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Witnesses of coherence and dimension from multiphoton indistinguishability tests

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The quantum interference [1] is a useful tool for the characterization of the single photon sources, for quantum computing and for quantum communication. In particular, the indistinguishability and the superposition are the key elements of the quantum interference and for this reason, it is worth to develop better methods for their identification and quantification. We present an indistinguishability test for a multiphoton state based on two-photon Hong-Ou-Mandel tests. Our approach [2] consists of an interferometer that allows measure simultaneously the three photon overlaps on a four photon state produced by a spontaneous parametric down conversion(SPDC) source. As shown in Ref. [3], we quantify the indistinguishability from the obtained value measured overlaps. Starting from these measurements we infer precise bounds for the unmeasured overlaps. For this purpose, we assume two different models for the multiphoton state: generally mixed four-photon state [3], and the tensor product of pure single-photon state [4]. Each model provides different inequalities for the unmeasured overlaps. Furthermore, changing the number and the arrangement of HOM tests performed between pair of photon, i.e having access to different pairwise overlaps, other information can be retrieved on the system. From the same inequalities, we also can formulate a coherence witness and dimension witness based on this overlaps estimation, as shown in Ref. [4]. This basis-independent coherence witness attests that it is not possible to diagonalize the state on a given reference basis. We experimentally test this new coherence witness. In order to have a three photon state in input and measure the three pairwise possible overlaps, we rearrange our interferometer. To obtain the coherence witness violation, we tune the different input state by photon polarization. We also experimentally measure the Hilbert space dimension witness which attests if the space dimension of each photon state is up to two. For this purpose, we use the photon delay times as degree of freedom. In this way, we have three qudit states that violate the dimension witness. Our results confirm the validity of these novel coherence and dimension witnesses and they provide a complete characterization of the single photon sources. Moreover, the identification of an undesired degree of freedom makes the dimension witness very useful for quantum cryptography.

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[3] D. J. Brod, et al., “Witnessing genuine multiphoton indistinguishability,”Phys. Rev. Lett. 122, 063602 (2019).
[4] D. J. Brod and E. F. Galvão, “Quantum and classical bounds for unknown two-state overlaps”

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