Graduate Lecture within CRC 1277 in Summer 2024

Lecturer: Dr. Marco Aprili, Univ. Paris Saclay

Superconductivity : from nanoscale to quantum circuits

Superconductivity is a consequence of pairing of electrons in many metals. The characteristic length scale of these pairs is the choherence length ranging from a few to some ten nanometers. However the condensate resulting from a macroscopic number of these pairs maintains phase coherence over much larger length scales and makes superconducting devices and circuits an interesting platform for quantum technologies. The aim of this course is an introduction into the main advances in the field in the last years and to provide the necessary background for understanding these advances.

Contents:

0. Elements of Superconductivity
   - i) Gap equation
   - ii) Bogoliubov-DeGennes Hamiltonian
   - iii) Quasiparticle excitations and Density of States

1. Hybrid devices
   - i) Proximity and finite size effects
   - ii) Andreev reflexion and Andreev bound states
   - iii) From ballistic to diffusive quantum transport
   - iv) Phase-Current coupling : the Josephson effect
   - v) Recent experiments on Josephson hybrid junctions

2. Defects and pair-breaking of isolated impurities
   - i) spin dependent scattering
   - ii) spin dependent scattering
   - iii) some key experiments using scanning tunneling spectroscopy (quasiparticle interference, Shiba and Kondo resonances…)

3. Spin dependent phenomena
   - i) singlet and triplet condensates
   - ii) 2D Ising superconductors
   - iii) Spin-Phase coupling : magneto-electric effects
   - iv) towards topological superconductivity
   - v) some key experiments on the Edelstein effects

4. Quantum circuits
   - i) superconducting resonators
   - ii) high impedance micro-wave modes
   - iii) the strong coupling regime
   - iv) some examples of quantum simulators

Lecture times:

The lecture starts on 8. Juli (in SS 24) and takes place in two blocks:
1. Block: 8. to 24. Juli at 12h15 on Mondays and Wednesdays in PHY 8.1.09;
2. Block: 9. Sept. to 2. Oktober at the same place and time.

Classification of the course

a) The course is a lecture that targets the frontier between teaching at advanced level and research in Quantum Science and Technology.

b) Elective course

c) The course is mainly intended for master students.

d) The course counts 4 CP (2 SWS) for 60 CP required in the 'Wahlbereich' of the Master degree in Physics and Nanoscience.

Language of instruction

All lectures will be given in English.

Number of contact hours for the duration of your stay, number of (ECTS) credit points

The course is organized in two blocks of 12 hours each.

Anticipated number of participants

We expect between 15 and 20 Master and graduate students.