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Photonic Quantum Communication and One-Way Quantum Computation[1]

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A century after Einstein's invention of the photon concept and 80 years after the introduction of entangled states by Einstein-Podolsky-Rosen and by Schrodinger, entangled photon states have become important in quantum communication and quantum computation schemes. Quantum communication with entangled states is approaching large distances and experiments involving even satellite-bases systems become possible. In some schemes like teleportation and entanglement swapping active feed forward of Bell state measurement results is an essential part of the scheme: together with the intrinsic randomness of the individual measurement result a violation of Einstein relativity is avoided that way. Active feed forward then plays a central role in the completely novel concept of one-way quantum computation as proposed by Raussendorf and Briegel. That concept is qualitatively different from all quantum computer concepts where a sequence of one- and two-qubit quantum gates acts on a suitably chosen input state. In contrast the one-way quantum computer scheme starts with a sufficiently complex and general highly entangled initial state, a cluster state. The specific calculation performed is then defined as a specific sequence of measurements performed on that initial state. An important point is that the specific choice of later measurements is defined by the results of earlier measurements. Using such active feed-forward the one-way quantum computer overcomes the problem of the intrinsic randomness of the individual results in quantum measurement. For photons, the one-way quantum computer can be seen as an extension of the linear optics quantum computation proposal by Knill, Laflamme and Milburn. Recently we realized a one-way quantum computer using four- photon entangled cluster states (P. Walther, K. J. Resch,, T. Rudolph, E. Schenk, H. Weinfurter, V. Vedral, M.Aspelmeyer & A. Zeilinger, submitted to Nature). The state was characterized by full four-qubit tomography. Using various types of cluster states a universal set of 1- and 2-qubit operations was demonstrated. Finally, a Grover search algorithm was implemented.

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