Quantum interference with photon-number superposition states from a coherently driven quantum emitter

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Quantum emitters (e.g., atoms and quantum dots) are excellent single-photon sources for quantum technologies. A common method to generate single-photons of high quantum purity is the use of coherent excitation techniques. It was shown in 2019 that such excitation techniques result in the transfer of coherence imprinted on the emitter onto the photon-number basis through spontaneous emission, generating a photon-number superposition state of the form $|\psi\rangle = \sqrt{p_0}|0\rangle + e^{i\varphi}\sqrt{p_1}|1\rangle$ with optical phase φ [1].

In this study, we experimentally show that the often overlooked presence of photon-number coherence impacts core building blocks of quantum optics protocols. We exemplify this by performing phase-resolved correlation measurements using a Hong-Ou-Mandel interferometer with photon-number superposition input states (Fig. 1). We demonstrate that photon-number coherence leads to phase φ-dependent coincidence measurements as shown in Fig. 2 where we plot the coincidences for a single-photon (grey) and a superposition input state (purple) as a function of interferometer delay τ_p, revealing the suppression of coincidences at long delays as a result of coherence.

We show that the presence of photon-number coherence forces us to not only re-examine common normalization procedures used to extract photon indistinguishabilities, but also leads to new quantum interference phenomena, which in turn can seriously impact quantum computing schemes relying on partial qubit measurements as we demonstrate using the Perceval framework [2].

References

[1] Loredo et al., Nature Photonics, 13 (2019) 803-808
[2] Heurtel et al., Quantum, 7 (2023) 931

Figures

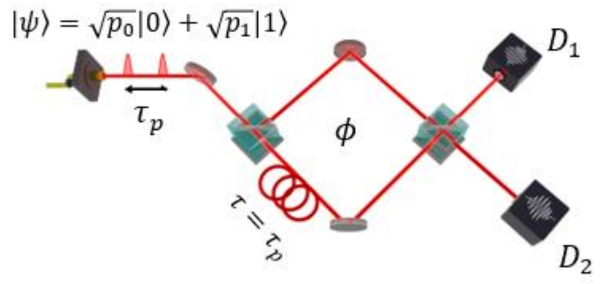

Figure 1: A Mach-Zehnder-based Hong-Ou-Mandel interferometer with photon-number superposition input states separated by excitation repetition rate τ_p and two detectors registering coincidences.

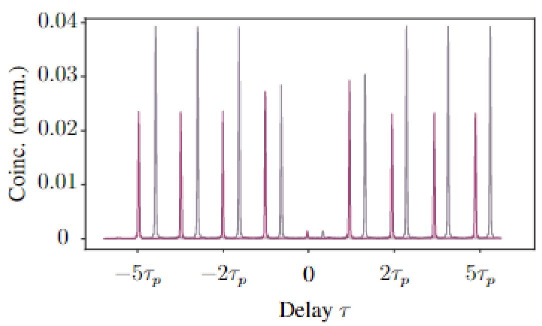

Figure 2: Normalized coincidence histograms for a single-photon input state (grey and shifted along x-axis) and a photon-number superposition state (purple).