

Watching Microfluidics in Action: Time-Resolved Imaging with Scanning Acoustic Microscopy

Combining Lab-on-Chip Systems and SAM for Process Observation

Type of Thesis: Diploma, master, bachelor, student thesis

Suitable for: process engineering, physics, material science

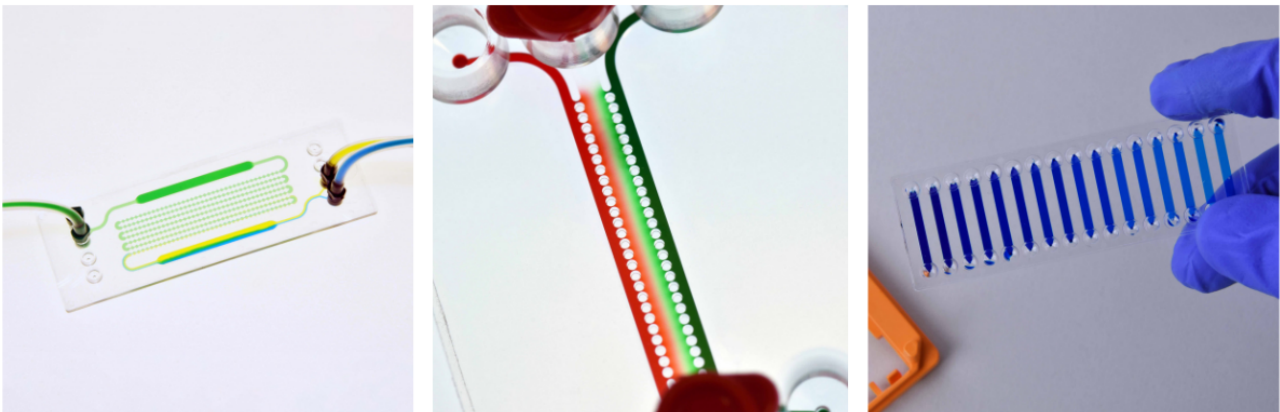
Motivation & Background:

Process monitoring with micrometer resolution is becoming increasingly important as many modern technologies rely on materials and structures whose internal state evolves during operation. Understanding such dynamic processes requires experimental techniques that can observe **subsurface structures non-destructively and in real time**.

Scanning Acoustic Microscopy (SAM) provides a unique capability in this context. By focusing high-frequency ultrasound into a specimen, SAM can image internal structures with micrometer-scale resolution while being sensitive to mechanical material properties such as **elastic stiffness, acoustic impedance, and mass density**. Traditionally, SAM has been widely used for quality control and failure analysis in **microelectronic packaging**.

However, the potential of SAM extends far beyond static diagnostics.

At the same time, **microfluidic technologies**—often referred to as **Lab-on-Chip systems**—are rapidly gaining importance in chemistry, biotechnology, and materials science. These systems contain micro-scale channels in which fluids are transported, mixed, or reacted. Many important processes occur inside such channels, including mixing of fluids, particle transport, chemical reactions, bubble formation and phase transitions.



Despite their importance, **visualizing these processes inside opaque materials or enclosed microchannels remains challenging**.

This makes microfluidic systems an ideal testbed for expanding the capabilities of SAM from a static inspection tool toward **time-resolved imaging of dynamic processes**.

In this project, commercially available microfluidic chips (example: <https://www.microfluidic-chipshop.com>) will be used as experimental platforms to explore how SAM can monitor microfluidic processes in real time.

Goals & Objectives:

The goal of this thesis is to explore the combination of **microfluidic systems and Scanning Acoustic Microscopy** in order to observe and analyze dynamic processes inside microchannels.

The student will contribute to extending SAM from a purely diagnostic imaging tool toward a **method for time-resolved observation of processes** in microstructured systems.

The specific process to be investigated can be chosen according to the student's interests and may include, for example:

- fluid flow in microchannels
- mixing of liquids
- particle transport
- bubble formation
- other micro-scale processes compatible with the SAM setup

After selecting the process of interest, the student will:

- design and realize an experimental setup based on a microfluidic chip
- record acoustic microscopy data during the process
- apply signal processing techniques to reconstruct volumetric images
- evaluate the achievable spatial and temporal resolution
- visualize and interpret the observed processes

A particular focus will be the application of **synthetic focusing techniques** to reconstruct the acoustic images in different depths.

Milestones:

M1: Literature review on Scanning Acoustic Microscopy and microfluidic systems; identification of suitable processes that can be observed with SAM.

M2: Selection of a microfluidic experiment and design of the experimental setup.

M3: Implementation of the microfluidic experiment and integration with the SAM system.

M4: Acquisition of acoustic microscopy data during the selected microfluidic process.

M5: Development of a data processing workflow (Python) including synthetic focusing and visualization.

M6: Evaluation of spatial and temporal resolution and analysis of the observed process.

M7: Visualization and interpretation of the results.

Character of the work:

50% Experimental work, 10 % Python programming, 40 % Data evaluation and interpretation

Supervision & Workflow:

- Meetings: weekly meetings between student and supervisor to evaluate status and progress and identify need for support; time and location (also possibly online) will be determined at the beginning of the work; additional meetings for any necessity are highly encouraged
- Lab works: The project pursues several works in the lab, which requires a reliable and structured workflow. Furthermore, the student will get a safety briefing for the house and the lab and the clean room.
- Weekly reports: The student is required to write a weekly report at the end of each week and to send it to his advisors or document it in git. The idea of the weekly report is to briefly



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summarize the work, progress, and any findings made during the week, to plan the actions for the next week, and to bring up open questions and points. The weekly report is also an important means for the student to get a goal-oriented attitude to work.

- Mid-term presentation: Students are encouraged to give a mid-term presentation as a preparation for the final presentation of the thesis. This is an opportunity to discuss the results with a broader audience and get important feedback on the current state of the work.

Technical Details:

- A **commercial Scanning Acoustic Microscope (SAM)** is available for the experiments.
- **Commercial microfluidic chips** can be used to realize the experimental setup.
- Data processing will be performed using **Python** with common scientific libraries (NumPy, SciPy, Matplotlib).
- Existing scripts and data processing tools are available and can be extended during the project.

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