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Superconducting qubits on the way to a quantum processor[1]

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Experimental research on supeconducting qubits has seen an enormous progress in recent years. About 10 years after its first theoretical proposals, experiments have demonstrated the necessary building blocks for the exploration of quantum information along several avenues: Single qubit-rotations, long coherence times, high-fidelity nondemolition readout, two-qubit interactions and gates, coupling to delocalized qubit modes. With this progress, analogies to other qubit candidates such as magnetic resonance systems, atomic, and optical systems are evident, but we also see the specific strengths of superconducting qubits play out - in situ tunable strong qubit-qubit coupling, strong coupling between qubits and the quantized electromagnetic field, strong intrinsic nonlinearity, and the possibility to fabricate large circuits. Most of these achievements will be discussed later in the session. I will give an introduction to superconducting qubits in the perspective of quantum information processing [1] accessible to outsiders in the field. I will put the different elements of the session in the perspective of an actual scalable architecture which allows for fault-tolerant quantum computation [1,2]. In order to make further progress in direction, the fidelities of quantum operations need to be improved. I will discuss the crucial topic of understanding and further supressing noise from material defects in these systems, which can influence both the phase and bit-flip error rate [3,4]. I will show, how optimal control theory can help to find fast and high-fidelity shaped pulses for superconducting qubits, even though they, other than spin 1/2 systems, have relatively close leakage levels outside the qubit manyfold [5,6]. This technique also allows to optimize pulses in the presence of telegraph noise [6]. Finally, I will describe how the strong nonlinearity of Josephson circuit can be used for the generation of single microwave photons [7] and lead to a nonlinear generalization of cavity quantum electrodynamics effects [8].

[1] M.R. Geller, E.J. Pritchett, A.T. Sornborger, and F.K. Wilhelm quant-ph/0603224
[2] A.G. Fowler, W. Thompson, Z. Yan, A.H. Majedi, and F.K. Wilhelm, in preparation
[3] R. de Sousa, K.B. Whaley, F.K. Wilhelm, and J. von Delft, Phys. Rev. Lett 95, 247006 (2005)
[5] A.K. Sporl, T. Schulte-Herbrueggen, S.J. Glaser, V. Bergholm, M.J. Storcz, J. Ferber, and F.K. Wilhelm quant-ph/0504202
[6] P. Rebentrost, I. Serban, T. Schulte-Herbrueggen, and F.K. Wilhelm, in preparation
[7] M. Mariantoni, M.J. Storcz, F.K. Wilhelm, W.D. Oliver, A. Emmert, A. Marx, R. Gross, H. Christ, and E. Solano, cond-mat/0509737
[8] I. Serban, E. Solano, F.K. Wilhelm, cond-mat/0606734.

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