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Research Interests

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My current research interests include quantum simulations[1], topological quantum computation[2], studies on decoherence and entanglement[3] and quantum information processing with graphene[4,5,6]. A recent work of mine has been featured in the nanotechweb.org website http://nanotechweb.org/cws/article/tech/36343
My recent research has encompassed diverse fields in the field of theoretical condensed mater physics. The underlying link in all my works is quantum interference. These effects are accentuated in mesoscopic systems, which lie inbetween the classical and atomic scales. The distinguishing feature of these systems is that at extremely low temperatures an electron retains its phase coherence throughout the sample. These systems provide an opportunity to explore quantum effects beyond the atomic realm. Some of my works which include especially a novel proposal of generating pure spin currents[11,15], if experimentally realized, would substantially change the future of the electronics industry. A topic wise break up of my past research is outlined below.

- Quantum simulations- The power of a quantum computer can only be harnessed when one can utilize them in tasks which are almost impossible on a classical computer. One of them is quantum simulations. Simulations imply replicating the statics and dynamics of another system exactly or almost exactly, such that the distinction between them disappers with the avowed purpose of understanding the other system better. One such example is molecular collisions. Herein as the number of elements in a reaction grow larger, classical simulation, i.e., simulation on classical computer becomes increasingly anachronistic. However quantum simulations are not so. Infact in our work[1] we show how a simple chemical reaction can be very effectively simulated by a superconducting phase qubit based quantum computer in a relatively short time with very good fidelity.
- Toplogical quantum computation- Quantum computer as shown earlier are exteremly powerful. However they have massive disadvantages too. They can only work for relatively short periods of time and secondly errors during compuation are very difficult to manage. To overcome these odds one takes recourse to topology as encoding qubits in topological degrees of freedom will free the qubits fro environment and thus make them immune to decoherence and errors. One of the most well known topological degree of freedom is what is known as a Majorana fermions, a neutral quasi-particle which is it's own anti-particle. These are predicted to occur in some special systems

but are very difficult to detect. We predict given their unique properties with respect to Magnetic and electric field one can have situations where their detection is relatively easy[3].

- Time in quantum mechanics- Several methods have been proposed based on scattering phase shifts and using different quantum clocks, where the time taken is clocked by some external input or indirectly from the phase of the scattering amplitudes. In our work we have proposed a new method of determining the time spent by a given particle in a scattering region of interest[21,23].
- Dephasing in mesoscopic systems- Dephasing is the process by which quantum-mechanical interference is gradually destroyed. Inelastic scattering, i.e., scattering of electrons with electrons , phonons or with other quasi particles leads to dephasing. The Aharonov-Bohm (AB) effect is one of the best examples for illustrating and analyzing how quantum interference effects are affected by dephasing. We deal with the problem of dephasing of AB oscillations using a simple model based on wave attenuation[24]. We have worked on the Fano effect. Fano resonances arise when a discrete set of states are coupled to the continuum. Especially Fano resonances are caused by interference of two alternative paths, a resonant and a non-resonant one. In close proximity to recent experimental results we find the transition from Fano to Lorentzian line-shapes with increasing incoherence[16,17].
- Persistent currents in Aharonov-Bohm interferometers- In the presence of transport currents(non-equilibrium situation), circulating currents can flow in a ring even in the absence of magnetic field [25]. Magnetic moments calculated via currents are strongly dependent on the topological configuration while that evaluated through the eigenenergy spectra are independent of any topological variations[22] with the coupling between system-lead and the reservoir playing a non-trivial role[14].
- Spintronics in the domain of quantum adiabatic transport- Pure spin current can be generated using adiabatic quantum pumping. In this process, in absence of any net bias, a dc current can be generated via adiabatically modulating two independent parameters of a coherent system. We show how via adiabatic quantum pumping a maganetic barrier system, which does not transport any spin current in presence of a voltage bias, can produce a pure spin current. In another work we show how to generate a pure spin current using the twin effects of crossed Andreev reflection and adiabatic quantum pumping[11,15].
- Detecting the order parameter of unconventional superconductors-The pairing symmetry of High Tc superconductors can be easily deciphered using the phenomena of quantum pumping. On the other hand crossed Andreev reflection can be exploited to unravel the pairing symmetry of Ferromagnetic superconductors[9,12].
- Detecting a true quantum pump effect-Even though quantum pumping is a very promising field, it has unfortunately not been unambiguously experimentally detected.

The reason being that in the experiments the rectification effect overshadows the pumped current. One can however exploit the fact that in some systems the pumped and rectified current have exactly opposite properties enabling an effective distinction between them[8].

- Controllable π junction: We consider a model for a single molecule with a large frozen spin sandwiched in between two BCS superconductors at equilibrium, and show that this system has a π junction behavior at low temperature[8]. In a graphene based Josephson junction, one can have a controllable π junction which further can be exploited to fashion a qubit system[4].
- Detecting entanglement in the solid state: Shot noise cross-correlations can be a good indicator of entanglement for spin-singlet electronic sources. We link this fact to detect entanglement in a non-adiabatic pure spin pump where decoherence is the reason for entanglement[2], a superconductor normal metal hybrid junction where interface strengths and interactions can play a non-trivial role[7] and finally in graphene based superconducting junctions where a small gate voltage can change the sign of cross-correlations[5,6].

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