Ernst-Abbe-Hochschule Jena
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Instrumental Analysis Group

Optimierung eines Mikromischers für pulsatile Volumenströme

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outline

workgroup instrumental analysis

motivation

micromixing - simulation

mesh- comparison and sensitivity study

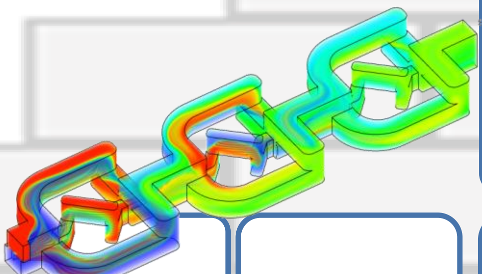
optimization

conclusion and outlook

workgroup

chemical

biological



additive manu-facturing

experimental

immortal cell line

primary cells

chemical reactors

biological reactors

optimization tasks

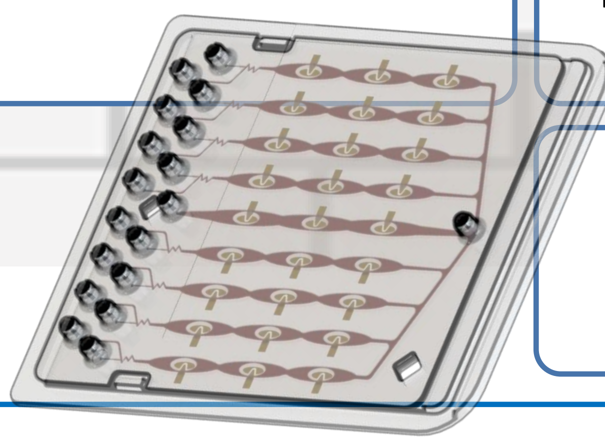
incubator independent

staining

fluor-escence

simulation

microfluidic



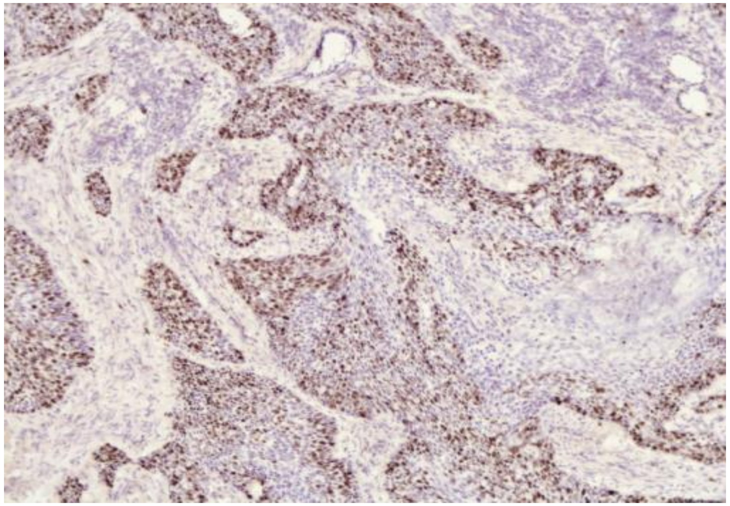
cell based systems

spectros-copy

outline

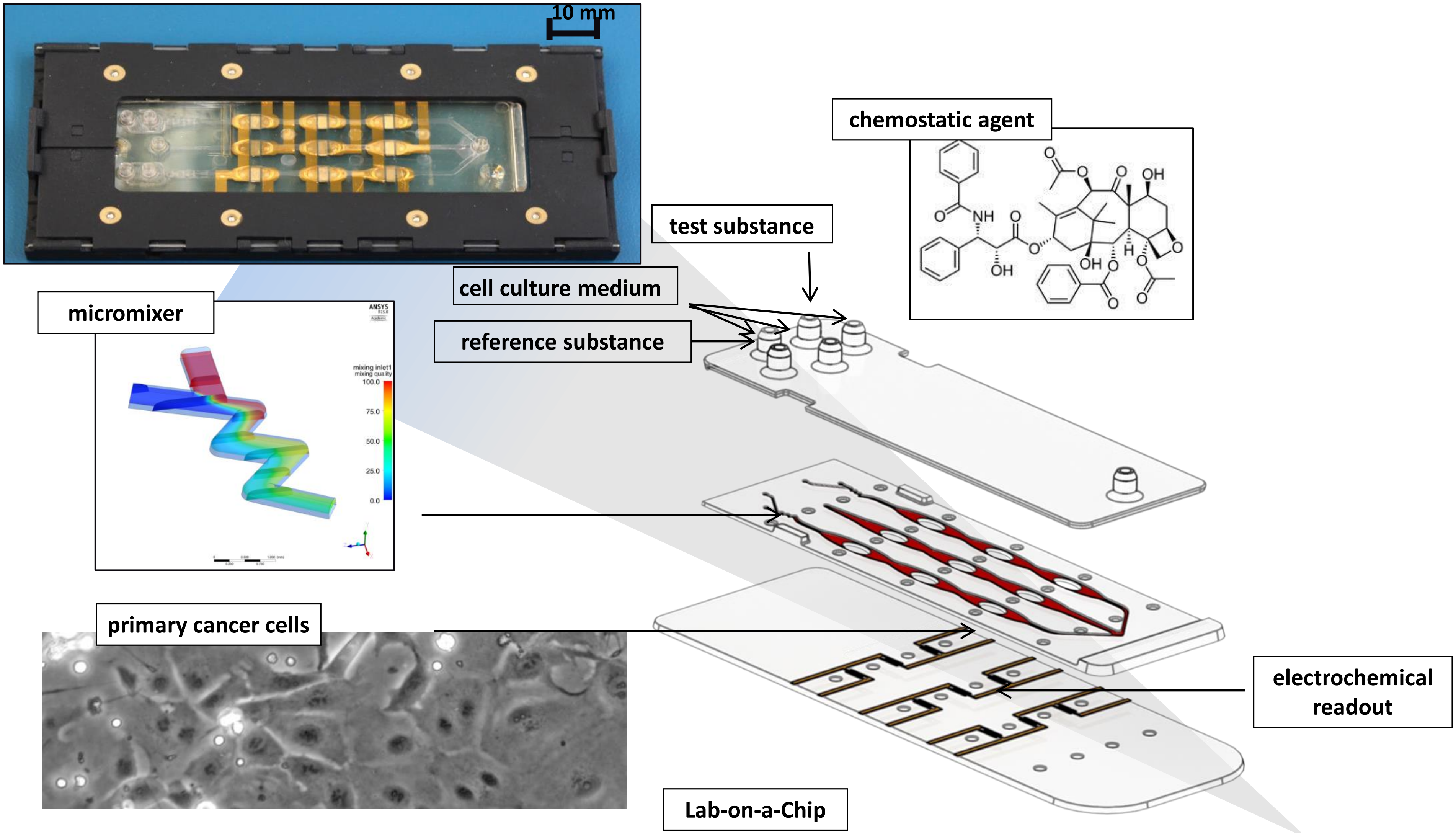
lung cancer

- lung cancer is the most common cancer in the world
- a lot of types of lung cancer with different staging (27):
  - small cell carcinoma
  - large cell carcinoma
  - Adenocarcinoma
  - Carcinoid
  - …
- many chemostatics in the first line therapy



IHC staining

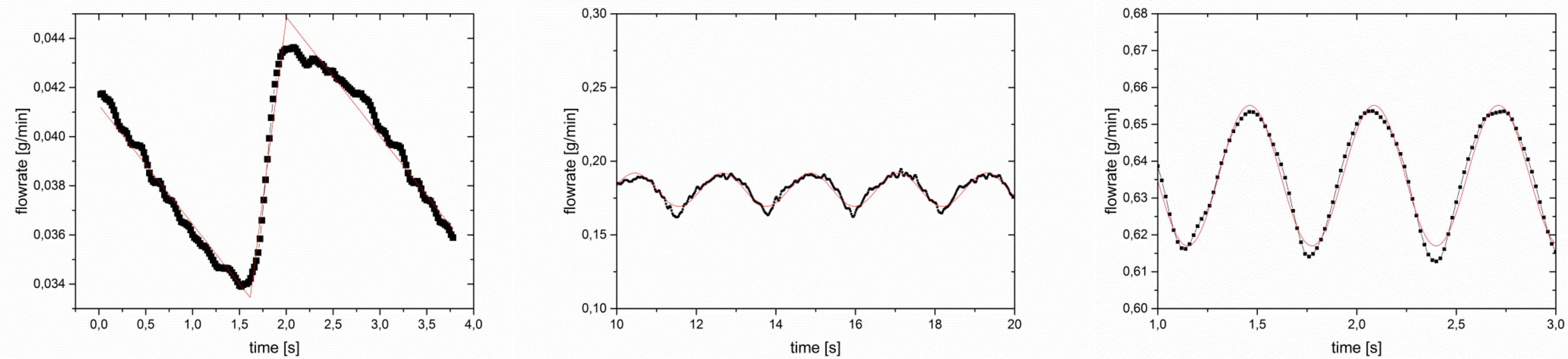
lab-on-a-chip


10 mm
chemostatic agent
test substance
cell culture medium
reference substance
micromixer
ANSYS
mixing inlet1
mixing quality
100.0
75.0
50.0
25.0
0.0
primary cancer cells
electrochemical readout
Lab-on-a-Chip

peristaltic pump

flow profile

- profile 1
- profile 2
- profile 3



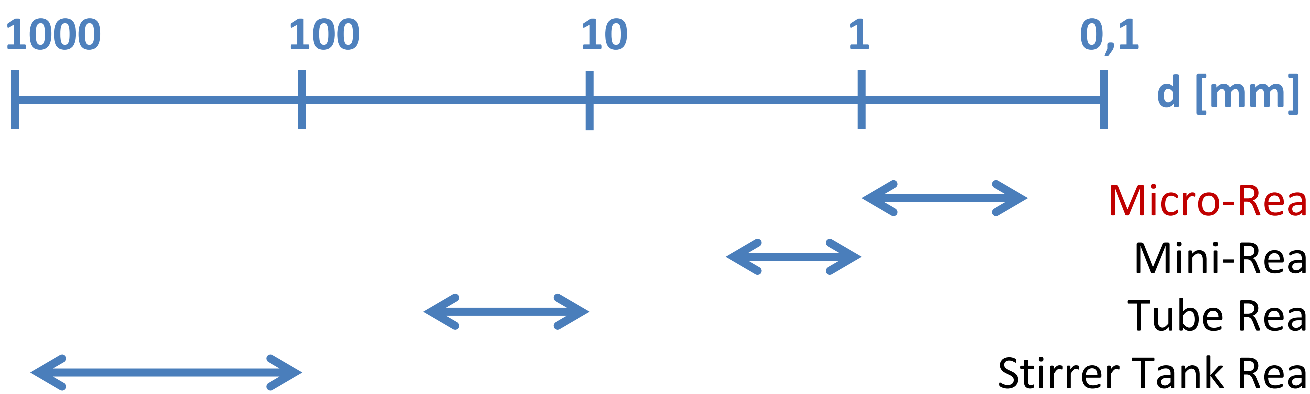
microfluidic

pro:

- low material consumption (cell culture media, toxin and biological sample)
- little risk of contamination
- high energy transfer

con:

- laminar flow



	$A/V\ [m^2/m^3]$
Micro-Reactor	**4.000 – 20.000**
Mini-Reactor	1.500 – 4.000
Tube Reactor	100 – 400
Stirrer Tank Reactor	4 – 40

comparison of different reactor types and sizes

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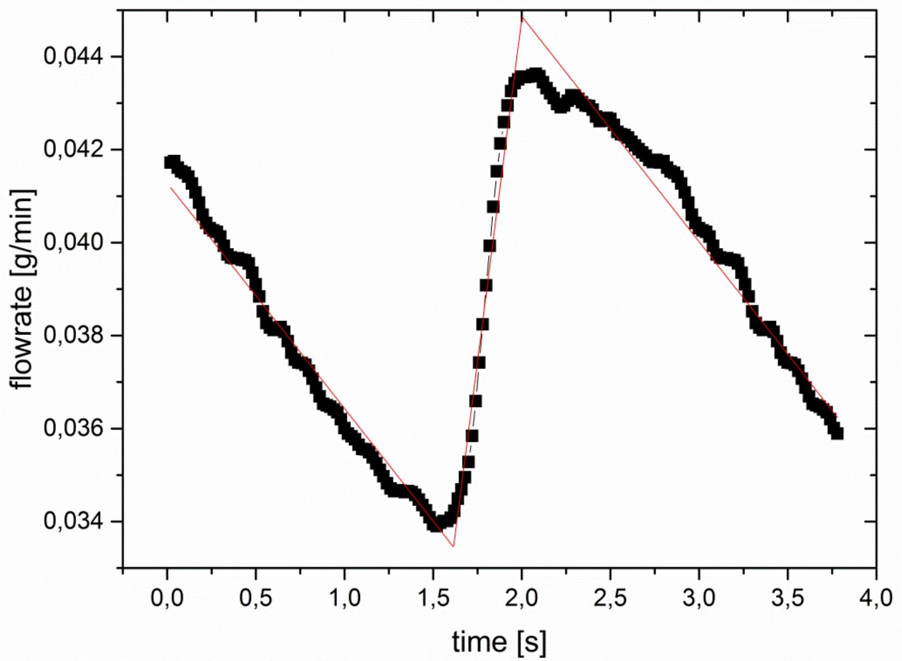
simulation method

- usage of variables for simulations
  - diffusion coefficient : 0 $m^2 * s^{-1}$
- transient simulation
  - pulsation of pump
    - flowrate dependent
- total time → 3 signal periods
  - last for results
  - mean value: mixing quality
  - standard derivation: mixing quality

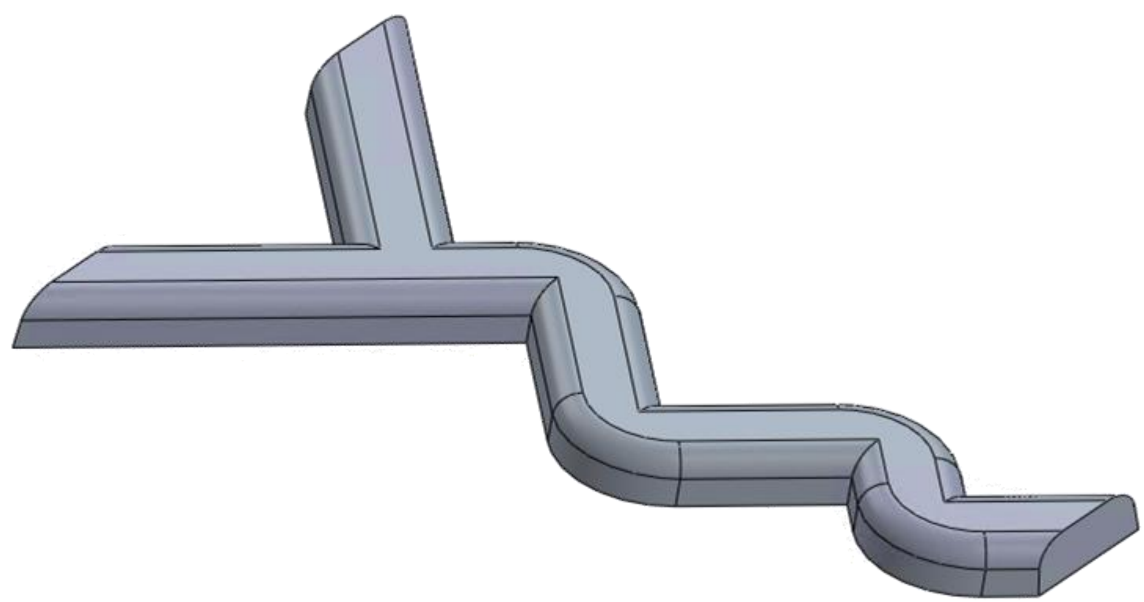


flowrate with fitting

simulation method

boundary conditions:

- single water phase
- 2 inlets
  - different variables
- 1 outlet: 0 bar
- transient



Ansys CFX Pre Setup

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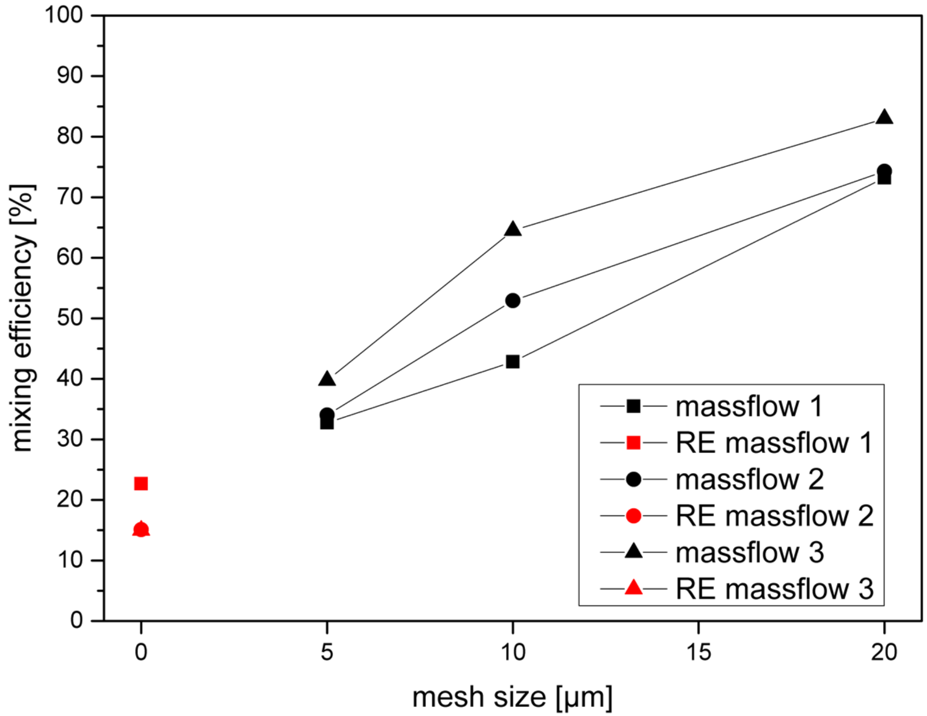
mesh-independence

result:

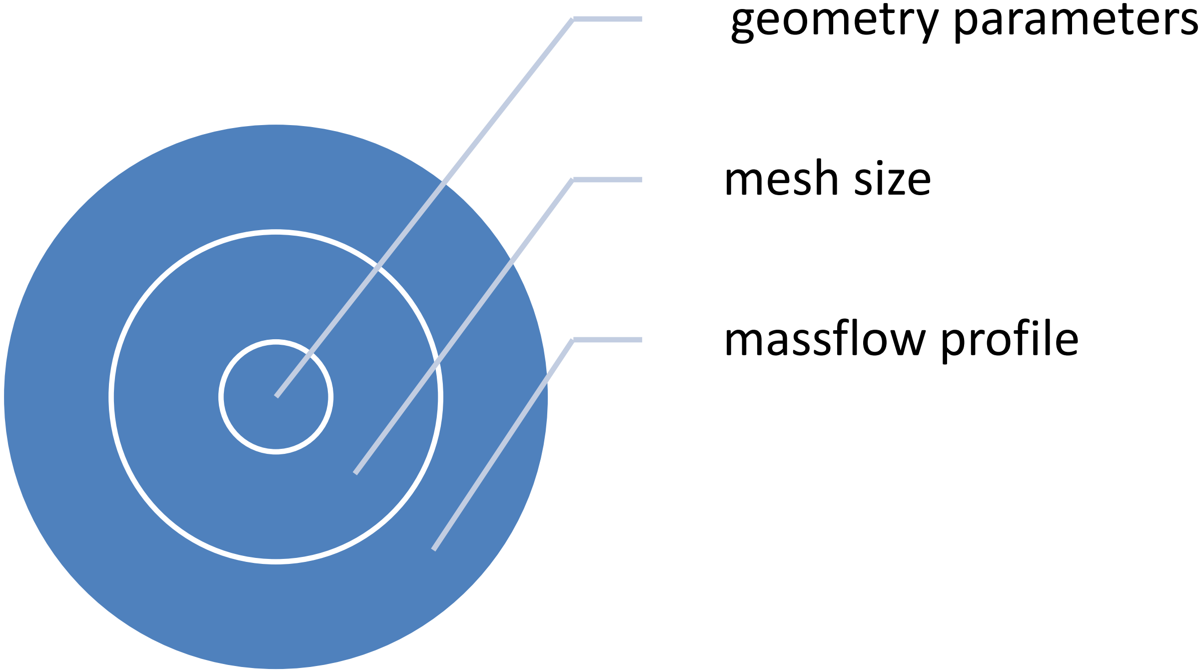
- independence hard to achieve
    - numerical diffusion affected mixing efficiency
- only two dimensional snap of parameter region



mesh-independence study

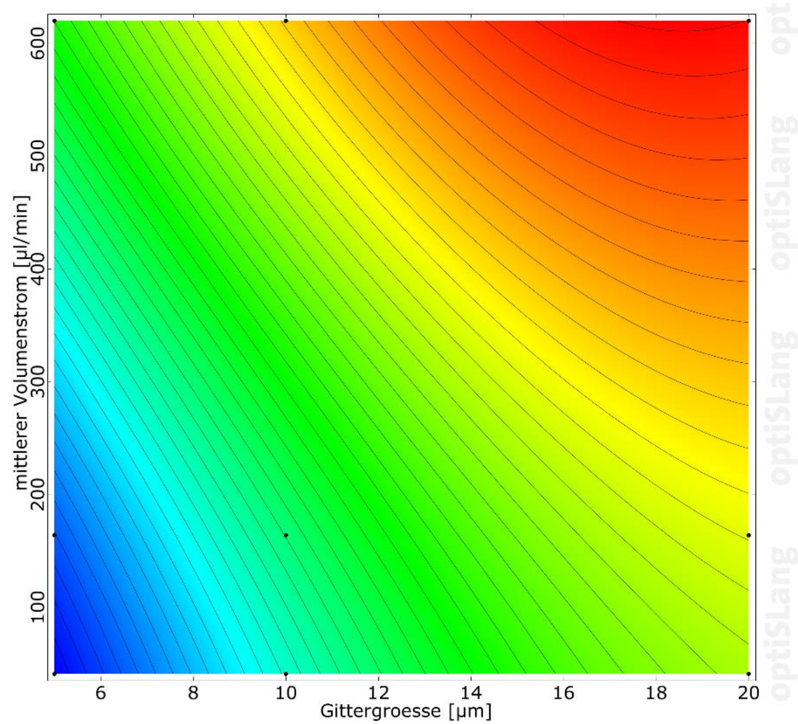
sensitivity-study

- combination of advanced Latin- Hypercube and Full- Factorial Design
  - 100 Designs for geometry parameters (aLHS)
  - 3 mesh sizes and 3 massflow profiles



sensitivity-study

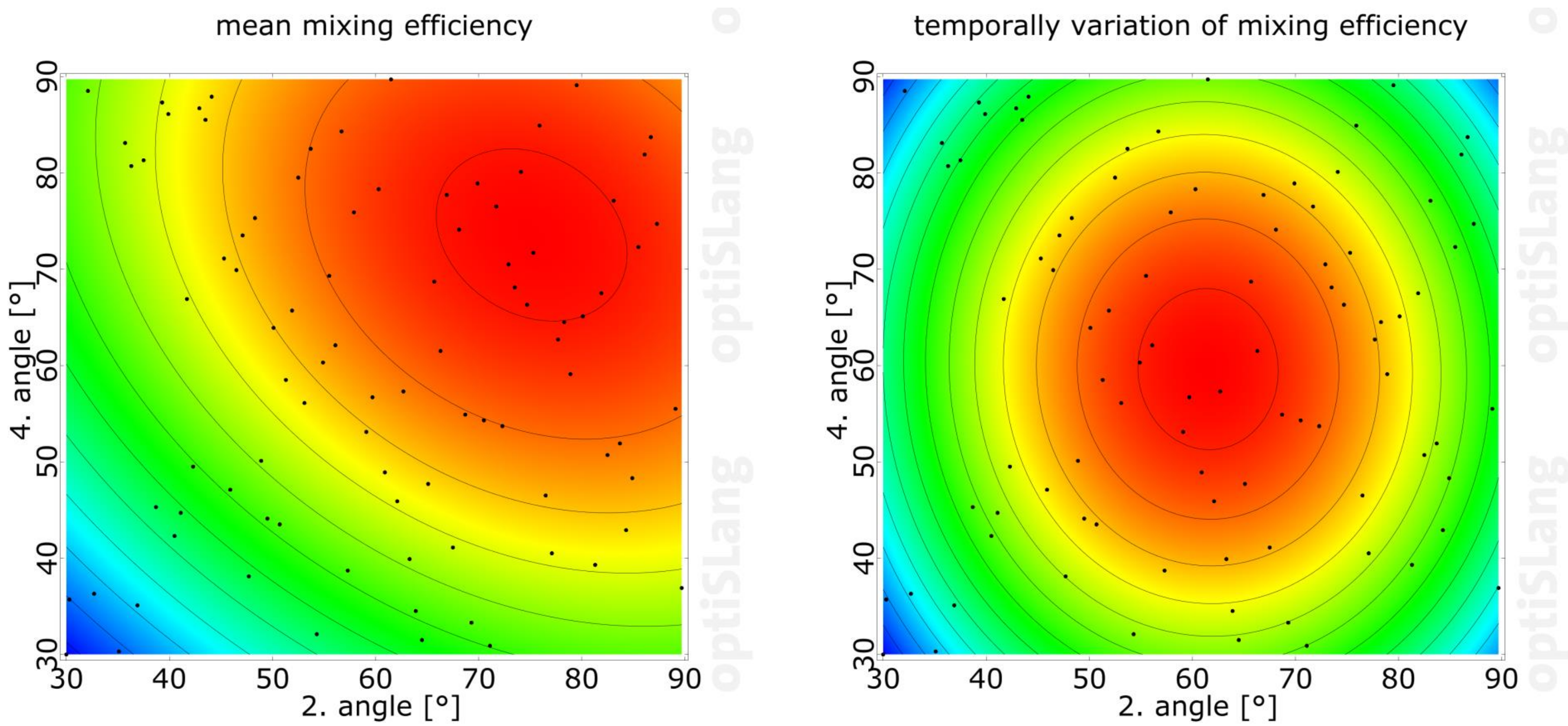
- sensitivity study combined with mesh independence study
  - more dimensional of snap mesh influence
    - linear-influence of mesh size can be assumed



surrogate model for mixing efficiency

sensitivity-study

- angle of mixer → crucial influence on mixing efficiency



surrogate models

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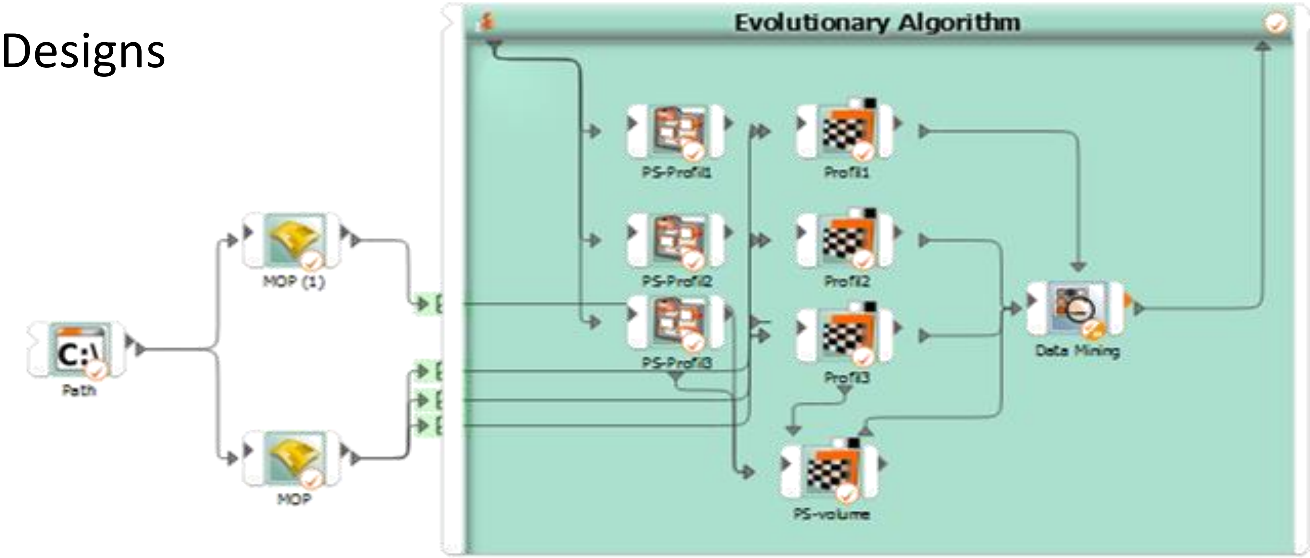
optimization-algorithm

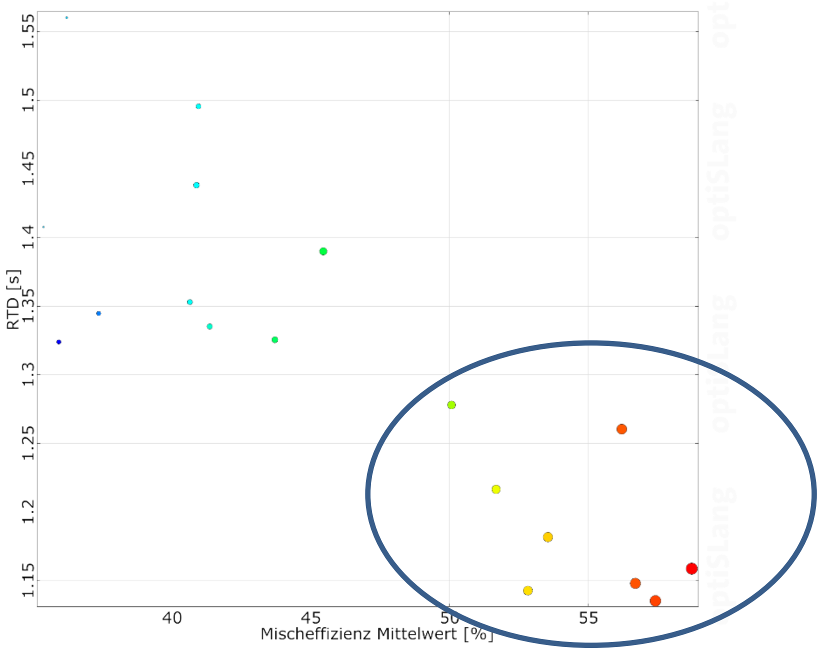
- aims of optimization:
  - high mixing efficiency
  - low mixer volume
  - low temporally variation of the mixing efficiency

- EA 10.000 with and without stochastic Design improvement
  - selection of 18 Designs

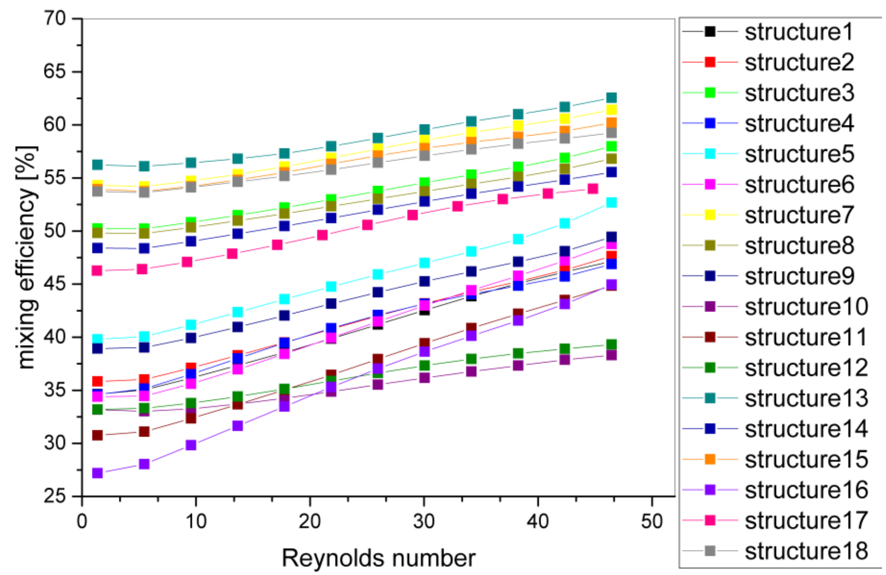


optimization-validation

- 8 designs are outstanding
  - used for prototyping
    - injection moulding



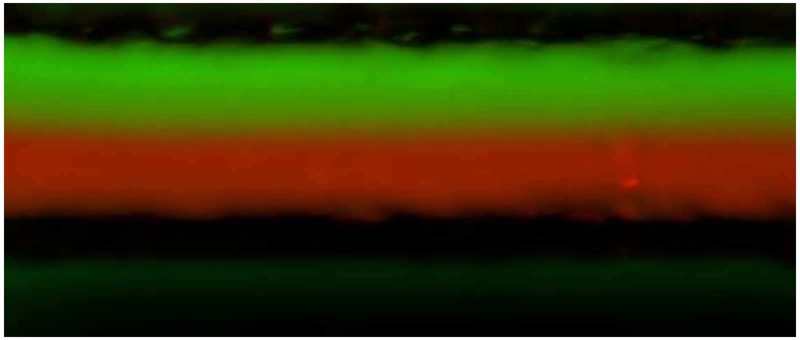
anthill- Plot with mixing efficiency and RTD



flowrate dependency of mixing efficiency

interim conclusion

- quite good initial mixer design
- mesh element size linear influence on the mixing efficiency
- 8 similar design after optimization
  - difficult to distinguish between them
    - robustness study with deterministic assumptions
    - usage of SoS planed



inhomogeneity of an microfluidic channel

review state of the art

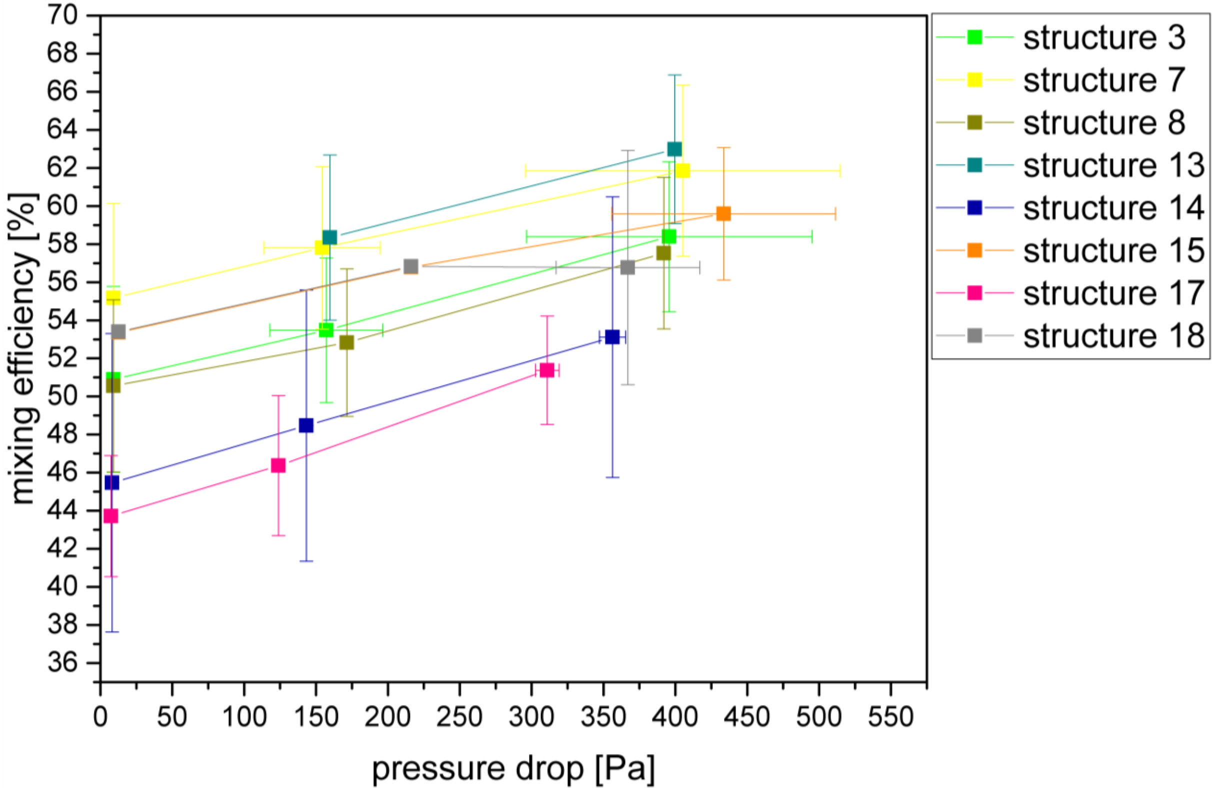
set up parametric simulation model

sensitivity analysis

optimization

robustness with deterministic assumptions | robustness with stochastic effects

- geometrical changes mixing efficiency and pressure drop
- some structures are less robust



robustness evaluation of the best designs

outline

conclusion and outlook

conclusion:

- optimization possible with non mesh independence set up
- optimized mixer shows:
  - good mixing
  - sufficient residence time distribution

outlook:

- manufacture of prototypes and validate simulation results
  - measure tolerances and set-up an SoS-model

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thank you!