The Abdus Salam
International Centre
for Theoretical Physics

Quantum Microwaves, Heat Transfer and Many-Body Physics in Superconducting Devices | (SMR 3704)

16 May 2022 - 20 May 2022
ICTP, Trieste, Italy

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A continuous and efficient microwave photon to electron conversion using a high impedance circuit

P02

A continuous and efficient microwave photonto electron converter using a high impedance circuit

We use granular aluminum to build a high impedance microwave resonator strongly coupled to a Superconductor/Insulator/Superconductor junction. The engineered Fabry-Perot cavity has a large bandwidth set by the finite impedance mismatch on one side and by the junction on the other. By adjusting the dc-voltage applied to the junction, we tune the photon to electron conversion rate up to a point where it matches the microwave coupling rate of the resonator on the other side. At this critical coupling, microwave photons are efficiently and continuously converted into a flow of electrons across the junction. Remarkably, the quantum efficiency estimated from the measured photo-assisted current approaches unity.

P04

Nonreciprocal transmission with quantum optoelectromechanics

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Nonreciprocal systems breaking time-reversal symmetry are essential tools in modern quantum technologies enabling the suppression of unwanted reflected signals or extraneous noise entering through detection ports. It has been demonstrated that nonreciprocal transmission can be obtained by balancing any given coherent interaction with a properly tuned collective dissipative process [1] and this sight led to proposing and imple- menting nonreciprocity using optomechanical devices where these ingredients are available and controllable. An optical-microwave, four-modes nonreciprocal conversion scheme using exclusively optomechanical interac- tions has been proposed in Ref. [2] and realized in Ref. [3] in a superconducting electromechanical circuit in which both the optical and the microwave cavity are bichromatically driven. Here, similarly to the approach used in Refs. [2, 3] which does not require any direct interaction between electromagnetic modes, we consider a four-mode optoelectromechanical system composed of an optical cavity and an rf resonator, each coupled to two intermediate mechanical modes [4]. Two distinct paths of transmission between the two electromagnetic modes through the two mechanical modes are established and their relative phase forms the basis of nonreciprocity and directionality. The nonreciprocal transmission is obtained by interference of two dissipative pathways of transmission between the two electromagnetic modes established through two distinct intermediate mechanical modes. In our protocol, we apply a bichromatic drive to the cavity mode and a single-tone drive to the rf res- onator, and use the relative phase between the drive tones to obtain nonreciprocity. We analytically show how to adjust the driving parameters for achieving nonreciprocal wavelength conversion and numerically show that this is possible within an experimentally feasible parameter regime. In this way one can add the additional feature of nonreciprocity to the variety of optoelectromechanical devices which have been proposed and demonstratedfor the transduction of rf and microwave signals to the optical domain.

[1] A. Metelmann and A. Clerk, Physical Review X **5**, 021025 (2015).

[2] Xun-Wei Xu, Yong Li, Ai-Xi Chen, and Yu-xi Liu, Phys. Rev. A **93**, 023827 (2016).

[3] N. R. Bernier, L. D. Tóth, A. Koottandavida, M. A. Ioannou, D. Malz, A. Nunnenkamp, A. K. Feofanov, and T. J. Kippenberg, Nat. Commun. **8**, 604 (2017).

[4] **Najmeh Eshaqi Sani, Stefano Zippilli, and David Vitali, arXiv:2202.13231 [quant-ph], (2022).**

P06

Spin-Boson Quantum Phase Transition in Multilevel Superconducting Qubits

Phys.Rev.Lett.127, 237702(2021)

Abstract

Study of dissipative quantum system is an active topic of research. Recent research on two level systems like Rabi model; shows interesting progress, which motivates us to work in this direction. However, experimental isolation of such two level system is difficult. We studied experimentally more promising system of artificial atom made from electronic components. Variational theory and numerical renormalization group (NRG) methods are implemented on a dissipative quantum system of superconducting qubits coupled to a bath of harmonic oscillators. We study ground state properties of the system and calculate the system parameters as a function of coupling strength. From the results we observed that there is no quantum phase transition in transmon regime, therefore the system remains in delocalized phase. An unexpected behavior of spin-coherence is observed in that limit which makes the system more phase coherent.

P07

Thermally activated superconductivity in insulating Josephson chains

Chains of Josephson junctions are model quantum many-body systems which can be driven through a superconductor-insulator transition. In previous experiments, nominally insulating Josephson chains have displayed superconducting behaviour. This superconductivity, though not understood, is essential for technologies such as quantum-limited amplifiers and inductively shunted qubits. We resolve the nature of superconductivity in Josephson chains by extensively comparing transport and circuit quantum electrodynamics measurements. Analysing observed scaling behaviour in transport with constraints from microwave measurements, we find that apparent superconductivity is in fact the high-temperature fate of a melted insulator.

P09

Parity switching and destructive Little-Parkseffect in a hybrid full-shell superconductor- semiconductor nanowire qubit

A semiconductor transmon with an epitaxial Al shell fully surrounding an InAs nanowire core is investigated in the low E J/E C regime. Little-Parks oscillations as a function of flux along the hybrid wire axis are destructive, creating lobes of reentrant superconductivity separated by a metallic state at a half quantum of applied flux. In the first lobe, phase winding around the shell can induce topological superconductivity in the core. Coherent qubit operation is observed in both the zeroth and first lobes. We demonstrate the use of the qubit as a charge parity detector and use it to measured charge-parity switching by directly monitoring the dispersive shift of a readout resonator. At zero magnetic field, the measured switching time scale is on the order of 100 ms. Two-tone spectroscopy data post-selected on charge-parity is demonstrated. With increasing temperature or magnetic field, TP is at first constant, then exponentially suppressed, consistent with a model that includes both non- equilibrium and thermally activated quasiparticles. As TP is suppressed, qubit lifetime T1 also decreases. The long quasiparticle poisoning time at zero field is promising for future development of qubits based on hybrid nanowires.

P10

A continuous and efficient microwave photonto electron conversion using a high impedance circuit

We use granular aluminum to build a high impedance microwave resonator strongly coupled to a Superconductor/Insulator/Superconductor junction. The engineered Fabry-Perot cavity has a large bandwidth set by the finite impedance mismatch on one side and by the junction on the other. By adjusting the dc-voltage applied to the junction, we tune the photon to electron conversion rate up to a point where it matches the microwave coupling rate of the resonator on the other side. At this critical coupling, microwave photons are efficiently and continuously converted into a flow of electrons across the junction. Remarkably, the quantum efficiency estimated from the measured photo-assisted current approaches unity.