DAY 3: 9:00 – 9:40

Observation of the Berry phase in a superconducting charge pump

Mikko Möttönen
Helsinki University of Technology

The fundamental phenomena of quantum mechanics first found in atomic scale particles are now manifesting themselves in macroscopic quantum systems such as superconducting nanocircuits. The Berry phase is a direct consequence of quantum coherence. We present the first experimental results on the Berry phase accumulated to the ground state of a flux assisted Cooper pair pump, the sluice, during an adiabatic pumping cycle. Our observations pave the way for further experiments on Cooper pair pumping in closed circuits, on the quantum standard of electric current, and for applications of geometric phases in holonomic quantum computation.

DAY 3: 9:40 – 10:20

From superconducting circuits to current standards

Laurent P. Lévy and Raphael Leone
Institut Néel

Superconducting circuits made of superconducting islands connected by Josephson junctions, capacitors and inductances are quantum circuits with few degrees of freedom. There are tunable using classical parameters such as gate voltages and magnetic fluxes. They have natural periodicities coming from the charge-phase duality of superconductors. Some circuits with loops of Josephson junctions have isolated degeneracies between their two lowest eigenstates for specific values of their parameters. This is the case of Cooper pair pumps which has conical intersections between the lowest eigenstates for specific values of the gate voltages and a half flux-quantum through this one-loop circuit. The quantum phase of the eigenstates is not defined at the degeneracy, which looks like an isolated defect for the quantum-mechanical wavefunction. These defects can be characterized by a topological charge, proportional to a magnetic flux through a surface in the parameter space defined by the tunable elements (gates and fluxes) enclosing the degeneracy. For any closed surface in this parameter space, the Chern index measures the number of degeneracies enclosed within the surface. The periodicitic properties of the Hamiltonian turn a cylinder with a 2π height into a closed surface (torus). Using this property, the charge transferred through the circuit along a closed path which covers densely this cylindrical surface is quantized by the cylinder Chern index. This topological quantization allows to make a high accuracy current standard for which there is a high demand in metrology: to redefine the international system of units, it is necessary to close the "metrological triangle" relating time, voltage and current standards using the Josephson effect, the quantum Hall effect and this current pump based on the electrical charge and the frequency of operation. By using a voltage and current standard coming from the same clock, it is possible to redefine the kilogram through the Watt balance, and make an all electrical international system of units.
An implementation of this current standard requires a sufficiently accurate readout technique appropriate to this small quantized current and which allows an easy current comparison/amplification with other current sources through an integrated cryogenic current comparator.
A novel technique using an original variable SQUID device integrated in a resonant readout circuit has been developed to achieve these requirement. It also appears to be a very promising general purpose readout method for quantum circuits and can also be useful to quantum computation with superconducting qubits.