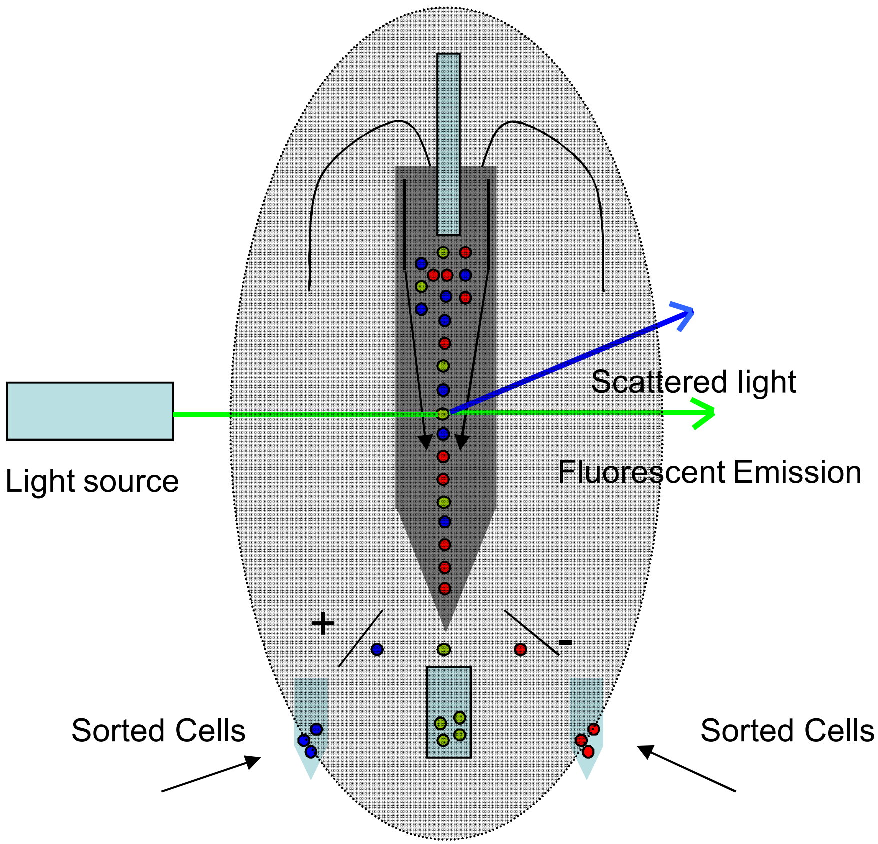
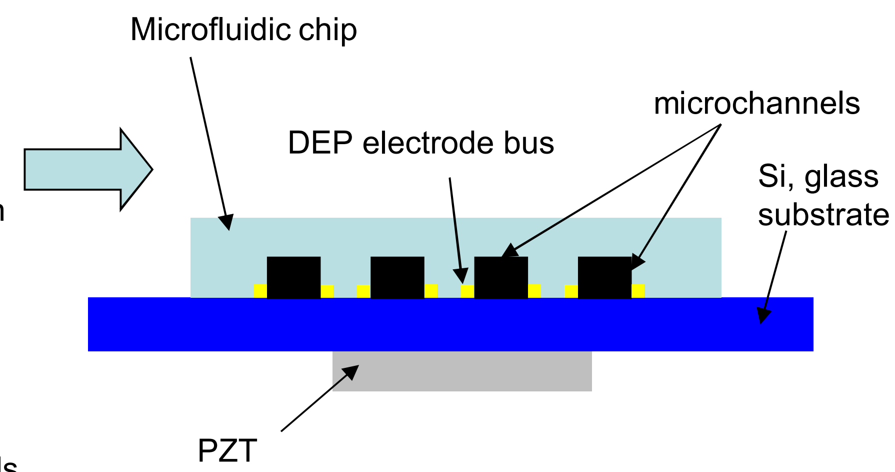
for the United States Department of Energy's National Nuclear Security Administration
under contract DE-AC04-94AL85000.

Introduction to Flow Cytometry

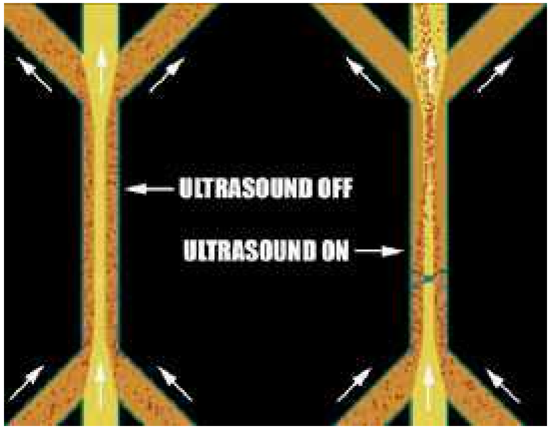
- An analysis tool for understanding chemical and physical properties about biological cells
- A sheath flow focuses cells into a single file line
- A laser through scattering or florescence generates a signal that gives a signature of the cell.
- Optical signals converted to electrical signals which are correlated to the biological features.

Concept

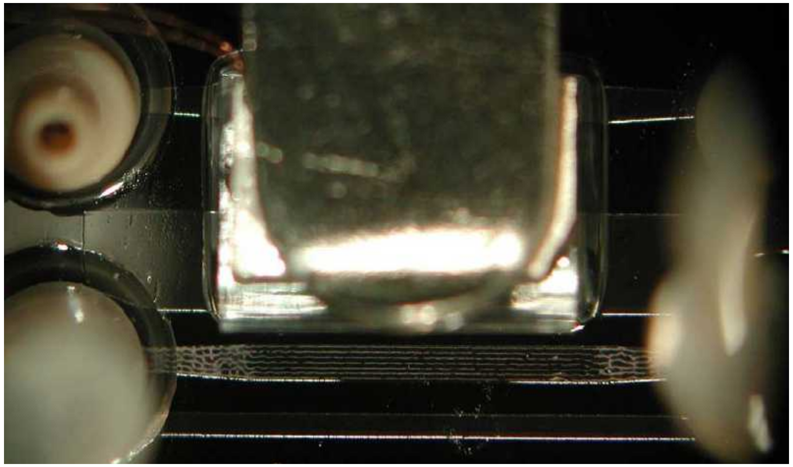

Scattered light
Fluorescent Emission
Light source
+
-
Sorted Cells
Sorted Cells


Microfluidic chip
microchannels
DEP electrode bus
Si, glass substrate
PZT

Background



Laurell, Anal. Chem. 2005



Wiklund, Lab Chip 2006

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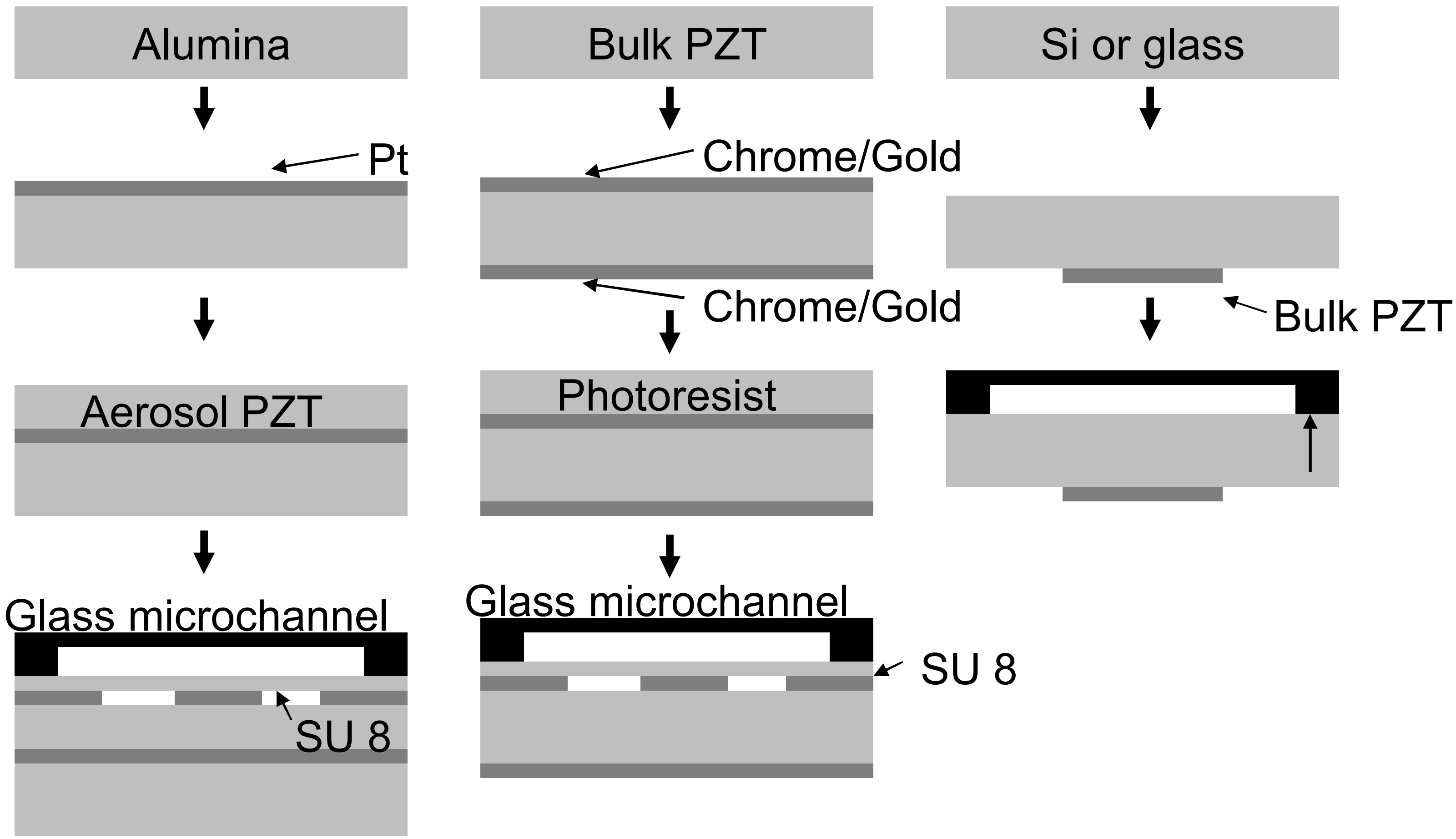
Fabrication Schemes



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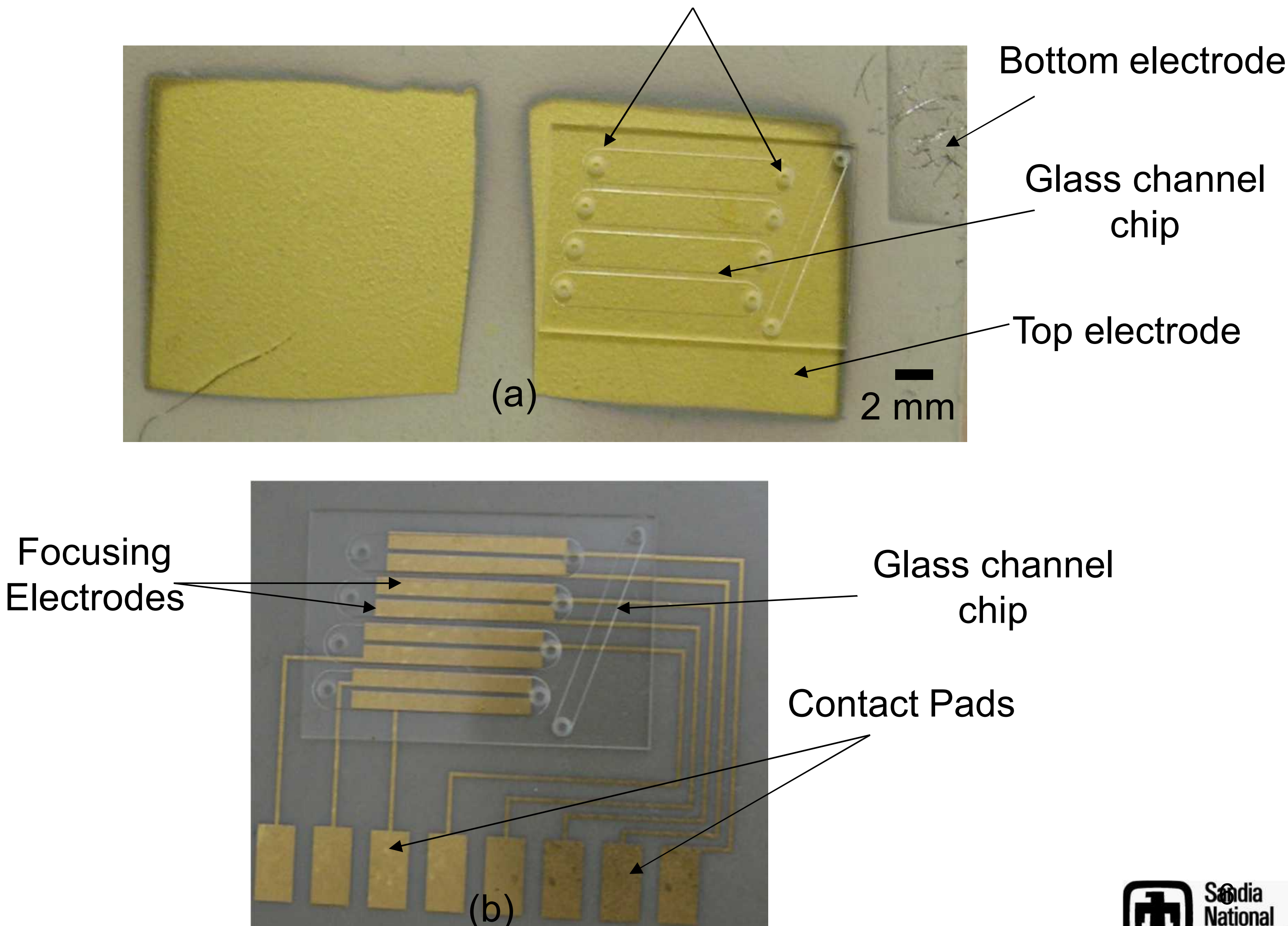
Fabricated Systems



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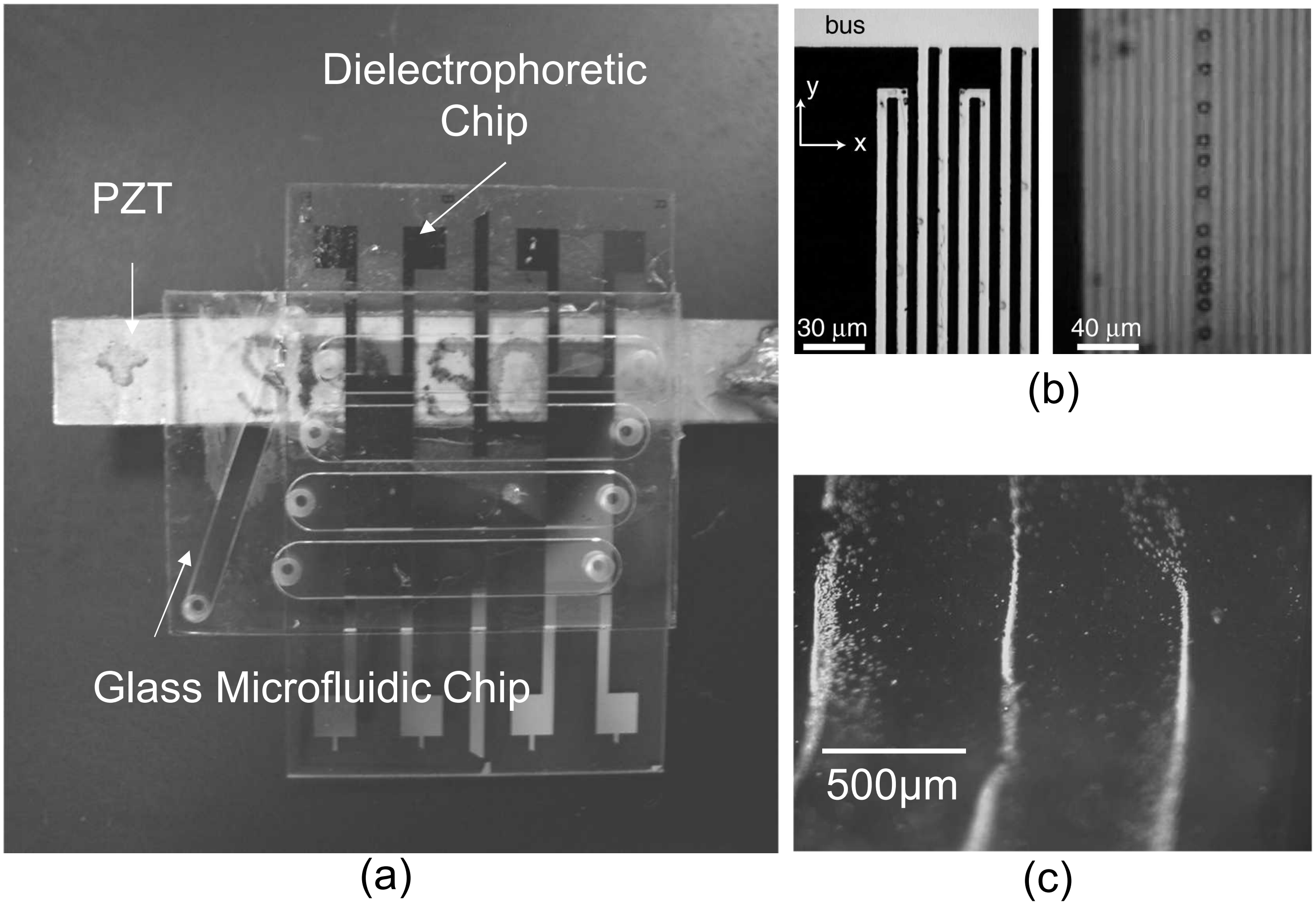
Fabricated Systems



SKVR1

Modeling Paradigm

- 1-D Transmission Line model based on Dion et. al., 1997 in *IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control*

$$Z_e = \frac{1}{j\omega C_0} + \frac{h_{33}^{\ 2}}{\omega^2 A}\left(\frac{2[\cosh(\gamma a)-1]Z_f + (Z_L + Z_R)\sinh(\gamma a)}{\left(Z_L Z_R + Z_f^2\right)\sinh(\gamma a) + Z_f (Z_L + Z_R)\cosh(\gamma a)}\right)$$

Where C_o is the clamped electrical capacitance, h_{33} is the piezoelectric stress constant, A is the surface area of the transducer, γ is the propagation function, Z_L is the impedance seen to the left, Z_R is the impedance seen to the right, Z_f is the transducer impedance, and a is the transducer thickness.

- Use the impedance addition rule to add impedances seen to the left or right for a film stack

$$Z^*(\omega, x) = Z_i^*(\omega)\frac{Z_{LD}^*(\omega)\cosh[\gamma(L-x)] + Z_i^*(\omega)\sinh[\gamma(L-x)]}{Z_i^*(\omega)\cosh[\gamma(L-x)] + Z_{LD}^*(\omega)\sinh[\gamma(L-x)]}$$

Z_i is the intermediate layer impedance, Z_{LD} is the impedance of the load, and L is the thickness of the intermediate layer

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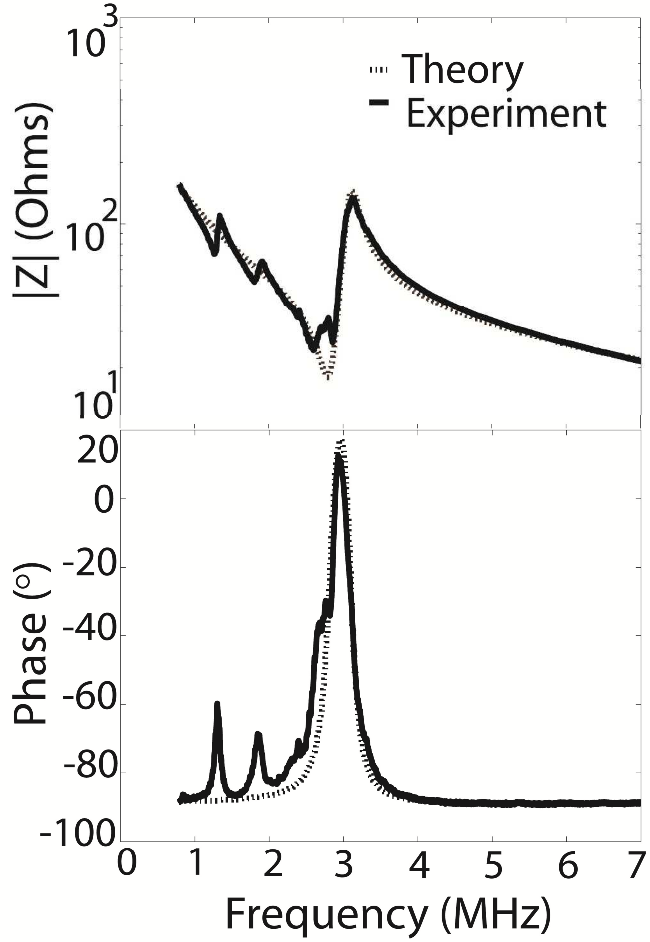
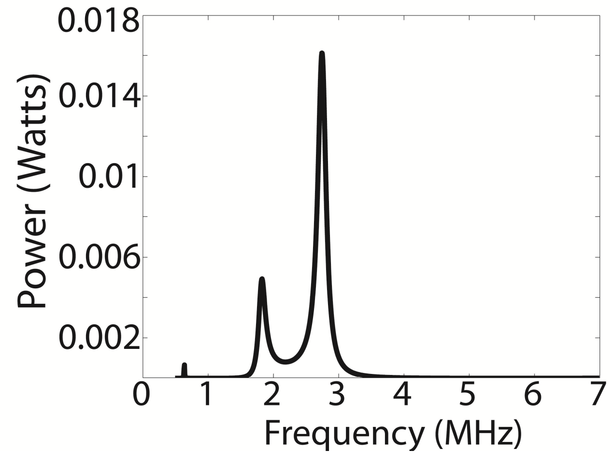
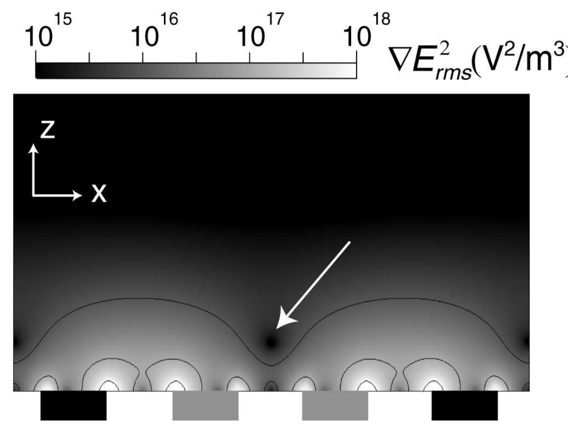
SKVR1 transducer mispelled
Surendra Ravula, 3/2/2007

Modeling of the System







Focusing of Beads in Channels

Bead focusing characteristics during PZT actuation (n=4)

Frequency of Operation (MHz)	Amplitude of Applied Voltage (V) (peak-to-peak)	Number of Streams	Average Stream Width (μm)	Average Levitation Height (μm)
1	10.17	1	20±3	12±3
1.12	12.22	2	15±3	24±2
1.23	12.32	3	6±1	22±7

Values are mean±standard error of measurement.

Cell positioning characteristics during DEP actuation (n=4)

Frequency of Operation (MHz)	Average "Pearl chain" Width (μm)	Number of "Pearl chains"	Average Levitation Height (μm)
1	11±2	8±3	5±3
1.3	10±1	14±3	8±2
2.1	15±3	4±1	12±7

Values are mean±standard error of measurement.

Summary

- Integrated acoustic electrodes in a microfluidic system
- Detailed model allows for device design and analysis
- Experimental results show that beads can be manipulated in microfluidic channels when frequency is tuned

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