Assignment of the Master's Thesis in the Program Nano Optoelectronics

Topic: Optimization of active layer in resonant tunnelling diodes

Task:

In the terahertz (THz) range between 300 GHz and 4 THz, many novel applications are currently being developed: contactless material detection and characterization, ultrafast wireless data transmission of several Tbit/s, and detection of concealed objects in robotics and security applications. For these application areas, compact signal sources and detectors are needed that can efficiently provide high output power, detect with high sensitivity and low noise, and be produced in a compact, robust, and cost-effective manner.

In the Collaborative Research Center/Transregio 196 (SFB/TRR196) MARIE, we investigate the resonant tunneling diode (RTD), a device based on the quantum mechanical tunneling effect, capable of generating signals up to 2 THz to date. By improving the vertical structure of the semiconductor, manufacturing processes of the devices, and their integration into arrays, we aim to enhance the performance of these THz components.

A particular challenge lies in the design of the active layer stack of an RTD. There are few tools available for reliably estimating DC and RF performance based on the layer stack design. Therefore, a physical simulation in Silvaco Atlas will be established as part of this work. The calculation basis will be the non-equilibrium Green's function (NEGF), which needs to be implemented in Silvaco, and the results will be verified. Verification can be conducted by comparing with literature data and/or an existing simple direct calculation tool.

Subsequently, the influence of the active layer parameters, such as barrier thickness, quantum well width, and quantum well material, on the DC performance for application as a THz oscillator will be investigated. Ideal design parameters for the aforementioned application will be extracted from this analysis. In the final step, measurements will be conducted on existing RTD structures with different layer stacks, and these results will be compared with the simulation. Optionally, a simplified method for estimating transit time by calculating the group velocity in the materials used can be developed. With the known transit time, a simple equivalent circuit can then be used to calculate the maximum achievable frequency of the diode.