Multitone Scanning Tunneling Spectrosopy (STS)

(Optimizing harmonic excitation for ultrafast STS)

Bachelor/Master Project

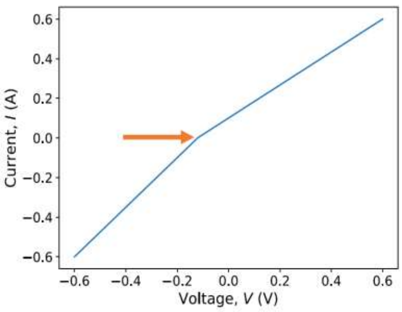
Exploring Quantum Materials

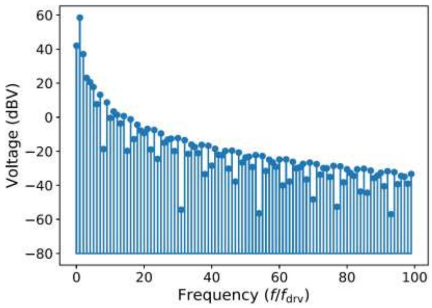
At the **Quantum Sensing and Quantum Materials Lab (Prof. Fabian Natterer)**, we use **Scanning Tunneling Spectroscopy (STS)** to investigate the electronic band structure of quantum materials, including **two-dimensional systems** and **superconductors**. Our work aims to develop and pioneer **advanced spectroscopic techniques** that significantly accelerate measurement processes. Ultimately, we aspire to resolve fundamental questions in condensed matter physics. Most notably, the mystery of **high Tc superconductivity** .

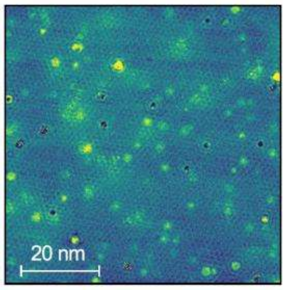
Parallel Spectroscopy

To measure the **local density of states** (LDOS) of electrons at specific points on a surface, we record **current–voltage (I–V) curves**, which are typically **non-linear**. When such non-linear systems are **driven** at any one given frequency, **harmonics** naturally emerge. By employing a **Multilock-in Amplifier (MLA)**, we can simultaneously drive the system and measure these harmonics to rapidly reconstruct the I–V curve - a technique we refer to as **Parallel Spectroscopy**.

While the MLA can drive and detect **multiple harmonics**, we currently operate it with a **single-tone excitation**. Preliminary simulations suggest that **multitone excitation** could further improve measurement quality and accelerate data acquisition.







Your Mission: Optimize the Harmonics

We invite you to contribute by simulating **multitone excitations** (preferably using **Python**). Your goal will be to identify optimal combinations of **tone, amplitude, and phase** - "chords" - that improve the signal quality of the measured I-V curves.

You are welcome to explore different **optimization** strategies, such as **Monte Carlo** or **Machine Learning** techniques, to efficiently search the parameter space. Part of your work will involve defining suitable **performance metrics** and implement these strategies in our setup. Through your contribution, you will help us make **STS even faster**.

Want to learn more? Contact gleb.neplyakh@physik.uzh.ch

Semester projects also available