**Master Thesis Project**

**Behavioral & Large Signal Modeling of Josephson Junctions/SQUIDS for Parametric Amplifiers in Qubit Readout Chain**

Reading the state of a superconducting quantum bit (qubit) gate requires low noise amplifiers. Instead of noisy transistors (active devices), the first stage of amplification is implemented with passive nonlinear inductances of Josephson Junctions (JJ) which helps in transferring the power from a large pump tone to the weak signal. Strong nonlinearity of JJ leads to other sophisticated mixing mechanism which needs deeper study and modeling e.g., mechanism which creates unwanted pump harmonics. The fast turn-around design, simulation and test of these amplifiers requires a precise behavioral and large signal model of JJ in standard circuit simulation tools e.g., ADS® or Cadence®. In contrast to lengthy transient simulations or small-signal models, behavioral large signal modeling helps in catching the real physics of the amplifier without including any approximation and importantly speeds up the simulation significantly.

An example of a TWPA developed in our lab. It is composed of 500 unit-cells made by nanolithography. Each unit cell has one SQUID (2 JJs in parallel) and a parallel capacitor to the ground.

In this project you will learn the physics of JJ and parametric amplification and you will interact with our theorists and experimental colleagues working on travelling wave parametric amplifiers (TWPA). You will develop a black-box behavioral model of an amplifier unit-cell using descriptive languages like Verilog-A and study the JJ using large signal S-parameters or X-parameter. You will analyze & compare your simulation results in ADS and Cadence with experimental data available in our lab, write your thesis and help in publishing your results in relevant journals or conferences.

**Prerequisites:** Good background in electric circuit simulation and programming (Spice, MATLAB, ADS), interest or background in quantum physics, independent & critical thinker. Previous experience with Verilog or VHDL is a plus but not necessary.

**Interested?** Please contact supervisors: Dr. Daryoush Shiri (shiri@chalmers.se) and Professor Christian Fager (Christian.fager@chalmers.se) (Microwave Electronics Lab, MC2)

**Examiner:** Professor Per Delsing (per.delsing@chalmers.se) (Quantum Technology Lab, MC2)