Time correlation of photon pairs from a triply-resonant optical parametric oscillator far below threshold

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Abstract

We present for the first time a complete theoretical description of the temporal correlation of the signal-idler pair and the signal-signal-idler photon correlation of two photon pairs from a triply-resonant OPO. The theoretical results match exactly our measurements of two and triple coincidences from our SPDC source.

Spontaneous parametric down-conversion (SPDC) in a non-linear crystal is a commonly used photon source in many quantum optical experiments. The SPDC process generates two photons, called signal and idler, with strong temporal and frequency correlation. These can be exploited for applications in quantum technology, such as quantum cryptography [1] or quantum interfaces [2]. The latter often requires matching the photon properties to specific optical transitions in different physical systems, e.g. semiconductor quantum dots on the one hand and alkali gas cells on the other. This can be achieved by placing the non-linear crystal in a cavity, i.e., realizing an optical parametric oscillator (OPO). The cavity then determines the frequency and time correlation of the generated photons. Surprisingly, the time correlation in the triply-resonant (signal, idler and pump) scenario is described in the literature only for special configurations [3].

We derived a theory of the temporal correlation of the signal-idler pair and the signal-signal-idler photons of two photon pairs based on the emitted spectrum of a triply-resonant OPO, pumped far below threshold. Two and triple coincidence measurements of our type-II SPDC source [4] verifies our theory very well. To measure the signal-signal-idler correlation (see Figure 1), we have to equally split up the signal photons to detect them individually and herald them with the idler photons. We utilized superconducting single photon detector (SSPD) with very high temporal resolution to reveal most correlation features.

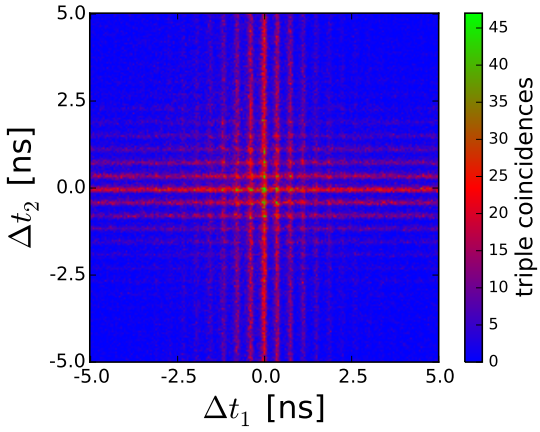

Figure 1: Signal-signal-idler correlation. Δt_1 (Δt_2) is the time difference between detecting an idler photon and a signal photon at SSPD1 (SSPD2). Signal photons without any correlation to the detected idler photon cause the stripes. The spacing between the stripes correspond to the round-trip time in the cavity.

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