Focusing constraints on coupling efficiency of collinear type-I degenerated SPDC photon pairs into a single-mode fiber

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Entangled photon pairs represent an essential resource for various quantum technologies, such as quantum key distribution, quantum computing or quantum imaging. A common process to produce correlated pairs is spontaneous parametric downconversion (SPDC) of pump photons into pairs of entangled photons which are then coupled into a single-mode (SM) fiber. For most applications, it is desirable to maximize the coupling efficiency of the entangled pairs into the SM fiber, as well as the rate of pairs that can be collected. Systematic studies about the maximization of these quantities have been carried out for specific parameters of SPDC, e.g. using type-II phase-matching condition [1]. However, despite advances on theoretical modelling [2, 3], other SPDC configurations still lack experimental evidence to confirm the dependence of the coupling efficiency on the main parameters of the setup. This study focuses on collinear degenerated co-polarized SPDC photon pairs, which separation requires special techniques [4]. They are relevant for various applications such as single mode squeezed states for gaussian boson sampling or non-linear interferometers.

We investigate the dependence of coupling efficiency on pump and collection beam waists by continuously varying their size thanks to two *beam expanders* made of one fixed and two mobile lenses (Fig. 1). We generate type-I SPDC by pumping a bulk beta barium borate (BBO) crystal of 3 mm length with a continuous wave (CW) 404 nm laser. We measure the coupling efficiency using coincident detections from single photon counting modules (SPCMs), and study the impact of different focusing conditions of the pump and collection beam. The estimated coupling efficiency shown in Fig. 2 was obtained by considering the losses of the optics and the experimentally determined quantum efficiencies of the SPCMs. The observed coupling efficiency reached up to 75%.

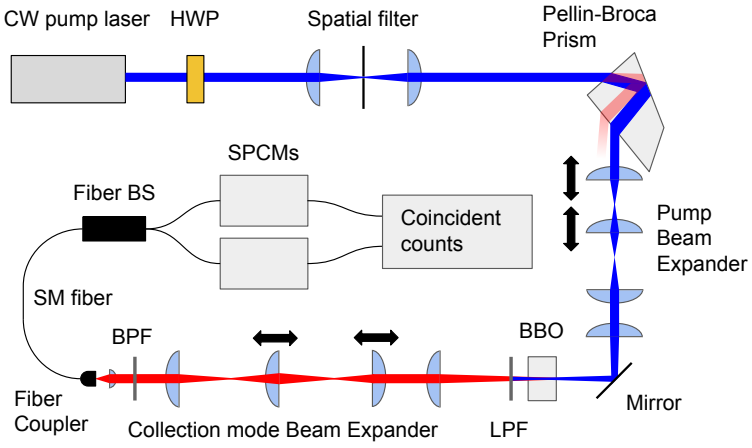

Figure 1: Experimental setup. HWP half-wave plate; LPF long-pass filter; BPF band-pass filter; BS beam splitter.

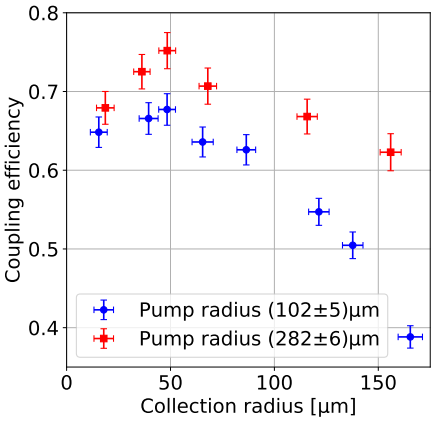

Figure 2: Measurements.

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References

[1] Dixon, P. Ben, *et al.* (2014). Phys. Rev. A 90(4), 1–9.
[2] Bennink, R. S. (2010). Phys. Rev. A 81(5), 1–10.
[3] Guilbert, H. E., *et al.* (2015). IEEE J. Sel. Top. Quant., 21(3), 215–224.
[4] Kamei, Y., *et al.* (2020). 81th JSAP Autumn Meeting, 10 Sep. 2020, 10p-Z21-1.