Measuring non-commuting observables of a single photon via sequential weak values evaluation

Marco Gramegna[1], Fabrizio Piacentini[1], Alessio Avella[1], Eliahu Cohen[2,3], Rudi Lussana[4], Federica Villa[4], Alberto Tosi[1], Franco Zappa[4], Giorgio Brida[4], Ivo P. Degiovanni[1], and Marco Genovese[1]

[1]*INRiM, Istituto Nazionale di Ricerca Metrologica, Strada delle Cacce 91, Torino, Italy*
[2]*H.H. Wills Physics Laboratory, University of Bristol, Tyndall Avenue, Bristol, BS8 1TL, U.K*
[3]*School of Physics and Astronomy, Tel Aviv University, Tel Aviv 6997801, Israel*
[4]*Politecnico di Milano, Piazza Leonardo da Vinci 32, Milano, Italy*

This communication reports on the first experimental verification of the peculiar predictions regarding single and sequential weak values on a unique quantum particle, and to be specific related to the simultaneous measure of non-compatible polarization observable of a single photon [1]. This experimental evidence could result at odd with "one of the canonical dicta of quantum mechanics" [2]: the impossibility of measuring two non-commuting observable at the same time because of the wave function collapse. Nevertheless, in the framework of weak measurements (WMs) this impossibility can be partially smoothed if sequential or joint weak values evaluation is taken into account [2–5]. In fact, operating within this quantum measurement paradigm, weak values are obtained extracting only a small amount of information from a single measurement, preventing the collapse of the initial quantum state. Up to now only WMs on a unique observable (eventually followed by a strong measurement) or joint WMs performed on commuting observable and on different particles (or optical modes), have been realized in laboratories [6–9]. On the contrary, sequential weak measurements, which present features very sensitive to the systems dynamics and whose time order plays a primary role, have not been performed yet. The main experimental results of this research will be presented, showing a remarkable agreement with the theoretical simulations. The most paradoxical situations, typical of weak values behavior, will be put in evidence.

[1] F. Piacentini, et al., Phys. Rev. Lett. 117, 170402 (2016).

[2] G. Mitchison, R. Jozsa, and S. Popescu, Phys. Rev. A 76, 062105 (2007).

[3] K. J. Resch, et al., Phys. Rev. Lett. 92, 130402 (2004).

[4] Y. Aharonov, D. Z. Albert & L. Vaidman, Phys. Rev. Lett. 60, 1351-1354 (1988).

[5] A. G. Kofman, S. Ashhab & F. Nori, Phys. Rep. 520, 43-133 (2012).

[6] O. Hosten & P. Kwiat, Science 319, 787-790 (2008).

[7] D. J. Ressel, et al., Rev. Mod. Phys. 86, 307-316 (2014).

[8] K. J. Resch, Science 319, 733 (2008).

[9] G. J. Pryde, et al., Phys. Rev. Lett. 94, 220405 (2005).