SPIE Photonics West

THE UNIVERSITY OF ARIZONA

Development of terahertz microfluidic devices for "Lab-on-a-Chip" applications

Qi Tang[1], Min Liang[1], Yi Lu[2], Pak K. Wong[2], Gerald J. Wilmink[3], and Hao Xin*[1, 3]

[1]Dept. of Electrical and Computer Engineering, Univ. of Arizona
[2]Dept. of Aerospace and Mechanical Engineering, Univ. of Arizona
[3]Air Force Research Laboratory, Radio Frequency Bioeffects Branch

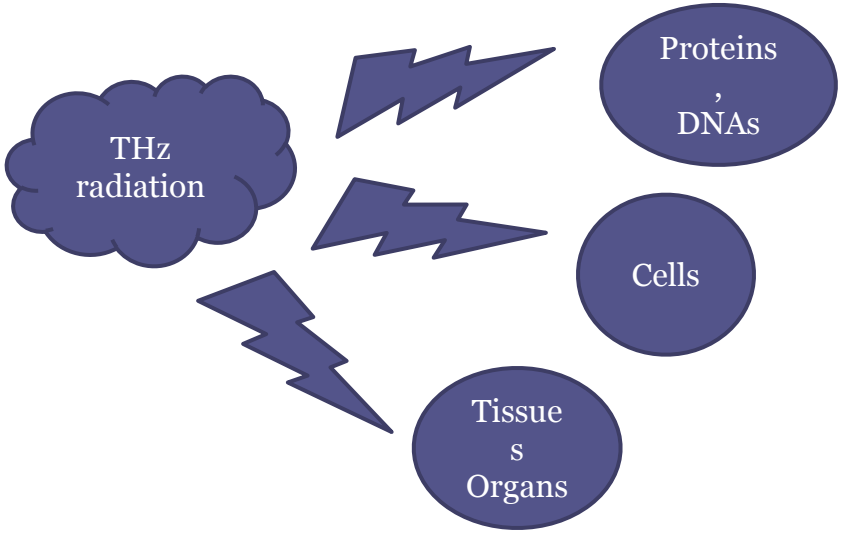
Outlines

- Backgrounds
- Motivations
- Device structure
- Trapping experiment
- THz spectral measurement
- Conclusion
- Acknowledgement???

Backgrounds

THz exposure in
1. Medical imaging
2. airport security checkpoint
3. Telecommunication
4. THz spectroscopy

THz Spectroscopy in
1. DNAs
2. Cells
3. Proteins…



1. Is there potential THz-induced biological effects?
2. Are there any unique spectral "fingerprints" in the terahertz range?

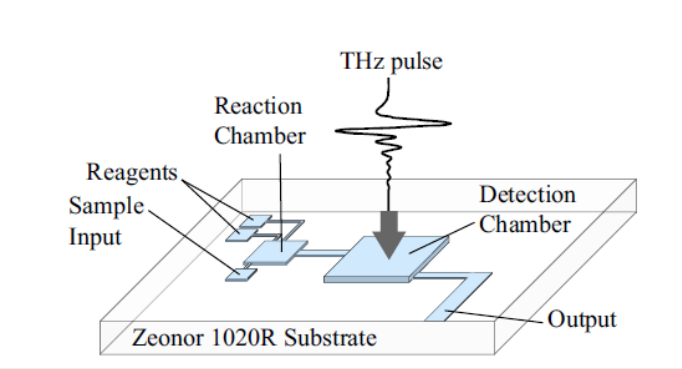
Motivations

- THz induced biological effects on individual cells
  - Cell control
  - Lab-on-a-chip application
- THz spectroscopy of individual cells
  - Subwavelength cell size (sensitivity)
  - Large absorption by aqueous medium (SNR)

Why use microfluidics?

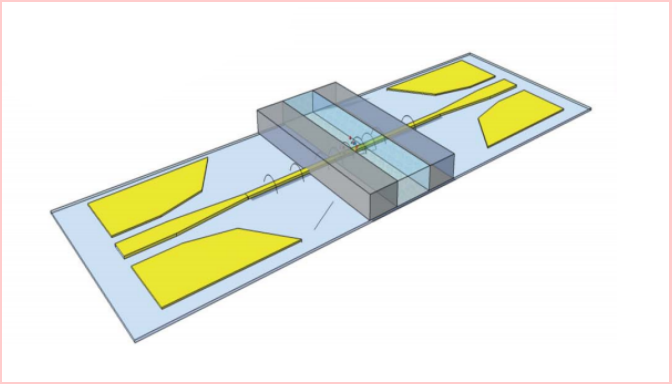
1. A good container.
2. Single-cell analysis, such as selection, navigation, or positioning.
3. Micro-dimensional features to avoid excessive THz absorption by aqueous media.
4. Low cost, high efficiency and accuracy.

THz microfluidics in literature



- by George, P. A. *et al.*[1]
- Measure the absorption spectra of vibrational modes of bovine serum albumin from 0.5 - 2.5 THz
- Detect molecular quantities as small as 10 picomoles without integrated probes.

[1] George, P. A. *et al.* Microfluidic devices for terahertz spectroscopy of biomolecules. *Optics Express* **16**, 1577 (2008).

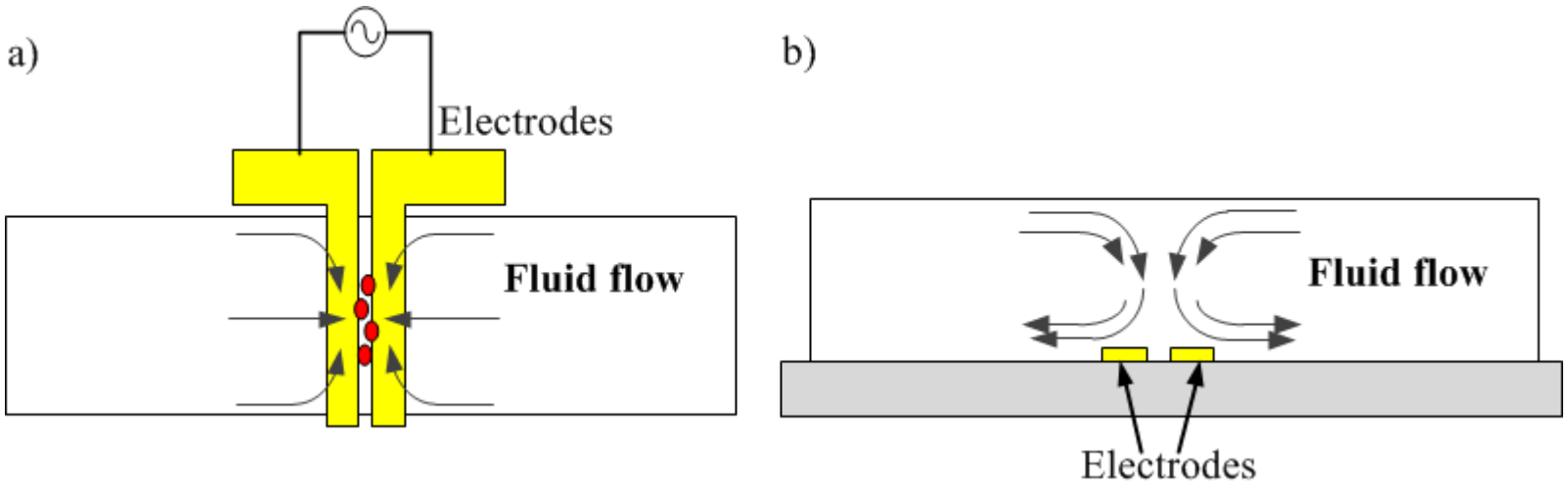


- by Laurette, S. *et al.*[2]
- Measure the absorption spectra of BSA, lysozyme and chymotrypsine proteins.
- By combining THz waveguides, the sensitivity can be down to 0.6 picomoles (5mg/mL BSA solution).

[2] **Laurette, S. *et al.*** Highly sensitive terahertz spectroscopy in microsystem. *RSC Advances* **2**, 10064 (2012).

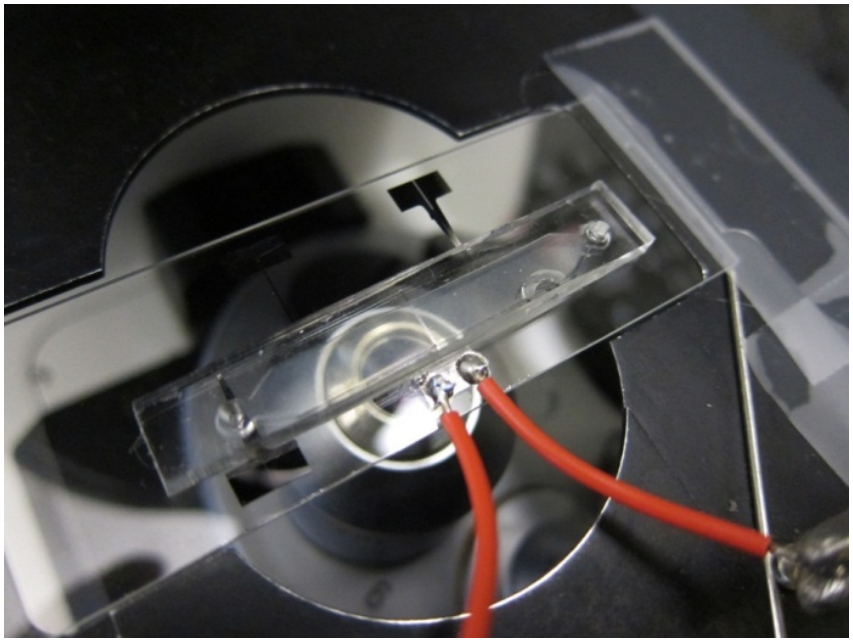
Cell trapping mechanism

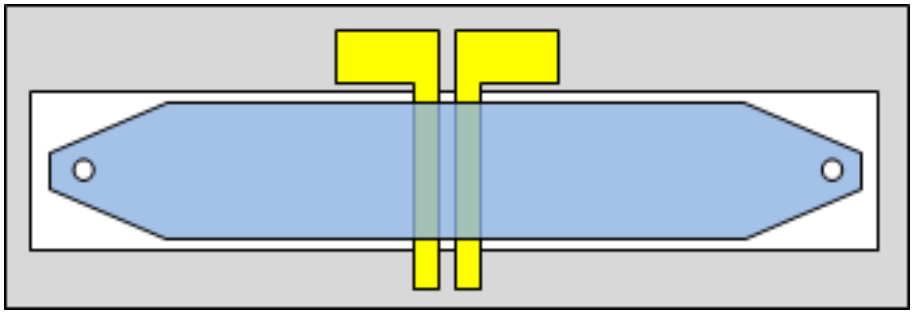
- A combination method of electrokinetic forces and fluid motion



The applied bias frequency of 1 MHz is selected after some trial and error experiments. Larger voltage amplitude generates more heat in the fluid, which would induce faster fluid motion.

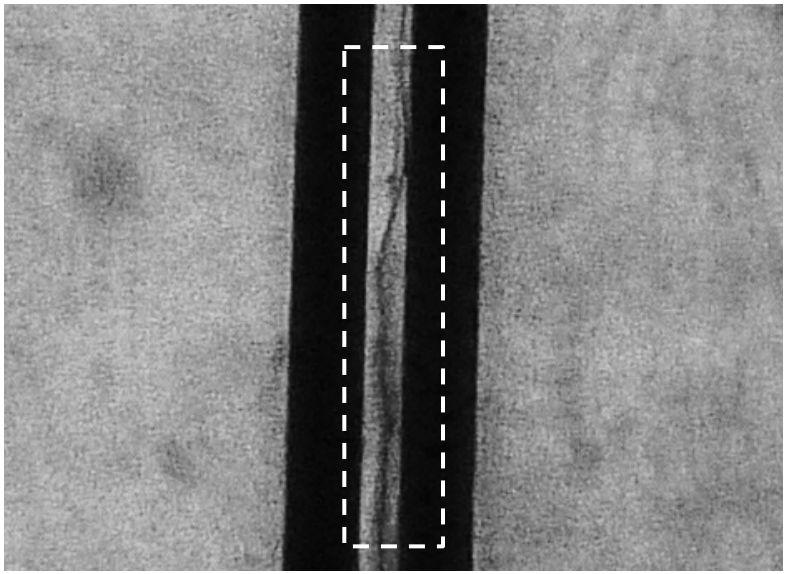
Structure dimensions



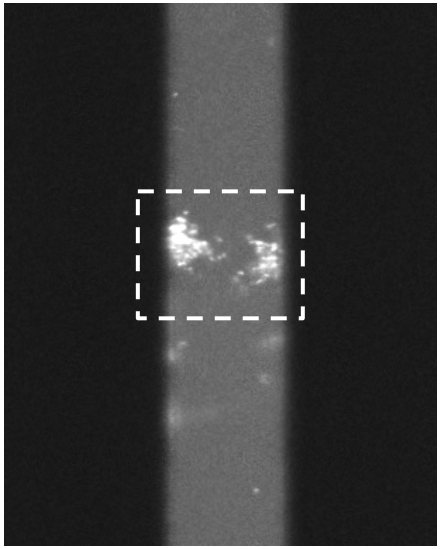


The channel length is 30 mm; the channel width is 5 mm; the electrode width is 100 μm; the gap width is 50 μm.

Trapping bacteria (E. Coli)



microscope image

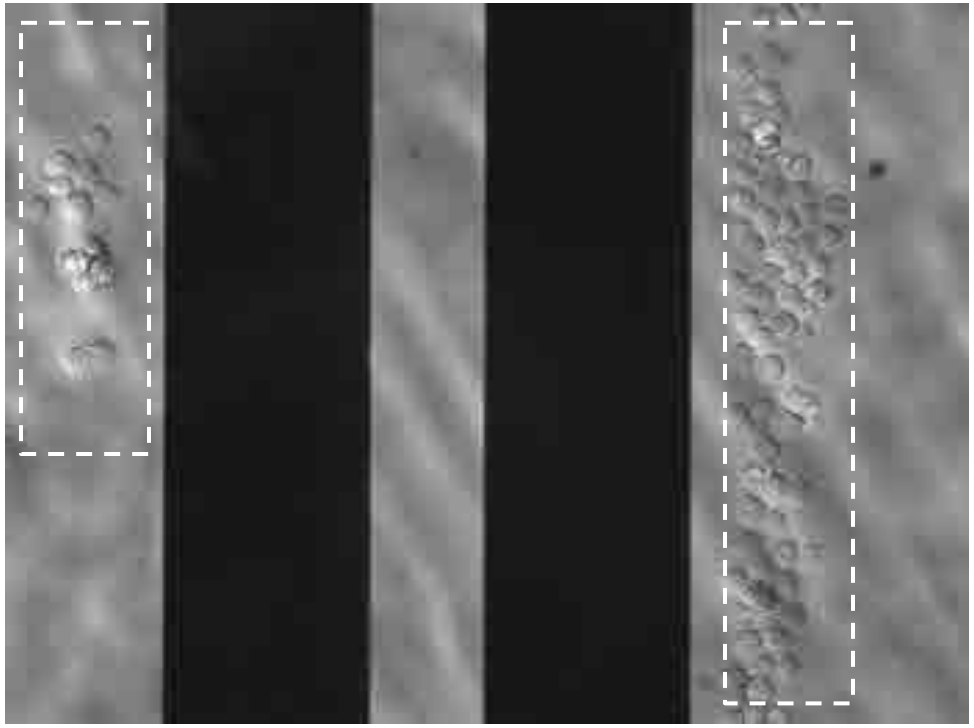


fluorescent microscope image

Positive DEP would result in cells being attracted to high field points

E. coli (~1–2 μm in diameter) bacteria in LB media (8.3×10^{-8} CFU/mL)

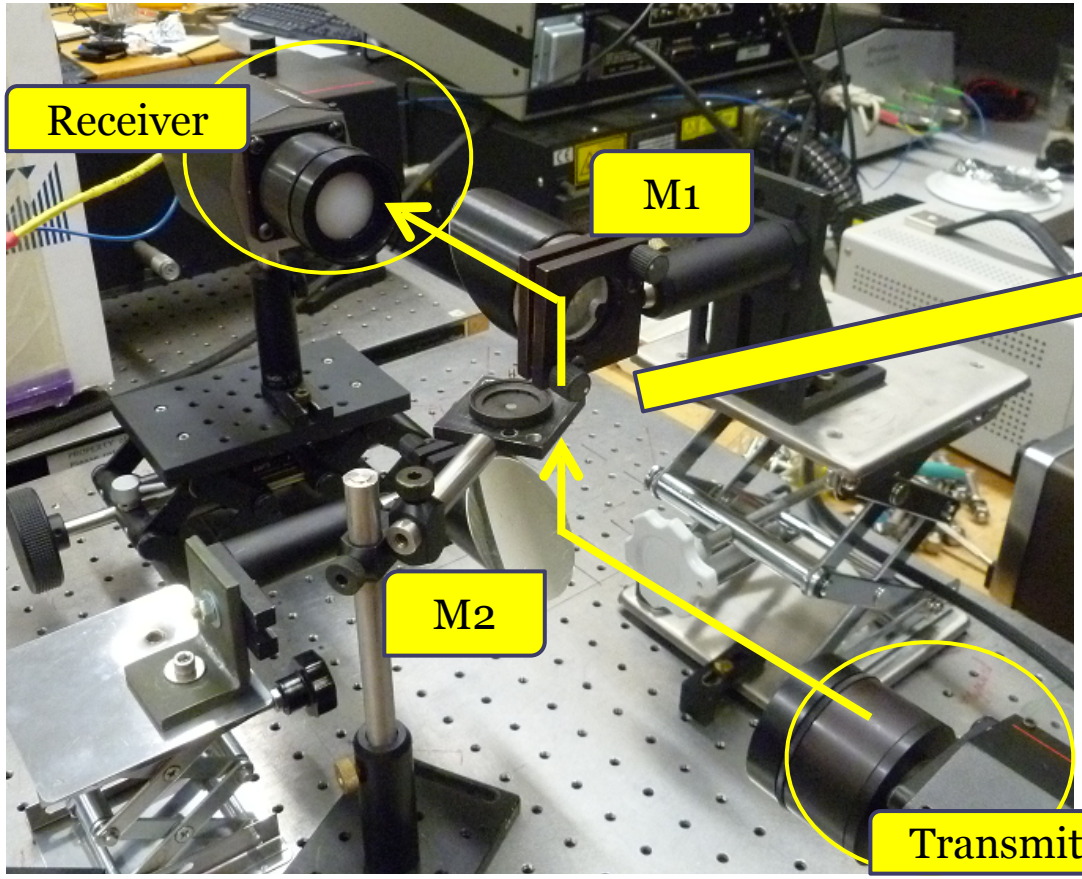
Trapping T lymphocytes (T-cells)

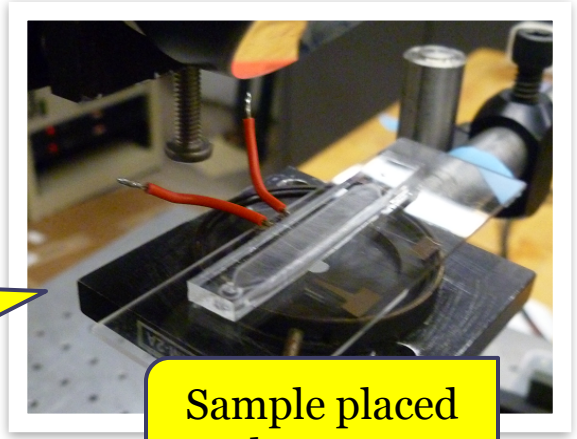


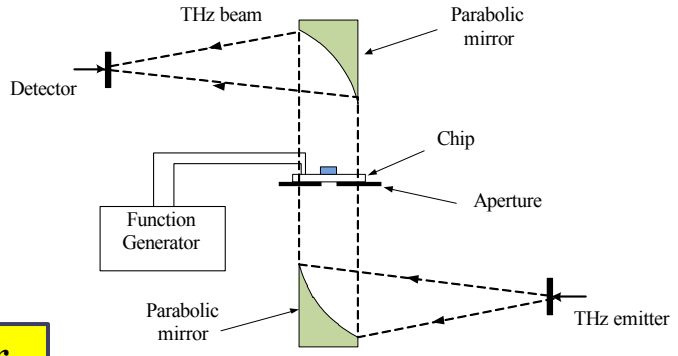
Negative DEP forces occur when the cell is less polarizable than the aqueous medium, and cause the movement of the particles away from the high field regions

T-cells (~12 μm in diameter) in RPMI media (4.7×10^3 cells/mL)

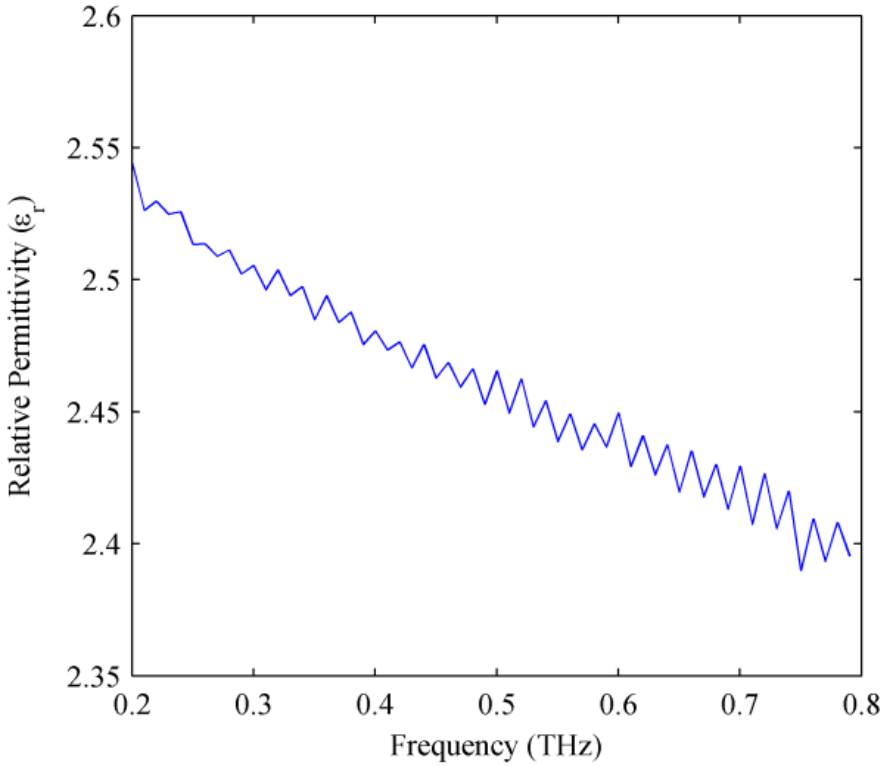
TDS measurement setup

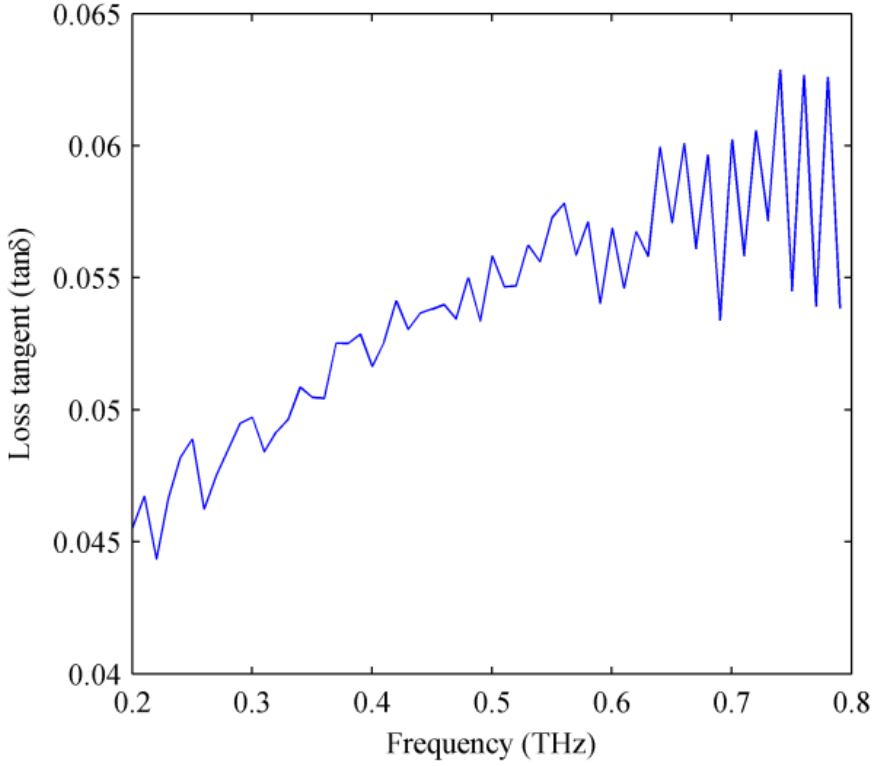




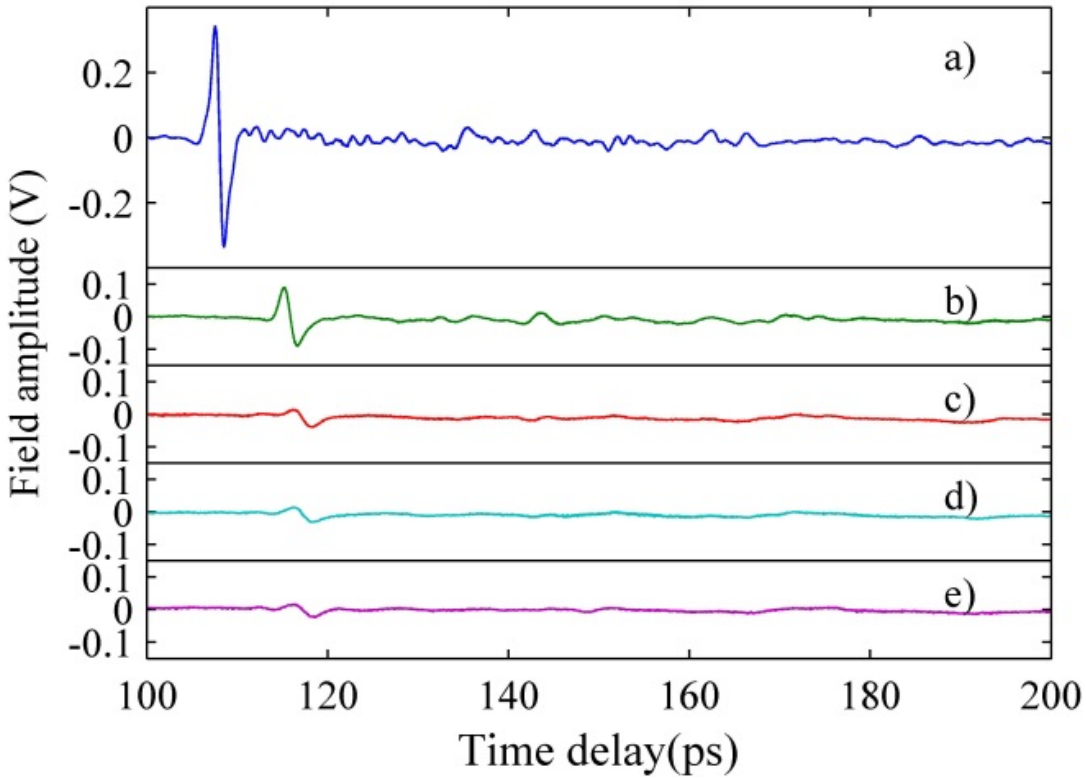


PDMS dielectric properties



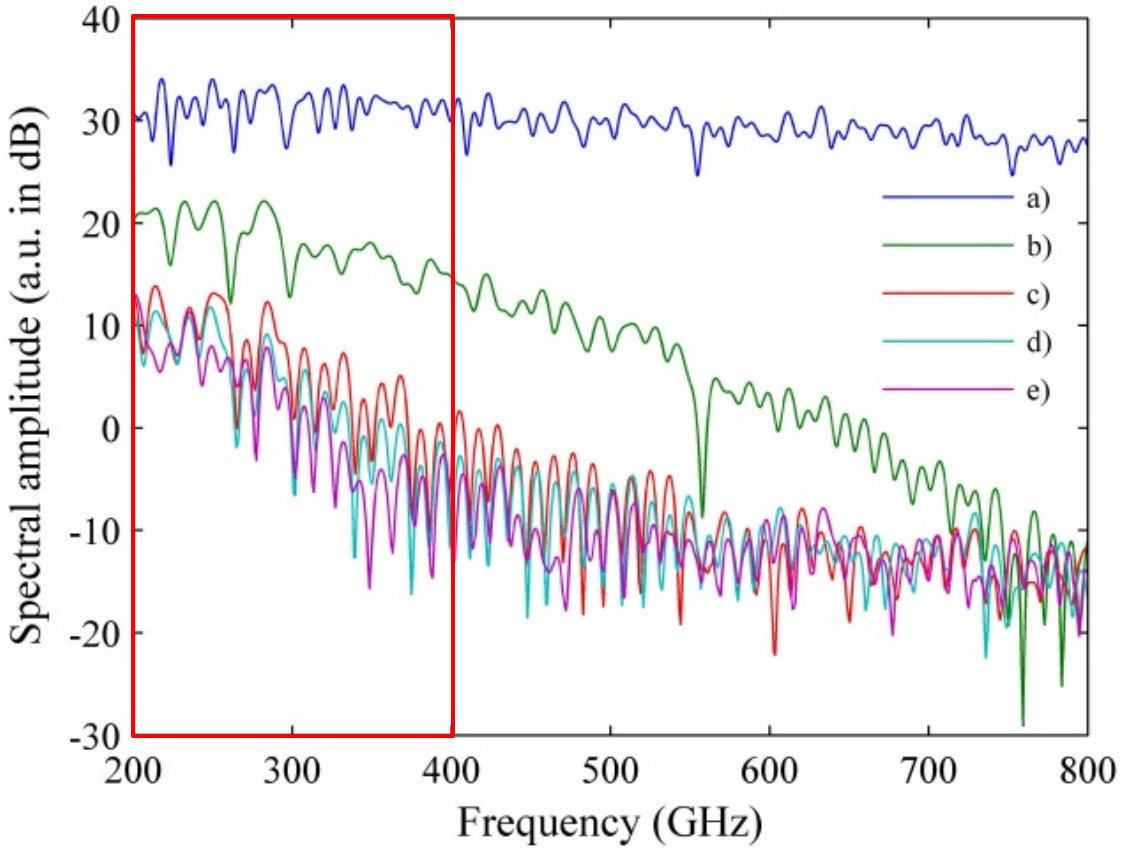


THz time-domain signals



(a) Aperture reference
(b) Empty chip reference
(c) Chip filled with LB solution;
(d) Chip filled with E. coli in LB media without AC bias
(e) Chip filled with concentrated E. coli in LB solution with continuous AC bias.

FFT of the THz time-domain signals



(a) Aperture reference
(b) Empty chip reference
(c) Chip filled with LB solution;
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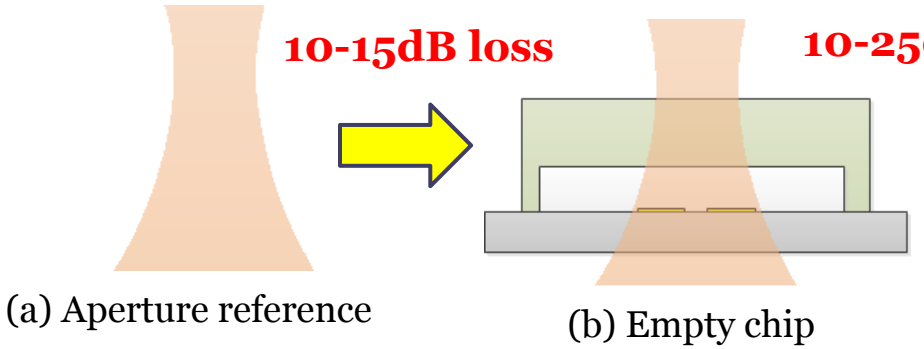
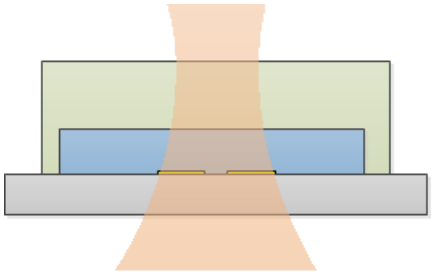
Analysis of loss

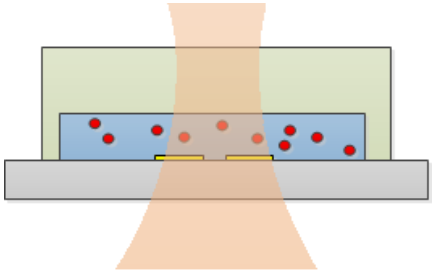


(a) Aperture reference

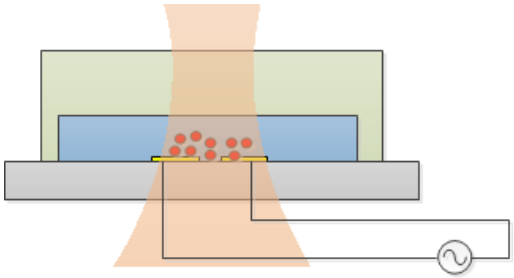
(b) Empty chip



(c) Chip filled with LB solution

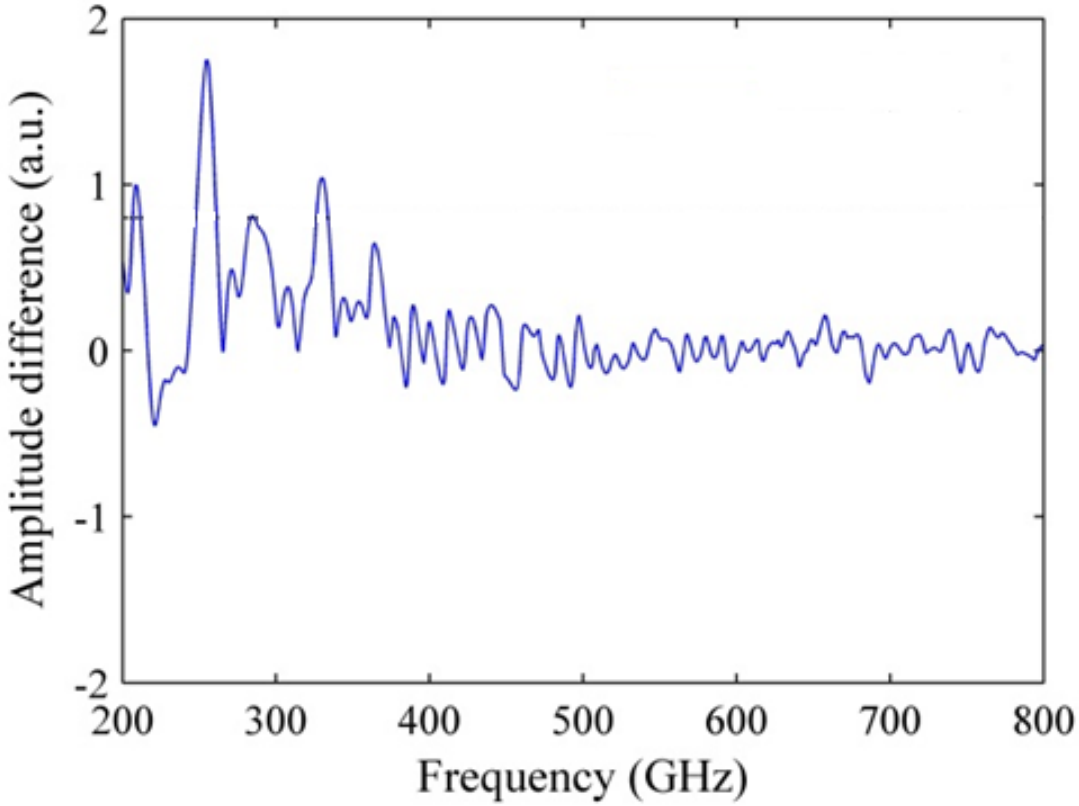


(d) Chip filled with E. coli in LB media without AC bias



(e) Chip filled with concentrated E. coli in LB solution with continuous AC bias

The spectral difference between the concentrated and non-concentrated states of the chip



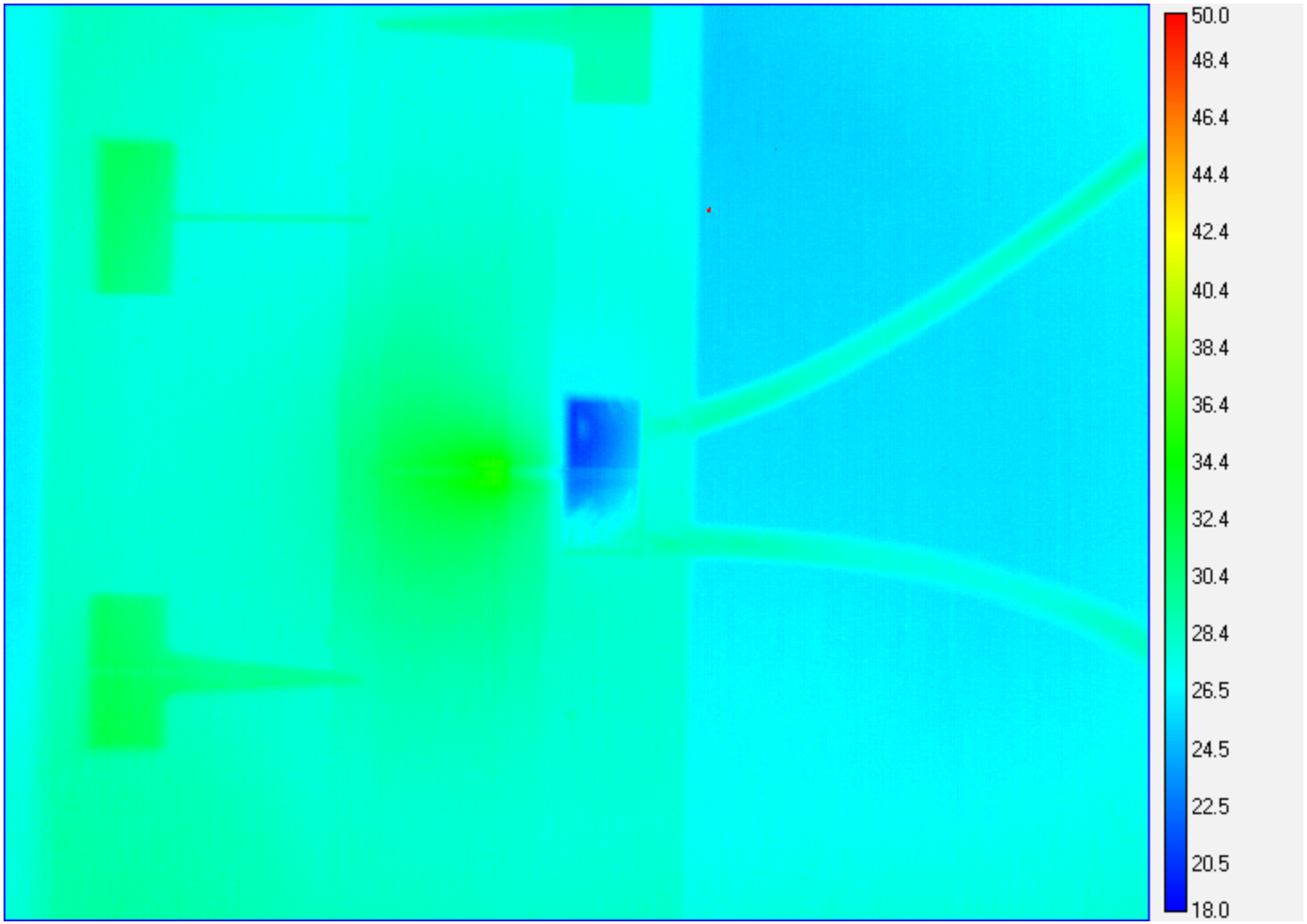
Conclusion

- E. coli and T-cells can be easily trapped near the electrodes by feeding AC signal.
- THz transmission spectrums of microfluidics channel, channel with solution, with cells, and with concentrated cells were measured and compared.

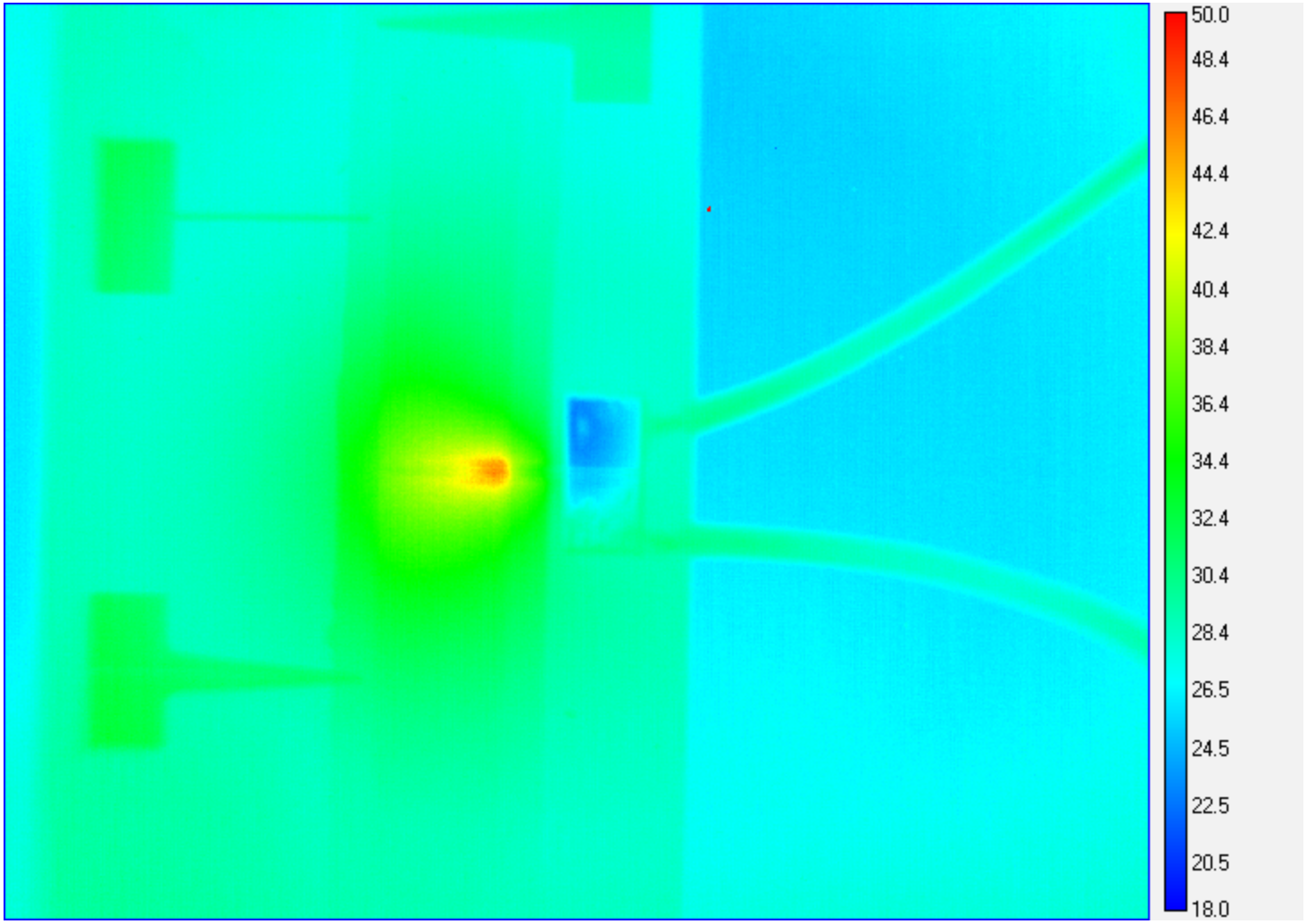
Thank you!

Do we need add information shown in the flollowing slides?

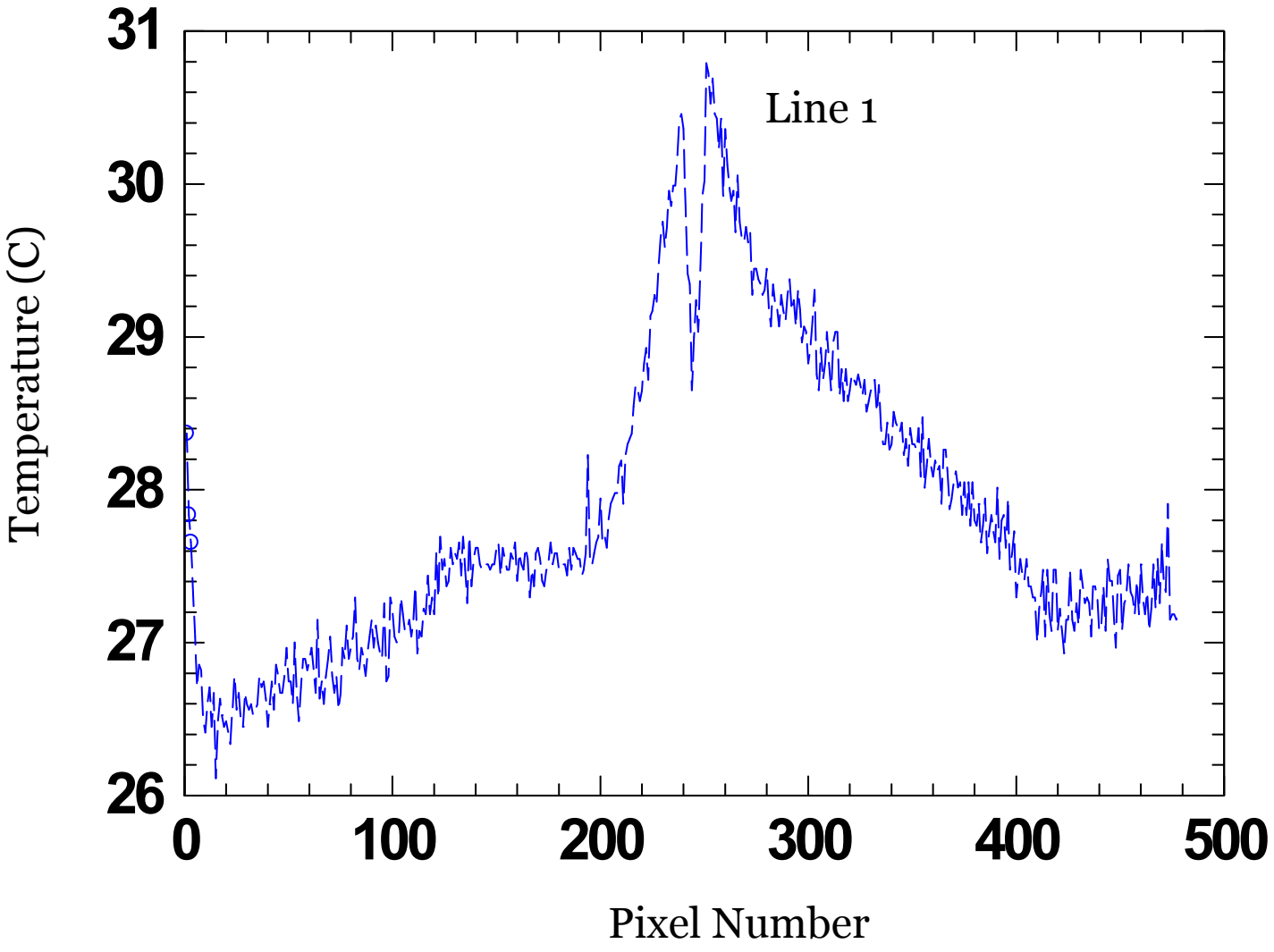
Channel Image – 3.5V @ 5 min



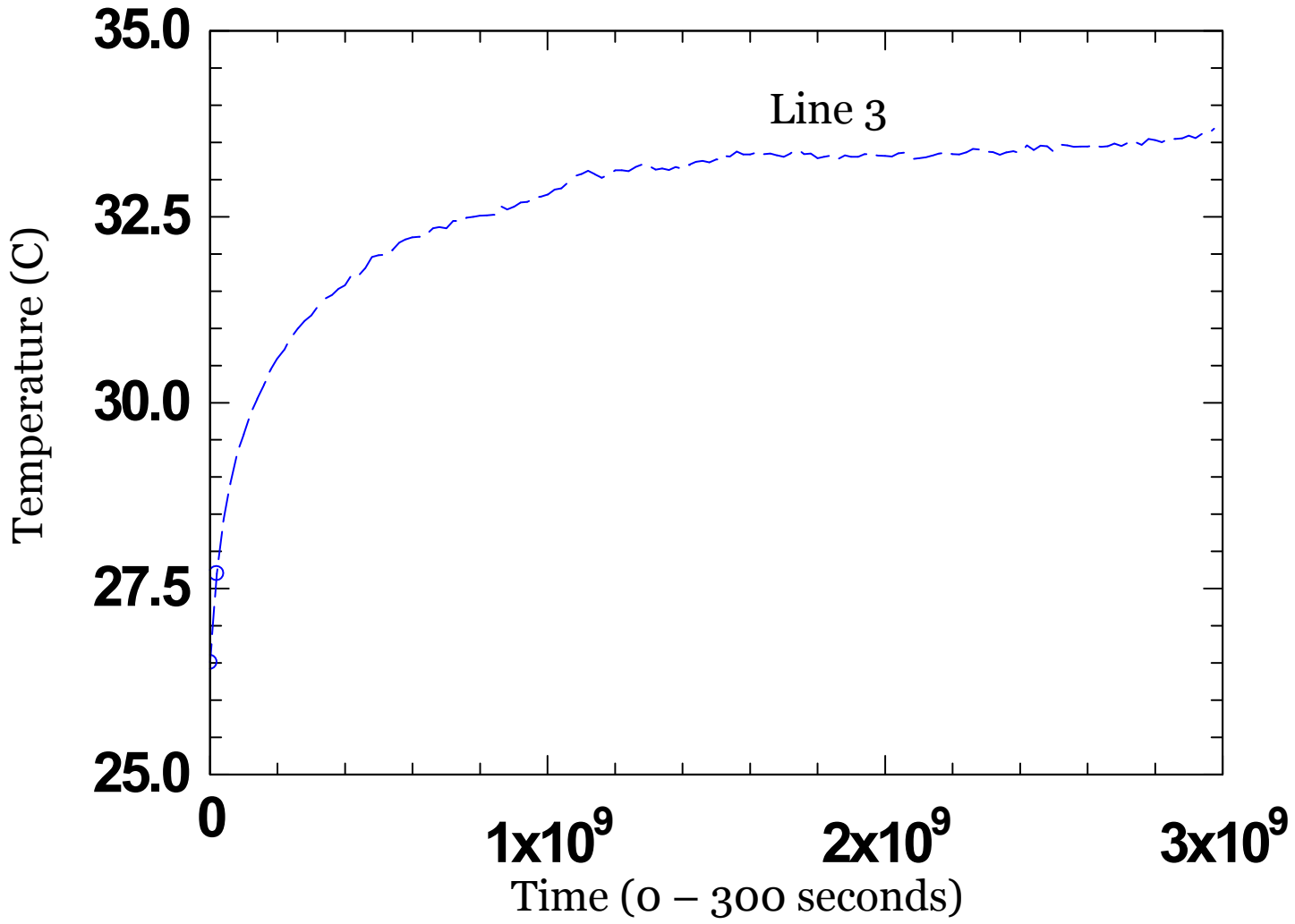
Channel Image – 5.0V @ 5 min



Channel Image – 3.5V @ 5 min



Channel Image – 3.5V vs. time



Maximum Temperature vs. Vpp