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Multiplexed single-photon sources with optimal structure. – We proposed a spatially multiplexed single-photon source where the structure of the applied binary-tree multiplexer is optimized systematically during its construction. Along the building procedure of this type of multiplexer, the position of a binary photon router appended to the tree in a step of the expansion is determined by taking into account the current achievable single-photon probability of the source. The method chooses the position where this probability is maximal. We determined the stepwise optimized binary-tree multiplexers for experimentally realizable values of the loss parameters, and for a fixed number of routers. The method is scalable, that is, it is possible to determine the multiplexer with an optimal structure for any number of photon routers. We showed that single-photon sources based on stepwise optimized binary-tree multiplexers yield higher single-photon probabilities than single-photon sources based on any spatial multiplexer types discussed in the literature thus far in the considered ranges of the loss parameters.[1]

Activation of metrologically useful genuine multipartite entanglement. – We considered quantum metrology with several copies of bipartite and multipartite quantum states. We characterized the metrological usefulness by determining how much the state outperforms separable states. We identified a large class of entangled states that become maximally useful for metrology in the limit of large number of copies, even if the state is weakly entangled and not even more useful than separable states. This way we activated metrologically useful genuine multipartite entanglement. Remarkably, not only that the maximally achievable metrological usefulness is attained exponentially fast in the number of copies, but it can be achieved by the measurement of few simple correlation observables. We also made general statements about the usefulness of a single copy of pure entangled states. We surprisingly found that the multiqubit states presented in a previous paper, which are not useful, become useful if we embed the qubits locally in qutrits. We discussed the relation of our scheme to error correction, and its possible use for quantum metrology in a noisy environment. [2]

Chaotic behavior in iterated quantum protocols. – One of the simplest possible quantum circuits, consisting of a cnot gate, a Hadamard gate, and a measurement on one of the outputs is known to lead to chaotic dynamics when applied iteratively on an ensemble of equally prepared qubits. The evolution of pure initial quantum states is characterized by a fractal (in the space of states), formed by the border of different convergence regions. We examined how the ideal evolution is distorted in the presence of both coherent error and incoherent initial noise, which are typical imperfections in current implementations of quantum computers. It is known that under the influence of initial noise only, the fractal is preserved, moreover, its dimension remains constant below a critical noise level. We systematically analyzed the effect of coherent Hadamard gate errors by determining fixed points and cycles of the evolution. We combined analytic and numerical methods to explore to what extent the dynamics is altered by coherent errors in the presence of preparation noise as well. We showed that the main features of the dynamics, and especially the fractal borders, are robust against the discussed noise, they will only be slightly distorted. We identified a range of error parameters, for which the characteristic properties of the dynamics are not significantly altered. Hence, our results allow to identify reliable regimes of operation of iterative protocols. [3]

Implementing no-signaling correlations. – We dealt with no-signaling correlations that include Bell-type quantum nonlocality. We considered a logical implementation using a trusted central server with encrypted connections to clients. We showed that in this way it is possible to implement two-party no-signaling correlations in an asynchronous manner. While from the point of view of physics our approach can be considered as the computer emulation of the results of measurements on entangled particles, from the software engineering point of view it introduces a primitive in communication protocols that can be capable of coordinating agents without revealing the details of their actions. We presented an actual implementation in the form of a Web-based application programming interface (RESTful Web API). We demonstrated the use of the API via the simple implementation of the Clauser–Horne–Shimony–Holt game. [4]

Characterization of errors in a CNOT between surface code patches. — As current experiments already realize small quantum circuits on error corrected qubits, it is important to fully understand the effect of physical errors on the logical error channels of these fault-tolerant circuits. We investigated a lattice-surgery-based CNOT operation between two surface code patches under phenomenological error models. (i) For two-qubit logical Pauli measurements -- the elementary building block of the CNOT -- we optimized the number of stabilizer measurement rounds, usually taken equal to d, the size (code distance) of each patch. We found that the optimal number can be greater or smaller than d, depending on the rate of physical and readout errors, and the separation between the code patches. (ii) We fully characterized the two-qubit logical error channel of the lattice-surgery-based CNOT. We found a symmetry of the CNOT protocol, that results in a symmetry of the logical error channel. We also found that correlations between X and Z errors on the logical level are suppressed under minimum weight decoding.[5].

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