MAX PLANCK INSTITUTE
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Dissipation desired

Novel concept for universal quantum computers exploits dissipative processes.

Press & Public Relations,
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Classical computers are not powerful enough to describe even simple quantum systems. All the more it is difficult to understand complex many body systems. Quantum computers which use quantum particles instead of classical bits may help to overcome this problem. Up to now complete isolation of the quantum system from the environment has been considered to be a precondition for the realisation of a universal quantum computer – a high challenge for experimental physics. A new concept, developed by Prof. Ignacio Cirac, director at Max Planck Institute of Quantum Optics and head of the Theory Division, and two former members of the Theory Division, Dr. Michael Wolf (now at Nils Bohr Institute in Copenhagen), and Prof. Frank Verstraete (now at the University of Vienna) turns these ideas upside down. As the scientists report in Nature Physics (AOP 20 July 2009, DOI 10.1038/NPHYS1342), quantum systems that are coupled to the environment by dissipative processes can be used for efficient universal quantum computation as well as the preparation of exotic quantum states. Furthermore, these systems exhibit some inherent robustness. Though still being a proof-of-principle demonstration the concept can in principle be verified with systems such as atomic gases in optical lattices or trapped ions.

Standard quantum computation is based on a system of quantum particles such as atoms or ions that serve at storing and encoding information. It exploits the unique property of these particles to take on not only states like ‘1’ or ‘0’ but also all kinds of superposition of these states. Manipulations acting on these qubits are always reversible, dubbed ‚unitary‘. Standard circuits consist of quantum gates that entangle two qubits at a time. However, this concept faces a strong adversary: once the system starts leaking information to the environment the quantum effects that give rise to the power of computing, cryptography and simulation – superposition and entanglement of states – get destroyed. Therefore the system has to be extremely well isolated from the environment.

On the contrary, the new concept of Cirac, Verstraete and Wolf makes use of these dissipative processes to perform efficient quantum computation and state engineering. In order to do so the dissipation dynamics has to be engineered such that it drives the system towards a steady state. This steady state can then represent the ground state of the system, it could be a particular exotic state, or it could encode the result of the computation. An advantage is the fact that, given the dissipative nature of the process, the system is driven towards its steady state independently of the initial state and hence of eventual perturbation along the way. That’s why ‘Disspative Quantum Computation’ (DQC) exhibits an inherent robustness.

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Though neither state preparation nor unitary dynamics are required DQC turns out to obtain a computational power that is equivalent to that of standard quantum circuits. Furthermore, this method is particularly suited for preparing interesting quantum states: for example, topological systems give rise to exotic states that play an important role in novel quantum effects like the fractional quantum Hall-effect.

Right now this concept is a proof-of-principle demonstration that dissipation provides an alternative way of carrying out quantum computations or state engineering. It aims however at being adapted in experiments with systems that use atomic gases in optical lattices or trapped ions. “This way of performing quantum computation defies most of the requirements that were thought to be necessary to build such a device”, Prof. Cirac points out. “This may lead to different kinds of realizations of quantum computers that are either most robust or easy to implement. But what is more important, it gives a completely different perspective to the way a quantum computer may work in practice.” [OM]

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