Quantum Information

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Introduction

Quantum computers and communication systems are devices that store and process information on quantum systems such as atoms, photons, superconducting systems, etc. Quantum information processing differs from classical information processing in that information is stored and processed in a way that preserves quantum coherence. The Quantum Information Group is investigating methods for constructing quantum computers and quantum communication systems using atomic physics,quantum optics, and superconducting systems. In addition, the group is investigating applications of quantum information processing including novel quantum algorithms and communication protocols.

1. Quantum Internet

Sponsors
Army Research Office (MURI) DAAD19-00-1-0177

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A quantum internet consists of quantum computers connected by quantum communication channels. The problem of maintaining the coherence of quantum information as it is moved from atoms to photons, transported through space, and moved back from photons to atoms, is a difficult one. Exactly because quantum information provides additional opportunities for storing and processing information, it also provides additional opportunities for errors, loss, and the corruption of that information. We have developed designs for a quantum internet that allow the robust transmission of quantum information even in the presence of high levels of errors and loss. We are currently implementing those designs. If a quantum internet can in fact be constructed, as our work suggests, then it is imperative to develop applications and techniques for using such quantum computation and communication systems in ways that take advantage of their unique capabilities. Accordingly, we are also developing protocols and applications for the quantum internet.

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2. Secure Quantum Communication and Clock Synchronization

Sponsors
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Quantum mechanics offers a variety of opportunities both to protect information (quantum cryptography) and to improve the precision of measurement, positioning and timing techniques. We are developing the world's brightest source of narrow band entangled photons and are planning to use this source to demonstrate secure quantum communication via teleportation and to demonstrate the phenomenon of quantum magic bullets --- quantum systems that exploit entanglement to pass through potential barriers with a much higher degree of success than is allowed classically. In addition, we have developed and are implementing techniques that use quantum entanglement to surpass the shot noise limit for timing and positioning.

3. Superconducting Quantum Computers

Sponsors
Army Research Office, DAAG55-98-1-0369, DURINT F49620-01-1-1351

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Superconducting systems present a variety of opportunities for quantum information processing. In collaboration with Delft Institute of Technology, we have demonstrated the first macroscopic quantum superposition of circulating supercurrents, and have designed devices in which such systems function as quantum bits in a quantum computer. We are investigating mechanisms of errors and decoherence in superconducting quantum bits and are designing experiments to demonstrate quantum logic operations and quantum entanglement using superconducting systems.

Publications

Journal Articles Published

Lloyd, S., "Ultimate Physical Limits to Computation," *Nature* **406** , 1047 (2000).

Tian, L. and S. Lloyd, "Resonant Cancellation of Off-Resonant Effects in a Multilevel Qubit," *Physical Review A.* Forthcoming.

Viola, L., and E. Knill, S. Lloyd, "Dynamical Generation of Noiseless Quantum Subsystems," *Physical Review Letters.* Forthcoming.

van der Wal, C.H., and A.C.J. er Haar, F.K. Wilhelm, R.N. Schouten, C.J.P.M. Harmans, T.P. Orlando, S. Lloyd, J.E. Mooij, "Quantum Superposition of Macroscopic Persistent-Current States," *Science.* Forthcoming.

Journal Articles, Submitted for Publication

Lloyd, S., and S.M. Shahriar, P.R. Hemmer, J.H. Shapiro, "Teleportation and the Quantum Internet," submitted to *Physical Review Letters.*

Lloyd, S., and J.H. Shapiro, N.C. Wong, "Quantum Magic Bullets via Entanglement," submitted to *Journal Optics Letters.*

Lloyd, S., and L. Maccone, V. Giovanetti, "Quantum Enhanced Positioning and Clock Synchronization," submitted to *Nature.*

Meeting Papers, Presented

Lloyd, S. and S.M. Shahriar, P. Hemmer, J. Shapiro, "Design for a Quantum Internet." MURI meeting, *CECOM*, Ft. Monmouth, NJ, 2000.

Meeting Papers, Published

Lloyd, S., "Ultimate Physical Limits to Computation," *QCMC*, Capri, 2000.