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Entangling Superconducting Qubits over Optical Fiber – Towards Optimization and Implementation

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This poster presents the work being conducted at the National Institute of Standards and Technology (NIST) and University of Colorado Boulder towards building a two-node quantum network. This network will use a 2 km long optical fiber and two of our state-of-the-art quantum transducers to entangle two superconducting quantum bits — one at the NIST campus and the other at the University. We describe the novel devices which will enable the integration of microwave and optical domains into a single network. Doubly parametric transducers (DPTs) implement a 4-wave mixing interaction between two optical/microwave signal modes which are on resonance with their respective resonators and two optical/microwave pumps which are detuned from their respective resonators [1]. The sign of the pump detunings determines the nature of the interaction. When both pumps are red detuned a beamsplitter-type interaction is implemented, whereas when one pump is red detuned and the other blue detuned a two-mode squeezing-type interaction is realized. After more than a decade of development, our electro-optomechanical DPT devices are ready for integration into a larger network, as was presented in our recently published paper "Entanglement thresholds of Doubly Parametric Quantum Transducers" [1,2]. With two possible interactions implemented by DPTs and a very large set of experimentally accessible states, operations, and measurements we must determine which combination of these elements will give us the best chance of successfully entangling microwave superconducting qubits over lossy optical fiber. We begin addressing this problem by presenting a circuit diagram for the most general two-node network which can produce continuous variable (CV) entanglement. The problem of optimizing the network around two transducers with a given set of fixed parameter values reduces to the problem of finding the optimal unitary operations and measurements. We are currently working to prove, and here we provide evidence, that in the low optical loss limit the optimal topology consists of symmetric entanglement swapping on two transducer Choi States. The swapping is performed by two EPR measurements (also known as CV Bell measurements) on the optical modes. When optical loss is significant the EPR measurements are separable [6] and therefore in this case we expect that local quadrature measurement are superior since they are also separable but avoid the transmission losses. After having introduced the optimal topologies we evaluate how these networks would perform with realistic previously demonstrated parameter values. We find that all of the optimal topology candidates produce entanglement when there is no optical transmission loss. Additionally, we find that the topology where the transducers

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operate as squeezers and the measurement is of the EPR type is the best for our set of network parameters. This topology has the potential to produce ebits at a rate of 10 Hz or span a distance of 10 km. However, practically the ebit rates fall off dramatically after about 1 km of fiber. Finally a detailed schematic of the implementation of this topology is presented, in which the optical portion of this network is discussed with preliminary experimental results.

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