ICMA 2021
1st International Conference on Micromachines and Applications
15–30 APRIL 2021 | ONLINE
micromachines MDPI

Electrokinetic displays based on nano-particle dispersions

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Abstract

Electrokinetic displays have become one of the most important display technologies because of their low power consumption, wide viewing angle, and outdoor readability. They are regarded as excellent candidates for electronic paper. This type of display is based on the controlled movement of charged pigment particles in a non-polar liquid under the influence of an electric field. Free charges practically do not exist in nonpolar colloids, due to their low dielectric constant. However, the addition of a surfactant to non-polar colloids often leads to considerable charge-induced effects such as increased electrical conductivity and particle stabilization. In this project, we aim to develop a novel electrokinetically driven display, based on the combined action of **electro-osmosis** and **electrophoresis** in a non-polar fluid. This method could reduce the switching time for displaying information, and thus extend the use of electrokinetic displays towards video applications in the future.

Keywords: Electrokinetic displays; non-polar; surfactant; Electrophoresis; Electro-osmosis.

Introduction- Advantages and disadvantages of Electronic paper displays

- Reflective display.
- Low power consumption.
- Large viewing angle and high contrast under direct sunlight.
- Thin and flexible displays.
- Same readability as print.

- Low refresh rate
- Poor color saturation

Introduction- Applications

- E-paper Display for Transportation Information System.

- Gas Station Price sign.
- Menu Board.
- Electronic billboards.
- Smart watches.

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Introduction- Aims of the project

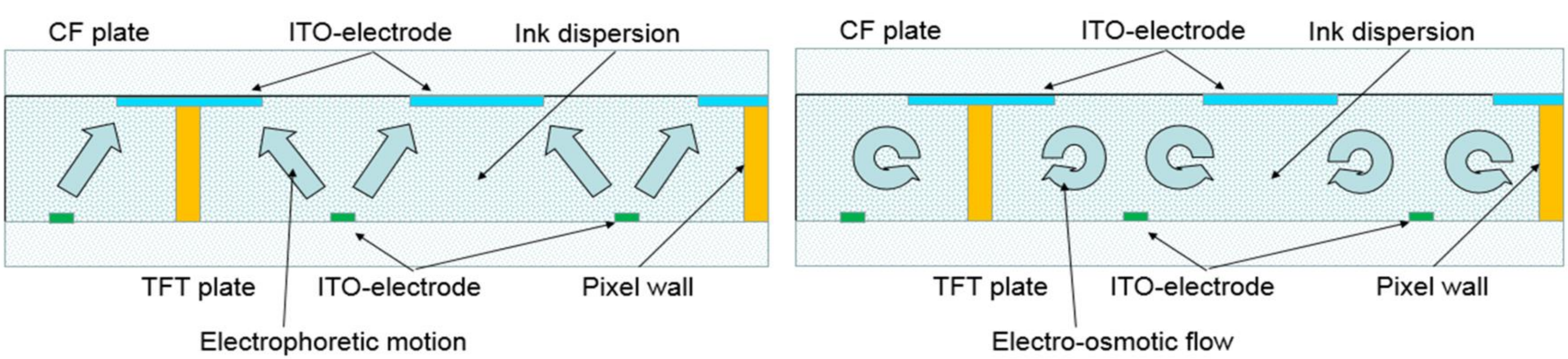
- To study the effects of the combination of electrophoresis and electro-osmosis in non-aqueous/non-polar systems.

- To create fundamental understanding of particle and fluid motion in electrokinetic nanoparticle dispersions.

- Use this fundamental understanding to design a novel electrokinetically driven display principle.

Introduction-the combination of electrophoresis and electro-osmosis in non-polar systems

- **Electrophoresis**: the movement of charged particles in a liquid under the influence of an electric field.
- **Electro-osmosis**: the motion of fluids near a charged surface under the influence of a tangential electric field.



Example of electrophoretic (left) and electroosmotic (right) interaction of the display medium with an electric field.

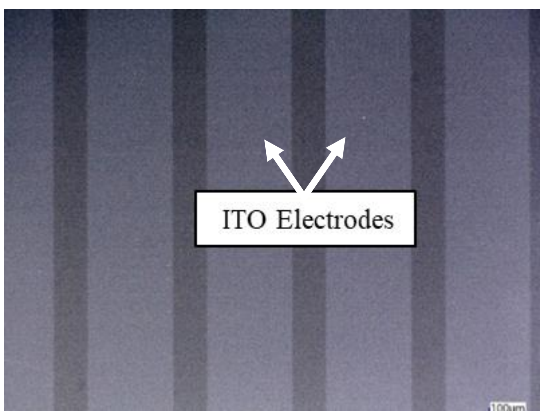
Fabrication process-Microfluidic cells

We use photolithography techniques to fabricate electrode patterns on a glass substrate. These patterned glass substrates form the bottom wall of our microfluidic cells.

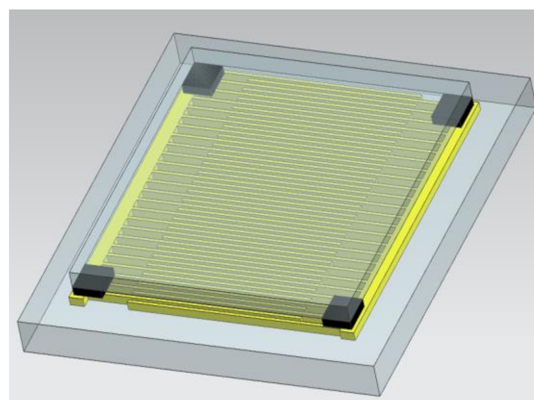
- SU-8 2050 (negative photoresist) spin-coated on ITO glass
- The Pre-bake treatment
- UV exposure
- The post-bake treatment
- Development

→

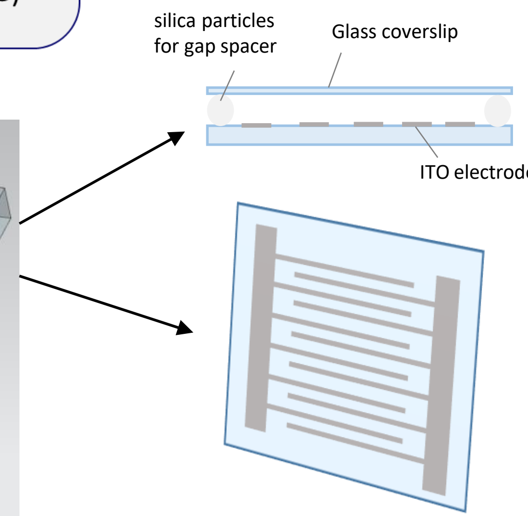
- Etching (HCL: H_2O: HNO_3 = 3: 2: 1 v%)
- Rinsed with DI water
- Blow dried with nitrogen.
- Removal of photoresist (Remover PG)



Top view of the ITO electrode pattern used in the experiments.



interdigitated symmetric ITO electrodes pattern used in the experiments.



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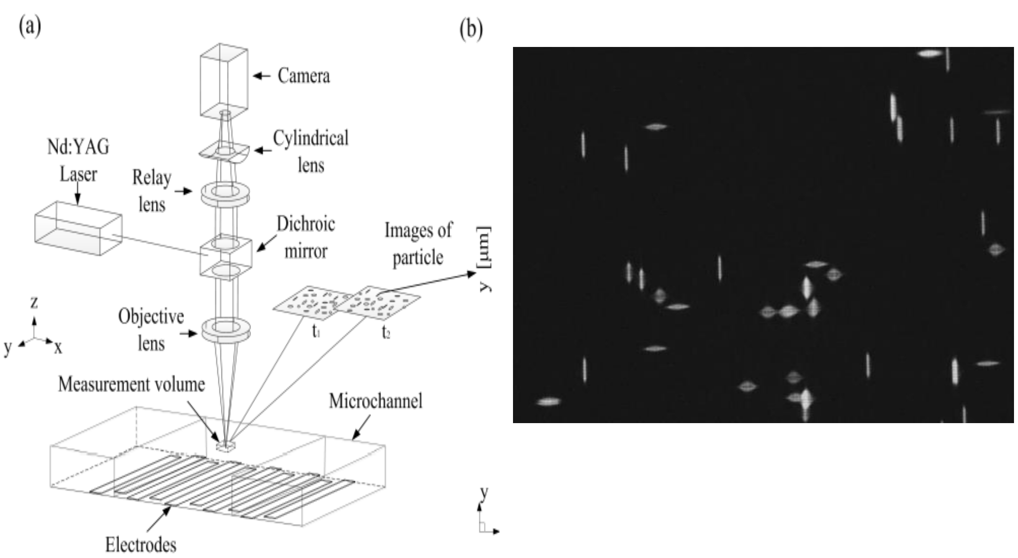
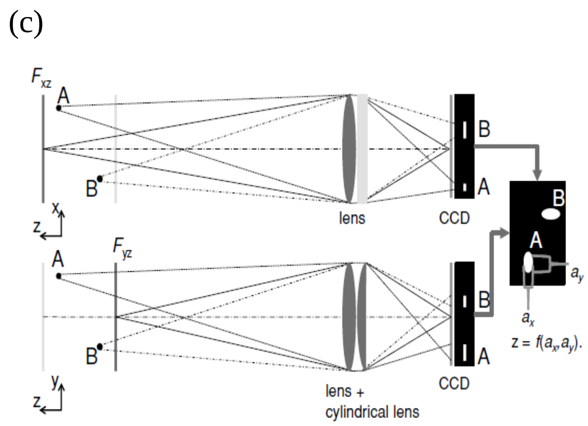
Measurement technique: Astigmatism micro-particle tracking velocimetry (A-μPTV)

A-μPTV has a great potential to perform 3D measurements in electro-osmotic flows.

- Due to the anamorphic effect of inserting a cylindrical lens, the A-μPTV system has two different magnifications in the two orthogonal orientations, resulting in a wave front deformation (elliptical shape) of a fluorescent particle image. Based on the aspect ratio of the ellipse we can detect the depth in the *z* direction for each particle.



(a): Schematic diagram of A-μPTV system. (b): Image of fluorescent particles, where the deformation of the particle image is a measure of depth in the *z*-direction.



(c): The upper part of this picture illustrates how the imaging system works in the *x* direction, and the lower part shows the system operation in the *y* direction.

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Experimental setup of Astigmatism micro-particle tracking velocimetry (A-μPTV)

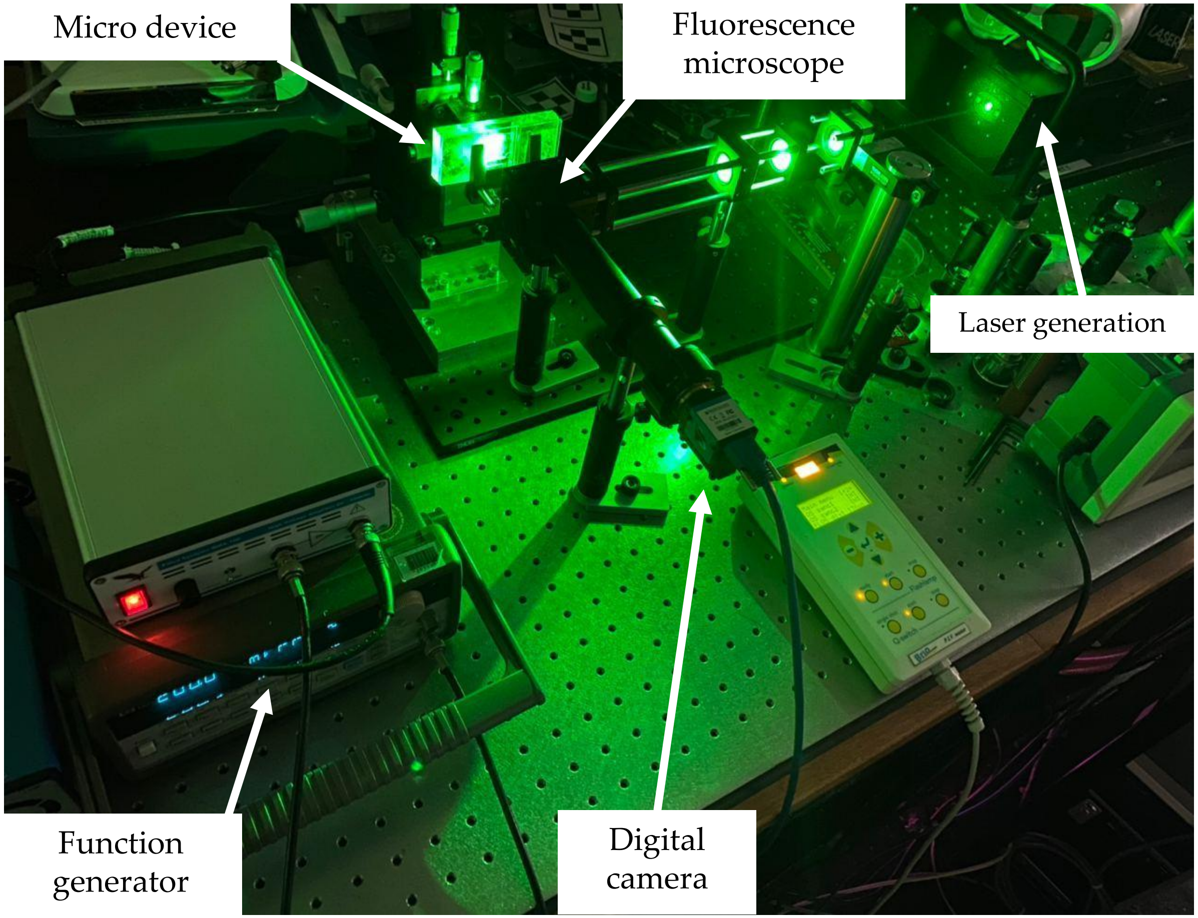

Photo of the experimental setup

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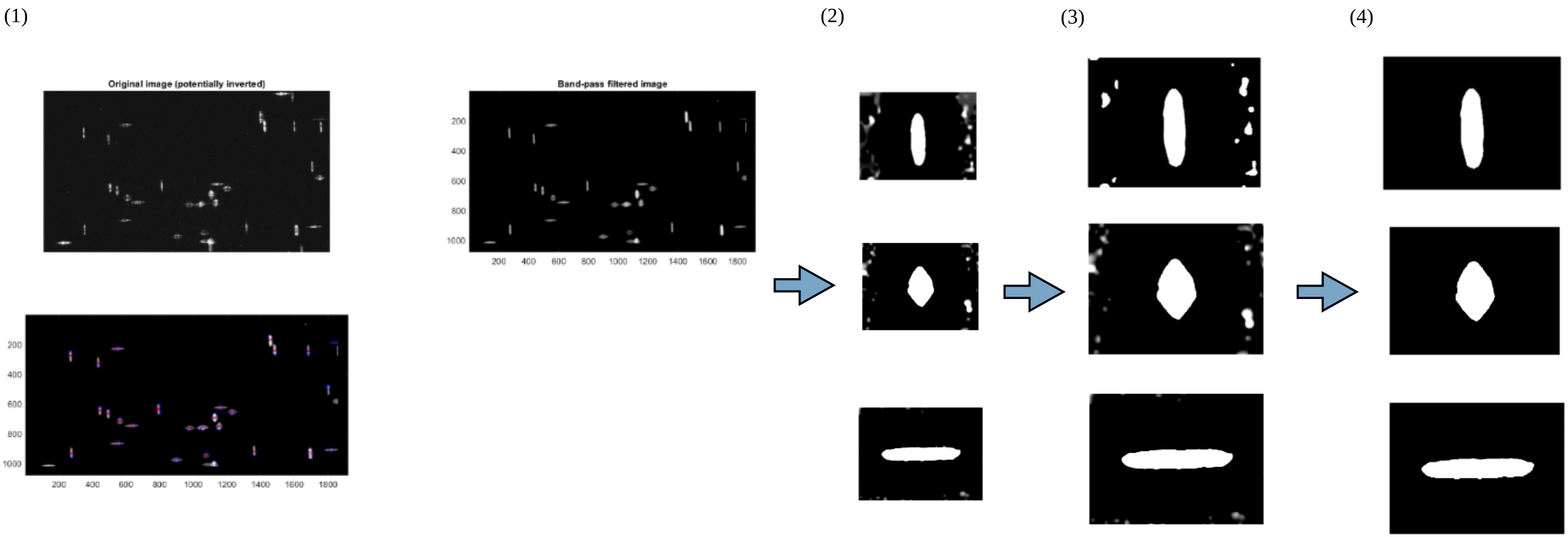
Image processing to detect the *z* position of the particles (particle shapes)



Steps of digital image analysis: **(1)** band-pass filtering and determination of the center of particles. **(2)** Based on the primary positions of the detected particle center, a detection region is defined. **(3)** Then Bicubic spline interpolation is applied on each detection region, to improve the resolution of the particle image. **(4)** finally, to quantify the image deformation of each particle, the detection region is converted into black and white, and the corresponding diameters of particle images are measured in the *x*- and *y*-directions.

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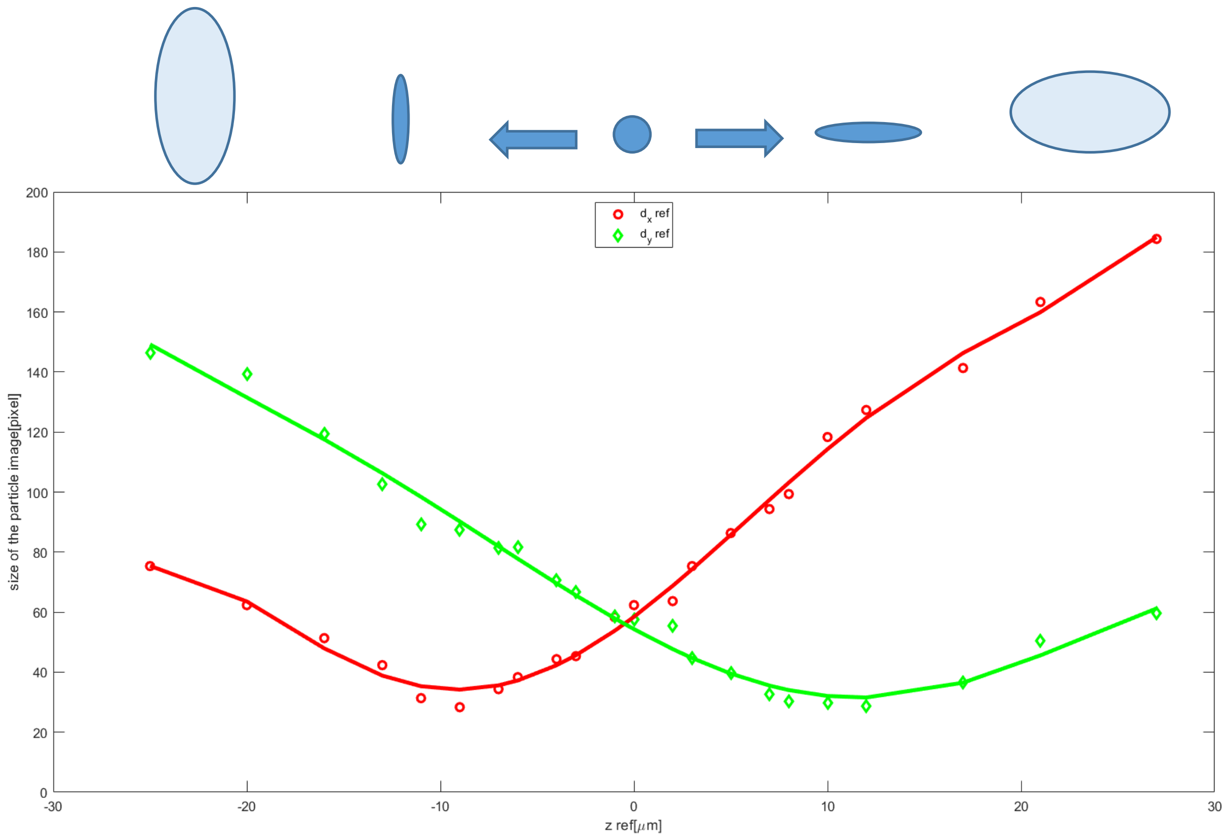
Detection of particle *z* position (calibration curve)

The calibration was done by relating the deformation of the particle image in the *x*-and *y*-directions to its relative *z*-position with respect to two focal planes. In our setup, a cylindrical lens with a focal length of 150 mm is used. Based on the calibration function, the three dimensional positions of particles were measured.



The width d_x and the height d_y as a function of the reference z-position for the case of a 2μm diameter particle viewed with a magnification of M = 20 and f_{cyl} = 150 mm.

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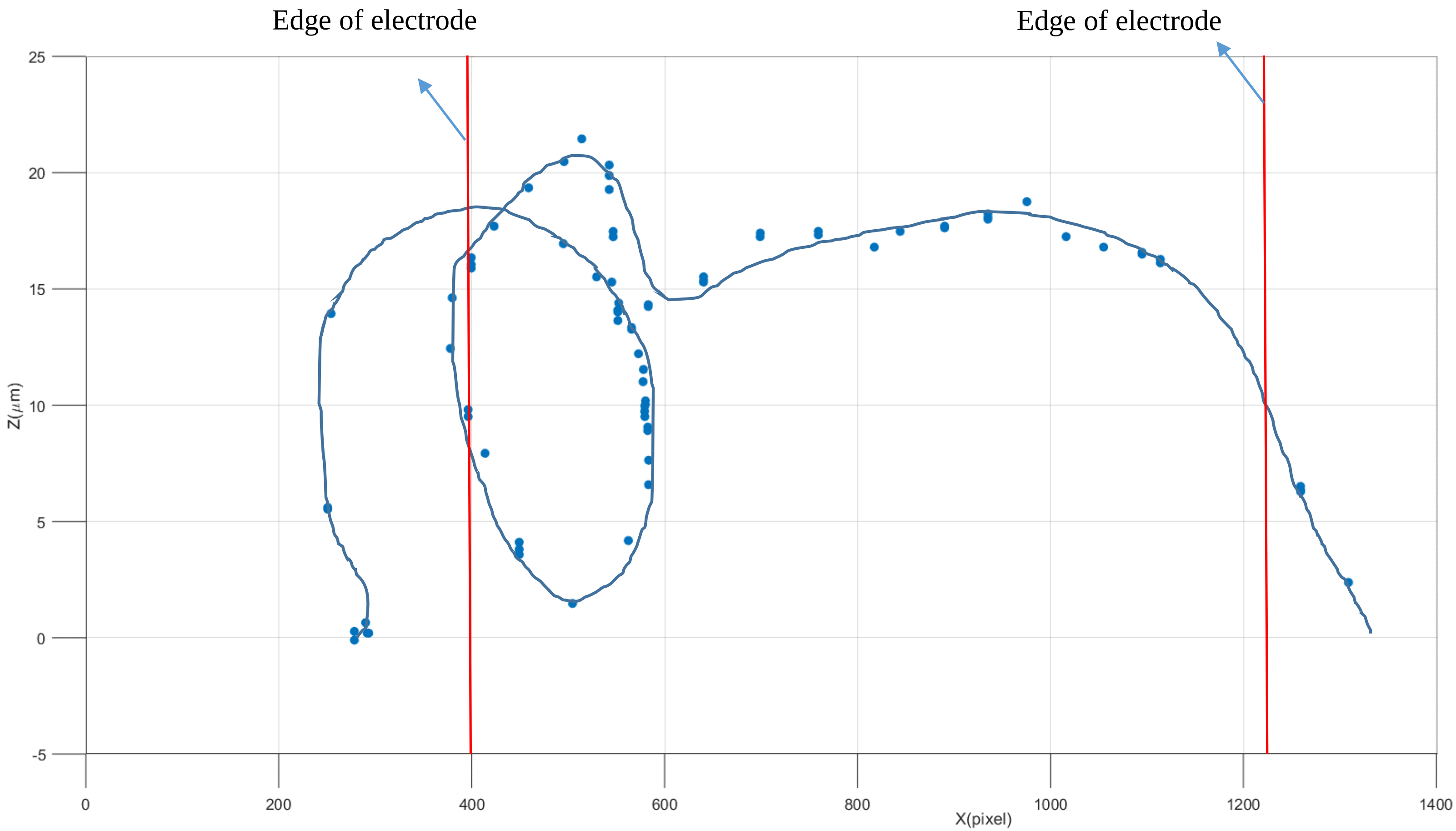
Results

particle trajectories



Trajectories of one particle measured at applied frequency of 50 *mHz* and voltage of 20 *V*.

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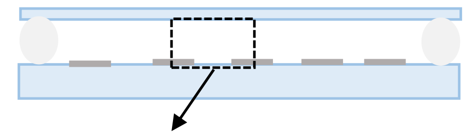
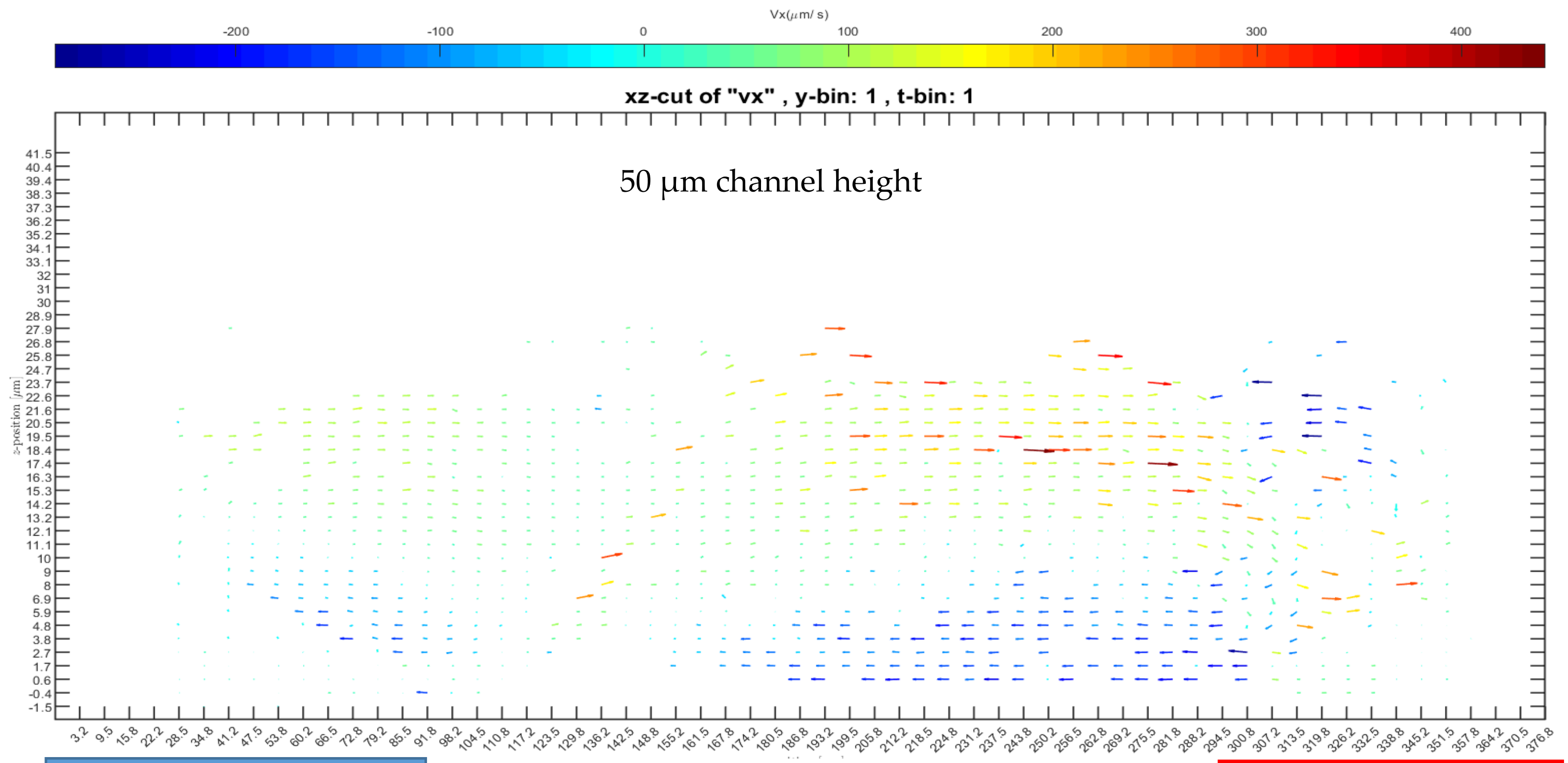
Results

Velocity field, x-component velocity , in-plane switching

In-plane switching, i.e.
coplanar electrodes





ITO Electrode

ITO Electrode

- Figure illustrates the velocity field in the domain Ω : [*x*; *z*] = [0; 380] × [0; 50] (μm × μm) for Δt = 0:05 s.
- The velocity field due to the combined action of electro-osmosis and electrophoresis on an array of interdigitated symmetric electrodes in micro-channels is experimentally analyzed using astigmatism micro particle tracking velocimetry.

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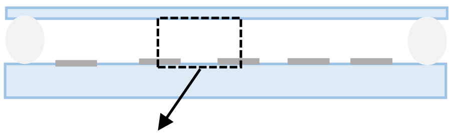
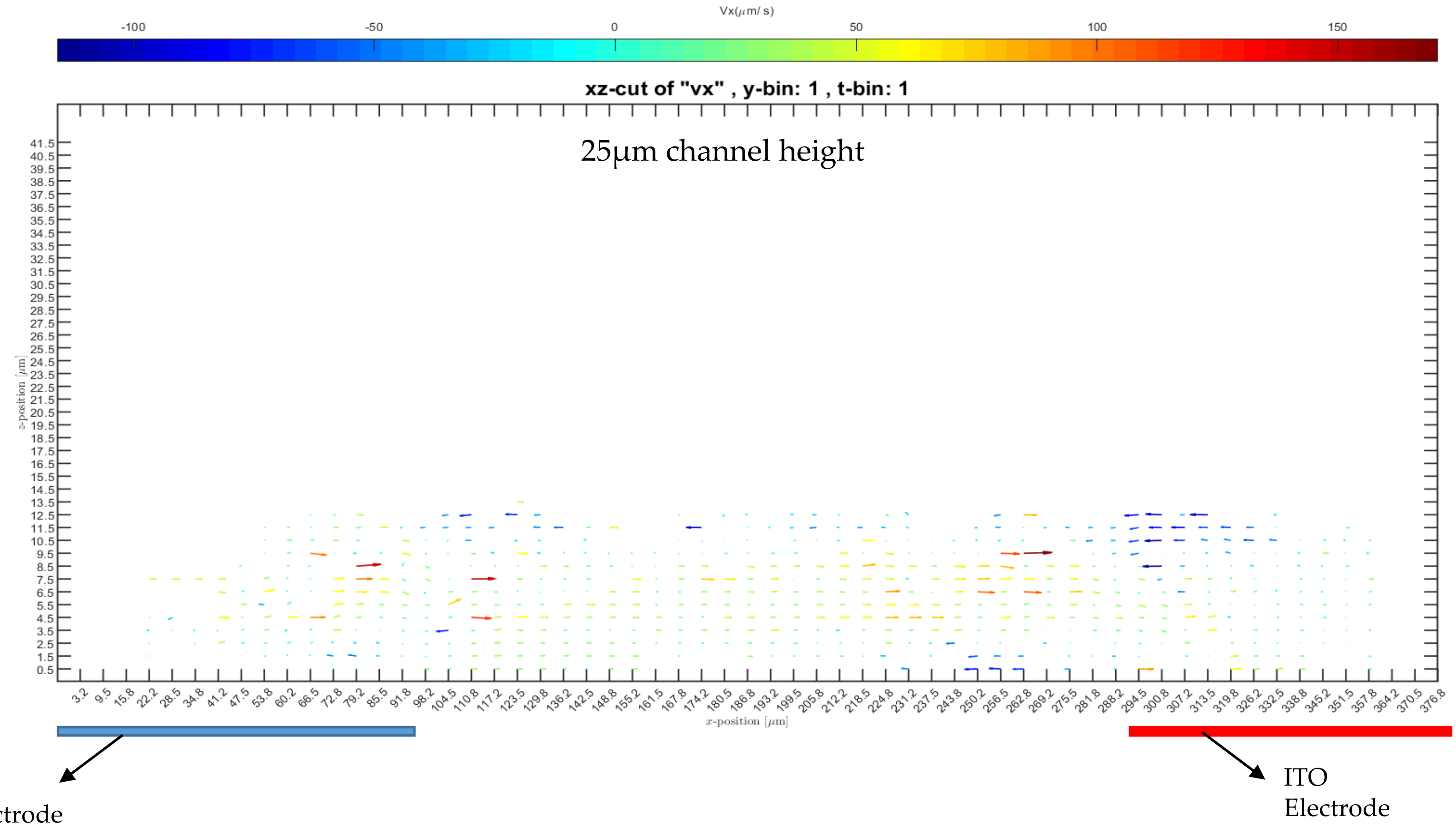
Results

Velocity field, x-component velocity , in-plane switching.





- Figure shows the velocity field in the domain Ω : [*x*; *z*] = [0; 380] × [0; 25] (μm × μm) for Δt = 0:05 s.
- The velocity field measured at applied frequency of 30 *mHz*, voltage of 20 *V* and during 150 frames, 7.5 seconds.

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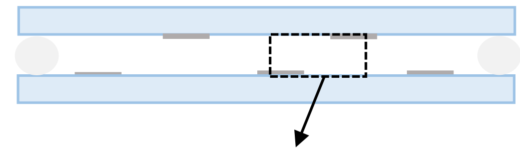
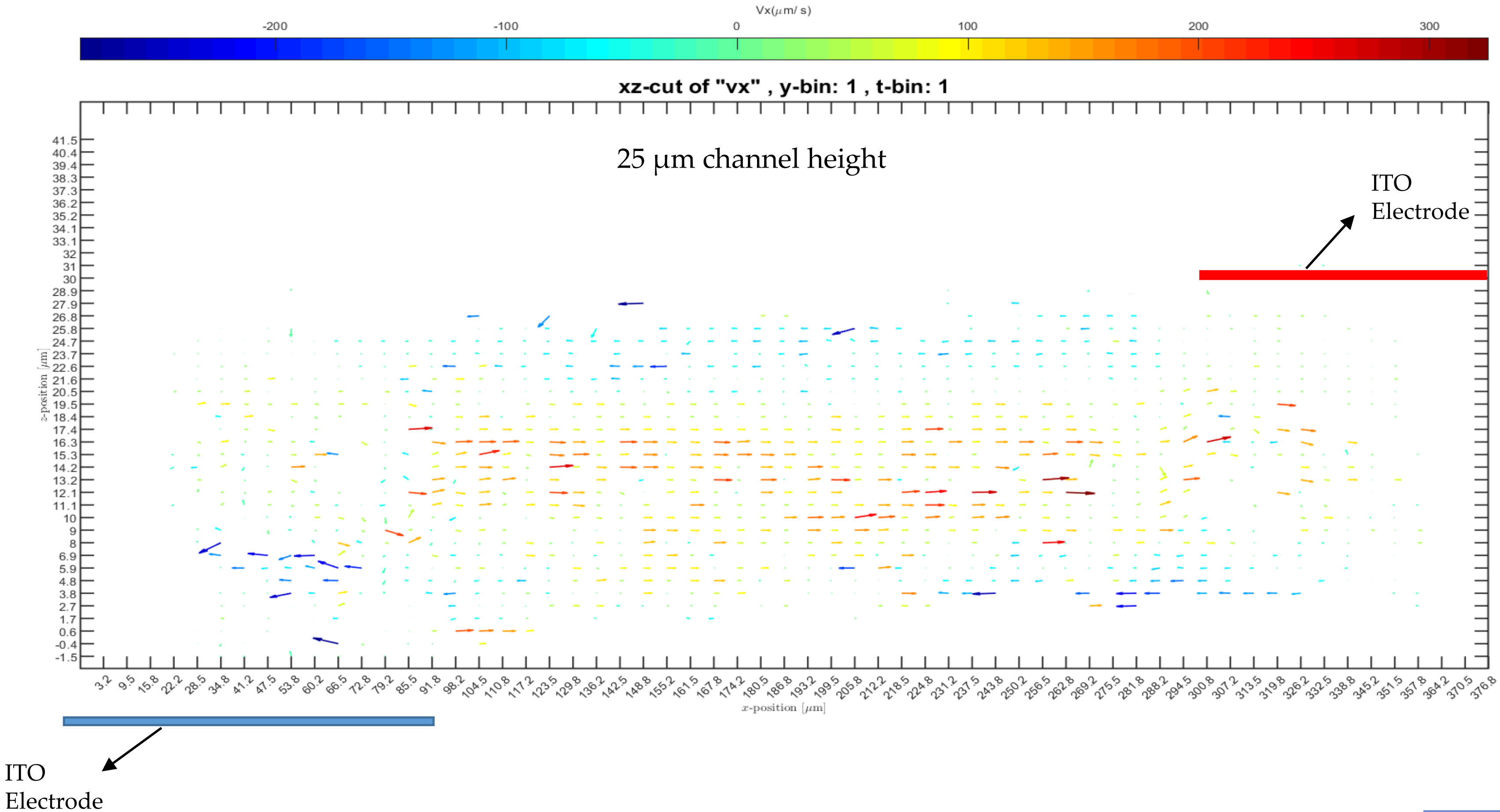
Results

Velocity field, x-component velocity , out-plane switching.

out-plane switching, i.e.
electrodes on opposing surfaces





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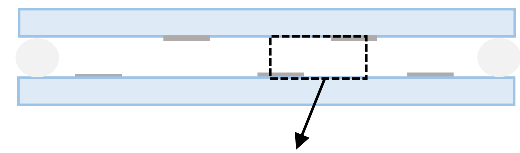

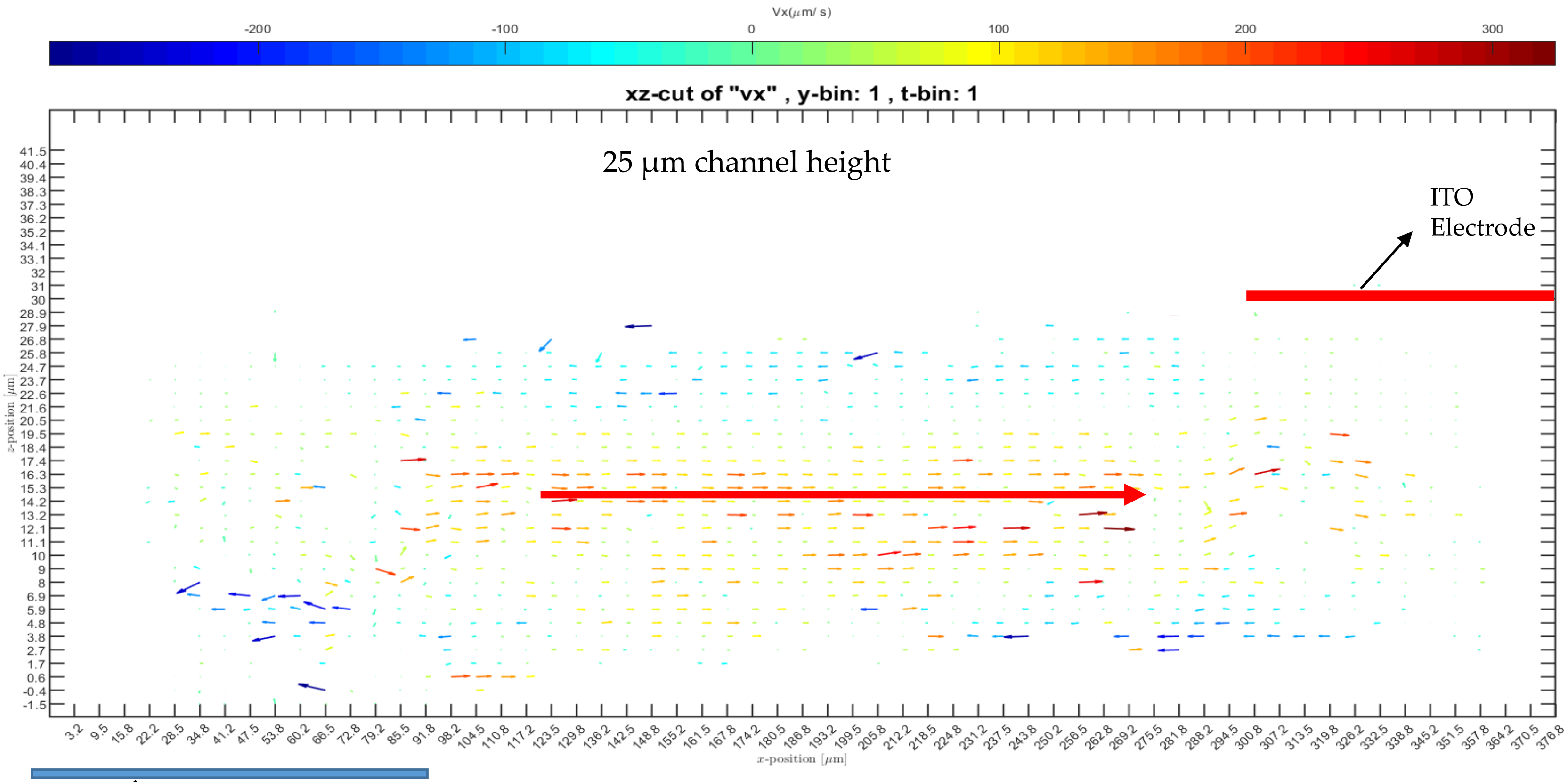

ITO
Electrode

Combined action of electrophoresis and electro-osmosis ⟶ higher transport velocity than in-plane case.

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Conclusion and outlook

- We have set up a model system for studying the combined action of electrophoresis and electro-osmosis.
- The components of the velocity field were obtained using the astigmatism micro-Particle-Tracking Velocimetry technique.
- Increasing the effect of electro-osmosis and improving the speed of the particles using out-plane switching.

Outlook

- Additional systematic measurements, link to simulation work.
- Testing more complex geometries to enhance electroosmotic flow.

Acknowledgments

- Microsystems group at TU/e
- South China Academy of Advanced Optoelectronics
- " NaPaS" project is supported by Science and Technology Project of Guangdong Province (No. 2018A050501013)