Violation of Bell inequalities and Quantum Tomography with Pure-states, Werner-states and Maximally Entangled Mixed States created by a Universal Quantum Entangler

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Abstract

Entangled pure-states, Werner-states and mixed-states of any structure, spanning a 2 x 2 Hilbert space have been created by a novel high-brilliance universal source of entangled photon pairs.

In this source a single Spontaneous Parametric Down Conversion (SPDC) NL crystal, cut for Type I phase-matching, is excited in two opposite directions ($\overrightarrow{k}$, $-\overrightarrow{k}$) by a UV back-reflected pump laser beam ($\lambda_p = 363.8nm$). The output 2-photon linear polarization- ($\overrightarrow{\pi}$-) entangled beam, finally emitted in direction $\overrightarrow{k}$, consists of the superposition of the SPDC created states in directions $\overrightarrow{k}$ and $-\overrightarrow{k}$, the last one after back-reflection and suitable phase and $\overrightarrow{\pi}$ transformation [1].

The λ-degenerate photons ($\lambda = 2\lambda_p$) are generated over the whole SPDC emission cone whose transverse circular section identifies the *Entanglement-ring.* The simultaneous detection of the *whole ensemble* of the SPDC entangled pairs enhances the brightness of the source outperforming by an order at least 10^3 the overall *source quantum efficiency* (SQE) of the common SPDC sources.

Consistently with the above considerations, this source has been applied to

two somewhat "extreme" experiments, both implying a bi-partite, two-qubit entangled state [2]. A first experiment consists of the first Bell inequality violation test involving a *pure-state,* $SQE \approx 1$, i.e. by which *all* the SPDC generated photon pairs excite the cathode of the test detectors. By a second experiment, the same inequality has been tested and a quantum tomographic analysis undertaken of Werner states with variable mixing parameters. At last, the "*maximally entangled mixed states*" (MEMS), today of common interest, has been created and tested by the same technique. All these states have been easily synthetized by our source for the first time.

[1] G. Giorgi, G. Di Nepi, P. Mataloni and F. De Martini, *Laser Physics*, 13, 350 (2003).

[2] M. Barbieri, F. De Martini, G. Di Nepi and P. Mataloni, *quant/ph*0303018.