Quantum Coherent Phenomena at Nanoscale

Report of Contributions

https://indico.unina.it/e/QCPN2019

Contribution ID : **3** Type : **contributed oral**

Quasiparticle transport properties in superconductor-ferromagnet-superconductor trilayers

giovedì 20 giugno 2019 18:30 (15)

A quantitative theory describing the behaviour of current/voltage characteristics (CVC) and conductances (G) for both s-wave (S) and d-wave (D) type of ballistic voltage-biased superconductor/ferromagnet (F)/superconductor (SFS or DFD) trilayers is developed. The calculation is based on the nonequilibrium microscopic theory of transport in isotropic s-wave superconductor/normal metal (SNS) junctions by Kümmel, Gunsenheimer and Nikolsky [1] in the relaxation time approximation using the time-dependent Bogoliubov-de Gennes equations [2-5]. The model operates for different barrier thicknesses d, the mean free path in the barrier l>d and different temperatures T. For given exchange energy h the shape of CVCs depends, first, on the barrier thickness, while the presence and number of nonlinear structures are determined by h. The behaviour of current-voltage characteristics (CVC) in SFS junctions, such as steep rise of the current and negative differential conductance at small voltage, as well as the exchange field dependent position of the peaks, are obtained for weak exchange energy h≤Δ, where Δ=Δ(T) is the superconducting energy gap. Such behaviour is interpreted to be induced by multiple Andreev reflections (AR), modified in presence of h in F. For DFD junctions, the AR suppression due to the presence of order parameter nodes in D, and the presence of h in the F barrier leads to relatively smooth CVC for any value of h and of d in contrast to the case of isotropic pairing in superconducting electrodes (SFS case). This provides an indication of the superconductor order parameter symmetry. For DFD junctions with misoriented superconducting electrodes we found that at low bias the coherence in the quasiparticle transport could be enhanced by magnetic field in F. For θ=π/4 (d-wave superconductor is oriented with its gap node facing the boundary with F), where the proximity effect is the strongest, there is an enhancement of the current (as well as zero bias conductance), starting from h=0 up to a maximum at h≈Δ(T). We find that conductance curves G(V) have a rich nonlinear structure in low-voltage multiple AR region. At higher voltages, the curves are almost flat, with characteristic dips whose position are not influenced by the type of order parameter anisotropy and electrodes misorientation, but vary only with the h in F and temperature dependent pair potential in superconductor, according to the simple law neV=2Δ(T)∓h, with n=0,1,…. We suggest that from observed dip's locations at given temperature one could determine experimentally the value of the exchange field in the barrier. We find that temperature dependence of zero bias conductance for h≤Δ, show a kink at some characteristic temperature Tˆ*such that Δ(Tˆ*)=h, what provides another reliable experimental method for measurements of small exchange field.\\

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Session Classification : session 5

Contribution ID : **4** Type : **contributed oral**

Analytical calculation of phase bistability switching rates in dissipative Jaynes-Cummings model

giovedì 20 giugno 2019 18:45 (15)

We study the dynamics of a dissipative Jaynes-Cummings model subject to a strong resonant drive. Above a certain drive threshold there appear two metastable states in the stationary state with roughly the same field amplitude but different phases which are well captured by the bifurcation in the neo-classical approach. Their appearance is associated with the splitting of the spectrum of the corresponding Liouvillean heralding the quantum bistability. We focus on the analytical evaluation of the switching rates between the two metastable states which we achieve by a generalized Fermi-golden-rule-like method based on a precise estimate of the character of the metastable states. We find simple analytical expression for the rate surprisingly of non-exponential (i.e., non-Arrhenius) form, which nevertheless matches nearly perfectly the numerical results.

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Session Classification : session 5

Contribution ID : **5** Type : **invited oral**

Coherent effects in junctions based on p-wave superconductor

mercoledì 19 giugno 2019 17:00 (30)

The famed p-wave superconductivity harbors a variety of exotic topological states. The practical ways for its implementing are being extensively discussed in literature, and the contact of a superconductor with the topological insulator is expected to become the most promising candidate. There have been reports of the 4π-periodicity in such contacts, which are a hallmark of the p-wave superconductivity. However, the phase-sensitive measurements of the Josephson currents that would serve as conclusive evidence of the p-wave symmetry are still lacking. In this work we report direct observation of the Josephson effect in the Nb/Bi2Te2Se/Nb structures which are characterized by ballistic electronic transport across the Bi2Te2Se nanocrystals. We show that in the mK temperature range the investigated junctions exhibit a new type of oscillations of the Josephson current in magnetic field with an ultra-short period ~ 1 Oe corresponding to energy spectrum with the level spacing of order of 1 μeV. We develop theoretical model explaining these oscillations in terms of fine structure of low-energy Andreev bound states. The results are consistent with emerging p-wave superconducting correlations induced at the Bi2Te2Se surface due to an interplay between the s-wave superconductivity in Nb and a peculiar symmetry of the topological insulator Bi2Te2Se. This work is supported by the Russian Science Foundation (Project No. 18-72-10118), the EU H2020-WIDESPREAD-05-2017-Twinning project "SPINTECH" (the Grant Agreement No. 810144) and by Dutch FOM.

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Session Classification : session 1

Contribution ID : **6** Type : **invited oral**

In situ tailoring of single superconducting junctions and nano-SQUIDs via current-induced atom migration

venerdì 21 giugno 2019 11:00 (30)

We demonstrate the in situ engineering of superconducting nanowires via modulation of material properties through high applied current densities [1]. We show that the sequential repetition of such customized electro-annealing in a niobium nanoconstriction can broadly tune the superconducting critical temperature Tc and the normal-state resistance Rn in the targeted area. Once a sizable Rn is reached, clear magneto-resistance oscillations are detected along with a Fraunhofer-like field dependence of the critical current, indicating the formation of a weak link with adjustable characteristics [2]. Applying this method to aluminum nanoconstrictions, it is possible to modify their geometry and consequently their weak links' properties beyond the limit of current lithography techniques [3]. Furthermore, conducting parallel electromigration in aluminum SQUIDs allows us to investigate the evolution of the superconducting properties of the SQUID as function of the cross section of the weak links and eventually access a regime where the SQUID can be operated in the dissipative state. We will also discuss the possibility to change the local oxygen doping in constrictions made of High-Tc materials [4].

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Session Classification : session 7

Contribution ID : **7** Type : **invited oral**

Cross-correlated shot noise in three-terminal superconducting hybrid nanostructures

giovedì 20 giugno 2019 11:00 (30)

We work out a unified theory describing both nonlocal electron transport and cross-correlated shot noise in a three-terminal normal-superconducting-normal (NSN) hybrid nanostructure. We describe noise cross correlations both for subgap and overgap bias voltages and for arbitrary distribution of channel transmissions in NS contacts. We specifically address a physically important situation of diffusive contacts and demonstrate nontrivial behavior of nonlocal shot noise exhibiting both positive and negative cross correlations depending on the bias voltages. For this case, we derive a relatively simple analytical expression for cross-correlated noise power which contains only experimentally accessible parameters.

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Session Classification : session 3

Contribution ID : **8** Type : **invited oral**

Identifying and Controlling Sources of Decoherence In Superconducting Quantum Devices.

giovedì 20 giugno 2019 15:30 (30)

Despite the promises of superconducting qubits, their performance is presently limited by short coherence times due to defects intrinsic to materials. As a result, future quantum computers would require massive error correction circuits, which seem to be very challenging to build. Another more promising path would be to improve this coherence time, which would relax the constraints on the quantum error correction circuits and would thus make a quantum computer more feasible. This task is considered one of the main challenges in the field. Our recent results [1] gave vital clues to the long-standing problem of noise and decoherence in superconducting devices: a technique for on-chip Electron Spin Resonance (ESR) [2], allowed to identify, for the first time, the chemical species responsible for the flux noise in superconducting circuits [3]. Furthermore, the most recent noise measurements in superconducting resonators point to the link between charge and flux noise in superconducting circuits [3]: a mild sample treatment has lead to tenfold reduction of the surface spins, responsible for the flux noise, as evidenced by ESR, and this treatment has also lead to tenfold reduction of the low frequency noise in superconducting resonator, usually associated with the charge noise. The chemical identification of the possible remaining sources of noise in superconducting devices allows for an active chemical intervention, aiming at silencing the defects and, therefore, improving the coherence in superconducting quantum devices.

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Session Classification : session 4

Contribution ID : **9** Type : **invited oral**

Coherent quantum phenomena in ultimate 2D superconductors: A STM study

giovedì 20 giugno 2019 09:30 (30)

In 1964 V. L. Ginzburg predicted that new superconducting phases could appear in ultrathin films deposited on insulating surfaces. In 2010 superconductivity below 2K was discovered in some crystalline atomic monolayers of Pb grown on atomically clean Si(111) [1,2]. Owing their peculiar electronic properties, these two-dimensional materials manifest a number of intriguing superconducting phenomena. In crystalline monolayers of Pb on Si(111) the superconducting condensate is an intrinsic Josephson network formed by superconducting terraces coupled by Josephson links at individual atomic steps [1]. The detailed atomic arrangement at each step decides the strength of the Josephson coupling. In a magnetic field, the superconducting vortex phase contains different kinds of vortices, ranging from Abrikosov (Pearl) to Josephson limits. By contrast, amorphous monolayers of Pb are non-superconducting correlated metals. Playing with geometry of in-situ grown samples enables realizing ultimately thin lateral SNS junctions, reveal and study Josephson proximity vortices inside their N-parts [2]. When individual magnetic impurities are added, the Cooper pairs are scattered in a peculiar manner, resulting in so-called Yu, Shiba and Rusinov (YSR) bound states. While in three-dimensional superconductors these states rapidly decay around impurities on atomic scale, superconductors with two-dimensional electronic structure such as 2H-NbSe2 or Pb-monolayers on Si(111) host YSR bound states with spatial extents orders of magnitude larger [3]. These long-range magnetic states could be used to produce new topological phases in hybrid systems such as arrays or clusters of magnetic atoms [4] and molecules coupled through the 2D-superconducting medium. In our lecture we describe a series of recent experiments which mapped superconductivity, vortices and YSR states in Pb/Si(111) and 2H-NbSe2 by scanning tunneling microscopy and spectroscopy at ultralow temperatures.

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Session Classification : session 2

Contribution ID : **10** Type : **invited oral**

Atomic scale scanning tunneling spectroscopy with superconducting tips

giovedì 20 giugno 2019 09:00 (30)

The scanning tunneling microscope (STM) allows for a rather unique control over matter at atomic scale. By measuring at very low temperatures, it also serves as a spectroscopic probe of low energy phenomena, such as superconductivity. As such, the STM can measure all known features of superconducting tunneling, namely density of states, inelastic tunneling, Andreev scattering and Josephson effect. I will review results obtained with this technique and discuss recent insight obtained in atomic scale Josephson junctions and in unconventional superconductors.

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Session Classification : session 2

Contribution ID : **11** Type : **invited oral**

Unveiling the bosonic nature in an ultrashort single-electron pulse

mercoledì 19 giugno 2019 18:30 (30)

Quantum dynamics is very sensitive to dimensionality. While two-dimensional electronic systems form Fermi liquids, one-dimensional systems - Tomonaga-Luttinger liquids - are described by purely bosonic excitations, even though they are initially made of fermions. With the advent of coherent single-electron sources [1- 3], the quantum dynamics of such a liquid is now accessible at the single-electron level. Very little is known, however, on the propagation of such single electron charge excitations. Here, we investigate in a time-resolved manner the propagation of an ultrashort single-electron charge pulse injected into a quasi-one-dimensional quantum conductor. This allows us to extract the collective charge excitation velocity. We show that the velocity of such a single electron pulse is found to be much faster than the Fermi velocity due to the presence of strong electron-electron interactions and can be tuned over more than an order of magnitude by electrostatic confinement. In addition, our set-up allows us to tune our system continuously from a clean one-channel Tomonaga-Luttinger liquid to a multi-channel Fermi liquid. Our results [4] are in quantitative agreement with a parameter-free theory and demonstrate a powerful new probe for directly investigating real-time dynamics of fractionalisation phenomena in low-dimensional conductors. [1] G. Fève, A. Mahé, J.-M. Berroir, T. Kontos, B. Plaçais, D.C. Glattli, A. Cavanna, B. Etienne, Y. Jin. "An On-Demand Coherent Single-Electron Source". Science 316, 1169-1172 (2007). [2] J. Dubois, T. Jullien, F. Portier, P. Roche, A. Cavanna, Y. Jin, W. Wegscheider, P. Roulleau and D.C. Glattli. "Minimal-excitation states for electron quantum optics using levitons.", Nature 502, 659-663 (2013) [3] C. Bäuerle, C. Glattli, T. Meunier, F. Portier, P. Roche, P. Roulleau, S. Takada, and X. Waintal, "Coherent control of single electrons: a review of current progress", Rep. Prog. Phys (2018) DOI: 10.1088/1361-6633/aaa98a [4] G. Roussely, E. Arrighi, G. Georgiou, S. Takada, M. Schalk, M. Urdampilleta, A. Ludwig, A. D. Wieck, P. Armagnat, T. Kloss, X. Waintal, T. Meunier, and C. Bauerle. Unveiling the bosons in an ultra-short single electron pulse, Nature Communications 9, 2811 (2018)

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Session Classification : session 1

Contribution ID : **12** Type : **invited oral**

Spinful quantum dot junctions probed by superconductivity and thermoelectricity

giovedì 20 giugno 2019 18:00 (30)

We investigate the properties of gate-tunable single quantum dot junctions, obtained by the electromigration technique, in the spin-1/2 Kondo regime with rather large U/Γ (U is the on-site interaction and Γ the tunnel coupling). In the first part we investigate the device response in the presence of superconductivity in the leads. We tune the ground state of the dot quantum spin from screened to unscreened, using the gate voltage, the temperature and the magnetic field. In the second part, we investigate the thermoelectric device response in the normal state of the leads, in the presence of a thermal gradient. We find a 2e-periodic response of the Seebeck coefficient with respect to the quantum dot charge state, which provides a characteristic signature of the spin degeneracy of the quantum dot levels. A sign change of the Seebeck coefficient with increasing temperature in the oddly occupied state provides a hallmark of Kondo correlations, in very good agreement with NRG calculations.

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Session Classification : session 5

Contribution ID : **13** Type : **invited oral**

Topology- and Geometry-Induced Properties of Advanced Nanoarchitectures

giovedì 20 giugno 2019 10:00 (30)

Study of topological matter is one of the fascinating main roads of modern physics. The present overview is aimed at topology- and geometry-driven effects, owing to special geometries of novel micro- and nanoarchitectures fabricated of both conventional and topologically nontrivial materials implemented by the high-tech techniques, in particular, self-organization [1, 2]. I will demonstrate how topology of the quantum fields determines electronic [3], excitonic [4], optical, superconducting [5], magnetic, thermal [6] properties of emerging nanostructured materials leading to their functionalization towards novel applications in advanced nanotechnologies. Self-assembled quantum volcanos, which are singly connected, surprisingly exhibit the Aharonov–Bohm behavior in experiment. This is explained by the fact that in a quantum volcano the electron wave functions are identical to the electron wave functions in a quantum ring from a topological point of view. Combination of a geometric potential and an inhomogeneous twist renders an observation of the topology-driven effects in the electron ground-state energy in Möbius rings at the microscale into the area of experimental verification. Advances in the high-tech roll-up fabrication methods have provided qualitatively novel curved superconductor micro- and nanoarchitectures, e.g., nanostructured microtubes and microhelices. Rolling up superconductor Nb nanomembranes into open tubes allows for a new, highly correlated vortex dynamics regime that shows a three-fold increase of a critical magnetic field for the beginning of vortex motion and a transition magnetic field between single- and many-vortex dynamic patterns. These results demonstrate pathways of tailoring nonequilibrium properties of vortices and phase slips in curved superconductor nanoarchitectures leading to their application as tunable superconducting flux generators for fluxon-based information technologies. For various micro- and nanoarchitectures, we have found a possibility of efficiently engineering the Seebeck coefficient and electric conductivity in one-dimensional stacks of quantum dots, acoustic phonon energy dispersion in one-dimensional quantum-dot superlattices, cross-section-modulated nanowires, Si wires ranging from nanoscale to microscale, and, more recently, multishell tubular structures, which are promising candidates for an advancement in thermoelectric materials and devices. I gratefully acknowledge the support of the COST Action "Nanoscale Coherent Hybrid Devices for Superconducting Quantum Technologies" CA16218 and the German Research Foundation (DFG) under grants #FO 956/4-1 and FO 956/5-1.

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Session Classification : session 2

Contribution ID : **14** Type : **invited oral**

Superconductor-insulator quantum transition in extra-long, one-dimensional chains of Josephson junctions

sabato 22 giugno 2019 11:00 (30)

A quantum phase transition (QPT) represents a discontinuous change of the ground state of an extended, ideally infinite, system. Such transitions occur at zero temperature and they are driven by tuning a parameter in the Hamiltonian. If an effective Hamiltonian is such that it includes some temperature-dependent parameters, then a temperature-controlled quantum transition (TC-QPT) can be expected. Here we present a TC-QPT between superconducting and insulating regimes in a chain of weakly coupled superconducting islands. The transition appears at a temperature where the Josephson energy equals the effective Coulomb charging energy, defined by the electric capacitance between the islands. The insulating state is manifested by a resistance peak, characterized by an exponential growth of resistance with cooling, while the superconducting state is represented by an exponential drop of the resistance with cooling. A scaling analysis, which takes into account the temperature-dependent critical parameter of the observed TC-QPT, is presented. The temperature dependence of the QPT critical point comes about because the Josephson coupling energy depends on the BCS energy gap, which is temperature dependent.

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Session Classification : session 9

Contribution ID : **16** Type : **contributed oral**

Low temperature characterization of low-dissipation ferromagnetic Josephson junctions

giovedì 20 giugno 2019 12:30 (15)

Ferromagnetic Josephson junctions present a rich emerging physics due to the coupling between ferromagnetism and superconductivity. The interplay between the two competing phases causes an oscillation of the superconducting order parameter within the ferromagnetic barrier, which is responsible for the appearance of a π ground state, and of triplet correlations in the Josephson junction [1,2]. Because of such properties, SFS junctions are sought to have applications in the emerging field of superconducting spintronics [3] and in quantum and digital superconducting computation as phase shifters [4] or as auxiliary circuit elements for error correction, readout and memory elements [5, 6, 7, 8]. Currently, their use is limited by their metallic, highly dissipative nature. In this work we will review the properties of a specific category of SFS, namely low dissipation spin filter junctions [9,10]. In particular, we will present a low temperature characterization of such devices down to 0.3K. We measured several junction parameters as a function of thickness, focusing our attention on critical current versus temperature dependencies at different thicknesses. We developed a model to describe the anomalous behaviour and the incomplete 0-π transition found in experimental data using short-range triplet correlations. These results offer new perspectives for the study of the role of short-range triplet correlations in the transport properties of low dissipation ferromagnetic junctions.

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Session Classification : session 3

Contribution ID : **17** Type : **invited oral**

Tuning of dissipation in tunnel-ferromagnetic Josephson junctions

giovedì 20 giugno 2019 11:30 (30)

Josephson coupling between superconducting and ferromagnetic layers is driving new fundamental physics and innovative applications for superconducting electronics and quantum circuits [1,2]. Examples are: the possibility to switch the ground state of a Josephson junction (JJ) from a 0 to a π phase state, the existence of JJs having a doubly degenerate ground state with an average Josephson phase $\psi = \pm\varphi$, the possibility to carry spin-triplet supercurrent in the presence of certain types of magnetic inhomogeneity.

We will report on a comprehensive study of dissipation in hybrid JJs composed by pure metallic ferromagnetic layers [3] or by ferromagnetic-insulator barriers [4,5,6]. Transport measurements highlight different dissipation sources, which reflect different properties of the barriers and of the composition of the junctions. This study provides the electrodynamic characterization [3,6,7] necessary for the possible use of these systems in more complex circuits, as cryogenic memories or spintronic devices, and suggests new solutions of ferromagnetic JJs in superconducting qubits.

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Session Classification : session 3

Contribution ID : **18** Type : **invited oral**

Superconductivity, ferromagnetism and Rashba spin-orbit coupling in oxide 2DES

venerdì 21 giugno 2019 12:00 (30)

Two dimensional electron systems (2DES) formed at the interface between insulating transition metal oxides have demonstrated an extraordinary range of properties. The coexistence among these properties can be studied vie electric field effect, making these systems an ideal test bench for the investigation of novel quantum phenomena. A notable example is the coexistence between superconductivity and Rashba spin-orbit coupling in the 2DES at the interface between LaAlO3 and SrTiO3 (LAO/STO). We will review the recent remarkable progresses in realization of complex LAO/STO superconducting nanodevices and focus on indications of an unconventional superconducting order parameter obtained in LAO/STO Josephson junctions [1]. Moreover, thanks to the introduction of a delta-doping layer of EuTiO3 sandwiched between STO and LAO, ferromagnetic correlations were recently added to this picture [2]. We will present a study of the interplay between ferromagnetism and Rashba spin-orbit coupling in LAO/ETO/STO heterostructures performed by analyzing the magnetotransport data as a function of the carrier density and of the temperature [3]. We will show also that the ferromagnetic correlations in this system can be tuned by light illumination.

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Session Classification : session 7

Contribution ID : **19** Type : **invited oral**

Quantum Fluctuation Phenomena in Quasi-1D Superconductors

sabato 22 giugno 2019 12:00 (30)

Superconducting properties of metallic nanowires can be entirely different from those of bulk superconductors because of the dominating role played by thermal and quantum fluctuations of the order parameter [1]. Fundamental attributes of superconductivity such as zero resistivity, persistent currents in closed loops, energy gap in excitation spectra can be drastically violated by fluctuations. Quasi-one-dimensional superconducting channels host sound-like plasma modes propagating along the sample which are associated with fluctuations of the phase of the superconducting order parameter [2]. Interaction between these electromagnetic excitations and charge carriers affects the electron density of states (DOS) [3]. Here we report the experimental study of I-V characteristics of tunnel S1-I-S2 junctions, where superconducting S2 electrode is a thin nanowire in the regime of quantum fluctuations. The observed broadening of the I-V dependencies at the gap edge is interpreted as the renormalization of DOS. The results are in reasonable agreement with the model [3], taking into consideration plasma modes in quasi-one-dimensional superconductors.

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Session Classification : session 9

Contribution ID : **21** Type : **invited oral**

Ultrastrong Coupling of matter and radiation: detection of virtual photons and multiqubit quantum gates

sabato 22 giugno 2019 10:00 (30)

Ultrastrong coupling (USC) between light and matter has been recently achieved in erchitectures of solid state artificial atoms coupled to cavities. They may provide new building blocks for quantum state processing, where ultrafast quantum gates can be performed thus meeting the requirements for fault-tolerant quantum computation. However it has been shown [1] that in the USC regime the dynamical Casimir effect (DCE), may pose limits on the fidelity of quantum operations, as for protocols based on quantum Rabi oscillations [1]. These latter are used for processing in strongly coupled (SC) circuit-QED systems where only single excitations are manipulated across the system the cavity working as a quantum bus. In the USC multiphoton generation deteriorates the fidelity of such quantum operations [1] even in absence of decoherence.

To overcome this problem we propose a communication channel based on an adiabatic protocol similar to STIRAP [2]. Ideally the cavity is never populated, operating as a virtual bus, thus it is expected to greatly reduce the impact of DCE. Indeed we show that high fidelity operations can be performed for moderate couplings in the USC regime [3] thus allowing to operate faster than in SC. Moreover properly crafted control exends the high fidelity region to even larger couplings. The protocol is extremely robust agaist DCE, in the absence of decoherence yields almost 100% fidelity for remote population [3] and state trensfer. It is also resilient to decay due to leakage from the cavity, which is the main decoherence mechanism for present USC architectures [3]. In this more realistic scenario it is seen that for larger coupling (entering the deep strong coupling regime) the fidelity decreases due to the interplay between decoherence and DCE.

The communication channel we address being a prototype of family of adiabatic protocols for state transfer and multiqubit gate, our results suggest that adiabatic manipulations, which has been recently proposed for detecting dynamically USC [4], may be a promising tool for quantum state processing in the USC regime.

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Session Classification : session 8

Contribution ID : **22** Type : **invited oral**

Critical current 1/f noise in graphene Josephson junction

giovedì 20 giugno 2019 12:00 (30)

Short ballistic graphene Josephson junctions (GJJ) sustain superconducting current with a strongly non-sinusoidal current-phase relation (CPR) up to a critical current threshold. The CPR, arising from proximitized superconductivity, is gate-voltage tunable and exhibits peculiar skewness observed in high-quality graphene-superconductors heterostructures with clean interfaces. These properties make GJJ promising sensitive quantum probes of microscopic fluctuations underlying relativistic transport in 2D. We demonstrate that fluctuations with 1/f power spectrum of the critical current of a short ballistic GJJ directly probe carrier density fluctuations of the graphene channel. Tunability with the chemical potential, close to and far from the charge neutrality point, and temperature dependence of the noise amplitude are clear fingerprints of the underlying material-inherent processes. These results provide also relevant figure of merits in view of the envisaged implementation of coherent quantum circuits in hybrid quantum information architectures.

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Session Classification : session 3

Contribution ID : **23** Type : **invited oral**

Spin-dependent thermoelectric effects in superconductor/ferromagnet hybrid structures

giovedì 20 giugno 2019 17:30 (30)

We report on the experimental observation of spin-dependent thermoelectric effects in superconductor-ferromagnet tunnel junctions in high magnetic fields. The thermoelectric signals are due to a spin-dependent lifting of particle-hole symmetry on the energy scale of the superconducting gap. Due to the small energy scale, the thermoelectric effects can be quite large, and we infer a maximum Seebeck coefficient of about 100 μV/K from our data. Nonlocal thermoelectric effects elucidate the coupling of spin and heat transport in high-field superconductors.

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Session Classification : session 5

Contribution ID : **24** Type : **invited oral**

Fast high fidelity quantum non-demolition qubit readout via a non-perturbative cross-Kerr coupling

giovedì 20 giugno 2019 16:00 (30)

Qubit readout is an indispensable element of any quantum information processor. In this work, we propose an original coupling scheme between a qubit and a cavity mode based on a non-perturbative cross-Kerr interaction. This scheme, using the same experimental techniques as the perturbative cross-Kerr coupling (dispersive interaction), leads to an alternative readout mechanism for superconducting qubits. This new process, being non-perturbative, maximizes the speed of qubit readout, its single-shot readout fidelity and its quantum non-demolition (QND) behavior at the same time, while minimizing the effect of unwanted decay channels such as, for example, the Purcell effect. We observed 97.4 % single-shot readout fidelity for short 50 ns pulses. Using long measurement, we quantified the QND-ness to 99 %.

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Presenter(s) : DASSONNEVILLE, Rémy (Institut Néel)

Session Classification : session 4

Contribution ID : **25** Type : **invited oral**

The Coulomb drag effect induced by the third cumulant of current

venerdì 21 giugno 2019 10:00 (30)

The Coulomb drag effect arises due to electron-electron interactions, when two metallic conductors are placed in close vicinity to each other. It manifests itself as a charge current or voltage drop induced in one of the conductors, if the current flows through the second one. Often it can be interpreted as an effect of rectification of the non-equilibrium quantum noise of current. Here, we investigate the Coulomb drag effect in mesoscopic electrical circuits and show that it can be mediated by classical fluctuations of the circuit collective mode. Moreover, by considering this phenomenon in the context of the full counting statistics of charge transport we demonstrate that not only the noise power, but also the third cumulant of current may contribute to the drag current. We discuss the situations, where this contribution becomes dominant.

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Session Classification : session 6

Contribution ID : **26** Type : **invited oral**

Full counting statistics of quantum phase slips

venerdì 21 giugno 2019 09:30 (30)

In our talk we present a microscopic theory describing complete statistics of voltage fluctuations generated by quantum phase slips (QPS) in superconducting nanowires. We evaluate the cumulant generating function and demonstrate that shot noise of the voltage as well as the third and all higher voltage cumulants differ from zero only due to the presence of QPS. In the zero-frequency limit voltage fluctuations in superconducting nanowires are described by Poisson statistics just as in a number of other tunneling-like problems. However, at non-zero frequencies quantum voltage fluctuations in superconducting nanowires become much more complicated and are not anymore accounted for by Poisson statistics. In the case of short superconducting nanowires we explicitly evaluate all finite-frequency voltage cumulants and establish a non-trivial relation between these cumulants and the current-voltage characteristics of our system.

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Session Classification : session 6

Contribution ID : **27** Type : **contributed oral**

Quantum fluctuations and phase coherence in superconducting nanowires

sabato 22 giugno 2019 11:30 (15)

Quantum behavior of superconducting nanowires may essentially depend on the employed experimental setup. Here we investigate a setup that enables passing equilibrium supercurrent across an arbitrary segment of the wire without restricting fluctuations of its superconducting phase. The low temperature physics of the system is determined by a combined effect of collective sound-like plasma excitations and quantum phase slips. At $T = 0$ the wire exhibits two quantum phase transitions, both being controlled by the dimensionless wire impedance g. While thicker wires with $g > 16$ stay superconducting, in thinnest wires with $g < 2$ the supercurrent is totally destroyed by quantum fluctuations. The intermediate phase with $2 < g < 16$ is characterized by two different correlation lengths demonstrating superconducting-like behavior at shorter scales combined with vanishing superconducting response in the long scale limit.

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Session Classification : session 9

Contribution ID : **28** Type : **invited oral**

Superconducting Quantum-Classical Information Processing Systems

giovedì 20 giugno 2019 16:30 (30)

Traditionally, the control and measurement of superconducting quantum devices including arrays of qubits are done using room-temperature classical electronics connected to cryogenic environment via high fidelity cables. This poses daunting technical challenges to quantum system scaling as the heat load, latency, noise associated with bringing signals in and out of the cryostat rise dramatically with number of quantum devices. By integrating the control and readout electronics into the cryostat in proximity to quantum devices, these problems can be drastically reduced to enable large-scale quantum arrays. This can finally lead to quantum processing systems that can outperform the best available classical supercomputers. Superconducting Single Flux Quantum (SFQ) digital logic can be a basis for the implementation of a proximal classical co-processor for low-overhead qubit control and measurement. SFQ digital circuits also can perform in situ classical processing of the results of quantum measurement to enable fast error tracking and feedback to stabilize the quantum array. Furthermore, hybrid quantum-classical systems integrating together the quantum and classical processing hardware units can match to various application algorithm architectures which typically combine quantum and classical algorithmic modules. Latest results in the SFQ-based digital control of superconducting qubits will be presented. The implementation of a scalable quantum-classical 3D integrated system extending across multiple temperature stages will be discussed.

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Presenter(s) : MUKHANOV, Oleg (SeeQC)

Session Classification : session 4

Contribution ID : **29** Type : **invited oral**

Elusive Bose metal is a Bosonic Topological Insulator

mercoledì 19 giugno 2019 17:30 (30)

Transport measurements of the superconductor-insulator transition (SIT) in disordered two-dimensional films and Josephson junction arrays showed the existence of an anomalous metallic phase that persists to low temperatures. The nature of this mysterious phase often referred to as "Bose metal," remains unclear. We develop a gauge theory of the Bose metal as the phase in which Cooper pairs and vortices are out of the Bose condensate due to strong quantum fluctuations and form an incompressible liquid of intertwined Aharonov-Bohm-Casher loops. As a result, the Bose metal emerges as an integer (Z) bosonic topological insulator in which bulk transport is suppressed by topological mutual statistics interactions, the Hall resistance vanishes, and longitudinal charge transport is mediated by U(1)-symmetry-protected gapless edge modes. The transport measurements in NbTiN films across the disorder- and magnetic field-driven SIT and observe a disorder and magnetic field–tuned transition from a true superconductor to a metallic phase with saturated longitudinal resistivity.

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Session Classification : session 1

Contribution ID : **30** Type : **invited oral**

Topological Superconductivity in Non-Centrosymmetric Materials

mercoledì 19 giugno 2019 18:00 (30)

Recent interest in the effect of intrinsic spin-orbit coupling in materials that exhibit an excitation gap has led to the notions of topological insulators and topological superconductors. Intrinsic spin-orbit coupling is enhanced in non-centrosymmetric materials, as in this case already band-diagonal matrix elements contribute. We study non-centrosymmetric superconductors with various point group symmetries. For self-consistent order parameter profiles we calculate the surface density of states, showing intricate structure of spin-polarised Andreev bound states. The topology's effect on the surface states and the tunnel conductance is thoroughly investigated, and a topological phase diagram is constructed for open and closed Fermi surfaces showing a sharp transition between the two for the cubic point group O.

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Session Classification : session 1

Contribution ID : **31** Type : **contributed oral**

Coulomb drag effect in a system of coupled superconducting nanowires.

sabato 22 giugno 2019 11:45 (15)

Al low temperatures superconducting nanowires demonstrate wide range of intriguing physical phenomena. Of particular interest are those that are due to quantum phase slips (QPS), as an example the change in nonlocal transport in superconducting nanowires. This work is devoted to studying the interplay between Coulomb drag effect and QPS in a system of coupled superconducting nanowires. It is important that QPS generate plasmon waves that propagate in separating wires and QPS in one wire affect on the physical properties of another.

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Session Classification : session 9

Contribution ID : **32** Type : **invited oral**

Adiabatic quantum computation in a dissipative environment

sabato 22 giugno 2019 09:30 (30)

Quantum annealing (QA) is getting more and more relevant as powerful solver of optimization problems. Thanks to the availability of"commercial"adiabatic quantum computers, based on QA, there is plenty of proposals both on the fundamental and on the applied side. In QA a target ground state encodes the solution of a computationally hard problem. Such ground state is approached exploring the energy landscape, employing quantum flutcuations that are adiabatically decreased towards to zero. Annealing machines are made by arrays of superconducting quantum interferometric devices embedded in classical circuits. They act as a dissipative environment, that is well known to modify the dynamics of any quantum two level system, affecting in a detrimental way the annealing performances. I will review some recent results regarding the role of dissipation in adiabatic quantum computation, discussing a simple model i.e. the ferromagnetic p-spin model that, in the large p limit, encodes in its ground state the solution to the Grover's algorithm for searching in unsorted databases (that is known to provide a quadratic speed-up with respect to its best classical counterpart). Unexpectedly, under some particular conditions, the system-bath coupling can improve the annealing performances. I will discuss the role of pausing as well as the problem of the embedding on real devices. To conclude, in the presence of a dissipative bath, the question whether the dynamics has driven the system to the target state through a quantum or a classical path, up to now, remained unanswered and only partially addressed in the literature, and the question is still controversial. Hence I will describe a new method that we have proposed to assess the quantumness of the system during its adiabatic dynamics, based on the Leggett Gargs inequalities (LGI), evaluated in the framework of weak measurements.

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Session Classification : session 8

Contribution ID : **33** Type : **invited oral**

Universal Scaling of Quantum Geometric Tensor in Disordered Metals

sabato 22 giugno 2019 09:00 (30)

The geometrical structure of the Hilbert space continues to receive a lot of attention. The Fubini-Study metric tensor of the Hilbert space, also referred to as Fisher information metric, provides a natural measure of distance in the Hilbert space, related to quantum fidelity – a fundamental concept in quantum information science. Interestingly, the concepts of the Fubini-Study metric tensor and the Berry phase can be unified through the so-called quantum geometric tensor (QGT).

In the work to be presented [1], we demonstrate that the quantum geometric tensor offers deep insight into a long-standing problem in condensed matter physics, Anderson's disorder-driven metal insulator (MI) transition in small external magnetic fields. In particular, the structure of the QGT reflects the universality class of the Anderson transition. Elements of the QGT display universal finite size scaling close to the metal-insulator transition, and capture the flow between the orthogonal (B = 0) and unitary (B 6=.. 0) universality classes. At the transition, the elements of the QGT have universal distributions, characteristic of the underlying symmetry of the transition, but, surprisingly, independent of the direction of the external field. We predict that these universal fluctuations show up as universal and isotropic Hall conductance fluctuations at the metal-insulator transition.

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Session Classification : session 8

Contribution ID : **34** Type : **invited oral**

Quantum Interference in Phase Slip Devices

venerdì 21 giugno 2019 09:00 (30)

The Coherent Quantum Phase Slip (CQPS) effect in superconducting nanowires is exactly dual to the Josephson effect – tunneling of Cooper pairs through a thin dielectric layer. CQPS has been experimentally proven for the first time in Ref. 1 and since then reproduced in different materials [2, 3]. CQPS is interesting from the fundamental point of view as well as for practical applications, particularly, for quantum metrology as it promises to build quantum current standards dual to voltage standards on the Josephson effect. An important milestone in this direction is the demonstration of interference of a pair of flux tunneling amplitudes similarly to charge tunneling amplitudes in SQUIDs. We demonstrate a device exactly dual to SQUID, which we call a charge quantum interference device (CQUID) [4]. The two nominally identical nanowires with constrictions separated by a superconducting island are fabricated to observe the quantum interference of two flux tunneling amplitudes. The effective tunneling energy depends on the gate induced charge on the island. In our experiment, the CQUID is incorporated into a superconducting loop, forming a phase-slip qubit with tunable energy. Such a circuit allows to measure the CQPS energy using spectroscopic methods. This is exactly dual to the charge qubit with a SQUID, where the effective Josephson energy is tuned by an external magnetic flux. Figure 1 demonstrates observed oscillations of energies of CQPS qubit with two junctions (nanowires with constrictions) as a function of gate induced charge. The oscillations are not harmonic and well described by the interference effect of two CQPS amplitudes.

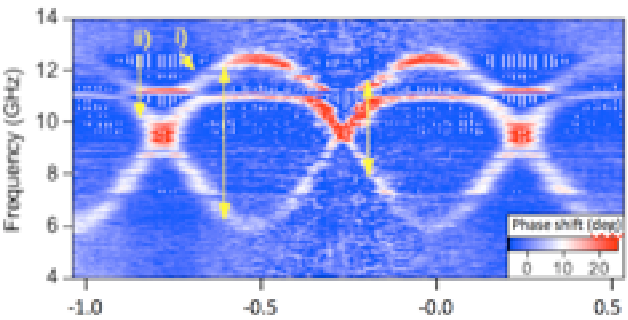

Figure 1: Energy oscillations in CQUID due to interference of two tunneling amplitudes.

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Session Classification : session 6

Contribution ID : **35** Type : **invited oral**

Unconventional superconductivity induced in the surface states of 3D Topological insulators

venerdì 21 giugno 2019 11:30 (30)

Josephson junctions involving a conventional superconductor and an exotic conductor, represented by the surface of a 3D topological insulator (TI), a Dirac semimetal or the edge states of two-dimensional quantum wells, are ideal systems to emulate topological superconductivity characterized by unconventional order parameter (OP), with an orbital component assuming the form of a chiral px + ipy wave. Topological superconductivity is instrumental for the nucleation of Majorana fermion at the basis for topological quantum computation Here I will report our results on phase-sensitive measurements, based on the quantum interference in a Josephson junction, realized using Al- Bi2Te3-Al devices. The experiment allows to establish that the proximity with a conventional superconductor induces an order parameter in the surface states of the topological insulator Bi2Te3, which is consistent with a chiral px + ipy (p-wave) order parameter (OP). This is achieved by measuring the magnetic field pattern of the junctions which shows a dip at zero external magnetic field, a signature of the simultaneous existence of "0" and "π" coupling within the junction, inherent to an OP with a non trivial phase1. The peculiar nano-textured nature of the morphology of the Bi2Te3 flakes, and the dramatic role played by thermal strain are the surprising key factors for the display of an effective induced chiral px + ipy OP. To reduce the number of modes and to reveal the 4π-periodic current-phase relation inherent to Majorana bound states in superconducting hybrids we have also realized Josephson junctions using 3DTI nanowires 2. In such devices we observe a contribution of 4π-periodic Majorana bound states to the supercurrent in Al- Bi2Se3-Al devices revealed by studying the junction under GHz microwave irradiation and the Josephson current as a function of the temperature.

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opening

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