Università di Pisa
Scuola di Dottorato
Galileo Galilei
School of Graduate Studies

Prof. Carlo Piermarocchi

Michigan State Univ.

"Quantum computation with spins and excitons in semiconductor quantum dots"

Lezioni per il corso di Dottorato in Fisica
Venerdi 11 Luglio 2008 - ore 16:00
Lunedi 14 Luglio 2008 - ore 15:30
Martedi 15 Luglio 2008 - ore 15:30
Aula 131 - Piano terra - Ed. C - Dip. di Fisica

Program: A quantum computer is a device for computation that makes direct use of distinctively quantum mechanical phenomena, such as superposition and entanglement, to perform operations on data. The logical unit of a quantum computer is the qubit, and, as in a classical computer, complex algorithms can be built from simpler single-qubit and two-qubit operations.

In this series of lectures, I will give an overview of how nonlinear optics and semiconductor nanostructures can be applied to quantum information processing. Both theoretical and experimental aspects will be discussed. In particular, I will focus on the optical control of electron-hole pairs (excitons) and spins in semiconductor quantum dots.

Semiconductor quantum dots are artificial nanostructures with electronic and optical properties very similar to those of atoms. Like atoms, optical control can be used to manipulate the quantum states but, unlike an atom, the dot is easy to locate and to integrate in a semiconductor device.

Recently, the optical control of excitons (photo-excited electron hole pairs) and bi-excitons in a single quantum dot have been experimentally demonstrated. I will show how these basic manipulations can be organized to run basic two-qubit quantum algorithms. Also, each dot can be prepared with an excess conduction electron. In this case, coherent optical techniques can be used to control the spin state of the single electron. I will show how an effective spin coupling between electrons on two neighboring dots can be induced and controlled optically. Applications to the control of spin entanglement and to the realization of quantum gates in an array of dots will be discussed.

In many quantum computing architectures individual qubits need to be placed close enough –nanometers apart- to ensure an effective two-qubit operation. This is technologically challenging, especially in the case of semiconductor-based implementations with quantum dots. One way to overcome these limitations involves the use of Cavity Quantum Electrodynamics, i.e. the physics of confined photons interacting with matter. I will show how cavity QED effects can be used to couple qubits at large separation in a semiconductor-based quantum computer. The key role in the two-qubit operation is played by special states, called cavity polaritons, with a half-matter and half-light character.

G.Grosso