Two-phase microfluidic systems for bioanalitical applications

PhD Report – 2nd semester

Zsombor Szomor

HUN-REN Centre for Energy Research
Institute of Technical Physics and Materials Science
Microsystems Laboratory

Supervisor: Dr. Péter Fürjes (EK-MFA)

E-mail: szomor.zsombor@ek.hun-ren.hu

www.ek.hun-ren.hu | www.mems.hu | www.biomems.hu

Motivation

Cheap, easy to use microfluidic device available to anyone e.g.

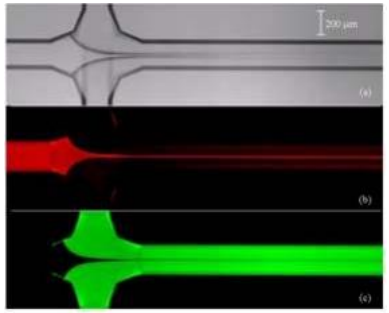
- to investigate the physiological response of cell populations / individual cells exposed to a chemical agent
- for cell analysis and sorting
- to control biochemical reactions

Objective of the semester

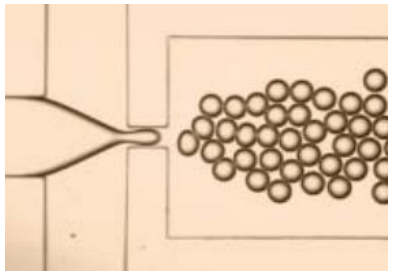
- Literature search for recent studies and applications
- Manufacturing microfluidic systems using micromechanical technologies
- Define the droplet diameter and generation frequency of the previously created systems

Introduction

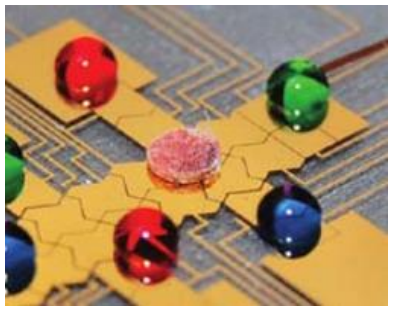
The specific types of microfluidics



Continuous



Two (or more) phase

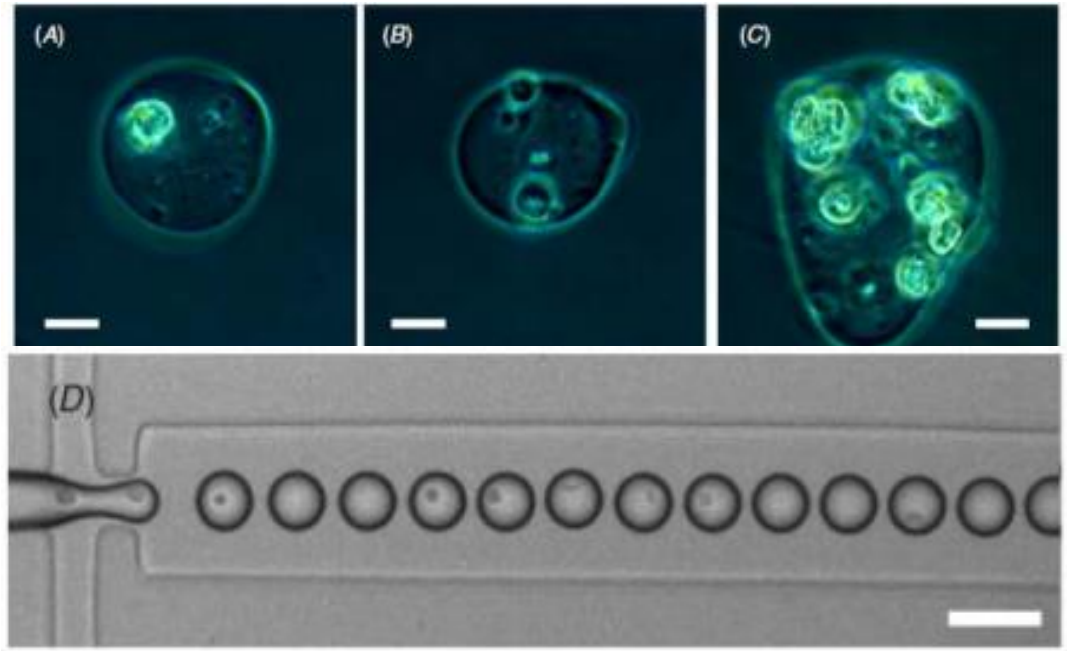


Digital

Source:https://biomems.hu/sites/www.biomems.hu/files/BME_ETT_BIOMEMS_mikrofluidika_2017.pdf

Application of droplet based microfluidics

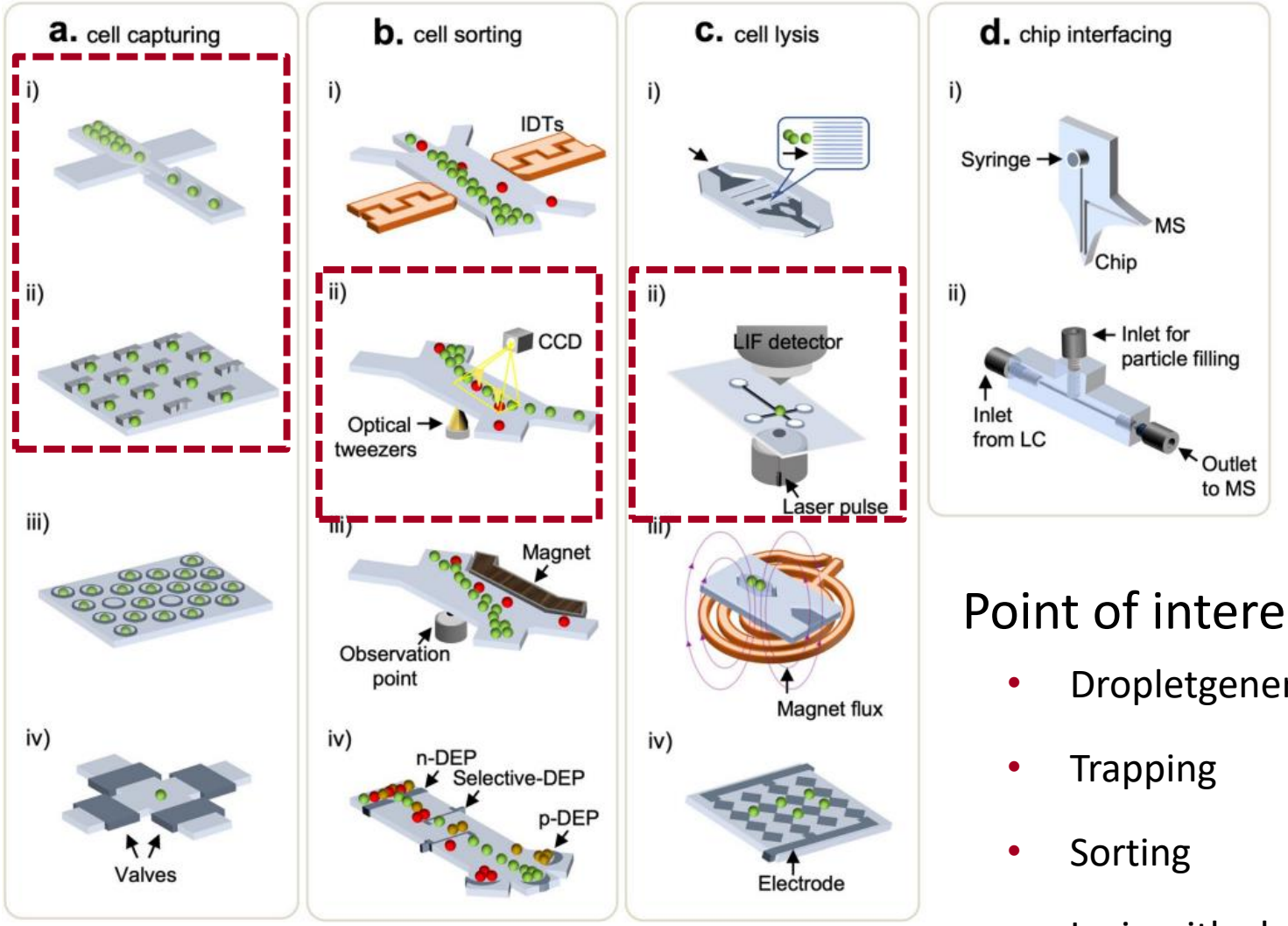
- Bioelectric scattering (BES)
- Individual study of cancer cells
- Examination of a unique chemical environment
- **Fluorescence-based cell separation**



Source: J. Hong, A. J. deMello, IOP Science, 2010

Recent studies

Droplet microfluidic devices used for single-cell studies



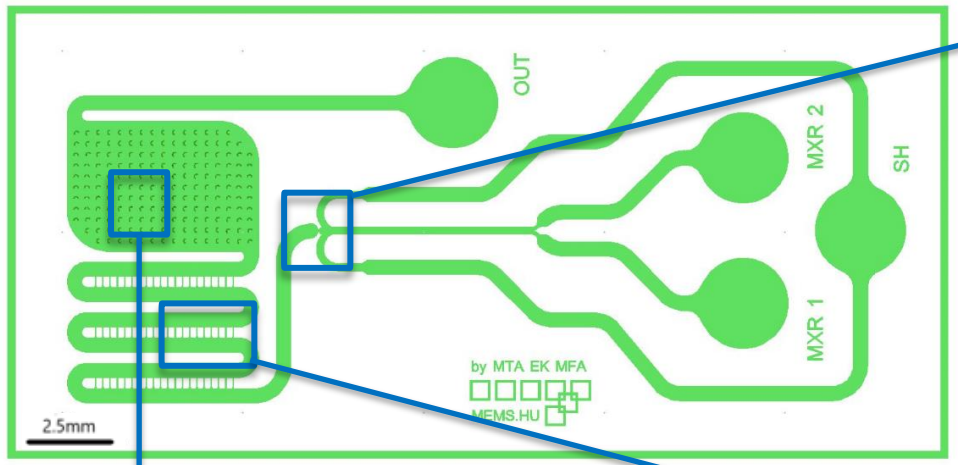
Source: A. M. Kaushik, K. Hsieh, Biosensors and Bioelectronics, 2017

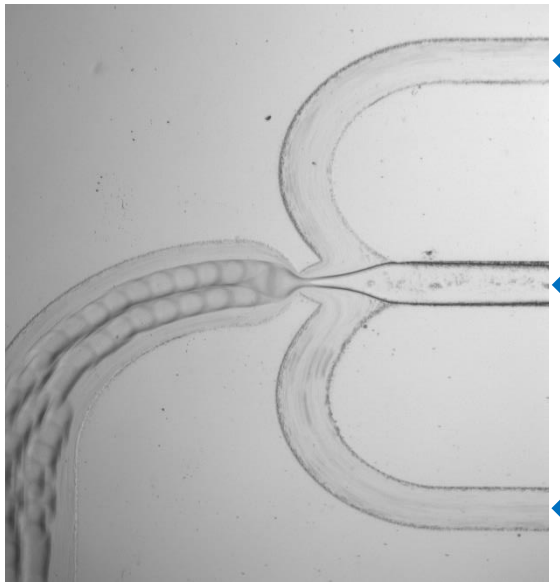
Point of interest

- Dropletgeneration
- Trapping
- Sorting
- Lysis with chemical reagent solutions

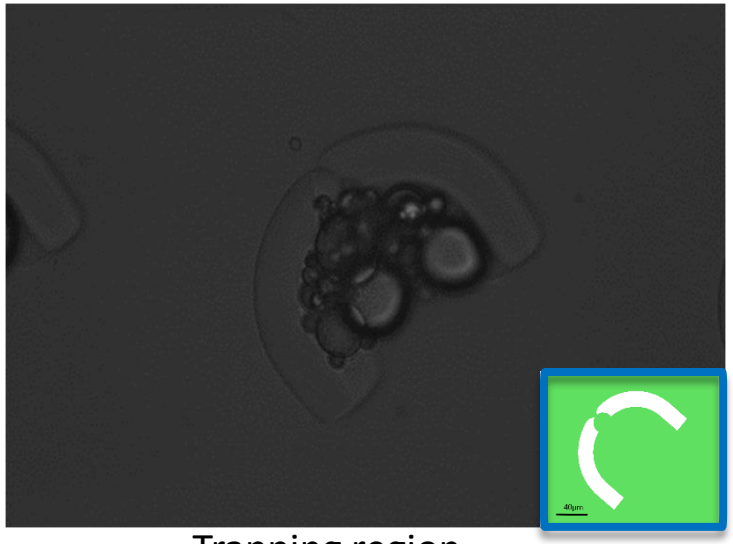
Microfluidic chip - Overwiev

The fabricated structure in CleWin

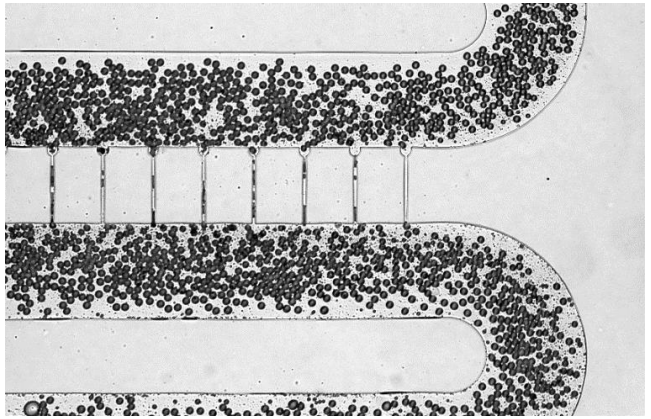


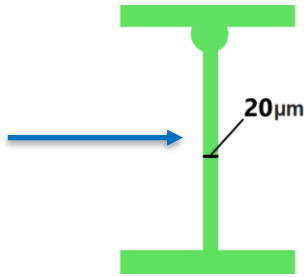


Droplet formation region



Trapping region

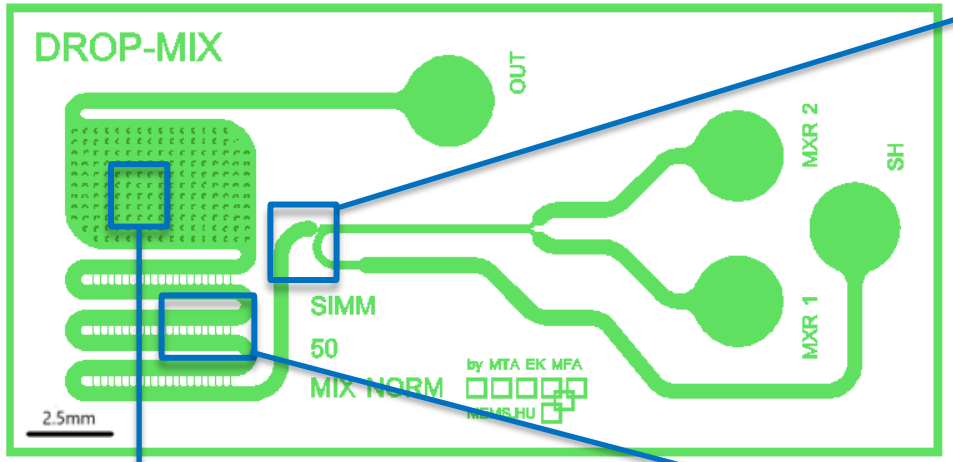


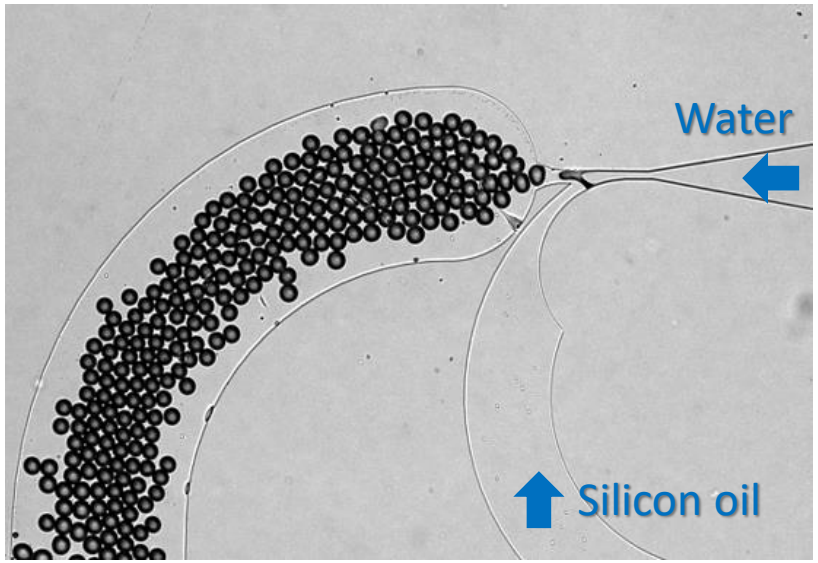


Winding channel region

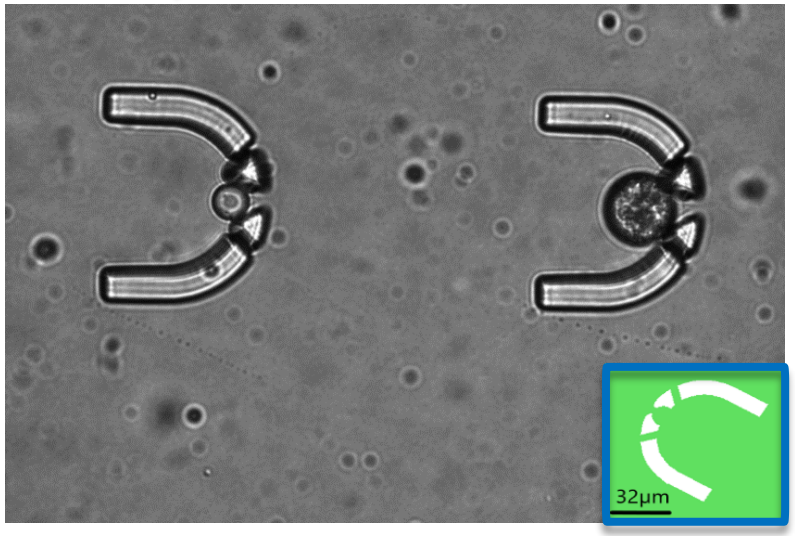
Microfluidic chip – Modifications

The fabricated structure in CleWin

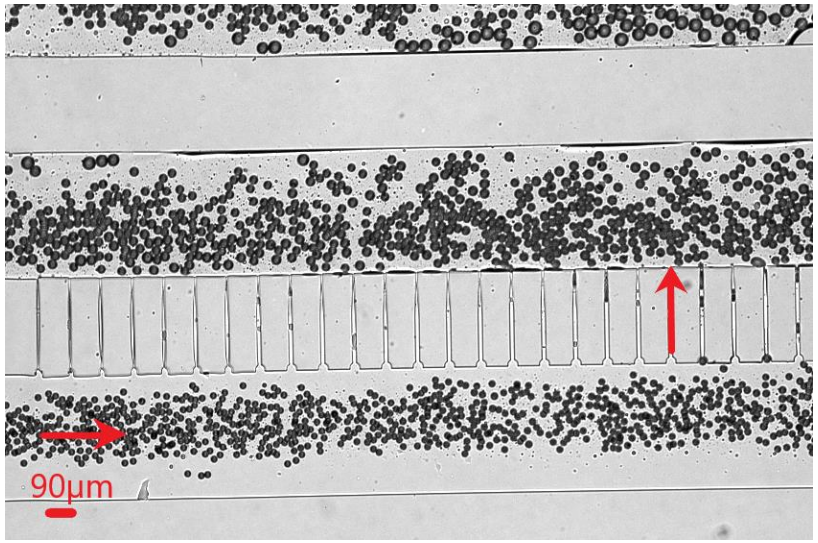




Droplet formation region

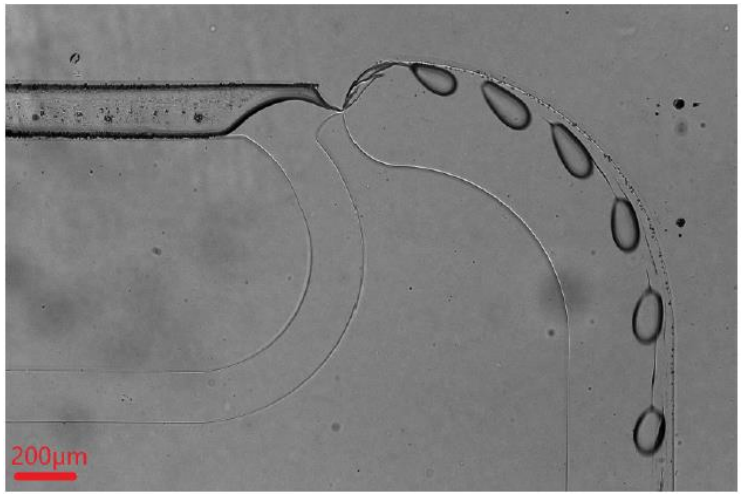


Trapping region

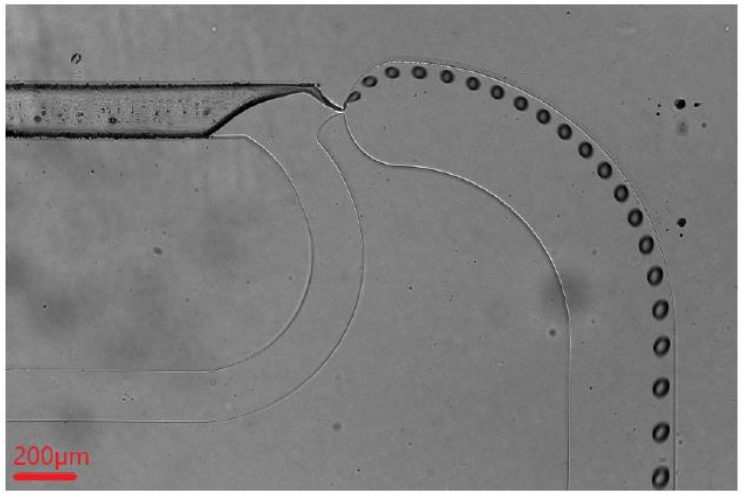


Winding channel region

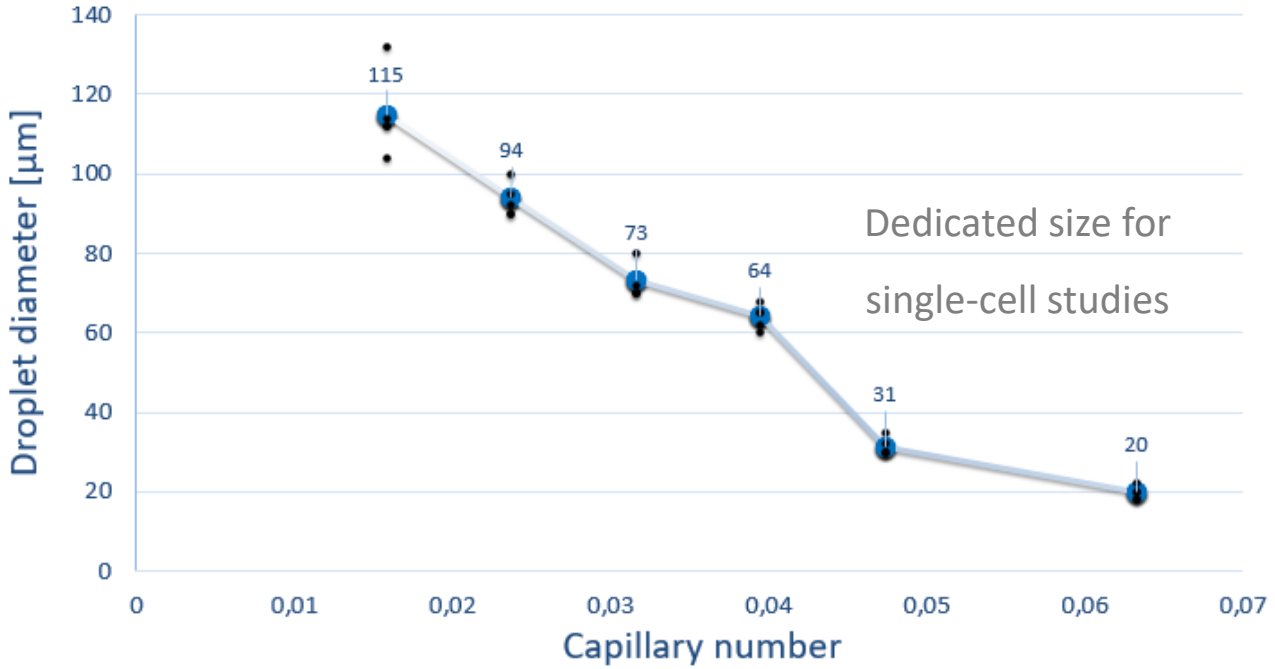
Results of the previous semester

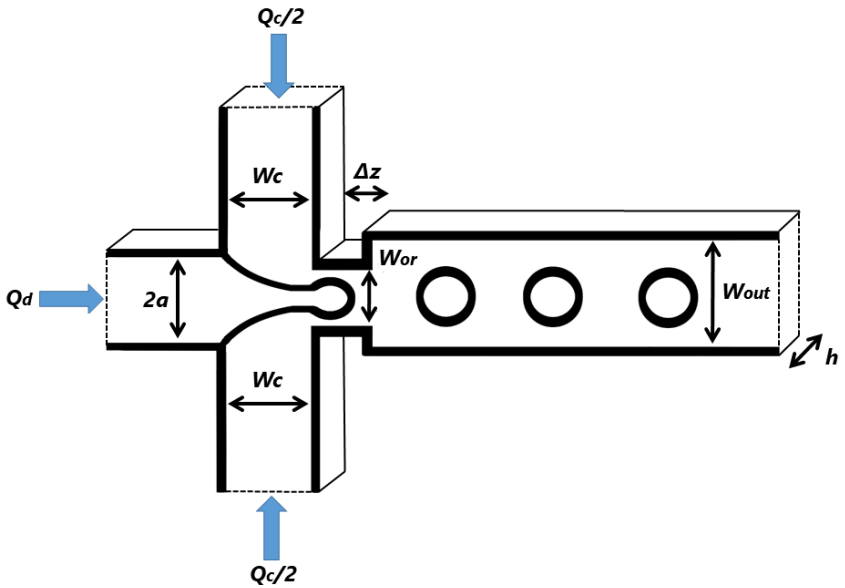


Oil 0.7 [µl/s], Water 0.5 [µl/s]



Oil 0.7 [µl/s], Water 0.3 [µl/s]





$$Ca = \frac{\mu_c a \Delta U}{\gamma \Delta z} = \frac{\mu_c Q_c a}{\sigma h \Delta z}\left(\frac{1}{w_{or}} - \frac{1}{2w_c}\right)$$

Increasing flow rate

↓

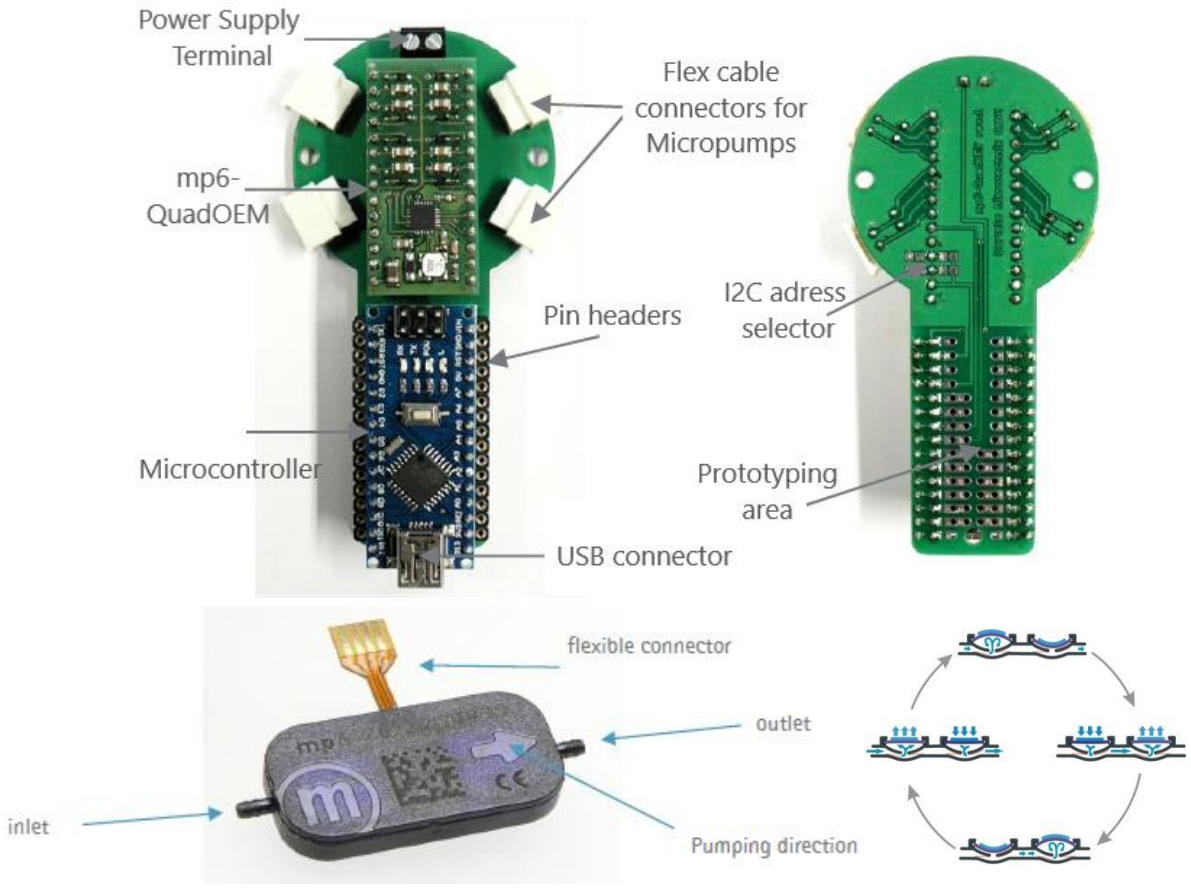
Increasing Capillary number

↓

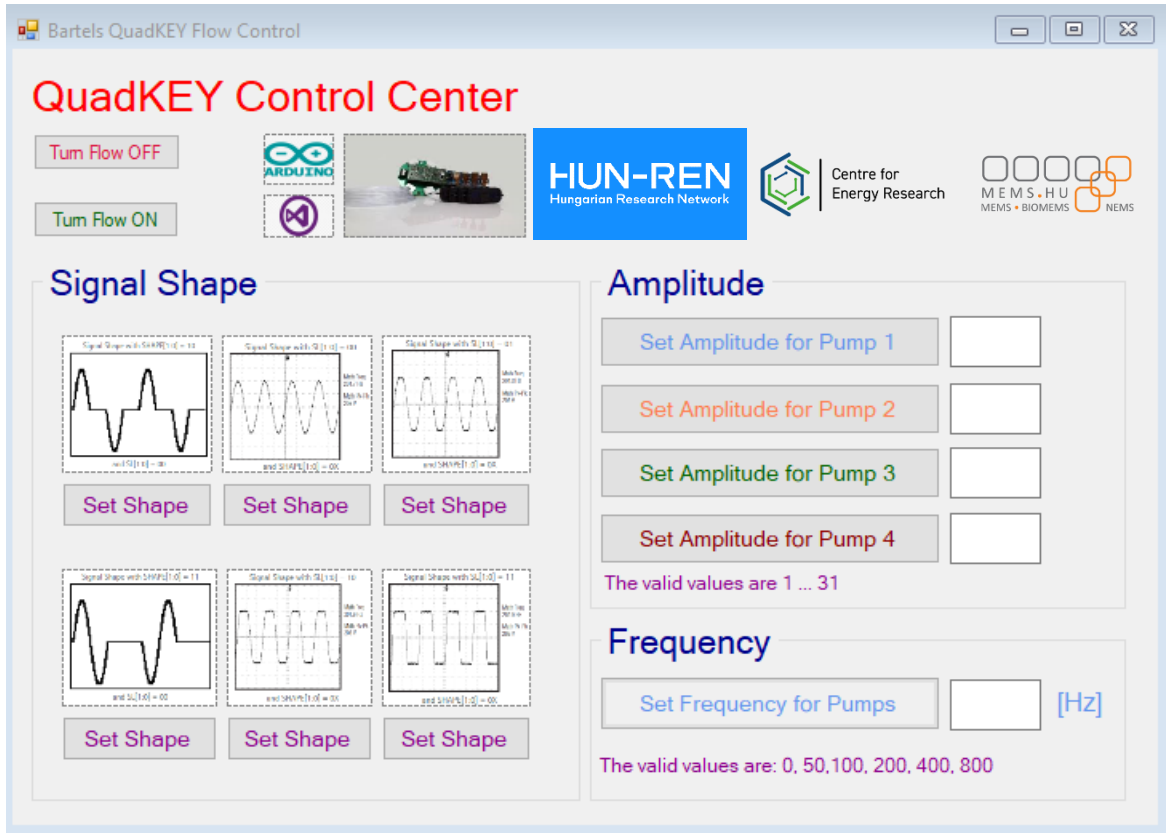
Decreasing droplet size

Development of a portable pumping system

Bartels mp6 micropump

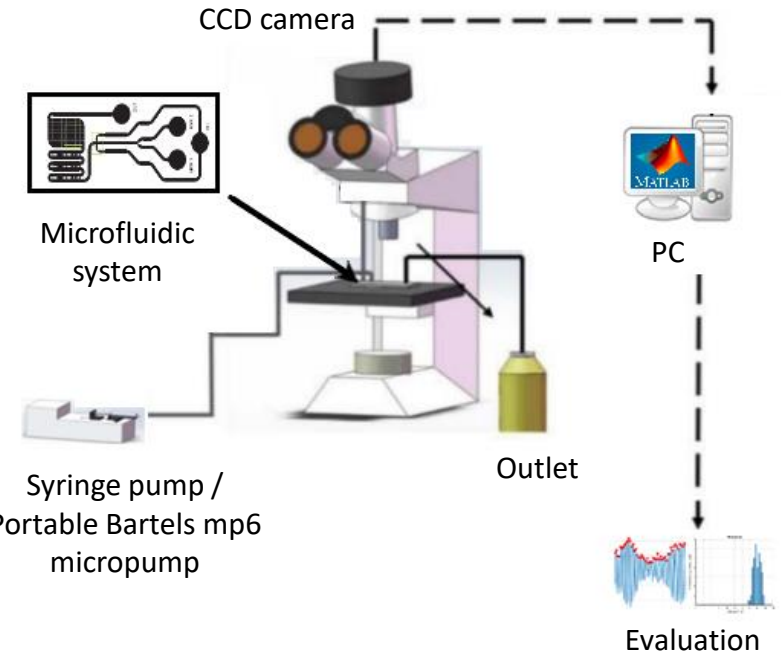


Graphical interface

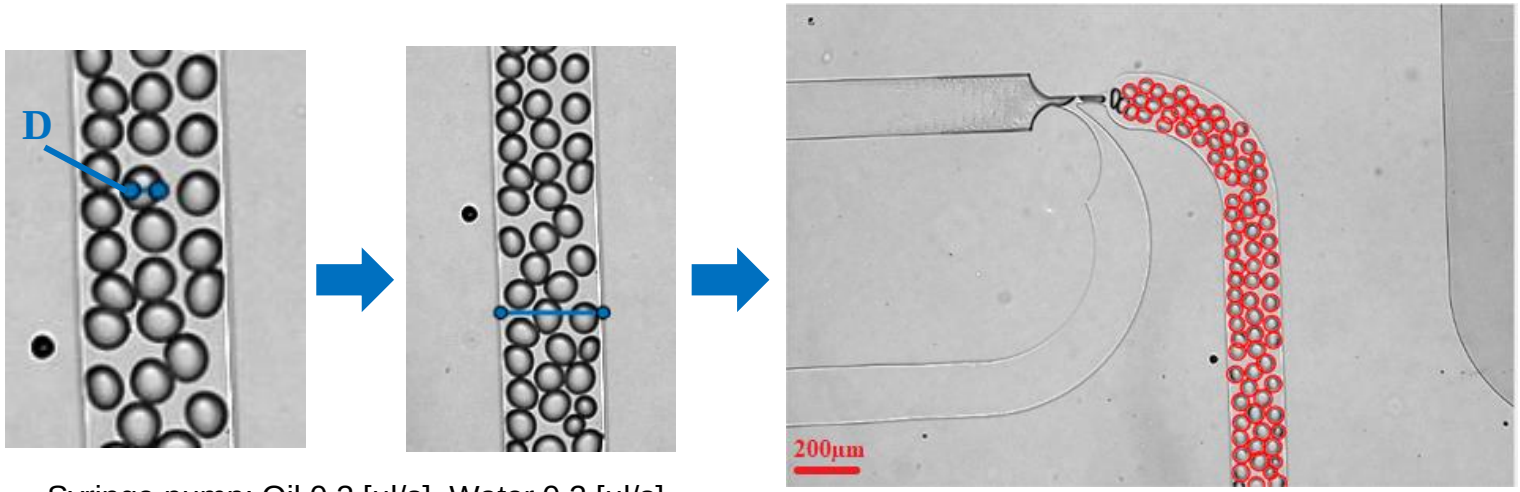


Results of the current semester

Measurement setup



Examination of droplet diameter



Syringe pump: Oil 0.3 [µl/s], Water 0.2 [µl/s]

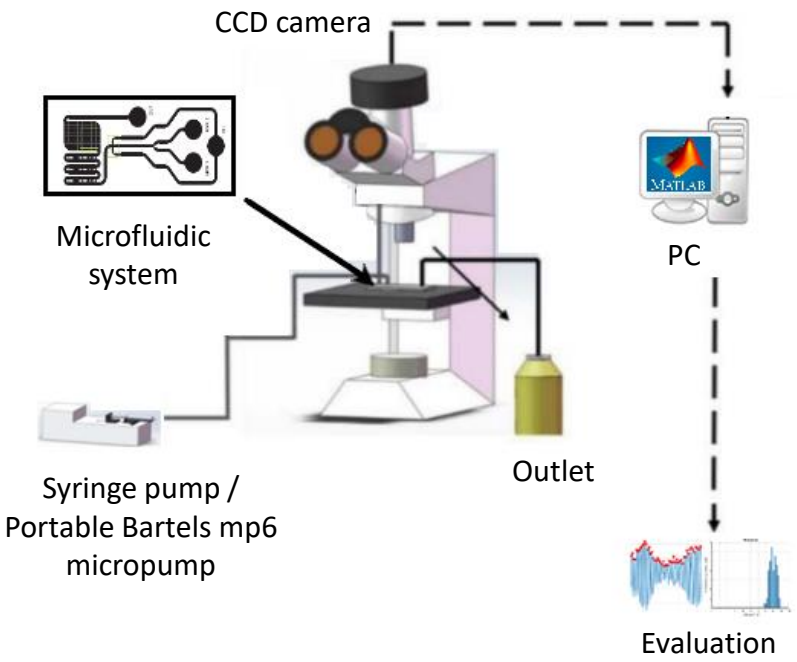
Average diameter: 43.71 [µm]

Measurement steps

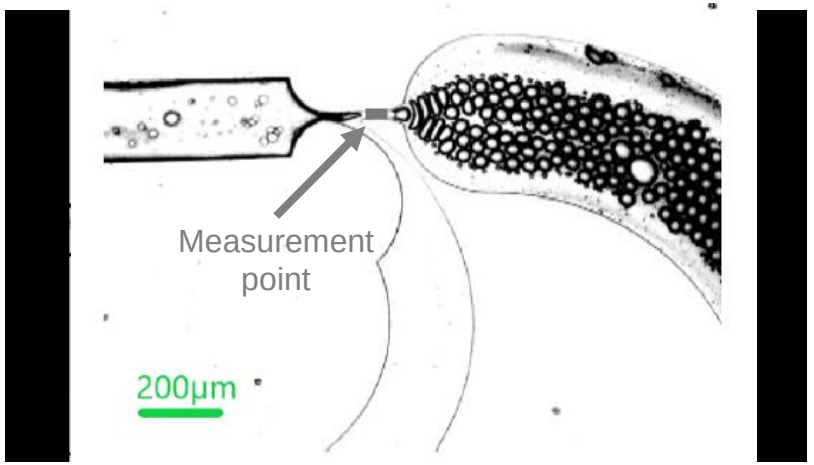
- Scanning data and determine the diameter of a selected droplet (D)
- Specifying the size range of the radius of selected droplet
- Find cilcular objects based on their radius
- Determination of the channel cross-section
- Calculation of diameters

Results of the current semester

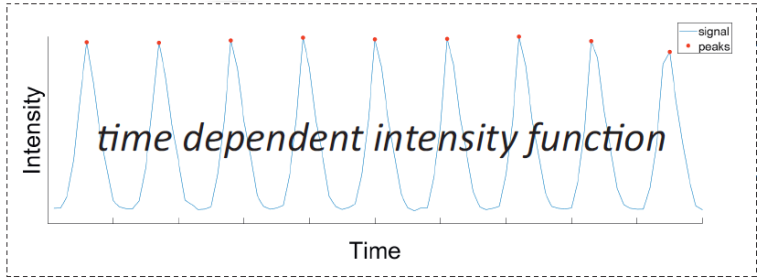
Measurement setup



Examination of droplet generation frequency



Bartels mp6 portable pump: Oil 23/31, Water 8/31, f [100Hz]



Droplet generation frequency: 4.5 [Hz]

Measurement steps

- Video preprocessing and input data into Matlab
- Definition of the measurement point
- Calculation of intensity change at the measurement point
- Finding peaks
- Frequency calculation

Future plans

- Creating a compact, intergrated optical platform (IR) for in-situ measurement of droplet size and generation frequency (and content analysis - fluorescent)
- Investigate droplet generation, mixing and trapping phenomena using Finite Element Method (COMSOL Multiphysics)
- **Publication:** Modelling and analyzing of fluid dynamic phenomena in two-phase microfluidic system

Publications during the semester

- Zs. Szomor, E. L. Tóth, P. Fürjes, ***Finite element modelling and analysis of fluid dynamic phenomena in two-phase droplet based microfluidic systems***, Hungarian Biophysical Society 29th National Meeting, Budapest, Hungary, 2023 – Poster
- Zs. Szomor, L. Bató, S. Stágl, O. Hakkel, A. Sulyok, Cs. Dücső, Zs. Baji, P. Fürjes, ***Non-Stoichiometric Titanium-Oxide Gate Electrodes for EGFET Based pH Sensors***, Micro and Nano Engineering Conference – MNE Eurosensors, Lecce, Italy, 2023 – Oral Presentation
- Zs. Szomor, E. L. Tóth, P. Fürjes, ***3D Finite Element Modelling of heat transfer in continuous flow two-phase droplet microfluidic systems using on-chip thermal control***, Therminic 29th international workshop, Budapest, Hungary, 2023 – Poster
  - ISBN: 979-8-3503-1862-3, DOI: 10.1109/THERMINIC60375.2023.10325685

Courses completed

- Chemical sensors: methods and applications (Abdul Ibdewi Shaban)
- Transmission electron microscopy for structural investigations of different materials (Katalin Balázsi)
- Technology and application of polymer based bionic interfaces (Zoltán Fekete)

Thank you for your attention!