HONG-OU-MANDEL INTERFERENCE BETWEEN PHOTONS FROM A SINGLE ATOM AND AN ATOMIC ENSEMBLE

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Introduction

Many proposed all-optical quantum-photonic networks are based on indistinguishable single photons carrying information between nodes and interacting with one another. It is important to demonstrate that single photons generated from different systems using different physical processes can indeed be indistinguishable and exhibit two-photon interference effects such as Hong-Ou-Mandel (HOM) interference [1], where two indistinguishable photons interfering at a 50:50 beamsplitter will always exit on the same side. This had previously been demonstrated with sources such as quantum dots, single atoms and parametric down-conversion [2–4].

Single Photon Sources

We interfere single photons generated by two different atomic systems. The first system is a cold atomic ensemble of ^{87}Rb atoms that generates photon pairs using a four-wave mixing (FWM) process via a cascade decay scheme [5]. The second system is a single ^{87}Rb atom in an optical dipole trap that is excited by a short resonant optical pulse and produces a single photon via spontaneous emission.

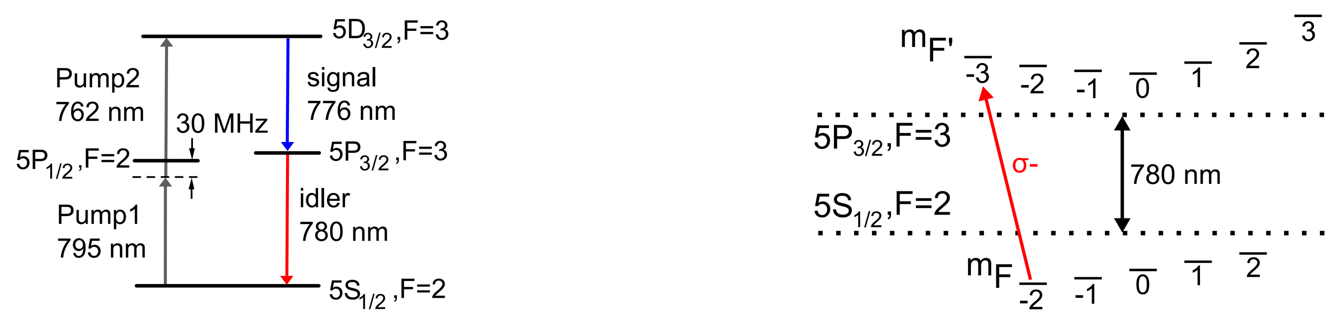

FIGURE 1: Energy level schemes of ^{87}Rb showing the cascade decay scheme of the FWM process (left) and the closed transition along which the single atom is excited and spontaneously emits a single photon (right).

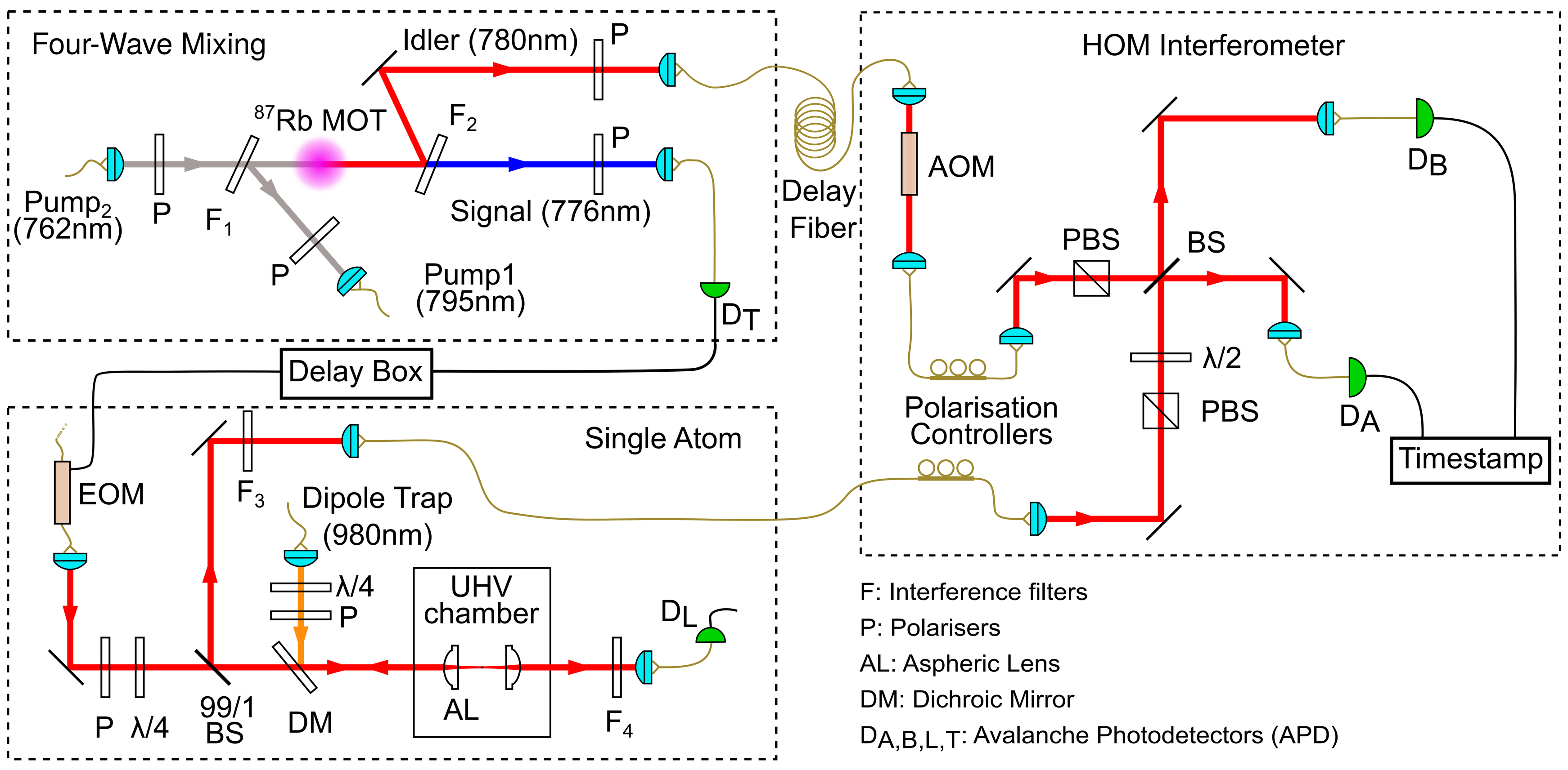

FIGURE 2: Pumps 1,2 are combined using filter F_1 and co-propagated through a cold atomic cloud of ^{87}Rb atoms. Photon pairs are generated and separated from residual pump light using filter F_2. A detection at D_T triggers the electro-optic modulator (EOM) to generate a pulse to excite the single ^{87}Rb atom trapped at the focus of two AL (NA = 0.55). A 230m long single-mode delay fiber and a variable delay box are used to match the photon arrival times at the BS. An acousto-optic modulator (AOM) compensates for the frequency mismatch of the photons.

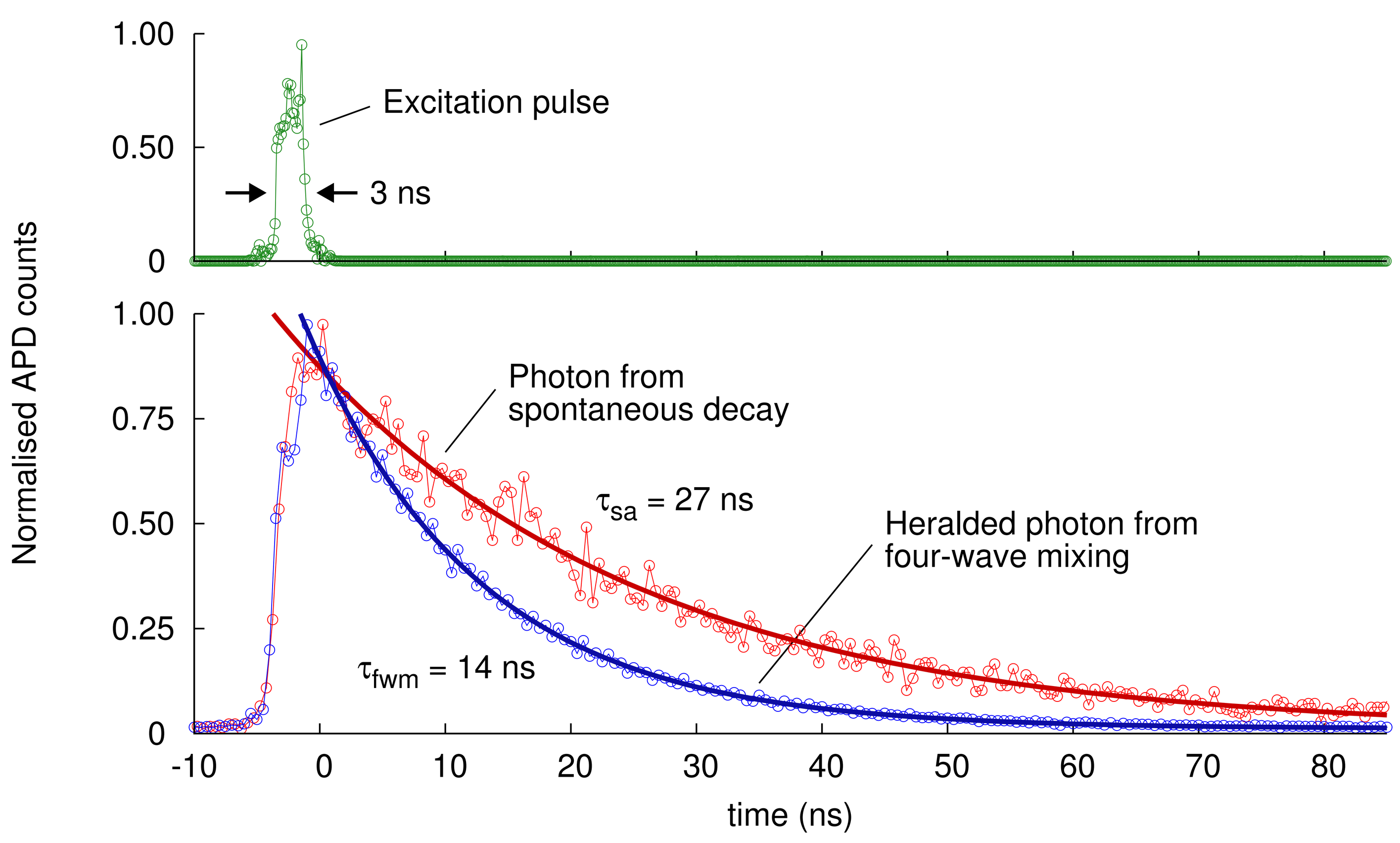

FIGURE 3: APD measurements, normalised to the peak of their detection time distributions. (Top) 3 ns pulse used to excite the single atom. (Bottom) Single photons from the single atom (sa) via spontaneous decay and from the atomic ensemble via four-wave mixing (fwm), with exponential fits showing decay times.

HOM Interference

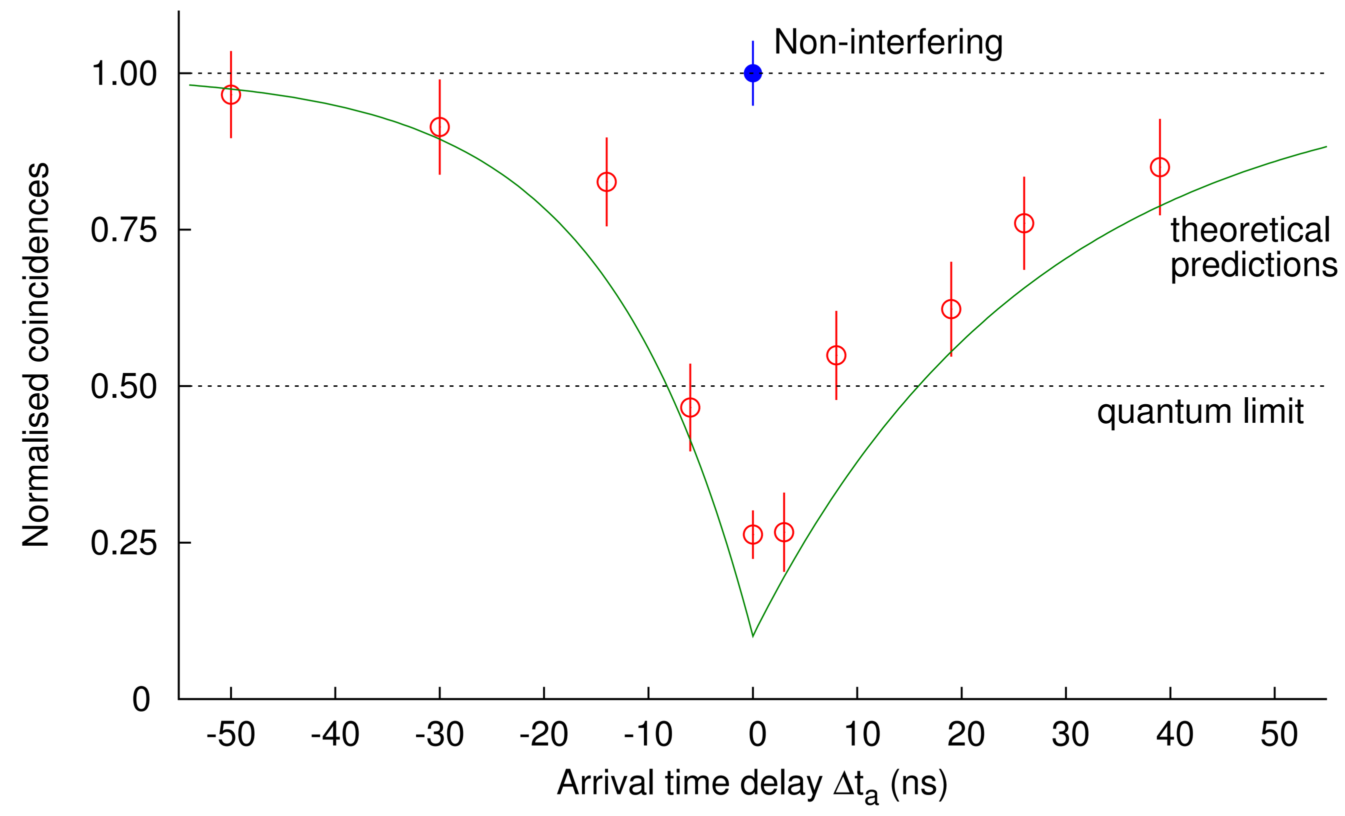

FIGURE 4: Coincident photons at D_A and D_B as a function of the arrival time delay between the two photons at the HOM beamsplitter Δt_a. Coincidence counts within a 80ns window are normalised to the non-interfering case and corrected for accidental events due to background noise. The solid line represents theoretical predictions based on a temporal overlap integral. A normalised coincidence value of 0.5 marks the quantum limit.

HOM Visibility

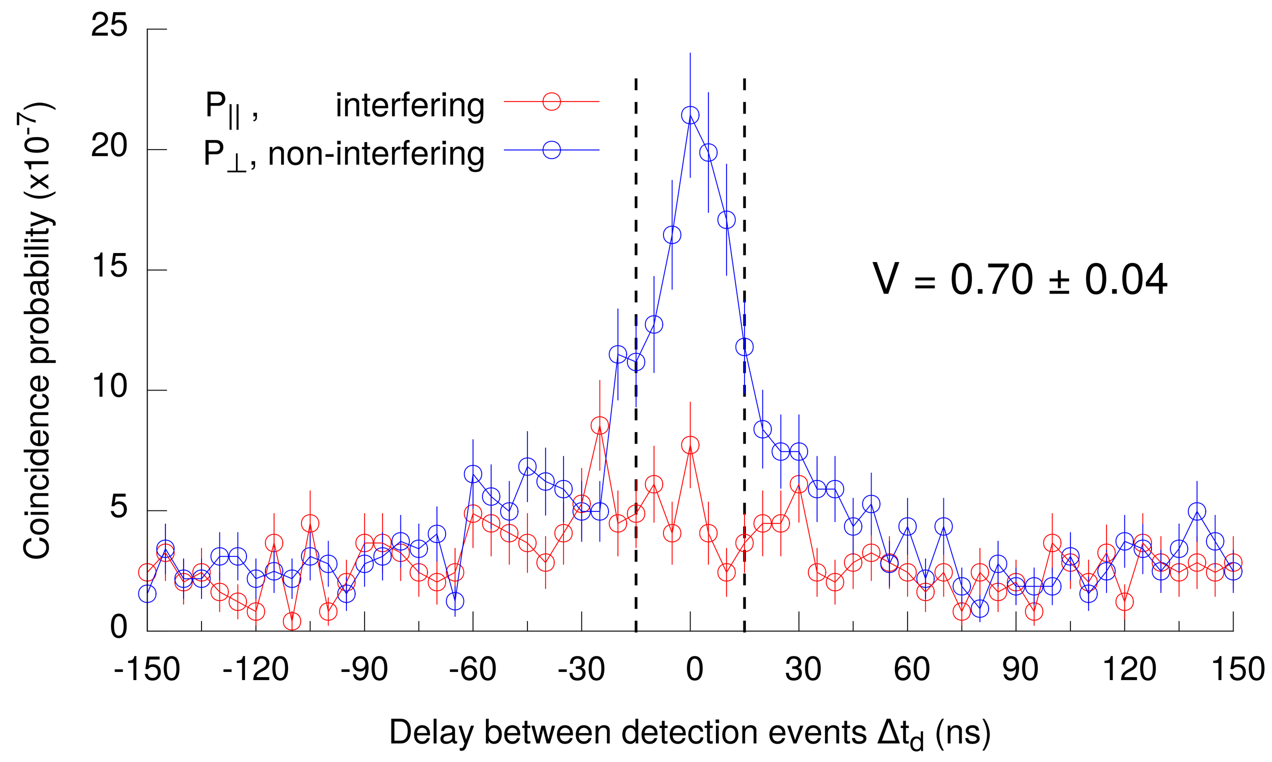

FIGURE 5: Probability of detecting coincident photons at D_A and D_B with parallel and perpendicular polarisations, as a function of the delay between the detection times Δt_d. The HOM visibility is calculated from the ratio of the integrals of $P_\parallel$ and $P_\perp$ over the range $-15\,\text{ns} \leq \Delta t_d \leq 15\,\text{ns}$.

Quantum Beats

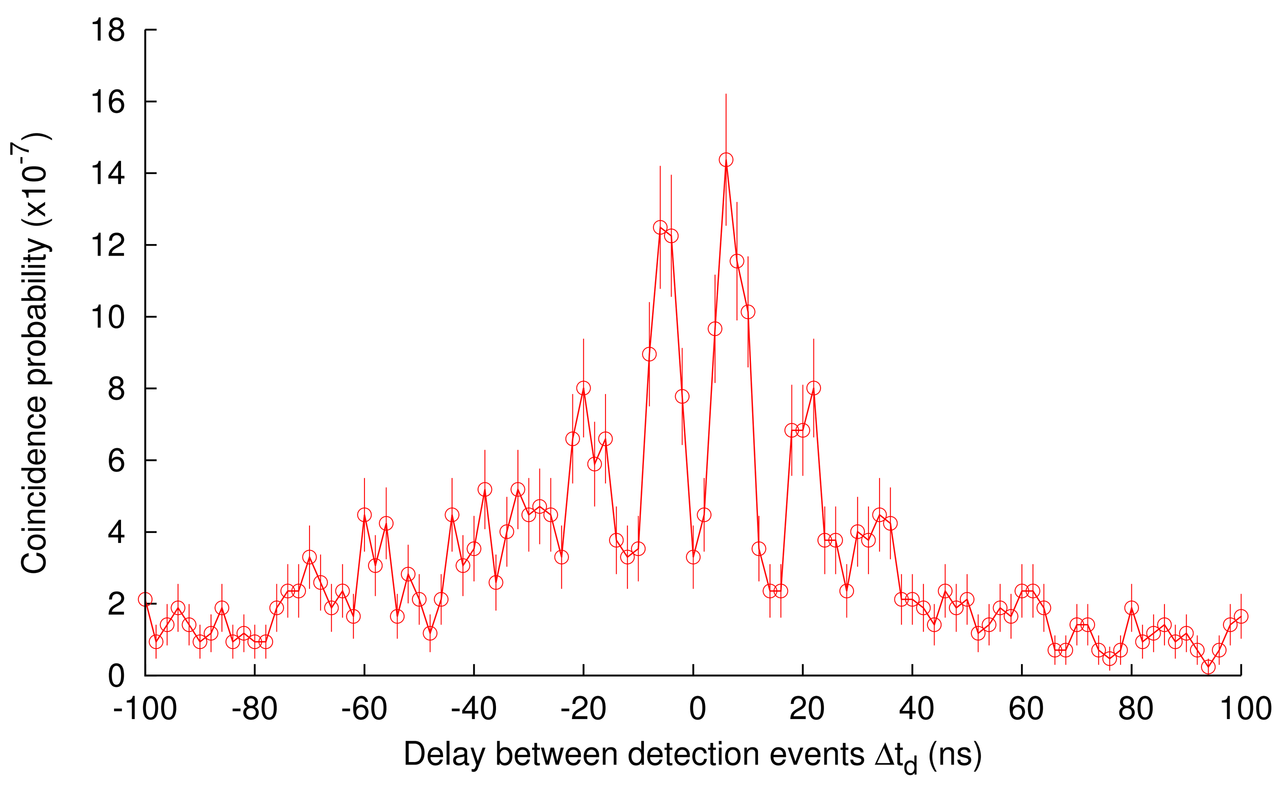

FIGURE 6: Probability of detecting coincident photons at D_A and D_B as a function of the delay between the detection times Δt_d. Here, the FWM photon bypasses the AOM, resulting in a frequency difference of 75±1 MHz with the photon from the single atom, which is consistent with the beat frequency in the coincidence probability.

References

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