Observation of genuine three-photon interference

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Entangled photons are a key requirement for realizing worldwide quantum communication [1], quantum cryptography and optical quantum computation. The photons can be entangled in various degrees of freedom, usually the photons are polarization entangled, since it is relatively easy to realize. Unfortunately, these photons have limited transmission length through fibers due to polarization mode dispersion. Therefore, the photons have to be entangled in a different, more robust degree of freedom; in this case, we use energy-time entanglement [2]. For some applications it is additionally required to have many photon entanglement, for example multipartite correlations exhibited in the Greenberger-Horne-Zeilinger (GHZ) state [3], where three particles are correlated while no pairwise correlation is found. In this work we present an experiment, which demonstrates three-photon interference that does not originate from two-photon or single photon interference by using energy-time entangled photon triplets produced via cascaded parametric down conversion [4, 5]:

Here we employ a continuous-wave laser at 404 nm to pump a periodically-poled potassium titanyl phosphate crystal cut for type-II down-conversions, which produces pairs of 842/776 nm photons. These photons are separated at a polarizing beam splitter. The 776 nm photons pump a periodically-poled lithium niobate waveguide to generate 1530/1570 nm photon pairs in type-0 down-conversion. Our source creates approximately 2000 entangled photon triplets per hour [5]. After splitting up those photons on a dichroic mirror, all photons are sent into a three-photon Franson-interferometer [2], which is in our case realized as three different spatial modes of an imbalanced single Mach-Zehnder interferometer ($\Delta T = 3.7$ ns). The phases of the photons can be adjusted via motorized glass plates in the long arm of each interferometer. At the output ports of the interferometer, the photons are detected with single photon detectors (avalanche photo diodes and superconducting nanowire detectors), and their arrival time is registered with a time tagger system.

As a result, we observe phase-dependent variation of three-photon coincidences with (92.7 ± 4.6)% visibility (see Fig. 1) while having negligible two-photon and single-photon modulation [6].

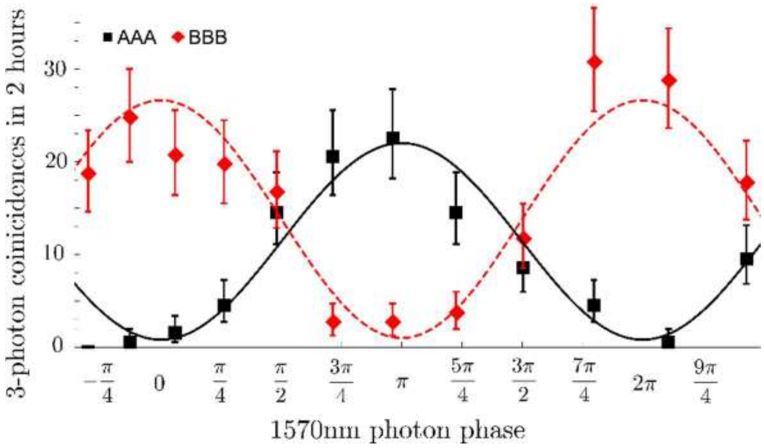

Fig. 1 Measured three-photon coincidences: By changing the phase in one of the interferometers we observe an interference with a visibility of (92.7 ± 4.6)%. The error bars are Poissonian count errors. AAA and BBB denote different output port combinations of the three interferometers.

References

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