Quantum Interference between Identical Photons from Remote Quantum Dots

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Advances in photonic quantum technologies calls for creation, manipulation and detection of a large number of identical single photons. Self-assembled quantum dots represent a semiconductor platform that creates single photons in a near-deterministic manner [1]. They benefit from the established semiconductor fabrication facilities; they can be integrated into various nano- and micro-structures. For applications, however, a significant roadblock is the poor quantum coherence upon interfering single photons created by two or more independent quantum dots [2, 3]. In other words, the photons created by different quantum dots are not identical.

Here, we present two-photon interference with a 93% interference visibility (Fig. 1) from two quantum dots separated in different cryostats [2]. This high visibility is achieved under rigorous conditions: no Purcell enhancement, no temporal post-selection, no narrow spectral filtering, and no frequency stabilisation. The key to the high value is the employment of gated GaAs quantum dots in a p-i-n diode [4]. Exploiting the current photonic engineering technologies, our result presents a route to creating single photons with more than 99% similarity in every aspect from separate quantum-dot based photon sources.

The identical photons allow a photon-photon entangled state to be created. We demonstrate a CNOT operation using the remote quantum dots photons and standard linear optics. The average CNOT process fidelity is ~88% and the output entanglement fidelity is ~85%. Such an entangled state marks a first step towards involving multiple – not just one – quantum-dot based single-photon sources for quantum applications. Our results establish gated GaAs quantum dots as interconnectable sources to scale the creation of identical single photons.

Figures

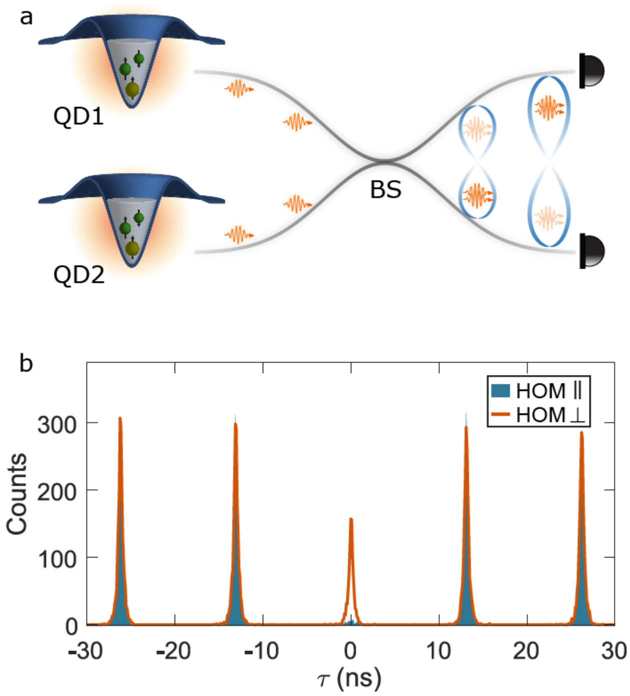

Figure 1: Hong-Ou-Mandel interference between photons from two separate quantum dots. (a) A sketch of the interference experiment. (b) Hong-Ou-Mandel (HOM) experiment showing an interference visibility of 93%.

References

[1] N. Tomm, et al., Nat. Nanotechnol. 16, 399 (2021)
[2] L. Zhai, *et al.*, arXiv:2106.03871 (2021).
[3] J. Weber, *et al.*, Nat. Nanotechnol. 14, 23 (2019)
[4] L. Zhai, *et al.*, Nat. Commun. 11, 4745 (2020)