PNRR Partenariato Esteso
NATIONAL QUANTUM SCIENCE AND TECHNOLOGY INSTITUTE "NQSTI"
Spoke 6 Quantum Integration

Workshop on Quantum Integration and Topology
INO CNR Firenze,
November 25th, 2024

Scientific Committee:
Luca Pezzè INO CNR
Berardo Ruggiero ISASI CNR
Augusto Smerzi INO CNR

Program

12.00 *Welcome - Francesco Cataliotti* INO CNR

12.30 *Lunch*

13.30 *Mikhail Lisitskiy* SPIN CNR Pozzuoli (Na)
Quantum Collettive States in Superconducting Quantum Networks -Part A (10 qubits)

13.45 *Berardo Ruggiero* ISASI CNR , Pozzuoli (Naples)
Quantum Collettive States in Superconducting Quantum Networks -Part B (5 qubits)

14.00 *Andrea Trombettoni* Dipartimento di Fisica , Università di Trieste and IOM CNR
Topologies in Superconducting Josephson Devices

14.15 *Francesco Romeo* Dipartimento di Fisica, Università di Salerno
Topologies and its impact on Superconducting Quantum Networks

14.30 *Giulia Del Pace* INO CNR
Atomic Systems

14.45 *Luca Pezze'* INO CNR Firenze
Stabilizing Persistent currents in a Josephson Junction Necklace

15.00 *Nicolò Defenu* INO CNR Trieste
Emulating long-range interactions via disorder

15.15 -16.00 *Round Table on Quantum Integration and Topology: State of Art, Platforms and Future Initiatives*

Abstracts

Quantum Collective States in Superconducting Qubit Network- Part A (10 qubits)
Mikhail Lisitskiy SPIN CNR , Pozzuoli (Naples)

Quantum Collettive States in Superconducting Quantum Networks -Part B (5 qubits)
Berardo Ruggiero ISASI CNR , Pozzuoli (Naples)

We have carried out a theoretical and experimental study of quantum collective dynamics of superconducting qubit network (SQN) embedded in microwave planar resonators. An experimental realization and theoretical investigation of quantum devices with 5 and 10 flux qubits was carried out. T-type two resonators SQN with 5 and 10 flux qubits were designed, fabricated, and measured at ultra-low temperatures (15 mK) in terms of microwave measurements of scattering parameters and two-tone spectra . In case of SQN with 10 qubits there was observed a sharp shift of the position of the resonant transmission dip as a function of the amplitude of the second-tone signal. Experimental results are in a good agreement with the model based on a non-linear multiphoton interaction between pump microwave signal and a qubit system of the SQN. The frequency shift is the sum of the multiphoton AC Stark shift values of each qubit and the increase of the dip sharpness manifests the observation of quantum collective state stimulated by the second-tone microwave signal. Moreover, quantum collective states were observed without any external microwave stimulation in the case SQN with 5 flux qubits.

Topologies in Superconducting Josephson Devices
Andrea Trombettoni, Dipartimento di Fisica , University of Trieste and IOM CNR

In the talk I will discuss various results of free and interacting models on non-homogeneous topologies, with particular reference to O(N) and BCS models, and their applications to systems of Josephson junction networks.

Topology and Its Impact on Superconducting Quantum Networks
Francesco Romeo Dipartimento di Fisica "E. R. Caianiello" University of Salerno, Italy

This talk delves into the intricate relationship between topology and superconductivity in quantum networks, aiming to demonstrate how topological properties can serve as a powerful lever to control the physical behavior of these systems. We begin by reviewing key milestones in the study of superconductivity on networks, including notable collaborative works that provide a comprehensive historical overview. The presentation then offers an in-depth analysis of the real-space BCS theory, emphasizing recent advancements in pairing mechanisms that go beyond conventional models. In the final section, we explore the impact of topology in quantum qubit networks, illustrating its influence on their physical properties and discussing potential applications in quantum computing.

Atomic Systems
Giulia Del Pace INO CNR

I will report on the realization of supercurrents in homogeneous, tunable fermionic rings. We gain exquisite, rapid control over quantized persistent currents in all regimes of the BCS-BEC crossover

Stabilizing Persistent currents in a Josephson Junction Necklace
Luca Pezze' INO CNR Firenze

We study finite-circulation states in an atomtronic Josephson junction necklace, consisting of a tunable array of tunneling links in a ring- shaped superfluid. We provide the stability diagram of the atomic flow by tuning both the circulation and the number of junctions. We predict theoretically and demonstrate experimentally that the atomic circuit withstands higher circulations (corresponding to higher critical currents) by increasing the number of Josephson links. The increased stability contrasts with the trend of the super- fluid fraction – quantified by Leggett's criterion – which instead decreases with the number of junctions and the corresponding density depletion. Our results demonstrate atomic superfluids in mesoscopic structured ring potentials as excellent candidates for atomtronics applications.

Emulating long-range interactions via disorder

Niccolo' Defenu INO CNR Trieste

In many physical systems, long-range interactions play a critical role in determining emergent behaviors and phase transitions. However, directly realizing or simulating these interactions in controlled experimental settings can be challenging. This talk will explore how disorder—often viewed as a complication in physical systems—can be harnessed as a tool to effectively emulate long-range interactions. By introducing disorder into well-defined systems, it is possible to induce correlation effects and interaction-like behaviors that mimic long-range forces. I will discuss recent theoretical. The implications of this approach span fields ranging from condensed matter physics to quantum computing, opening new avenues for understanding complex systems and designing novel materials.