Recent experiments with photons: Testing the foundations of quantum physics and developing new tools for quantum information

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Tests of the foundations of quantum physics have been crucial stepping stones for the development of the field of quantum information science. In the talk I will discuss two recent photonic tests. One experiment [1] closed a specific class of the freedom-of-choice loophole. That loophole suggests that the choice of measurement parameter in a Bell test is influenced by the emission event of the photons from the source. It was ruled out by having the decision which polarization to measure space-like separated from the emission. The experiment itself was performed at the European Northern Observatory on the Canary Islands of Tenerife and La Palma. The experiments violate a Bell Inequality by about 20 standard deviations. The fast feed-forward technology used in the experiment is also crucial for measurement-based quantum computation procedures.

Independent of the locality assumption, the Kochen-Specker theorem allows to investigate fundamental questions for individual systems. Recently Klyachko et al [2] proposed a strategy to test whether the predictions of quantum physics can be explained by underlying joint probability distributions. Both the original Kochen-Specker idea and the Klyachko proposal use the quantum predictions for spin-1 systems, i.e. qutrits. In the recent experiment in Vienna we realize the qutrits by coherent superpositions of three modes of a single photon. The experiment confirms the quantum predictions [3] and rules out that the measurement result may be understood by and underlying (classical) probability distributions by about 80 standard deviations. This confirms the nonclassicality of a system which does not even in principle allow entanglement between different internal or external variables.

[1] T. Scheidl, R. Ursin, Johannes Kofler, S. Ramelow, X. Ma, T. Herbst, L. Ratschbacher, A. Fedrizzi, N. K. Langford, T. Jennewein, and A. Zeilinger, Violation of local realism with freedom of choice, Proc Natl Acad Sci USA (2010) 19709.

[2] Klyachko, A. A., Can, M. A., Binicioğlu, S. & Shumovsky, A. S. Simple test for hidden variables in spin-1 systems. Phys. Rev. Lett. 101, 20403 (2008).

[3] R. Lapkiewicz, P. Li, C. Schaeff, N. K. Langford, S. Ramelow, M. Wieśniak & A. Zeilinger, Experimental non-classicality of an Indivisible Quantum System. Nature (23 June 2011).