Stanford University - Yoshihisa Yamamoto

Summary: This MURI at Stanford has stimulated the creation of a graduate course, Quantum Information (Spring 2001), by Yoshi Yamamoto, together with a full set of course notes. This has laid the foundation for dozens of students to work in this area.

The primary emphasis of Yamamoto's group under this MURI has focused on the theoretical and experimental implementations of the devices necessary to realize and test quantum information applications. Our intent has been to take advantage of quantum dots as essential parts of systems for probing the physics of individual quantum particles such as electrons and photons. This work has resulted in theoretical proposals for creating entangled photons and electrons in the laboratory. Quantum dots have been used in the laboratory to trigger invidual polarized photons. High efficiency coupling of a quantum dot to a single cavity mode has been achieved.

In electron systems, the quantum optics tools necessary to detect entanglement have been proposed and demonstrated [1-5]. We are continuing our efforts in the noise characterization of the 0.7 structure. Theoretical work has focused on electron entanglement via a quantum dot [6], the incorporation of the Rashba spin-orbit coupling into the coherent scattering formalism [7], and the effects of coherent multiple reflections in mesoscopic electron devices [8].

In photon systems, we have demonstrated single-photon turnstile generation from a quantum dot [9,10]. We are currently implementing quantum cryptography schemes that will utilize this source, and we are currently examining the feasibility of linear optical quantum computation. High efficiency coupling of a quantum dot to a single cavity mode has also been demonstrated recently. We continue our efforts in improving the generation and detection efficiency of single photons and photon pairs [11-16].

Electron Entanglement (William Oliver): We propose and demonstrate electron entanglement (spin-singlet states or "flying qubits") in two-dimensional electron gas systems. To this end, we have developed the fundamental quantum optical tools (a Hanbury Brown and Twiss-type intensity interferometer and an electron collision analyzer) necessary to probe entangled electrons. This leads to a proposal of a bunching/antibunching experiment with entangled electrons and a proposal for a Bell's inequality test with electrons. We also consider several systems that could act as a source of entangled electron pairs. This leads to our recent proposal for electron entanglement via a quantum dot. In addition, we consider the possibility of using the 0.7/0.5 structure in quantum point contacts as either a source of many-particle entanglement or as a polarization beamsplitter. We are able to give an experimental demonstration of noise suppression at the 0.7 structure. The degree of noise suppression is consistent with a model that has two channels split in energy through some particular interaction: one with transmission probability unity and the other transmission probability 0.4. We propose a collision experiment to determine if the two channels are spin polarized or unpolarized.

Our future work will be to extend the quantum dot entangler model and determine its efficiency. We will also continue to explore the 0.7 structure in experiments. In addition, we are beginning to explore new materials (carbon nanotubes).

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