SAND2007-3093C

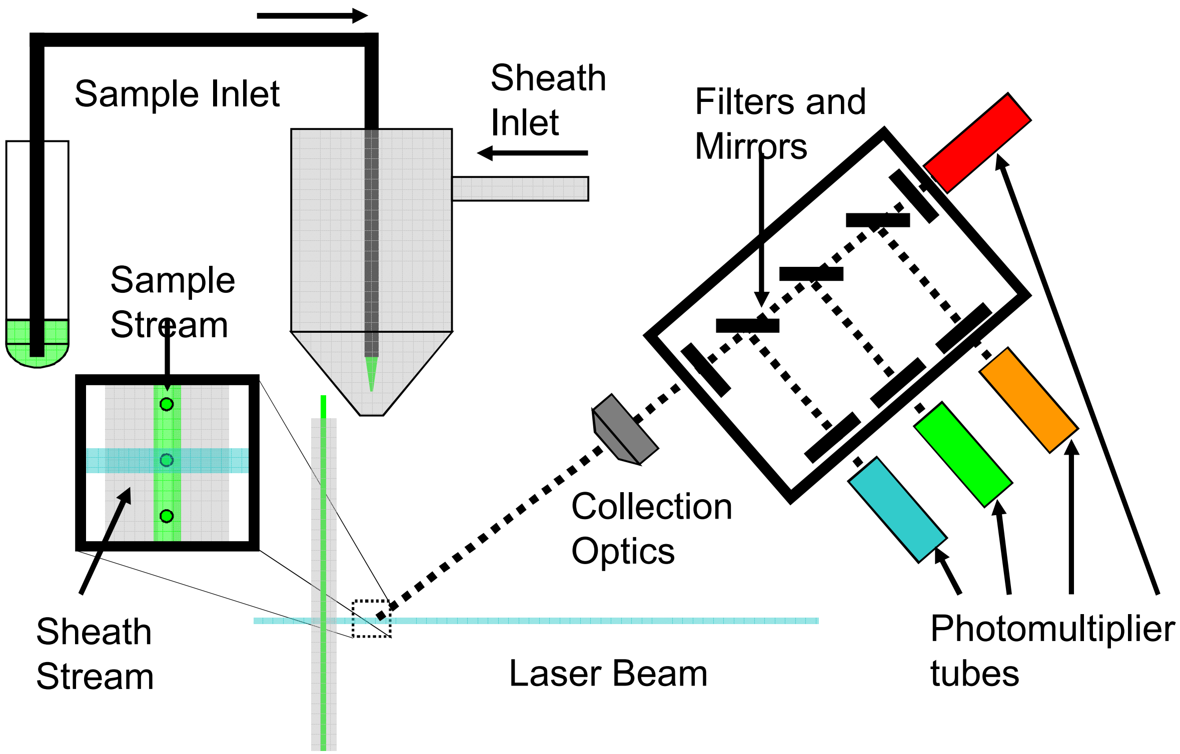
Microfluidics and Microacoustics for Miniature Flow Cytometry

Surendra K. Ravula, Darren W. Branch, Jennifer Sigman, Paul G. Clem, Igal Brener

Sandia National Labs, Albuquerque, NM

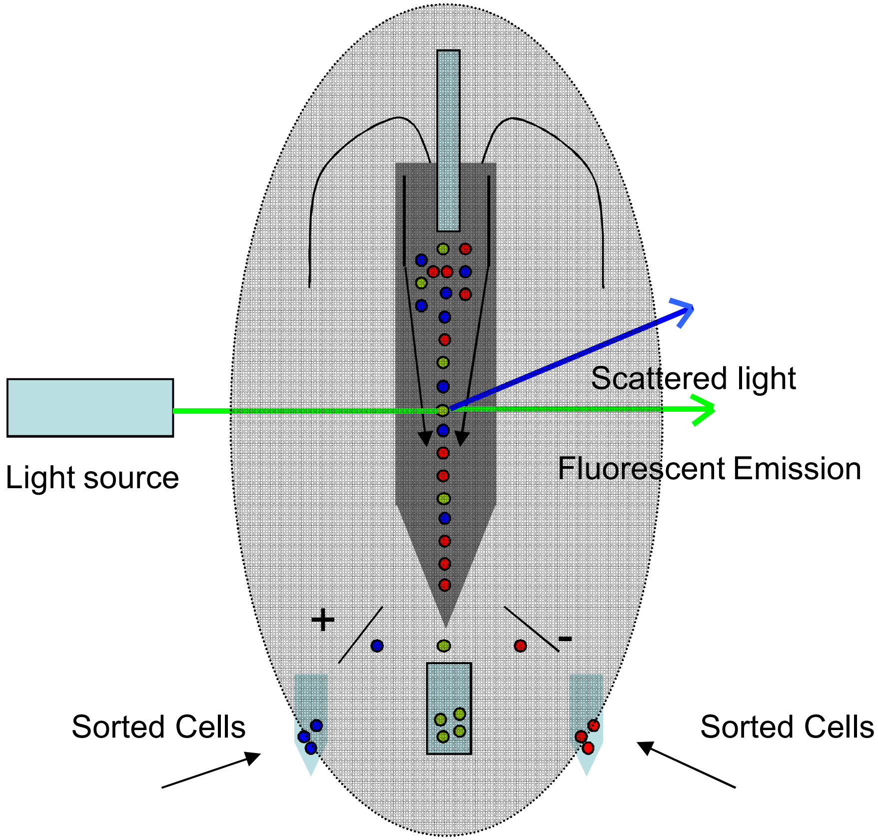
Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

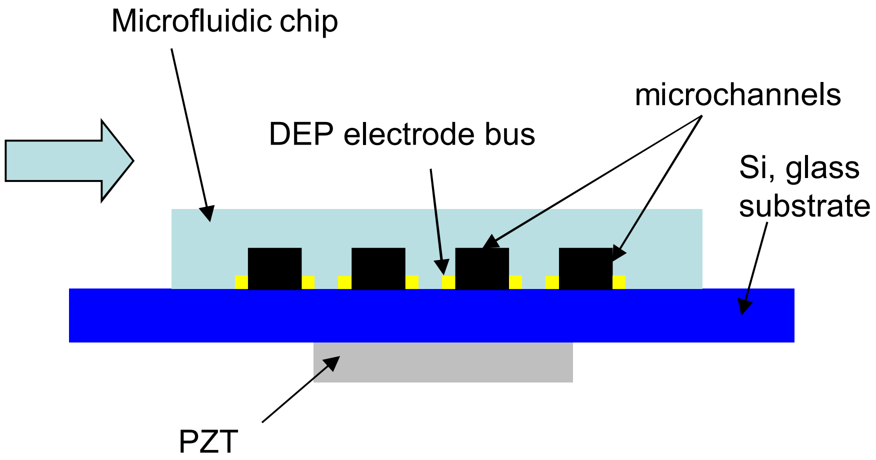
Introduction to Flow Cytometry



- 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.

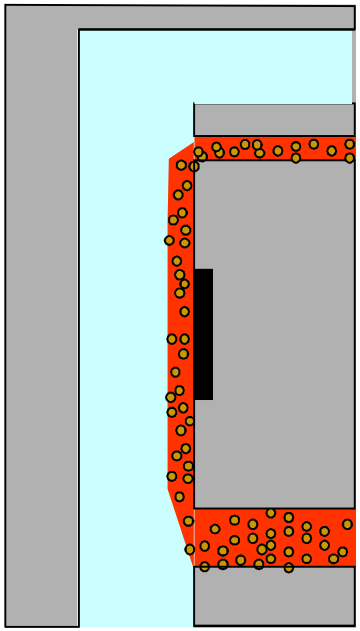
Concept



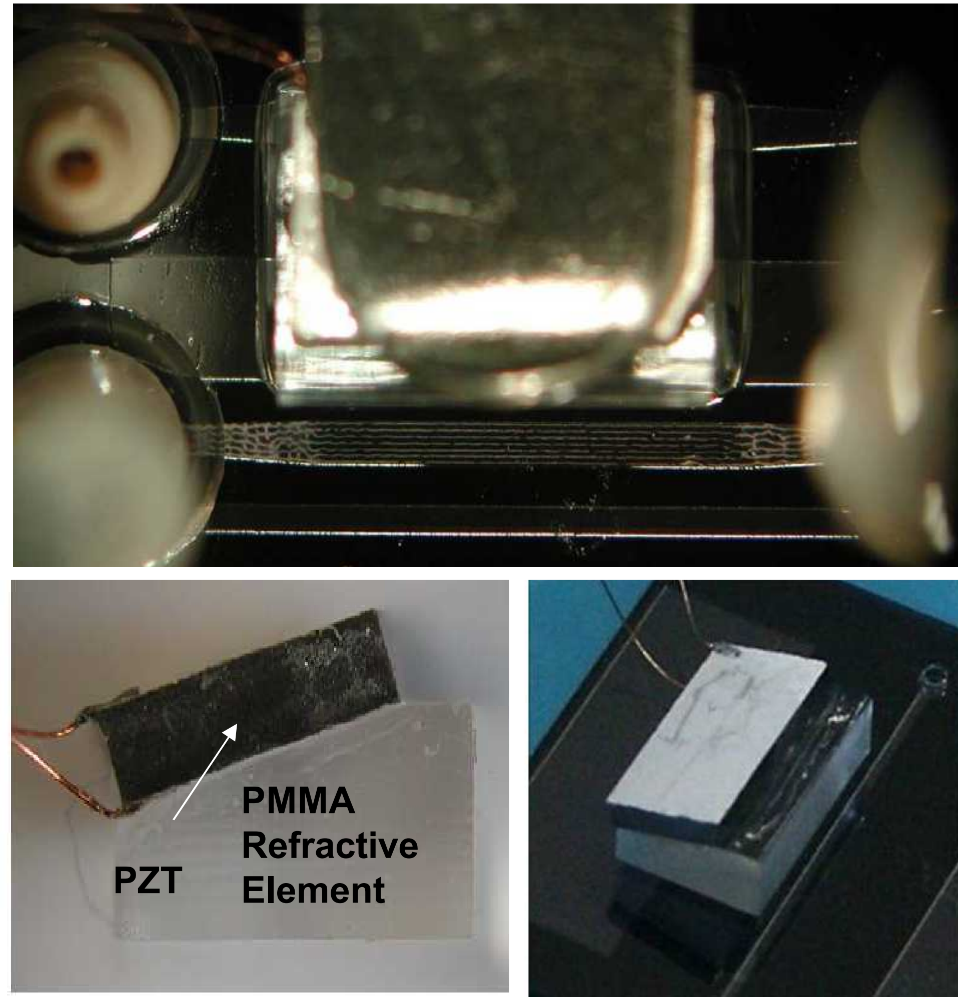


Sandia National Laboratories

Background

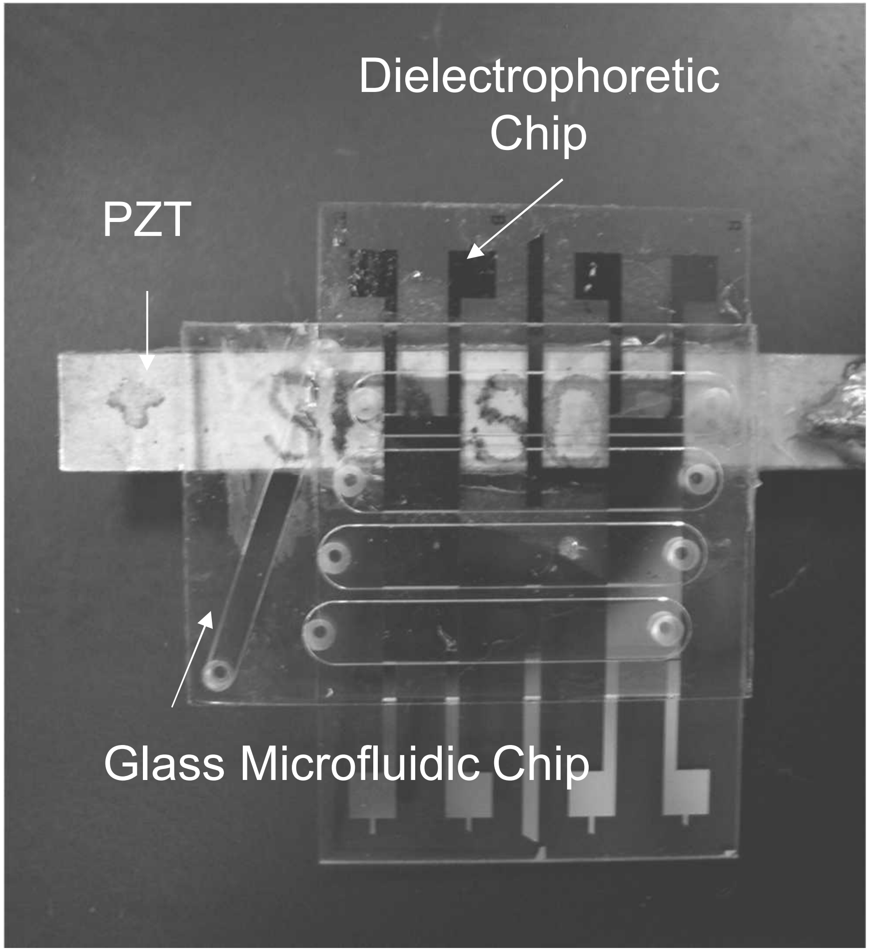


Hawkes et al. Lab Chip. 2004

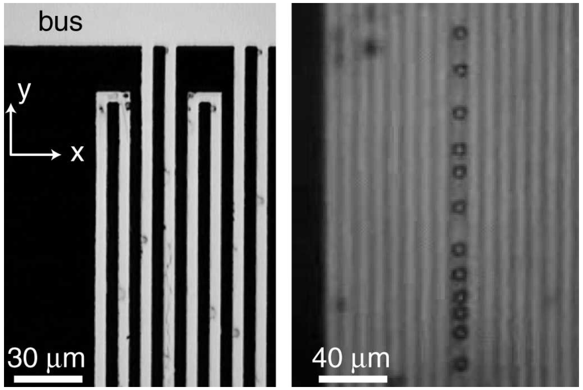


Wiklund, Lab Chip 2006

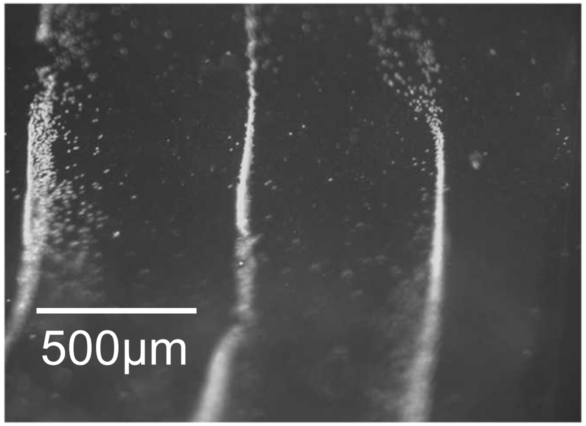
Fabricated Systems



(a)



(b)



(c)

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

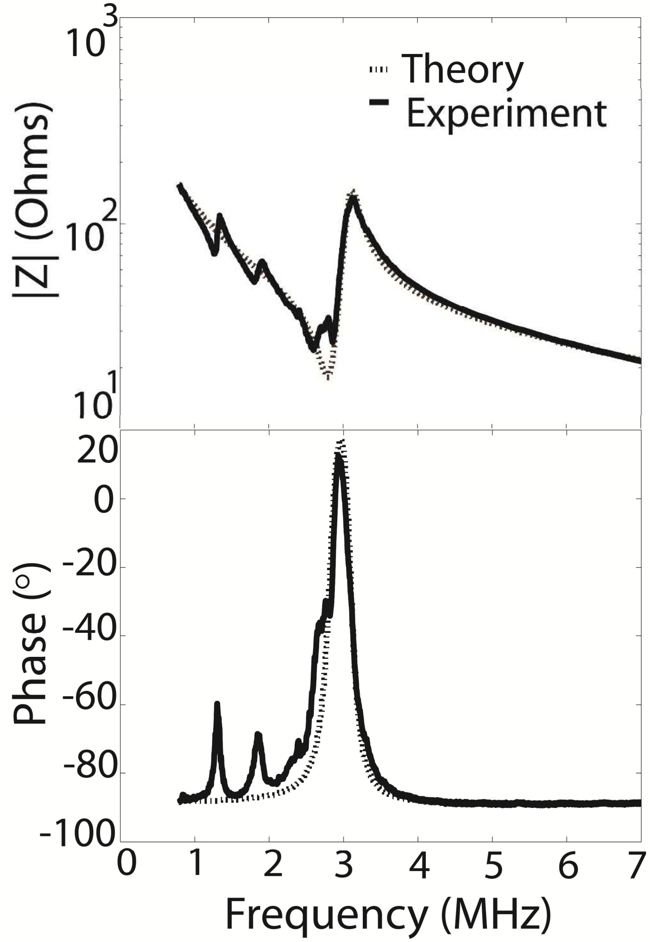
$$Z^*(\omega, x) = Z_i^*(\omega)\frac{Z_{LD}^*(\omega)\cosh[\gamma(L-x)] + Z_i^*(\omega)\sinh[\gamma(L-x)]}{Z_i^*(\omega)\cosh[\gamma(L-x)] + Z_{LD}^*(\omega)\sinh[\gamma(L-x)]}$$

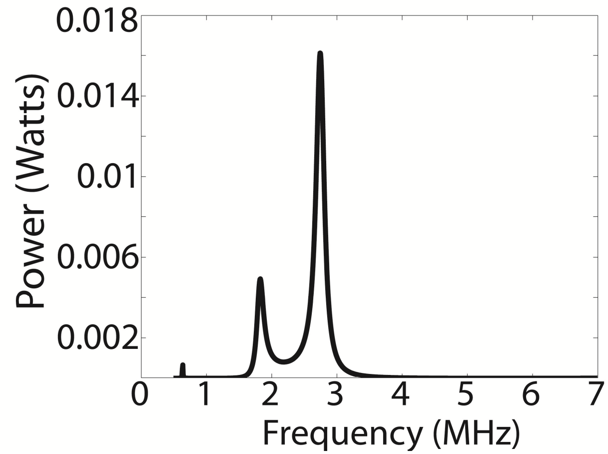
Z_i is the intermediate layer impedance, Z_{LD} is the impedance of the load, and L is the thickness of the intermediate layer

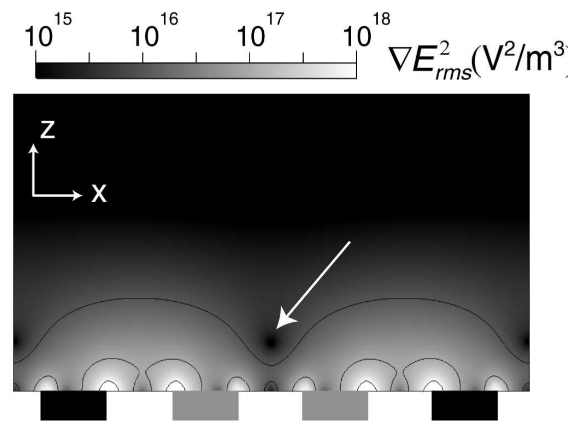
Slide 6

SKVR1 transducer mispelled
Surendra Ravula, 3/2/2007

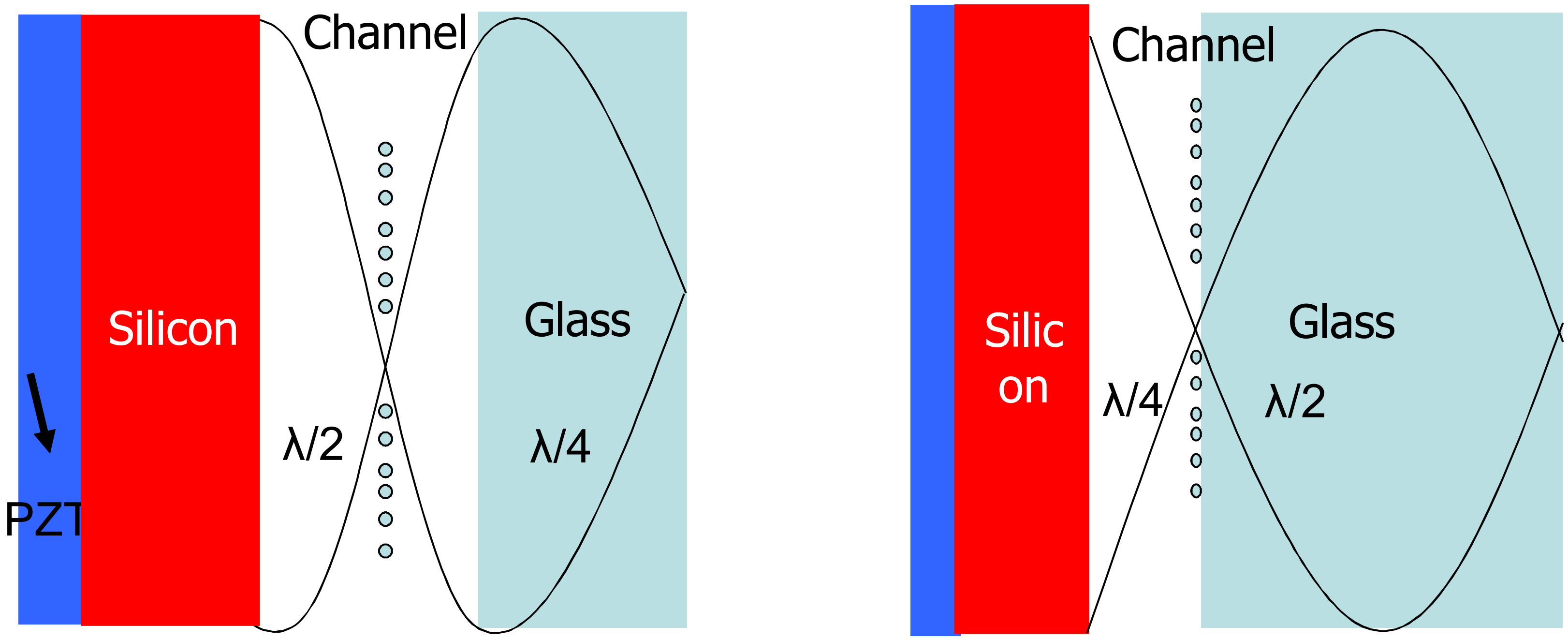
Modeling of the System







Positioning of streams within the channel



Sandia National Laboratories

Focusing Characteristics (λ/2 cavity, λ/4 roof)

Cavity height is 240μm.

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	6.17	1	26±2	99±3
1.59	8.24	2	15±3	110±2
2.13	9.32	3	6±1	119±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.

Focusing Characteristics (λ/4 cavity, λ/2 roof)

Cavity height is 240μm.

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	9.2	1	15±3	234±3
2.54	12.87	2	30±3	229±3
3.12	14.92	3	6±1	219±7

Values are mean±standard error of measurement.

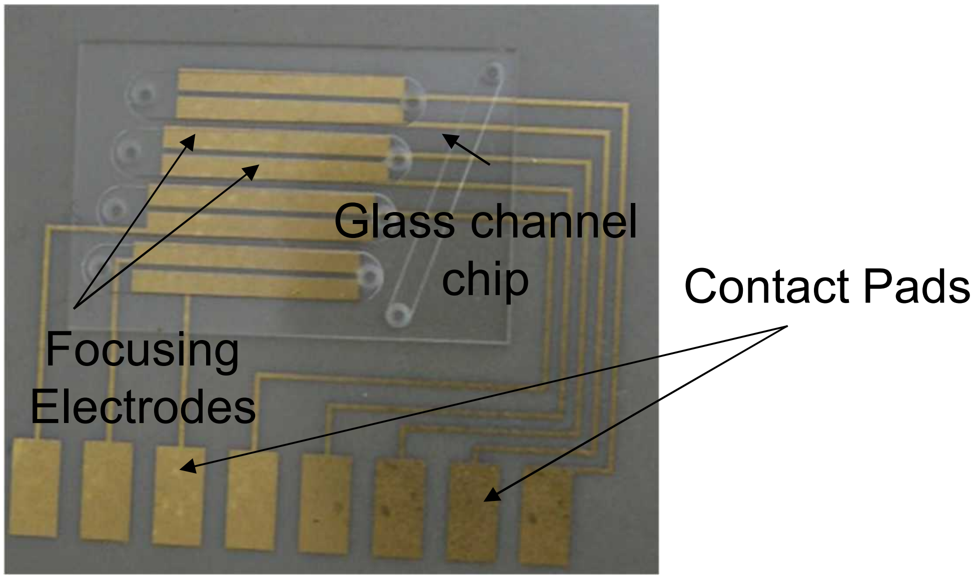
Cell positioning characteristics during DEP actuation (n=4)

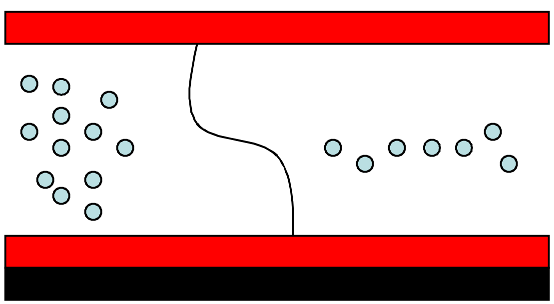
Frequency of Operation (MHz)	Average "Pearl chain" Width (μm)	Number of "Pearl chains"	Average Levitation Height (μm)
1	11±2	8±3	5±3
1.3	10±1	14±3	8±2
2.1	15±3	4±1	12±7

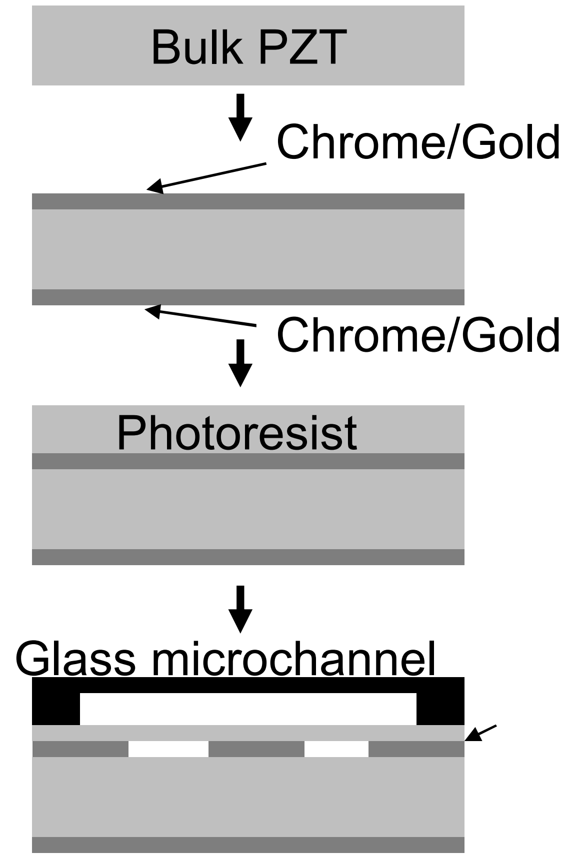
Values are mean±standard error of measurement.

Sandia National Laboratories

Planar Acoustic Transducers

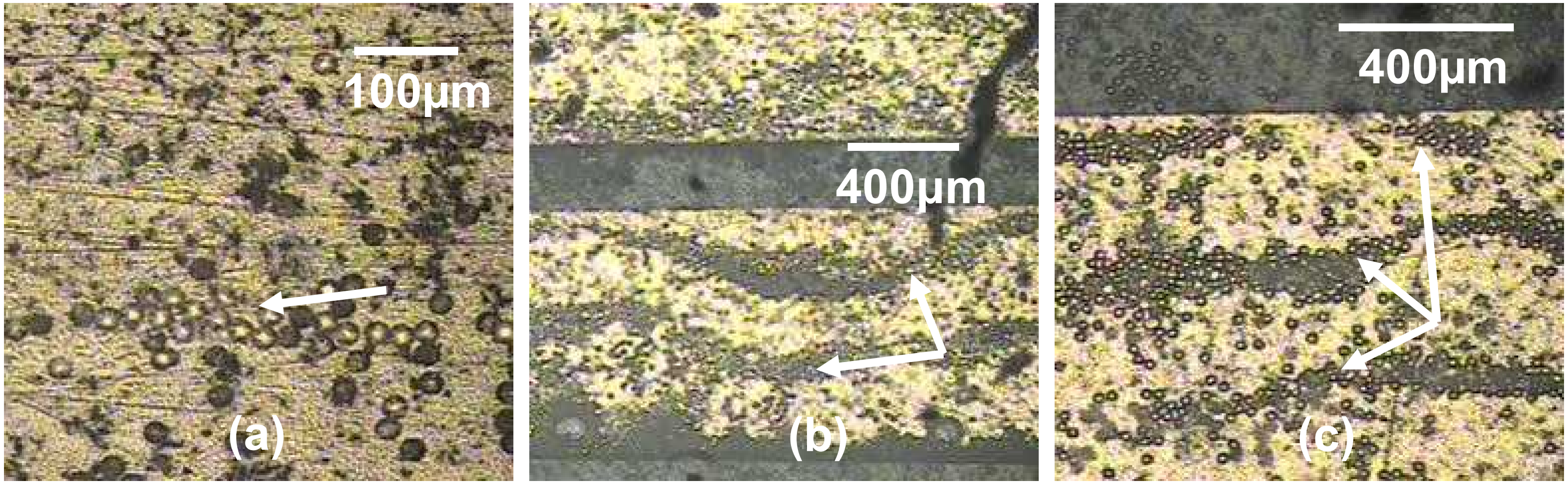






Sandia National Laboratories

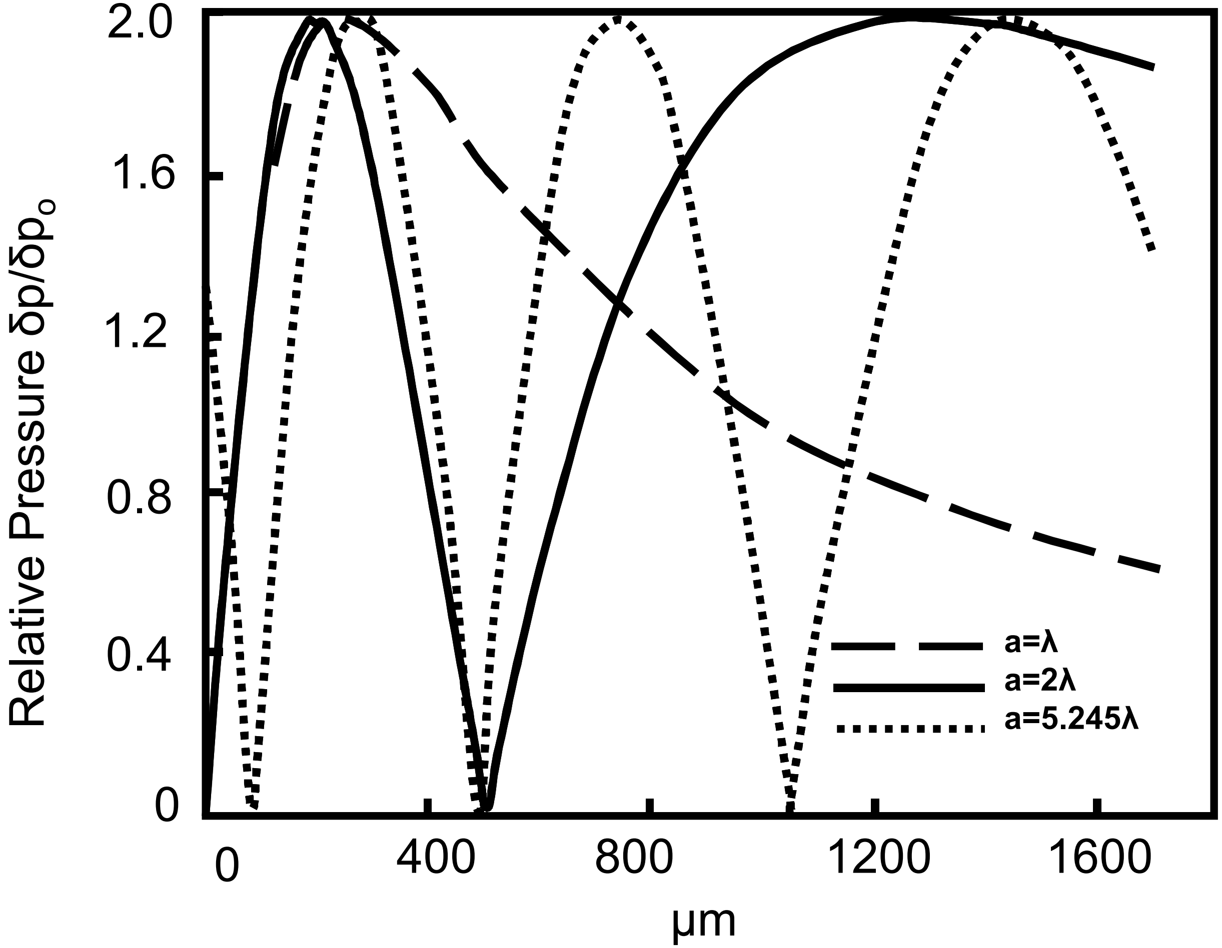
Focusing of Beads in Channels



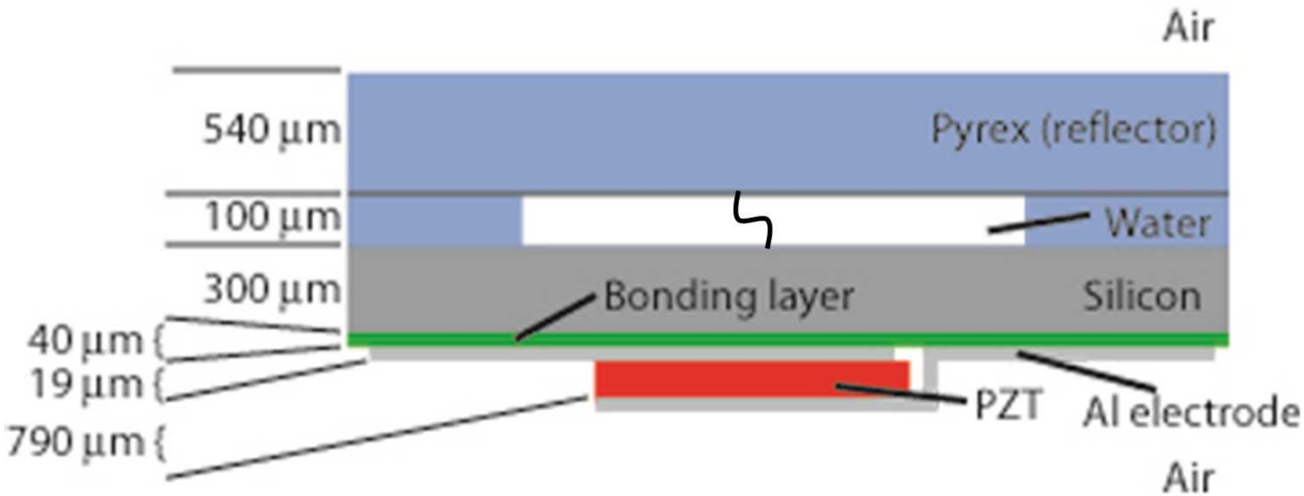
Acoustic streams (arrows) of beads due to lateral focusing in a microchannel. The PZT transducer was driven with a 10Vp-p sinusoidal signal. The frequency of actuation was 3.1MHz for (a), 3.7MHz for (b), and 4.2MHz for (c).

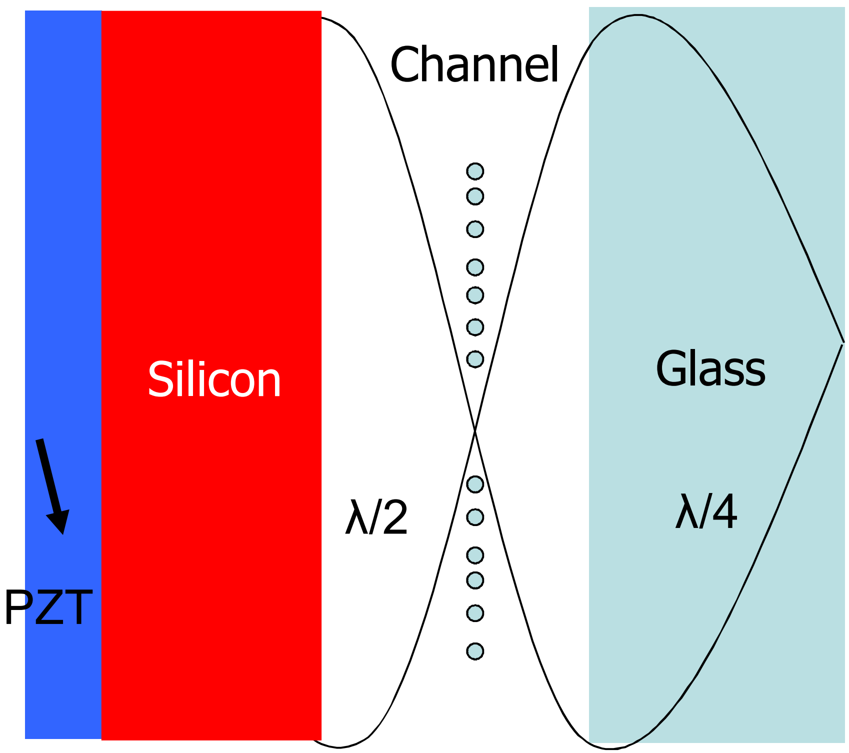
Sandia National Laboratories

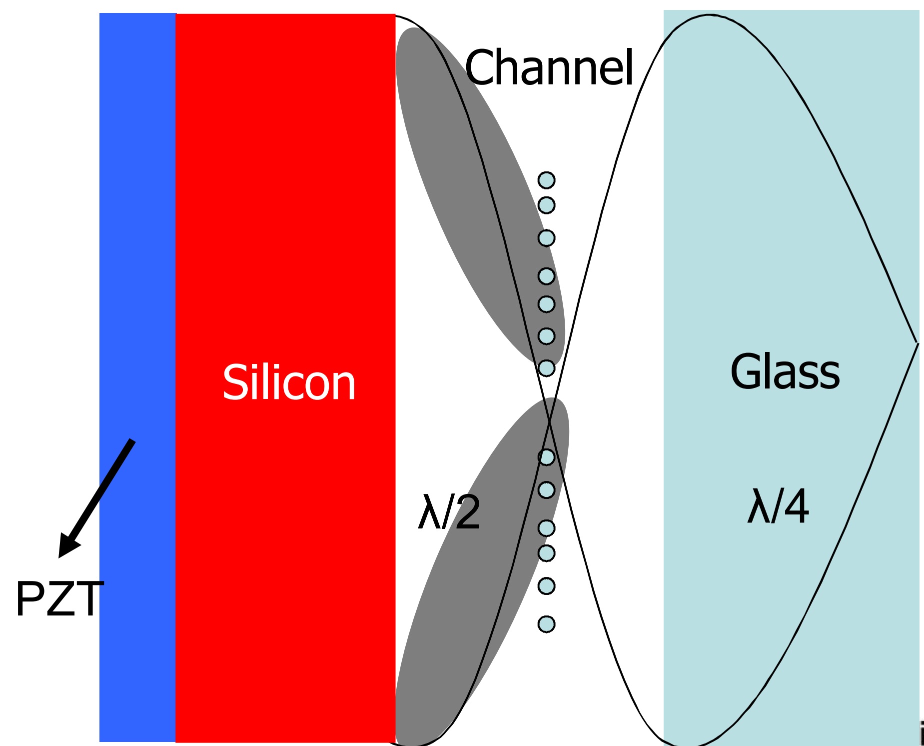
Near-Field Radiation Pressure



Sandia National Laboratories


Air
540 µm
Pyrex (reflector)
100 µm
Water
300 µm
Bonding layer
Silicon
40 µm {
19 µm {
790 µm {
PZT
Al electrode
Air


Channel
Silicon
Glass
λ/2
λ/4
PZT


Channel
Silicon
Glass
λ/2
λ/4
PZT

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 and when the geometry of the system is changed