Physics Institute – Solid State Physics – Microwave Team Tübingen

# Bachelor/Master thesis available!

# Magnetic-field-tolerant superconducting quantum circuits using the high-$T_c$ superconductor $YBa_2Cu_3O_7$

Nonlinear and frequency-tunable superconducting microwave LC circuits are extremely important and useful devices for many quantum technologies, such as quantum information processors (e.g. the ones from Google and IBM) and quantum sensors. The nonlinear circuit elements are typically Josephson junctions and superconducting quantum interference devices (SQUIDs). By integrating a SQUID in a microwave LC circuit, one not only gets a nonlinearity, but also a circuit whose resonance frequency can be adjusted by changing the magnetic flux through the SQUID loop.

The standard superconducting material for such circuits is Aluminum, but this severely limits the operation regime of the devices, since Aluminum has a critical temperature of about 1.2 K and a critical magnetic field of some 10 mT. Many interesting potential applications for these circuits like quantum SQUID optomechanics, quantum sensing of magnetic defects or quantum computation with magnons and spins can therfore not be implemented with the current standard technologies.

We in the microwave team Tübingen therefore work on realizing novel microwave quantum circuits based on the high-temperature super-conductor $YBa_2Cu_3O_7$ (short YBCO), which allows for magnetic fields and temperatures at least two orders of magnitude larger than Aluminum.

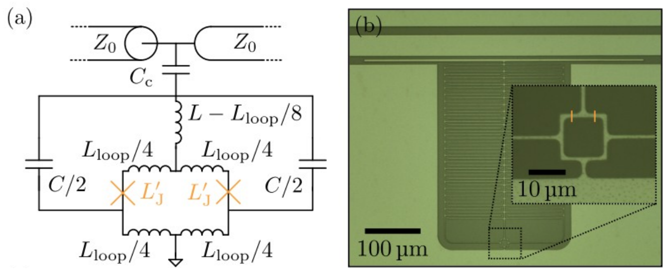


***Figure 1:*** *A YBCO quantum interference microwave circuit with helium-ion-patterned Josephson junctions. (a) Circuit equivalent and (b) false-color optical micrograph of a typical device. Inductors are labeled with L, capacitors with C, the microwave feedline has a characteristic impedance $Z_0$. In (b) bright parts are micropatterned YBCO, dark parts are the insulating substrate. The yellow lines in the inset show the writing lines of the helium ion beam for the Josephson junctions. From Ref. [1].*

Very recently, we succeeded in the first implementation of a microwave SQUID circuit based on YBCO and helium-ion-beam written Josephson junctions [1], see Fig. 1. Next, we want to realize more complex circuits such as Josephson parametric amplifiers (JPAs, SNAILs etc.), SQUID optomechanics or even a YBCO transmon qubit, all based on optimized YBCO thin films. This is where you can contribute with your bachelor and/or master project!

The main tasks and challenges during the thesis project will be:

- Design and simulation of superconducting microwave circuits
- Advanced nano-fabrication using lithography and ion beam patterning
- Characterization of circuits in cryogenic experiments using microwave spectroscopy
- Data analysis and measurement scripting using python

References:
[1] K. Uhl *et al.*, Applied Physics Letters **122**, 182603 (2023)

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