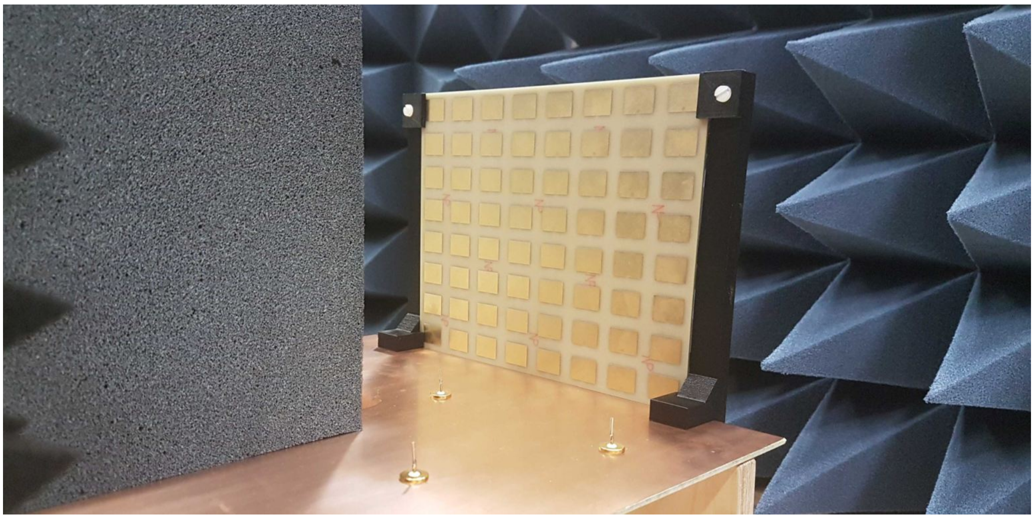
Project

Intelligent Reflecting Surface (IRS)-enabled Full-Duplex Communications

The focus of the chair of digital communication systems is the design and advancement of wireless transmission standards and systems. A new and very promising approach with respect to 6G wireless systems is the concept of intelligent reflecting surfaces (IRS). For decades, the radio channel between two nodes was considered given and could not be changed. By using an IRS, the radio channel can now be manipulated and optimized.
The intelligent surface can amplify signals by reflecting more power into shadowed areas in non-line-of-sight scenarios, but can also cancel signals at certain positions by destructive interference. This can be used, for example, to selectively cancel the signal for an eavesdropper. In our approach, an IRS is used for optimized suppression of self-interference in full-duplex nodes with two antennas. By optimized control of the RIS, a significant improvement of the self-interference suppression can be achieved compared to conventional full-duplex systems.
The aim of this bachelor's thesis is to build a transmission link consisting of two full-duplex nodes in the presence of two IRSs. After successful lab testing and optimization against dynamic channel changes, the constructed transmission link will be evaluated in several realistic field tests.



Tasks

- Setup of two IRS assisted Full-Duplex nodes
- Extend existing software in LabView
- Carry out extensive field testing
- Analyze and document the data

Requirements

- Experience in LabView
- Basic knowledge of Software Defined Radios
- Motivation to work with and debug hardware
- Independent way of working

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30. September 2021
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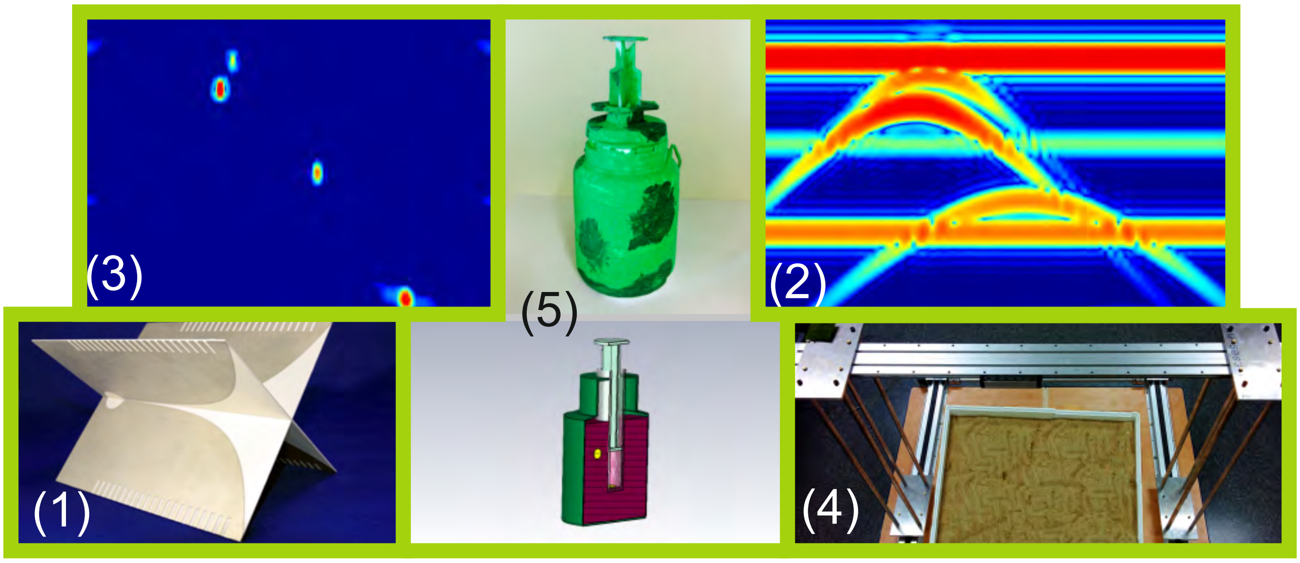
Institute of Electronic Circuits
Prof. Dr.-Ing. Thomas Musch

Project

Ground Penetrating Radar: Antennas, Simulation, and Signal Processing



Ground Penetrating Radar (GPR) is a metrological method for nondestructive, subsurface imaging. It is used in a broad variety of applications such as archeology, geophysics, glaciology, or humanitarian demining. Therefore, electromagnetic waves are radiated into soil by means of GPR antennas (Fig. 1). Soil inhomogeneities, like buried objects or soil layers, cause reflections which are monitored and evaluated. Gathering numerous measurements from different positions allow for the calculation of a two dimensional profile image as shown in Fig. 2. In order to increase the information content of the measured ground profile, advanced radar signal processing methods, like Synthetic Aperture Radar (SAR) algorithms, are applied to the raw data. Fig. 3 shows the processed data set from Fig. 2. For improving GPR methods, test measurements are performed under predefined laboratory conditions by using scanning frames and stepping motors as shown in Fig. 4. The efficient and reliable detection of shallow buried objects like anti-personal land mines (Fig. 5), demands for detection algorithms, which generally rely on 3D electromagnetic radar cross section (RCS) simulations.
Within this main project, we offer three different sub-projects:

1) **Simulation and characterization of GPR-antennas**
2) **GPR test measurements and signal processing**
3) **RCS simulation and detection algorithms**

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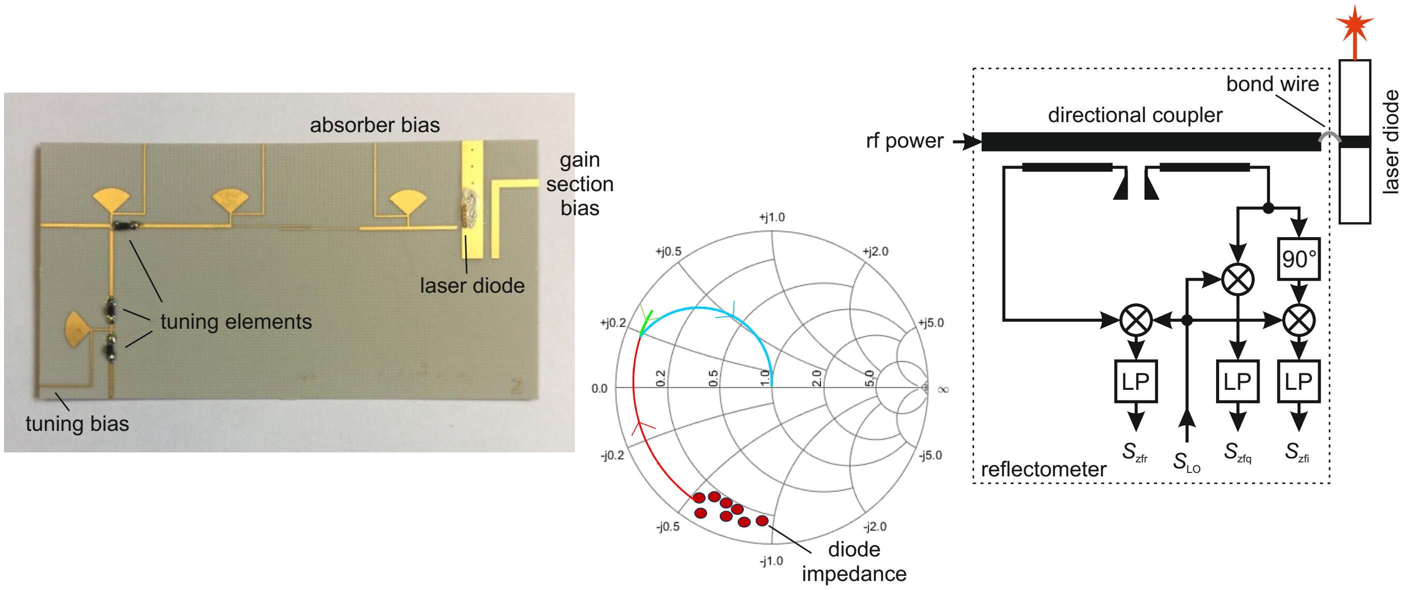
Project

Automatically tunable RF matching network for mode-locked laser diodes



Terahertz time-domain spectroscopy (THz-TDS) systems can be used for non-destructive testing and spectroscopic analysis of materials. In these systems, short pulse lasers are utilized to generate THz radiation. To reduce cost and to enable portable operation traditional laser systems can be replaced by hybrid mode-locked diode lasers. Hybrid mode-locking reduces the phase noise and therefore the time jitter of consecutive laser pulses. This requires an RF reference signal to be efficiently coupled into the laser resonator via a matching network. Because of manufacturing tolerances, both pulse repetition frequency and input impedance can vary drastically between different laser diodes, so an electronically tunable matching network is desirable. With a combination of microstrip transmission lines and varactor diodes, the network is controllable by applying a bias voltage. Any mismatch can be detected by measuring the magnitude and phase of the reflected power. With a closed-loop control, it is possible to automatically match the laser diode and compensate drift effects.

This project covers tasks in EM-simulation, PCB design and assembly as well as practical measurements with a vector network analyser.

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Performance and Aging Analysis on automotive lithium-ion cells: Electronic Circuits, Measurement Systems, Modeling and Parameter Estimation Techniques

The research group of Automotive Electronics conducts long-term aging studies on lithium-ion cells for use in battery electric vehicles. The tests are performed in close cooperation with leading German automobile manufacturers and are used to evaluate characteristics and cycle life under varying load conditions and to analyze the dynamic battery performance. For this purpose, specialized single-cell test equipment has been developed by our research group, allowing charge and discharge currents up to 600 A combined with wide bandwidth and high measurement resolution (Fig. 1). More than 150 testers and 13 temperature chambers are currently in use at our test facility, evaluating the next generation of automotive lithium-ion cells (Fig. 2).
The obtained measurement data are used for cell modeling and development of real-time parameter estimation techniques for use in onboard battery management systems. Special interest is taken in the inclusion of aging effects and advanced wideband analysis techniques like impedance spectroscopy.

Fig. 1 Single cell tester

Fig. 2 Test facility

An assortment of possible topics for a research project is listed below.

1. **Electronic circuits with high power and wide bandwidth for stimulation of lithium-ion cells with low distortion**

   Advanced frequency and time domain measurements require stimulation of the cell with high amplitude and low distortion. Different approaches for a suitable circuit topology are to be compared and evaluated by simulation and measurement.

2. **Methods for low-frequency cell stimulation and application to estimation algorithms**
   Low frequency stimulation of lithium-ion cells offers further insight into electrochemical aging processes, but state-of-the art measurement procedures are very time consuming. In this project optimized time-domain stimulation approaches are to be developed, implemented and compared to existing methodologies, especially with regard to applicability in estimation algorithms.
3. **Internal thermal behavior of lithium-ion cells – measurement procedures and modeling**
   The internal cell temperature is an important factor for cell aging, but cannot be measured directly. By exploiting the well-known temperature dependency of internal impedance, a suitable measurement concept is to be developed to accurately track impedance variations during arbitrary load profiles and correlate them to internal cell temperature.
4. **Bridging the gap between laboratory parameter estimation and real life application**
   In this project, various real-life driving cycles from our cell excitation database are to be used to evaluate and improve the performance of existing estimation algorithms in both simulation and measurement.
5. **Aging effects due to fast charging and cell modeling**
   Simulation of the electrical power train requires accurate battery models with inclusion of aging effects. In this project different aging mechanisms are analyzed and an adaptive cell model valid for different states of aging is developed. The performance of the model is evaluated using synthetic and real life driving cycles.

Interested students are kindly asked to contact us for detailed project descriptions or additional topics in our area of research.

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Chair for
Medical Engineering

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SUPER-RESOLUTION ULTRASOUND IMAGING

Project: The Chair for Medical Engineering is working on image acquisition and processing for medical diagnostics with a focus on applications of ultrasound. In our project on **ultrasound localization microscopy** we detect and track individual gas-filled microbubbles (contrast agents) in ultrasound sequences to get morphological and functional images of the microvasculature with a resolution beyond the limits of the conventional ultrasound. These images are used to characterize tumors, to identify pathological tissue in organs, or to monitor therapies [1,2]. You can help us to extend this method to 3D ultrasound data.

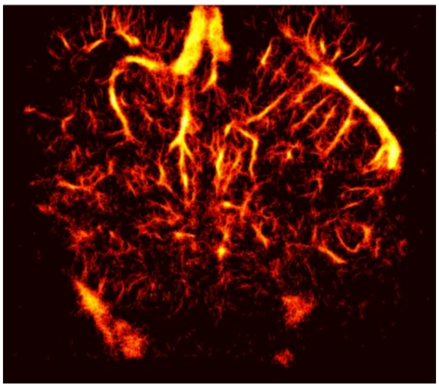

Figure 1 Reconstructed microvasculature of a mouse brain. The colormap shows the microbubble counts per pixel.

Within this main project, we offer **2 sub-projects**:
1) Modelling of the microbubble flow based on a literature search on morphological characteristics (branching, tortuosity, …) and flow dynamics (flow velocities) of the microvasculature. Implementation of simulations to test and improve the data processing steps. (*programming skills in Matlab)
2) Programming a toolbox (app) for visualization of 3D ultrasound datasets and their super-resolution results. Different imaging/display modes should be presentable (e.g., adjustable dynamic range, colormap, or transparency). With this toolbox, we aim to present every step of the entire ultrasound localization microscopy pipeline with all intermediate results, starting from beamformed ultrasound data to reconstructed microvasculature. (*programming skills in Matlab)

* would be helpful

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References:
[1] T. Opacic et al.: "*Motion model ultrasound localization microscopy for preclinical and clinical multiparametric tumor characterization*," Nat. Commun., vol. 9, no. 1, pp. 1–13, 2018.
[2] S. Dencks et al.: "*Clinical Pilot Application of Super-resolution US Imaging in Breast Cancer*," IEEE Trans. Ultrason. Ferroelectr. Freq. Control, vol. 66, no. 3, pp. 517-526, 2019.

Chair for
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CANNULA LOCALIZATION AND IMAGING IN SONOGRAPHY

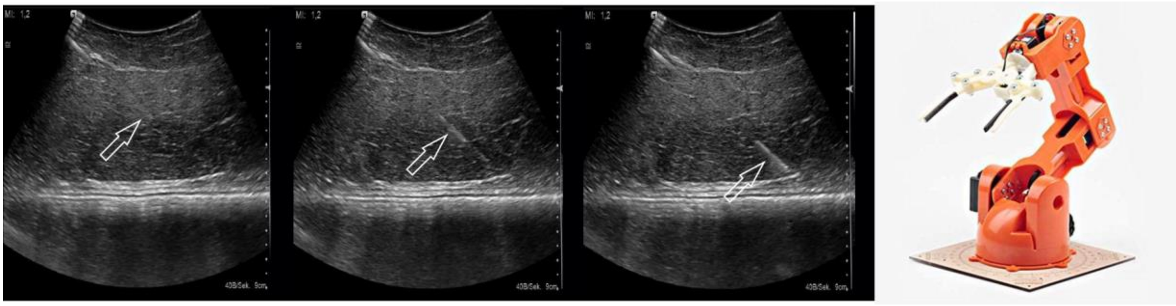

Figure 1 Monitoring the insertion of a cannula using ultrasound.

Project: The Chair for Medical Engineering is working on image acquisition and processing for medical diagnostics with a focus on applications of ultrasound.
Insertion of a cannula into the target anatomy is common in many minimally invasive procedures such as regional anaesthesia. This process is often monitored and imaged by ultrasound to improve targeting accuracy. However, good visibility of the cannula is often not guaranteed. In this project, you can help us to **ensure reliable and accurate localization of the cannula** by applying machine learning methods.

Within this project, we offer **2 sub-projects**:

1) Programming a graphical user interface (GUI) using Matlab AppDesigner to visualize cannulas in tissue. For this, the app has to communicate with Arduino or Raspberry Pie that are used to control the insertion of the cannula with a robotic arm. (*programming skills in Matlab)
2) Implementing a neural regression network/autoencoder in Keras/Tensorflow and evaluate its performance in cannula localization and segmentation. (*programming skills in Python, basic knowledge of machine learning and neural networks)

* would be helpful

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Photonics and Terahertz Technology
Prof. Dr. Martin Hofmann

Modern Microscopy (Photonics and Terahertz Technology)

A microscope is a typical tool to analyze tiny structures. Widely used in science and industry, microscopy is important in research of typically small modern devices and objects. Because of the on-going miniaturization of semiconductor and mechanical devices, the need for high resolution microscopes is still growing. It is our aim to improve known microscopy techniques and research new ones. We realized a flexible confocal laser scanning microscope (CLSM) to analyse semiconductor materials in reflection and in micro-photoluminescence mode. The capability to quickly change the laser sources, objectives and filters allows a wide range of experiments with different kinds of samples. Current projects implement phase based methods to improve the axial resolution, using synergy effects of the research projects in the field of holography and optical coherence tomography (OCT). Using various combinations of pinhole, objective and light source, the following specifications can be archieved:

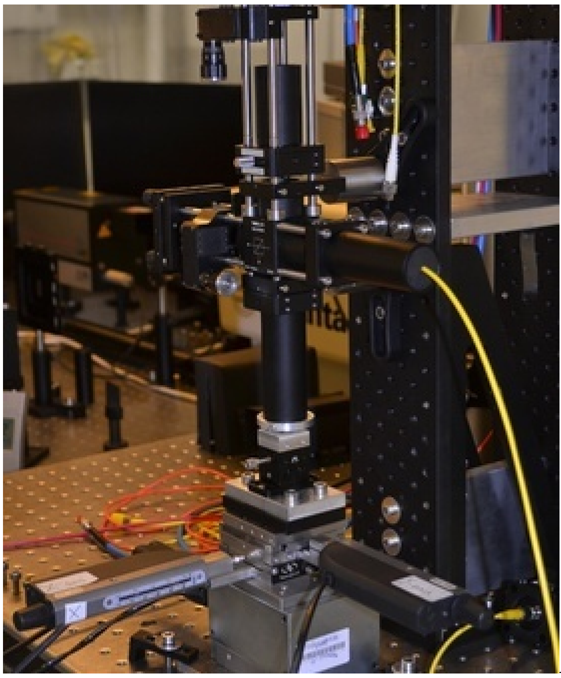

Figure 1: CLSM

- 500nm lateral resolutions
- 4µm up to 100µm axial resolution
- Laser sources: Diode lasers (405nm and 660nm), HeNe Laser and Ti:Sa Laser (700nm to 900nm)

An important subject is the analysis of semiconductor materials, especially the III/V semiconductors for optical integrated circuits. The micro-photoluminescence mode allows spectral imaging in the range of 400nm to 1700nm.

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Photonics and Terahertz Technology
Prof. Dr. Martin Hofmann

Ultra short pulse generation (Photonics and Terahertz Technology)

Semiconductor lasers are a key technology in the telecommunications sector. The feature of direct electrically pumping allows for a fast modulation of the laser in combination with a very compact setup. Since the end of the 1980’s there is an intense ongoing research of semiconductor lasers as a source for ultrashort laser pulses. But the complex carrier dynamics in the semiconductor material doesn’t allow the direct generation of femtosecond pulses with high average output power from an electrically pumped semiconductor laser. Thus, we have developed a modular system concept as de-picted in figure 1: in an oscillator based on a two section laser diode in an external cavity pulses with a duration of 5 ps are generated. The resonator geometry allows the compensation of the carrier dyna-mics in a fashion that the spectral bandwidth is greatly increased, while the pulse duration stays in the ps-regime.

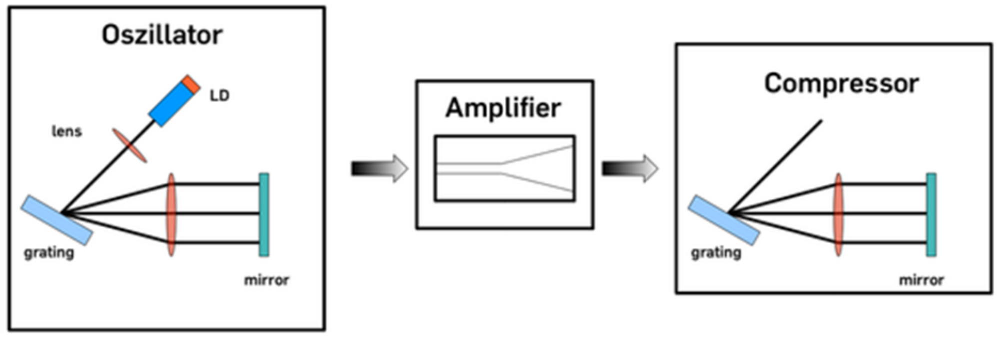

Fig. 1: Modular setup of high power femtosecond diode laser system

This enables the amplification by an optical amplifier which is also an electrically pumped semicon-ductor device. In a second step the pulse is compressed by an external pulse compressor to some 100 fs. The usage of semiconductor devices enables the possibility to build the whole laser with a foot print as small as 300 * 300 mm². Figure 2 shows the compact femtosecond diode laser system in front of a commercial Ti:Sapphire laser system. All components to generate high power laser pulses are in-cluded.

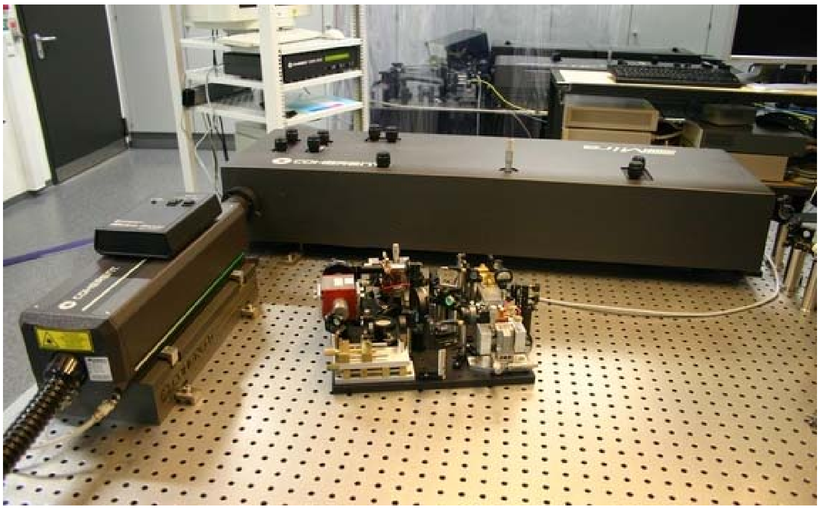

Fig. 2: Compact semiconductor laser system in front of a commercially available Ti:Sapphire laser

The resonator internal dispersion control allows to generate pulses with a duration as short as 158 fs. These are to our knowledge the shortest pulses which were generated by an electrically pumped semi-conductor laser. This closes the gap to fibre and solid state laser systems. After the pulse amplification pulse energies up to 2 nJ are generated. This leads to a peak power of 6.5 kW.

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FAKULTÄT FÜR ELEKTROTECHNIK
UND INFORMATIONSTECHNIK

PROF. DR.-ING. JAN LUNZE

Project
Design of a MATLAB GUI for an experimental test bed

What is the aim of this project?

As part of the work at the Institute of Automation and Computer Control, newly developed methods for the control of moving objects are tested in experiments at test beds. Such tests are important to verify that the theoretical method can be applied in realistic scenarios. Different test beds are used for UAVs (unmanned aerial vehicles) or cars (small robots). The adaptation of the methods to the different objects requires an appropriate parametrization of the methods.

In this project, a graphical user interface (GUI), exemplarily shown in Figure 1, should be developed with MATLAB with which an end user can easily parametrize a method for collision avoidance between moving objects. For the different types of objects mentioned above, the dynamics of the corresponding system can be chosen or parameters of the method can be modified to evaluate their influences on the collision avoidance requirement.

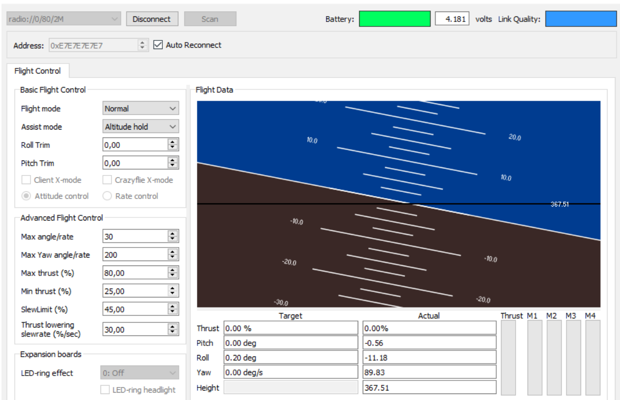

Figure 1: Example of a MATLAB graphical user interface.

Is there any prior knowledge required for this project?

The software used in this project is MATLAB. If some knowledge about programming in MATLAB is available, it will simplify the start, but it is neither expected nor required. It is more important to be interested in learning a new programming language, which is widely used at universities and in industry. To understand the collision avoidance method, it is sufficient to have a basic understanding of mathematics and a structured way of thinking.

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Institute of Communication Acoustics

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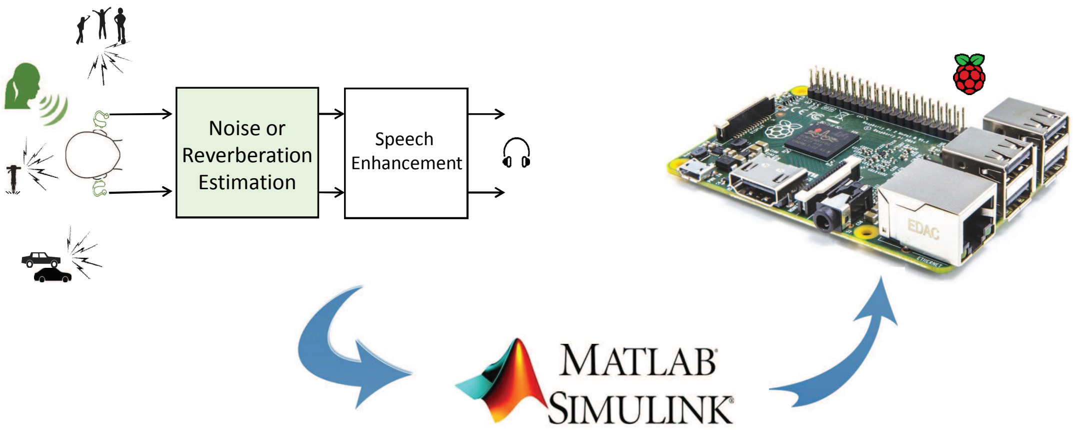
PROJECT (UNDERGRADUATE/GRADUATE)

Advanced Linux Sound Architecture in Applications of Adaptive Acoustic Signal Enhancement



The quality of speech signals captured by mobile devices can be easily degraded by the environmental noise of daily-life scenarios. Here, it will be beneficial to apply adaptive signal processing algorithms to reduce undesired ambient noise or reverberation in the signals. This will help to increase sound quality and intelligibility in speech communication or recognition.

The project investigates the utility of the Advanced Linux Sound Architecture (ALSA) to support the realtime implementation and demonstration of adaptive signal processing techniques, e.g., [1-2]. Matlab/Simulink will be used for technical computing and to enable a fast transition to a target, e.g., PC, Speedgoat, or Raspberry Pi. Algorithm performance will be investigated with speech in the presence of various noise types or reverberation levels.

[1] Schmid, D., Malik, S., Enzner, G., "An Expectation-Maximization Algorithm for Multichannel Adaptive Speech Dereverberation in the Frequency-Domain", Proc. ICASSP, 2012
[2] Thuene, P., Enzner, G., "Maximum-Likelihood Approach to Adaptive Multichannel-Wiener Postfiltering for Wind-Noise Reduction", Proc. ITG Symp. Speech Comm., 2016

PREREQUISITES: Linux, Matlab and Simulink, Signals and Systems

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Research Group for Biomedical Plasma Technology
Jun. Prof. Dr. Andrew R. Gibson

Bachelor Project

Influence of dielectric barrier discharge treatment on biological and artificial surfaces

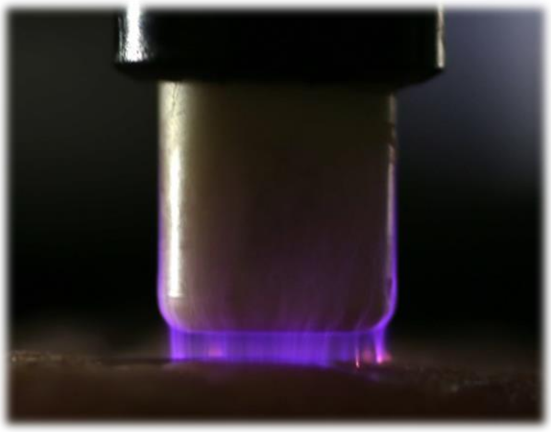

Figure 1: Image of dielectric barrier discharge interacting with a surface

Low temperature plasmas are weakly ionized gases containing a small fraction of free charged particles i.e. electrons and ions. The presence of free electrons allows for the production of a wide variety of reactive species at close to room temperature. These unique chemical and physical properties drive a wide range of applications of these devices in material processing and biomedicine, such as chronic wound treatment. A commonly used source geometry are so-called dielectric barrier discharges (DBDs).

The aim of this project is to investigate the effects of DBD treatment on various biological and artificial surfaces. For this purpose, plasma-induced modifications of surfaces such as bacterial colonies, biofilms and / or non-biological materials (plastics, metals) are to be characterized and quantified. Students will have the opportunity to define the specific project direction, and depending on the particular topics will have to opportunity to gain experience in areas such as:

- Cultivation of microorganisms and methods to study their inactivation
- Plasma characterisation techniques such as measurement of current-voltage curves, emission spectra and absorption spectra
- Surface analysis techniques such as profilometry, scanning electron microscopy (SEM) and measurement of hydrophobicity / surface energy

Special requirements: Enjoyment of experimental, multi-disciplinary research

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