Optimization of the Herringbone Type Micromixer Using Numerical Modelling and Validation By Measurements

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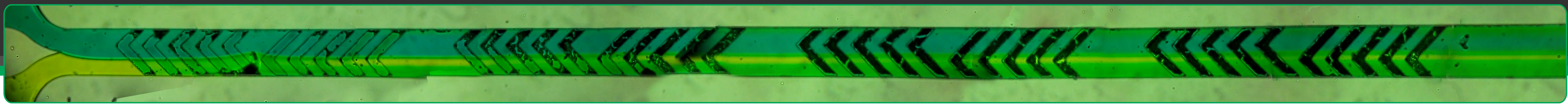

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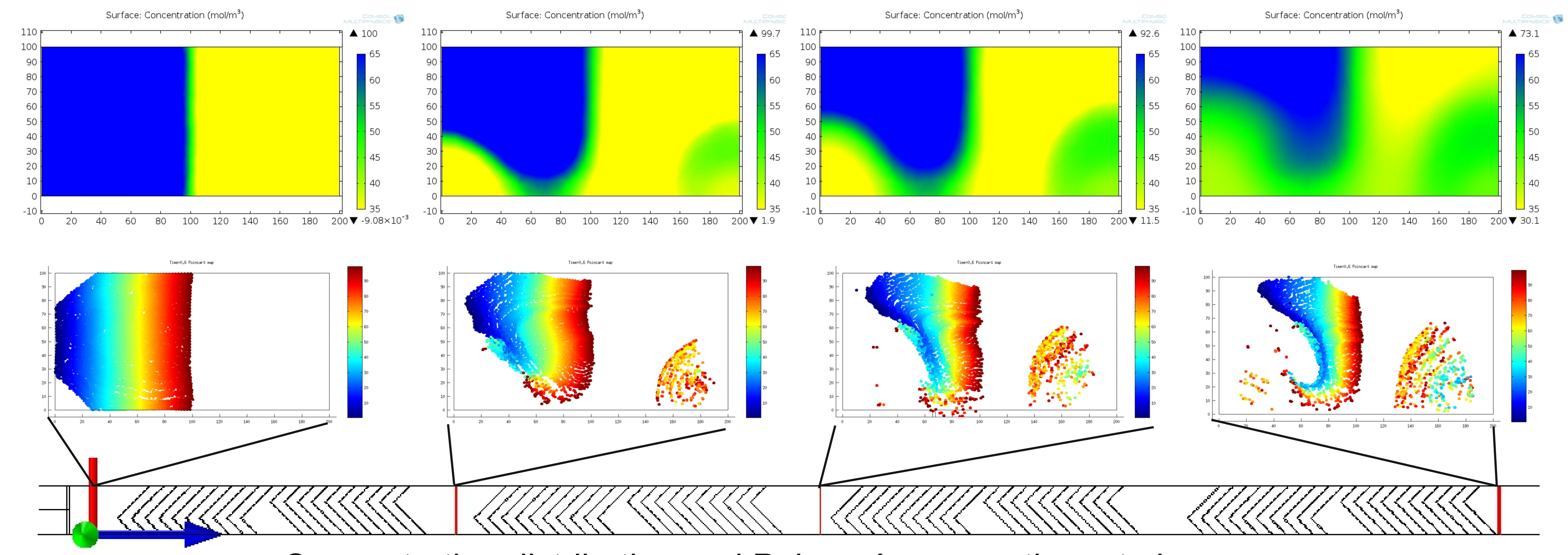
Abstract

One of the key features of **Lab-On-a-Chip devices** is **sample preparation** which includes the dilution and complete mixing of the analyte with reagents or adequate buffer solutions. The mixing possibilities are limited on microscale, since turbulent flow cannot occur due to dominant viscous forces.Chaotic advection can be considered as an ideal mixing method in microfluidic channels as the flows are laminar. **Laminar Flow** interface of COMSOL Multiphysics® was used to solve the velocity field of the **micromixer** to characterise fluid flow properties. Mixing by diffusion along the channel was modelled with **Transport of Diluted Species** interface. To avoid numerical diffusion and high computational cost we used the **Particle Tracing** Module to observe mixing at the level of particles. To optimize the mixing efficiency we conducted a parametric sweep on the thickness of the ridges. Modelled herringbone structures were fabricated in polydimethylsiloxane (**PDMS**) using multilayer technology and measured with dark field microscopy. Results agreed well with the measurement. Furthermore an optimal herring-bone structure was proposed for integration into a bioanalytical system.

Concentration based model and particle based model

Mixing can be modelled well with concentration distribution. However, in the case of low avaible mesh resolution (due to high computational cost) numeric diffusion may be an issue.

Modelling particles instead of concentration gives a better overall picture of the mixing. If we color the particles based on their initial position accross the channel we can visualise particle displacement relative to each other.



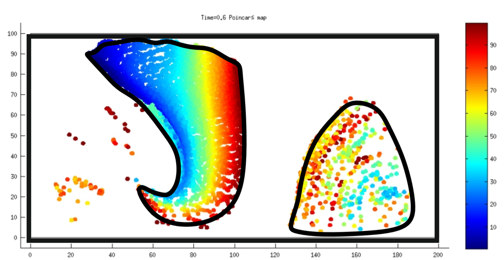
Concentration distribution and Poincaré map on the cut planes.

Optimization

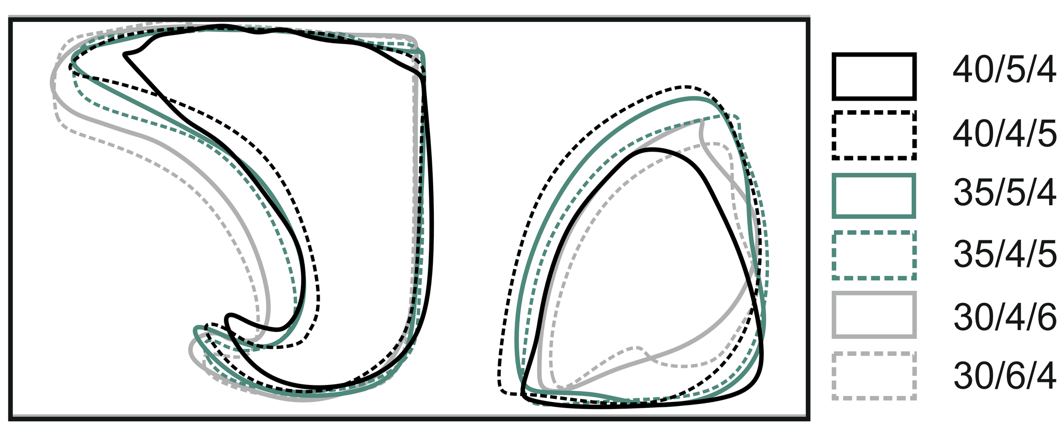
A parametric sweep on the number of herringbones per cycle, their width and the number of mixing cycles was conducted.

Modelling shows that mixing is more efficient with wider herringbones. More mixing cycles are more efficient than more herringbones in one cycle.

Herringbone width	# of Herringbones/cycle	# of cycles	
30 µm	4	6	30/4/6
30 µm	6	4	30/6/4
35 µm	4	5	35/4/5
35 µm	5	4	35/5/4
40 µm	4	5	40/4/5
40 µm	5	4	40/5/4



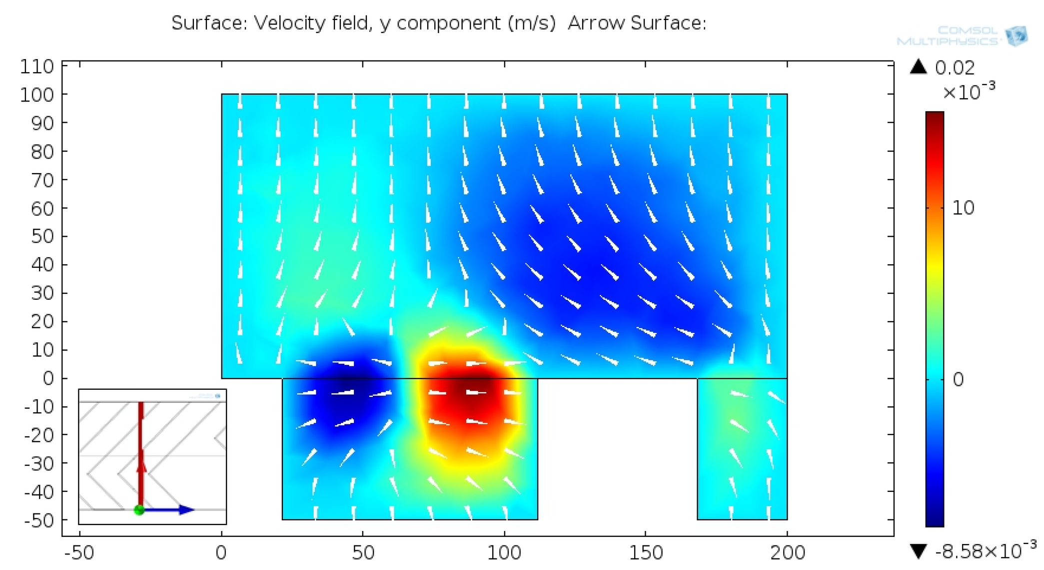
Outline of particles on the outlet.



Outline of particles on the outlet.
Widening of the mixed region is ovserable

Flow characterisation

Herringbone structures act as anisotropic fluid resistances causing secondary (transversal) flow.

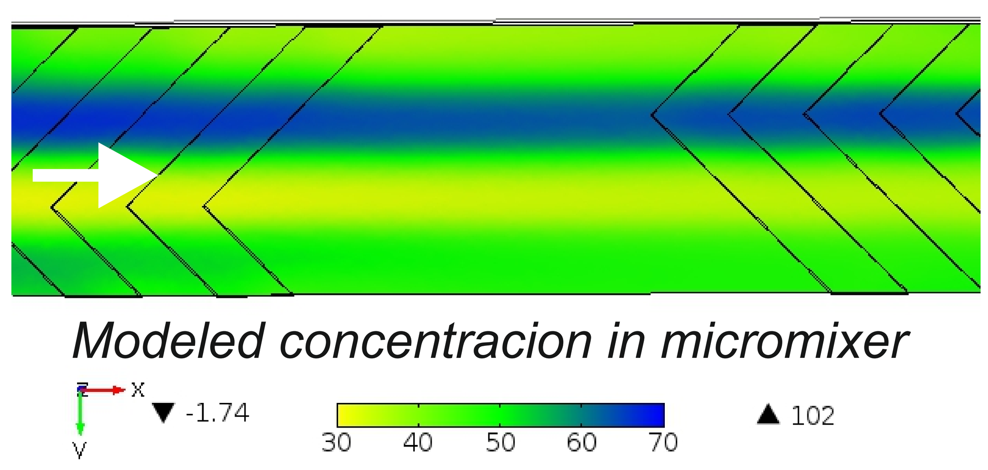


Rotation caused by the ridges in the velocity field plane

Validation

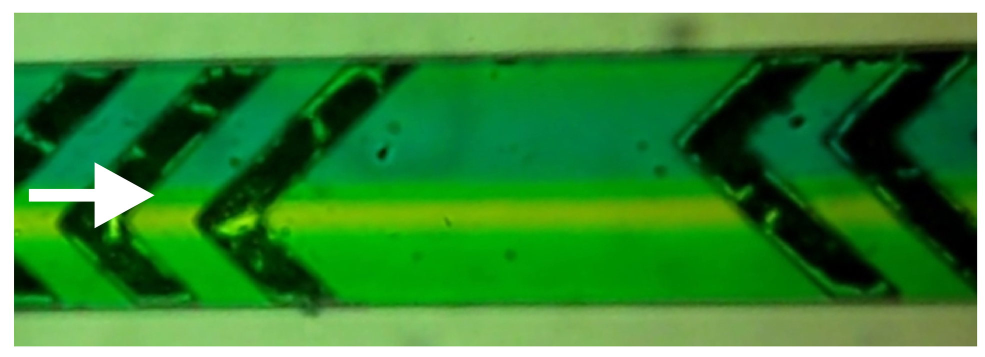
Modelled micromixers were realised in PDMS and measured. Images were compared to the modeling result.

Model result

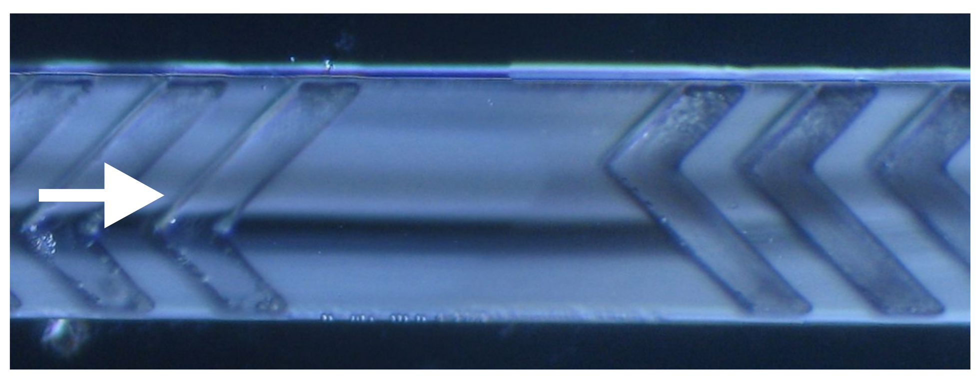


Modeled concentracion in micromixer

Measurement



Brigh field image of dye in micromixer



Dark field image of yeast cells in micromixer

Conclusion

- Flow properties and mixing of the herringbone mixer were characterised by numeric modelling using the Laminar Flow, Transport of Diluted Species and Particle tracing physics of COMSOL Multiphysics.
- Concentration-based and particle-based approaches were compared.
- Further investigation of the Herringbone mixer was made using parametric sweep on the herringbone width and the number of herringbones per mixing cycle.
- The modelled mixers were realised and measured model results were validated.

Acknowledgements: The partial support of the National Innovation Office (NIH) via KMR-12-1-2012-0107, TAMOP - 4.2.1. / B-10 and TAMOP - 4.2.1. / B-11 projects, the Hungarian National Research Found (OTKA) via grant the MEDinPROT fellowship (recipient: Péter Fürjes) of the Hungarian Academy of Sciences are gratefully acknowledge K 108366.