Tailoring Spatial Correlations in SPDC for Loophole-Free EPR Steering

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Bi-photon pairs produced by spontaneous parametric downconversion can be highly entangled in their transverse spatial/momentum degrees of freedom. This makes them a great potential resource for quantum communication, computing and imaging tasks. The precise nature of this entanglement, the correlations that can be observed from it and how they can be realised, depends intimately on the particular experimental setup, and one requires characterisation of its properties before one can design optimal means to utilise it. In this work, we present a practical means to experimentally determine the joint-transverse momentum amplitude (JTMA) of a bi-photon, which describes its entanglement, then go on to show how this information can be used to design discrete mode bases with a variety of figures of merit in mind, and present a number of such examples. We then focus on the case of optimising the one-sided heralding efficiency and present a new high-dimensional, single-detector steering inequality that permits observation of detection-loophole-free EPR steering at record low efficiencies.

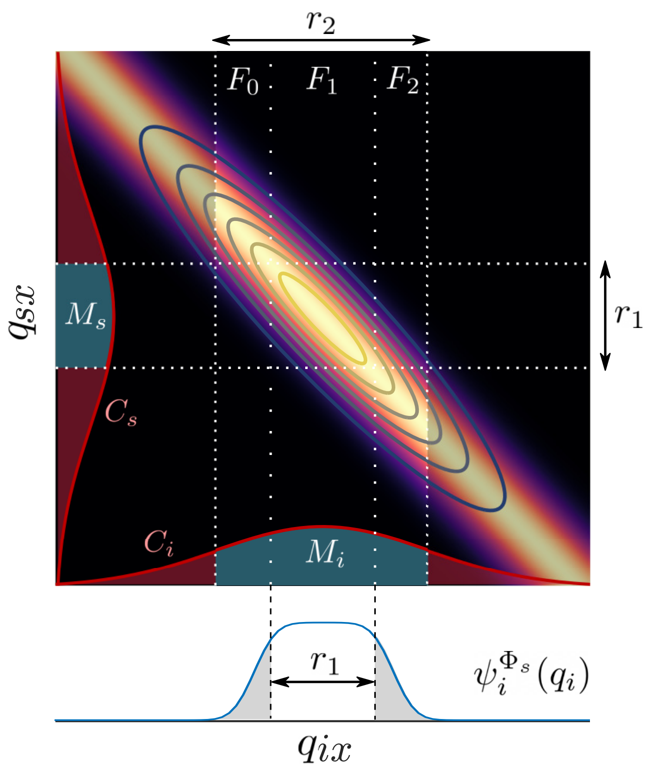

Figure 1: Heralding of the idler photon state by projection onto a signal photon. The signal photon is projected onto the measurement mode, $M_s(q_s) = \Phi_s(q_s)\mathcal{C}(q_s|\sigma_C)$ (turquoise, left axis) determined by the collection mode, $\mathcal{C}_s$ (red, left axis) and a pixel hologram Φ_s, of radius r_1. The JTMA (contours), which owing to the relative size of σ_C, can be approximated by the correlation term (density plot), dictates the resultant heralded idler photon state, $\psi_i^{\Phi_s}(q_i)$, (blue, bottom), according to Eq.**??**, which, owing to contributions from the regions F_0 and F_2 result in a width somewhat larger than r_1. For the idler measurement mode, $M_i(q_i) = \Phi_i(q_i)\mathcal{C}(q_i|\sigma_C)$ (blue region, lower plot axes) characterised by an increased pixel radius $r_2 gt; r_1$, the coincidence probability is given by the inner product, $\langle M_i, \psi^{\Phi_s}$