Spectral Two-Photon Quantum Interference via Electro-optic Modulation Between Light States Of Different Photon Statistics

Anahita Khodadad Kashi[1, 2] and Michael Kues[1, 2]

[1]*Institute of Photonics, Leibniz University Hannover, Nienburger Str. 17, 30167 Hannover, Germany*
[2]*Cluster of Excellence PhoenixD, Leibniz University Hannover, Hannover, Germany*

Abstract: Frequency-domain two-photon quantum interference between a thermal field and a heralded-state is studied theoretically and experimentally, revealing the dependency of visibility on the multiphoton components within the heralded-state.

Photonic frequency-encoded quantum information processing can pave the way for the realization of global-scale quantum networks [1], integral to which is the scalable implementation of the Hong-Ou-Mandel (HOM) effect between independent light states of different photon statistics [2, 3]. In this work we demonstrate the first-time experimental implementation of the spectral HOM effect between independent single photons as well as the quantum interference between a thermal and a heralded state. To this end, an intrinsically stable and reconfigurable frequency processing circuit was used, which consisted of a mode-locked pulsed laser, two programmable filters, an electro-optic phase modulator (EOPM) – acting as a frequency counterpart of a conventional spatial domain beam splitter – and four superconducting nanowire single photon detectors (SNSPD) (see Figure 1a). The synchronized collection of coincidence events with the pulsed laser repletion-rate allowed for on-the-fly acquisition of the HOM effect. For the HOM effect between single photon states we measured a visibility of 74.31%±3.57% (see Figure 1 b), which falls well beyond the classical limit of 50%, offering an appropriate candidate for quantum communication and information applications. In the case of the HOM effect between a thermal field and a heralded state, we derived a theoretical relation, $V_{theory} = 1/(1 + (\overline{n}_{1,th}^2 + \overline{n}_2^2 + \overline{n}_{1,th})/(\overline{n}_{1,th}\,\overline{n}_2 + \overline{n}_2))$, describing the dependency of the visibility on the fields' thermal mean photon numbers per pulse period, i.e. $\overline{n}_{1,th}$ and $\overline{n}_2$. Specifically, this demonstrates that multiphoton components in the heralded state get engaged in quantum interference. Experimentally, by assuming the absence of the HOM effect at zero delay, we defined a reference point (see Figure 1c), revealing a visibility of $V_{experiment} = 43.20\% \pm 4.28\%$, which is in good agreement with the predicted theoretical value $V_{theory} = 47.30\% \pm 0.66\%$. Our results enable the implementation of important concepts such as quantum teleportation, entanglement swapping and complex states in large-scale frequency-domain quantum circuits, and thus provides a key element for future frequency-multiplexed quantum networks.

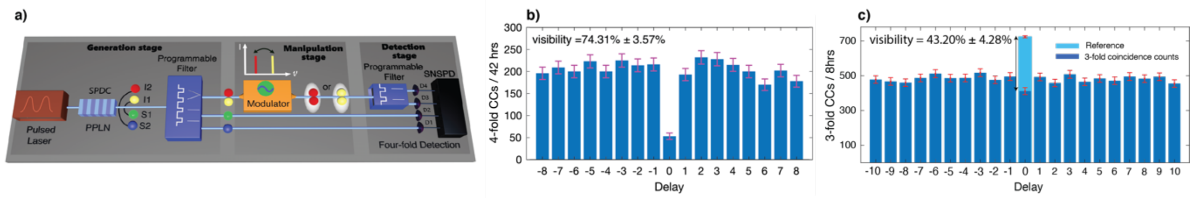

Figure 1. a) Experimental setup employed for HOM effect between two single photon states. (The setup for HOM between a thermal field and heralded state is not shown here.) **b)** Four-fold and **c)** three-fold coincidence counts as function of delay expressed as multiples of the pulse period.

References

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