Quantum Computing in Semiconductors: Current Status and Perspectives

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Any physical implementation of quantum information processing is known to be extremely demanding. One should be able to perform long coherent quantum manipulations (gating), precise quantum-state synthesis, and detection as well. Ever since the very beginning it has been recognized that the major obstacle arises from the unavoidable open character of any realistic quantum system. The coupling with external (i.e. non-computational) degrees of freedom spoils the unitary structure of quantum evolution, which is the crucial ingredient in quantum computation (QC). The only existing experimental realizations of quantum processors are based on quantum optics and atomic/molecular systems.

It is however generally believed that future applications of quantum information may hardly be realized in terms of such systems, which do not permit the large-scale integration of existing microelectronics technology. In contrast, in spite of the serious difficulties related to the "fast" decoherence times, a solid-state implementation of QC seems to be the only way to benefit synergistically from the recent progress in ultrafast optoelectronics as well as in nanostructure fabrication and characterization.

Following this spirit, we shall propose and discuss potential implementations of quantum computation/information based on semiconductor nanostructures. More specifically, as originally envisioned Zanardi and Rossi,[1] we shall present an all-optical implementation of QC based on semiconductor macroatoms.[2] In this context we shall discuss a number of excitonic encoding schemes based on charge and/or spin degrees of freedom. In particular, we shall review a novel implementation scheme[3] which merges ideas from both the fields of spintronics and optoelectronics and sets the stage for an all optical semiconducting spin based quantum information processing.

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1 P. Zanardi and F. Rossi, *Phys. Rev. Lett*. **81**, 4752 (1998).

2 E. Biolatti, R. C. Iotti, P. Zanardi, and F. Rossi, *Phys. Rev. Lett*. **85**, 5647 (2000).

3 E. Pazy *et al*., "Spin-based optical quantum gates via Pauli blocking in semiconductor quantum dots", cond-mat/0109337 (2001).