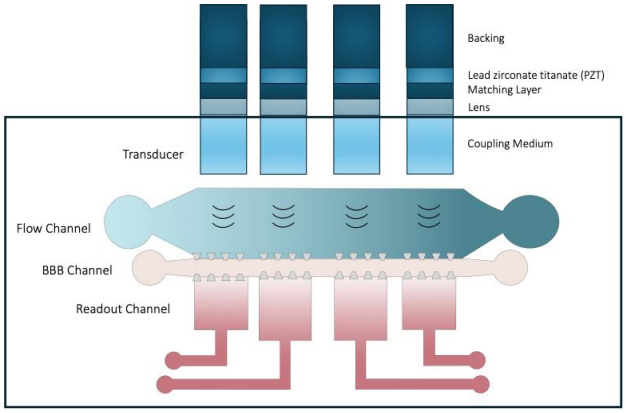
Karlsruhe Institute of Technology

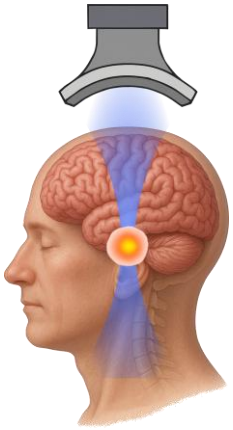
Institute for Data Processing and Electronics

Master's Thesis (Electrical Engineering / Physics)

Design and Simulation of a Multi-Channel Focused Ultrasound System for Microfluidic Blood-Brain Barrier Models

The blood-brain barrier (BBB) is a complex cellular interface that protects the brain from harmful substances while limiting drug delivery to the central nervous system (CNS). Focused ultrasound (FUS), when combined with microbubbles, has emerged as a promising method for transiently and non-invasively opening the BBB to enhance CNS drug delivery.
While rodent experiments are low-throughput, ethically challenging, and expensive, microfluidic organ-on-chip platforms offer a powerful alternative by mimicking the structural and functional characteristics of the human BBB. When combined with FUS, these platforms can serve as high-throughput tools for parameter optimization in targeted drug delivery.





Objectives
The primary aim of this thesis is to design, build, and validate a prototype four-channel FUS system using benchtop electronics for precise, controlled BBB opening in a microfluidic BBB-on-chip platform that has been designed by the Medical Faculty of Mannheim.

Specific Objectives

1. **Simulate, design, construct, and characterize** a FUS transducer compatible with the microfluidic chip model.
2. **Integrate transducers into a four-channel prototype FUS hardware platform**, including signal generation and amplification using benchtop electronics, as well as proper acoustic coupling into the microfluidic chip.
3. **Validate the system's ability to open the BBB in vitro** using microfluidic chips, assessing both permeability and safety.

Qualifications
- Programming skills in MATLAB required.
- Basic knowledge in electronics required.
- Interest in medical imaging and in particular ultrasound imaging.
- Basic knowledge in acoustic simulations beneficial.

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