Quantum Fourier transform on a two-dimensional array of qubits

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The increasing interest in quantum information and quantum computation culminates not only in a deeper understanding of the computational power of quantum theory, but in a broad variety of new experimental ideas and realizations. For specific computations the massive parallelism inherent in quantum mechanical systems allows an exponential speedup over any known classical algorithms. In most of the recently discussed algorithms the quantum Fourier transform (QFT) plays an essential role. It is therefore warrantable to study the properties of the QFT for its own sake.

Several encouraging candidates for an experimental realization of quantum computers have been proposed. In particular, the high level of expertise available in solid-state based technologies establishes Josephson junctions, quantum dots and spin-resonance transistors as leading candidates for quantum computers.

However, for most of the solid-state candidates the experimental state-of-the-art technique allows only qubit-qubit interactions between a small number of neighboring qubits. Moreover, due to the large number of degrees of freedom the coherence times for solid-state designs are very short. The optimization of quantum algorithms therefore turns out to be an important task.

On the other hand, the creation of solid-state devices allows a wide control over the spatial formation of the qubits and therefore makes two- and three-dimensional arrays of qubits accessible. In the present poster we concentrate on the quantum Fourier transform in two dimensions and highlight two main ideas. First, we concentrate on the optimization of the Quantum Fourier Transform. It turns out that, compared to the one-dimensional case, a two-dimensional array of qubits can help to reduce the number of operations necessary to implement a QFT algorithm. The multitude of neighboring qubits in a two-dimensional array allows us to reduce the number of operations and simultaneously to parallelize the QFT to some degree. Second we address the question of whether it is possible to implement independently for the 1-d case a "two-dimensional quantum Fourier transform". However, since in two dimensions no natural ordering of the qubits appears, it is not possible to define a unique two-dimensional QFT. Nevertheless the successive execution of a QFT in two orthogonal spatial directions results in a highly entangled state and bears several interesting phenomena.

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