Session 22DP

Interaction effects on the band structure of carbon nanotubes **22DP1**

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We will discuss how the Coulomb interaction gives changes to the single particle excitation energy of electrons in carbon nanotubes. We use an effective-mass scheme to describe their electronic states and calculate the self-energy in a GW approximation, where the Coulomb interaction between electrons is dynamically screened by a full dielectric function calculated in the random-phase approximation.

Spin-transport properties in a single-walled carbon nanotube with the mesoscopic Co contacts **22DP3**

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We have studied the spin-dependent transport properties of single-walled carbon nanotubes(CNTs) having the mesoscopic ferromagnetic Co electrodes. Although our CNTs turned out to have lots of disorder-induced dots with effective length of about 10-50 nm, the observed magnetoresistances change hysteretically as a function of the magnetic field, with the magnetoresistance ratio of 2.6-3.4 % at low temperatures. The estimated spin-flip scattering length was about 1 μm at 4.2K. The magnetoresistance ratio was enhanced by a factor of two as a bias voltage decreased to the Coulomb blockade regime, which could be explained by the co-tunneling process of electrons.

22DP4 Tomonaga-Luttinger-liquid behavior in conducting carbon nanotubes with open ends

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A carbon nanotubes with metallic bands is the typical one-dimensional conductor, where the exotic electronic state called as Tomonaga-Luttinger-liquid (TLL) is realized by the mutual interaction. In the present work, the TLL behavior of the metallic carbon nanotube with open ends is investigated based on the bosonization theory in the one-dimensional electron system with the finite length. The spatial and temperature dependence of various properties, such as charge density, density of states, nuclear spin relaxation rate and so on, are discussed with taking account of the shift of the chemical potential corresponding to carrier doping.

22DP5 The Unconventional Electronic Properties of Multiwall Carbon Nanotubes

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It has previous been a puzzle that, while the electron tunneling measurement seemed to indicate an unconventional feature for the electrons in a multiwall carbon nanotube, the previous transport measurements indicated a rather conventional weak localization behavior. In this work we will show the evidence of electron strong correlation in our thermoelectric power and magnetoresistance measurements on multiwall carbon nanotubes. The results indicate that the interplay of electron-electron strong correlation and electron-disorder scattering is the key clue to understand the electron system in multiwall carbon nanotube.

22DP6 Effect of Local Gates on the Electrical Transport Properties of Single-Walled Carbon Nanotubes

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We have studied the effect of local gates on the electrical transport properties of single-walled carbon nanotubes (SWCNTs). The local gates were fabricated by depositing Al thin film on top of the SWCNT in between the electrodes for source and drain. We compared current-voltage characteristics and gate modulation curves before and after depositing the Al local gates. Deposited Al film acts not only as an electrode for local gating but also as a tunnel barrier. In the presence of the Al gates, single electron tunneling effect and negative differential conductance were observed at 4.2 K.

Superconducting and density-wave correlation functions in carbon nanotubes 22DP7

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We calculate temperature dependences of various correlation functions for a single $(5,0)$ carbon nanotube (CN), with special emphases on superconducting and density-wave orders. We use one-loop renormalization group method within logarithmic accuracy. In this system we must specify scattering channels in terms of momenta along the circumferential direction as well as along the axis direction, because $(5,0)$ CN has two bands crossing the Fermi energy with doubly degenerate states carrying opposite angular momenta. Some of the couplings are found to cause essential differences among correlation functions for different channels. Especially those correlation functions for Cooper pairs with zero total angular momenta show two different temperature dependences, in both singlet and triplet channels; one is divergent and the other suppressed near the critical temperature $T_{\rm C}$.

Cap States in Capped Carbon Nanotubes by Effective-mass Theory 22DP8

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Localized cap states are studied analytically and numerically in an effective-mass approximation, for a cap consisting q graphene sheets of regular triangles ($1 \le q \le 6$) attached to a metallic armchair nanotube. Cap states associated with first excited conduction band and highest valence band are at $\varepsilon = 0$ and others are all in the vicinity of corresponding edges. In particular, an amplitude of the cap state at $\varepsilon = 0$ is almost constant in a pencil cap ($q = 6$) and $\propto r^{-1/5}$ in a bowl cap ($q = 5$), where r is a distance from the center of the cap.

Anomalous quantum Hall effect in η-Mo$_4$O$_{11}$ 22DP9

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We observed anomalous quantum Hall effect (QHE) in charge density-wave material η-Mo$_4$O$_{11}$ at low temperature. Hall resistivity with plateaus shows negative field dependence in the field range 10$<B<$25T in contrast to the conventional QHE. This fact can be explained by a field-dependent Fermi surface model. We will perform magnetotransport experiments at 80mK up to 55T using a pulsed magnet.

22DP10 Proper chaotic interaction of localized objects in quasi-integrable systems

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Multi-soliton solution to the unperturbed nonlinear Schrödinger equation is considered as a model for a group of localized objects. While the essential conservation laws are satisfied, the interplay of solitons' internal parameters gives the conditions when different solutions coincide at a certain moment and could transform one into another. Gathering all the parameters in the dephasing of solitons, we present these conditions in the form of a Kantor set, which is fractal. This means that in a system with any kind of weak perturbation, for mutual transformation, the solutions need to be very close to each other, not only coincide exactly. The behavior of the solitons well before and after the collision is almost like in the unperturbed system, while at the moment of the collision it is essentially chaotic. The slower the solitons (in a cold gas of particles), the stronger inelasticity and the brighter chaotic features of their interaction.

22DP11 Self-Similar Conductance Fluctuations in Coupled Dot Systems

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Self-similar conductance fluctuations have been studied by means of low temperature magneto-resistance in order to clarify the fractal transport behavior in coupled quantum dot systems. We have observed a clear three-fold or four fold self-similar structure in the magneto-resistance of the coupled dot systems. In our discussion based on a saddle-point potential model, the self-similar and unstable periodic orbits can be expected by isochronous pitchfork bifurcations due to harmonic saddles in curved walls of the dot.

22DP12 Chaotic Transport Behavior of Low Temperature Magnetoresistance in Quantum Wires

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Chaotic transport behavior in quantum wires has been studied by means of low temperature magneto-resistance in order to discover a fundamental relation to Quantum Chaos. In our estimation based on ballistic transport model, a clear change can be expected between regular and chaos transport in a narrow channel of the quantum wires having curved walls. We have observed a clear precursor on such a transition change in the magneto-resistance of our narrow wire at low temperatures.

Isolated resonances in conductance fluctuations in ballistic billiards **22DP13**

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We study the isolated resonances occurring in conductance fluctuations of ballistic electron systems with a classically mixed phase space. In particular, we calculate the conductance and Wigner time as well as scattering states and eigenstates of the open and closed cosine billiard, respectively. We demonstrate that the observed isolated resonances and their scattering states can be associated to eigenstates of the closed system. They can all be categorized as hierarchical or regular, depending on where the corresponding eigenstates live in the classical phase space.

Temperature Scaling of MOSFET Circuit Power Consumption **22DP14**

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We have analyzed fundamental physical limitations on power consumption of future semiconductor digital integrated circuits based on nanoscale silicon MOSFETs, using a simple but adequate model of these devices. Results show that the temperature dependence of the power is determined by the circuit speed requirements. For very high speed operation, both power P and the power supply voltage V_{DD} saturate when T is reduced below approximately 100 K. In the low speed limit, P scales as T^2, while V_{DD} drops linearly with T. However, thermal fluctuations may alter this scaling, leading to $P \propto T$ and $V_{DD} \propto T^{1/2}$, at low temperatures and/or large circuit densities. In our report, we will compare this scaling with those of other high-performance electron devices including superconductor RSFQ logic.

Transport properties in spatially modulated magnetic fields **22DP15**

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We have studied both classical and quantum transport in two dimensional electron gas numerically, where magnetic fields are perpendicular to the plane of 2DEG and periodically or randomly modulated. Due to the nonhomogeneous magnetic fields, the system is chaotic. In the classical model, we show the commensurability oscillation of magnetoresistance in periodic magnetic fields. The negative magnetoresistance in weak magnetic fields is observed under the condition that conductivity σ_{xx} is suppressed drastically. The quantum transport is also investigated, and the universal conductance fluctuation and the fractal behavior of the magnetoconductance are discussed.

22DP16 Interaction-induced magnetoresistance in the ballistic regime

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We study the interaction-induced magnetoresistance of a 2D electron system for an arbitrary type of disorder. In the case of smooth disorder the temperature dependence of the quadratic negative magnetoresistance changes from $\ln(T\tau)$ in the diffusive regime to $(T\tau)^{-1/2}$ in the ballistic ($T\tau/\hbar \gg 1$) one. Since in high-mobility samples $\hbar/\tau$ (where τ is the transport time) can be as small as 50 mK, it is the ballistic regime that is realized in a typical experiment. The ballistic regime manifests itself also in high-frequency ($\omega \gg \tau^{-1}$) magnetotransport. At frequencies larger than the cyclotron frequency ω_c the interaction correction to the resistivity shows a sequence of peaks at $\omega = n\omega_c$ related to the cyclotron returns. We further apply the method to 1D lateral superlattices, where the resistivity is anisotropic.

22DP17 THEORY OF CYLOTRON RESONANCE OF CORRELATED ELECTRONS

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The cyclotron resonance (CR) absorption of low-density 2D electrons in semiconductor heterostructures GaAs/AlGaAs doped with Si impurities in high magnetic fields is investigated. The theory explicitly takes the Coulomb correlation into account through the Wigner phonons. The n_e-dependence of the CR linewidth is in good agreement with the experimental results of Chou et al.[1] in the range of large electron densities at comparatively high T ($T = 4.2$K). Our theory also predicts that at lower Ts the CR linewidth sharply decreases with n_e in the low n_e range ($n_e \leq 2.10^{10}\text{cm}^{-2}$) but becomes flat in higher n_es. The two-peak structure of the diagonal conductivity is also obtained.

[1]M. J. Chou, D. C. Tsui, and G. Weimann, Phys. Rev. B **37**, 848 (1988)

22DP18 Electron dynamics in quantum wells under tilted magnetic field and intense AC field

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The electron dynamics in a double quantum well under strong AC electric fields and tilted magnetic fields is studied using a non-perturbative Floquet approach. For $B_{\|} = 0$, the energy spectra show two types of crossings: those related to different Landau levels (LL), and those due to dynamic localization (DL). We find that the system exhibits DL at the same values of the AC field suggesting a hidden dynamical symmetry identified with different parity operations. The return times exhibit complex behavior which is studied in detail. We analyze also the time evolution of the system, monitoring the elapsed time to return to a given well for each LL, and find non-monotonic behavior for decreasing frequencies.

Thermal correction to resistivity of 2D electron (hole) gas in low-temperature dc measurements at B=0 **22DP19**

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We calculate the zero magnetic field dc resistivity taking into account both the degeneracy of the 2D electron (hole) gas and the thermal correction[1,2] owing Peltier and Seebeck effects combined. The current causes heating(cooling) at the first(second) sample contact due to the Peltier effect. Under adiabatic conditions the temperature gradient found to be linear downstream the current, the contact temperatures are different. The measured voltage includes Peltier effect-induced thermoemf which is $linear$ in current. The total 2D resistivity is found to be universal function of dimensionless temperature kT/E_f, then expressed in units of $\frac{h}{e^2}(k_F l)^{-1}$ in egreement with recent experiments.

1. M.V.Cheremisin, Sov. Phys. JETP, 92, 357, 2001; cond-mat/0203387

Low-Temperature Transport of InSb Films on GaAs (100) Substrates **22DP20**

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Low-temperature magnetoresistance (MR) has been studied for undoped and Sn-doped InSb thin films grown on GaAs(100) substrates by MBE. In undoped films, almost whole carriers fall into the accumulation layer (induced by high-density misfit dislocations) at the InSb/GaAs interface at low temperatures, resulting in the advent of positive MR arising from the two-dimensional weak anti-localization due to spin-orbit interaction caused by the underlying band structure. Sn-doped films, on the otherhand, show the Shubnikov-de Haas oscillations which reflect a large g-factor (-g*=40 depending on the carrier concentration) of electrons in InSb films. In this contribution, the anomalous transport properties at low temperatures as well as the film-thickness dependence of those properties are presented.

Nonmagnetic Control of Spin Transport in InGaAs quantum wells* **22DP21**

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We have demonstrated the weak localization to weak antilocalization transition and have deduced the Rashba constant values α in the $In_{0.52}Al_{0.48}As/In_{0.53}Ga_{0.47}As$ quantum wells (QW), as a function of the degree of the structural inversion asymmetry (SIA). Here, we have controlled the SIA of the QWs both by the specific sample design and by the applied gate voltage. We have found that the deduced α values are in quantitative agreement with the theoretical values obtained from the $\mathbf{k}\cdot\mathbf{p}$-type calculation. Finally, we propose a novel spin-filter device that doesn't use any magnetic materials, but is based on the Rashba effect. *This researh work was supported by the NEDO International Joint Research Grant Program.

22DP22 Imaging Coherent Electron Wave Flow in a Two-Dimensional Electron Gas

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Recently it has become possible to image coherent electron flow from a quantum point contact (QPC) formed in a two-dimensional electron gas inside a GaAs/AlGaAs heterostructure by using a liquid-He cooled scanning probe microscope[1]. The images show interference fringes spaced by half the Fermi wavelength. Oscillating the tip voltage and measuring the QPC conductance at that frequency images the spatial derivative of the electron flow including fringes. We probe the coherence of electron flow by measuring the dependence of fringe amplitude on the energy of electrons accelerated by an applied voltage across the QPC. In addition, we demonstrate how the fringe spacing can be used to spatially profile the electron density.

[1]M.A. Topinka et al, Science 289, 2323 (2000) and Nature 410, 183 (2001)

22DP23 Dynamical correlations in Coulomb drag effect

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Interlayer resistivity of two two-dimensional (2D) electron gases as a function of temperature as measured in Coulomb drag experiments is calculated. Motivated by the recent experiments on low-density systems our aim is to assess the influence of correlation effects. We use the self-consistent field method to calculate the intra and interlayer local-field factors $G_{ij}(q,\omega;T)$ which embody the short-range correlation effects. We then construct the screened effective interlayer interactions using the local-field factors. Our results indicate an enhancement in the Coulomb drag rate as a result of dynamic (frequency dependent) interactions.

22DP24 Tunneling Images of a 2D Electron System in a Quantizing Magnetic Field

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We have applied a scanning probe method, Subsurface Charge Accumulation imaging, to resolve the local structure of a semiconductor two-dimensional electron system (2DES) in a tunneling geometry. We find that the application of a perpendicular magnetic field can induce striking spatial structure in the out-of-phase component of the tunneling signal. Near magnetic fields corresponding to six filled Landau levels, the structure forms distinct parallel lines that are not static as a function of the field, and extend as long as 5 μm. In some areas, sets of lines are observed to form micron-scale geometric patterns. We believe the observations likely reflect small modulations in the 2DES density. Present theories do not account for ordered density modulations on this length scale.

Investigations of the magnetic tranport properties of normal films under the non-uniform mangnetic field **22DP25**

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We have measured the magnetoconductance(MC) of two dimensional Bi films subjected to a periodic magnetic field H. In this work, such field was produced by a superconducting intermediate maze-structure of thick Pb film placed in the immediate vicinity of metal films. Non-linear H dependence of MC has been observed in low magnetic fields. This is not expected from a simple magnetic distribution of alternating normal($H = H_c$) and superconducting (H=0) domain structure in the intermediated state. For specimen of which Pb film has sharp edges, MC shows the step structure. On the other hand, in the case of broad edge of Pb film, MC shows the oscillation behaviour.

Nonlinear Interaction of Electromagnetic Wave and Transport Current in Thin Metallic Films. **22DP26**

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A new phenomenon of anomalous transparency of a metallic plate upon the passage of a strong transport current is predicted. It is shown that the electromagnetic field of an incident wave may be carried from the skin layer to the opposite face by electrons trapped by the alternating intrinsic magnetic field of the transport current even under the conditions of the extremely anomalous skin effect. The mechanism of the rf field transport effectively operates at low temperature, when the mean free path of electrons is large. The wave field spatial distribution is analized. The cyclotron resonance caused by the trapped electrons, which emerges due to their periodic return to the skin layer, is predicted and qualitatively analyzed.

Quantum Interference and Inelastic Scattering in a Which-Way Device **22DP27**

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A which-way device is one which is designed to detect which of 2 paths is taken by a quantum particle. One such device is represented by an Aharonov-Bohm ring with a quantum dot on one branch. A charged cantilever or spring is brought close to the dot as a detector of the presence of an electron. In this paper we show that, contrary to popular belief, it is in fact possible to change the state of the oscillator while preserving the quantum interference phenomenon, but that this tells us little about the path traversed by the particle.

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22DP28 Aharonov Bohm oscillation in ferromagnetic FeNi nano-ring

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The magnetoresistance in a ferromagnetic FeNi ring with 420 nm in inner diameter and 500 nm in outer diameter was measured at 30 mK. When the magnetic field is applied to the ring, the magneoreistance exhibits the oscillation whose period varies with changing the direction of the field. This indicates the Aharonov Bohm oscillation due to the conduction electrons in the ferromagnet. The amplitude of the oscillation changes with the magnetization of the ring. The result indicates that the quantum coherence in ferromagnets critically depends on the magnetic structure.

22DP29 Low Temperature Magnetoresistance in Ferromagnetic Thin Wires

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We measured the low-temperature magnetoresistance of thin wire of high-purity nickel down to 45 mK. Typical size of wires is 15nm thick and 30nm wide. We observed reproducible structure together with noise like oscillation. They diminish at high temperature (4.2K). We discuss the result in the light of mesoscopic coherence.

22DP30 Dual Aharonov-Casher effect in singlet-exciton systems

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Dual Aharonov-Casher (DAC) phase (or He-McKellar-Wilkens phase), which is defined as a quantum topological phase acquired by a *neutral* particle only with an *electric* dipole moment μ_E being taken on a closed path around a *magentic* monopole wire, is theoretically investigated in singlet-exciton systems. In the Sangster's interference scheme, a moving $2s$ exciton in magnetic fields feels an effective electric field in co-moving frame, which causes a superposition of opposite parity states, i.e., $|2s\rangle \pm |2p\rangle$, due to the *motional* Stark effect. The superposition gives rise to a nonvanishing electric dipole moment required for the DAC effect to the exciton. The accummulated phase is determined by detecting photon emissions from $2p$ states as a function of applied magnetic fields.

Read-out of a qubit with a radio frequency single electron transistor **22DP31**

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We have investigated the RF-SET as a detector of the quantum two-level system in a single Cooper pair box(SCB). We show that the RF-SET can be turned on/off fast and accurately and we have evaluated the back-action on the SCB during read-out. We conclude that the signal to noise between read-out and back-action, in a scheme with the SCB as a qubit, is greater than one and single shot read-out of the two-level system state is obtainable.

Decoherence and $1/f$ noise in Josephson qubits **22DP32**

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We analyze decoherence in Josephson qubits induced by background charges responsible for $1/f$ noise. To this end we introduce a quantum mechanical model of a discrete environment. Quantitative estimates of decoherence *during* time evolution for BCs responsible for $1/f$ noise show that decoherence due to slowly moving charges saturates. This has implications for the identification of the degrees of freedom of the charge environment which are effective both for relaxation and dephasing (E. Paladino et. al. cond-mat/0201449). Within the same framework we also calculate the reduction of the signal amplitude in an echo type experiment due to random telegraph fluctuators giving $1/f$ noise.

Pseudo-Digital Exchange Interaction for Solid-State Quantum Computation **22DP33**

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The exchange interaction provides a basis for quantum computation. However, the exchange coupling J frequently depends very sensitively on the gate voltages that may someday control large numbers of solid-state qubits. We present a new semiconductor qubit design that results in a pseudo-digital J, making it much easier to perform qubit operations with low error rates. Precise modeling of the design enables estimates of error-rates and comparisons to requirements for fault-tolerant error correction. We have previously demonstrated that these requirements can be met by existing electronics in the kHz-MHz range, xxx.lanl.gov/abs/cond-mat/0204035. The new digital design we describe should enable orders of magnitude faster operation.

22DP34 Counting statistics for entangled electrons

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The counting statistics (CS) for charges passing through a coherent conductor characterizes electronic transport in the most general way. CS depends on the transport properties of the conductor and also on the correlations among particles in the incident beam. We present general results for the CS of entangled electron pairs traversing a beam splitter and we show that the probability that Q charges have passed is not binomial, as in the uncorrelated case, but symmetric with respect to the average transferred charge. We also study the joint probability for transmitted charges of a given spin and we show that the signature of entanglement distinctly appears in a correlation which is not present for the non-entangled case.

22DP35 Single shot measurement of Schrödinger's cat state with SQUID

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Single shot measurement of a single qubit is of interest in error correction scheme of quantum computation and quantum cryptography. We achieved single shot measurement of a flux qubit which consist of a superconductor loop with three Josephson junctions. A DC-SQUID is used to readout the quantum state of this loop which has two states corresponding to circulating current with opposite directions. These current states generate the flux with opposite orientations and are clearly distinguished as state $|0>$ and $|1>$. We investigated the distribution of the switching current in the DC-SQUID and figure out the possibility of single shot measurement. We also report the relation between the quantum coherence and the measurement sensitivity.

22DP36 Quantum Information Processing with Cooper-Pair-Box Qubits in a Microwave Field

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We investigate the quantum dynamics of a Cooper-pair box with a superconducting loop in the presence of a nonclassical microwave field. We demonstrate the existence of Rabi oscillations for both single- and multi-photon processes and, moreover, we propose a new quantum computing scheme (including one-bit and conditional two-bit gates) based on Cooper-pair-box qubits coupled through microwave modes in a quantum electrodynamic cavity.

Scalable Quantum Computation with Superconducting Charge-Flux Qubits 22DP37

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A goal of quantum information technology is to control the quantum state of a system. However, scalability to many qubits and controlled connectivity between any selected qubits are two of the major stumbling blocks to achieve quantum computing (QC). Here we propose an experimental method, using superconducting charge-flux qubits, to efficiently solve these two central problems. The proposed QC architecture is scalable since any two charge-flux qubits can be effectively coupled by an experimentally accessible inductance. More importantly, we formulate an efficient and realizable QC scheme that requires only one (instead of two or more) two-bit operation to implement conditional gates.

Microwave excitation of the Rydberg states of electrons on helium 22DP38

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We present measurements of the resonant microwave excitation of the Rydberg energy levels of surface state electrons on helium. The temperature dependent contribution to the linewidth γ(T) was found to be Lorentzian and was measured down to 0.1 K. The values agree well with theoretical predictions and are very small below 0.3 K ($<$ 10 MHz for a resonant frequency of 190 GHz). Power saturation and power broadening of the absorption lines were observed. A fractional population of 45% in the first excited state was easily achieved. The experiments show that the conditions are met for the use of these states in an electronic qubit .