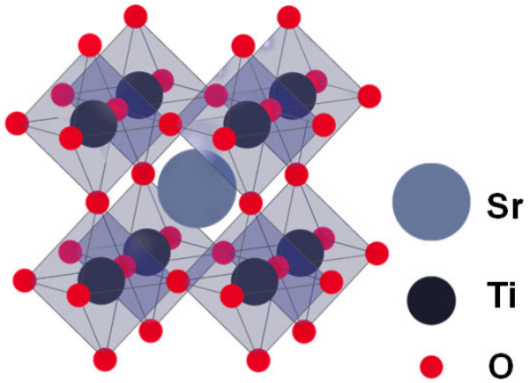
Master project: Transport in nanostructures of strontium titanate

Background: Strontium titanate (STO) is an artificial crystal formed of strontium, titanium, and oxygen atoms. It was first synthesised in the 1950s as a substitute for diamond, although it is no longer used as such (it has similar optical appearance and crystalline form, but is much softer). The material has a number of unusual properties that are still not fully understood even after over seventy years of research: For example, at low temperatures, quantum fluctuations are so strong that they prevent a classically-expected phase transition, and when doped, strontium titanate becomes superconducting, where the pairing mechanism that leads to superconductivity is "unconventional" (i.e., it is still under debate). Many of the insights from experiment and theory of STO have been hugely influential in other fields, such as the development of high-temperature superconductors or to understand superfluidity in quantum gases.

In recent years, there have been significant experimental improvements in the fabrication of strontium titanate structures. In particular, it has become possible to create heterostructures of STO and other materials with a conducting layer at the two-dimensional interface, or even design nanoscale circuits that consist of one-dimensional STO nanowires. Such systems are mesoscopic, where unusual interaction effects that lead to superconductivity interfere with the finite nanoscale size of the structure.



Left: Sketch of the strontium titanate crystal structure. Depending on the temperature, the precise ordering of the atoms will change, which in turn will affect how electrons move in the lattice. Right: The QR code links to a popular blog entry on the subject by thiscondensedlife.com called "Strontium Titanate – A Historical Tour".

Project proposal: The aim of this theory project is to develop and test a theory for electron transport in strontium titanate systems. You will apply methods from quantum field theory to study the influence of electron interactions on the transport properties and (ideally successfully) compare with recent experiments. There is an analytical component to the project where you design a model (i.e., a microscopic Hamiltonian for the electrons moving in STO) and a numerical component where you perform calculations with your model.

A basic knowledge of quantum mechanics and solid state physics is essential, some knowledge of quantum field theory and many-body theory would be useful.

Office space at Physics is expected to be available, but depending on future corona-virus restrictions we might have to work remotely.

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