Photon-Number-Resolved Joint Spectral Measurement of a Spontaneous Parametric Down-Conversion Source

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In quantum photonics, spontaneous parametric down-conversion (SPDC) sources are often used to generate entangled and heralded single photons. Understanding the multimode structure and photon purity of such sources requires characterizing their spectral correlations.

In this work, we experimentally study the photon-number-resolved (PNR) joint spectral properties of a degenerate SPDC source based on a periodically poled KTP crystal pumped at 774 nm, producing photon pairs at 1548 nm. A time-of-flight spectrometer is used to characterize the SPDC source. Building on work from Gerrits et al., [1], we use four-output beam splitters placed in both signal and idler arms to measure the joint spectral intensity (JSI) for photon-number-resolved events up to four photons, as the results shown in Fig. 1. In this way, we measure coincidences of equal photon number in the signal and idler modes, correlated to their frequencies. Fig. 1 shows the measured JSIs become gradually narrower and circular with increasing photon number. For photon numbers n = 2, 3, 4 the JSI plots include data points corresponding to all possible combinations of signal and idler photons for the respective photon-number cases. We will further discuss how the effective Schmidt number decreases, while the spectral purity increases with photon number. Our results indicate that, for a fixed pump power and spectrum, conditioning on higher photon-number events can produce photons with higher spectral purity than conditioning on lower events.

The results show that photon-number-resolved spectral measurements offer deeper insight into the multimode structure of SPDC sources and provide a pathway toward the generation of highly pure photons for quantum photonic technologies.

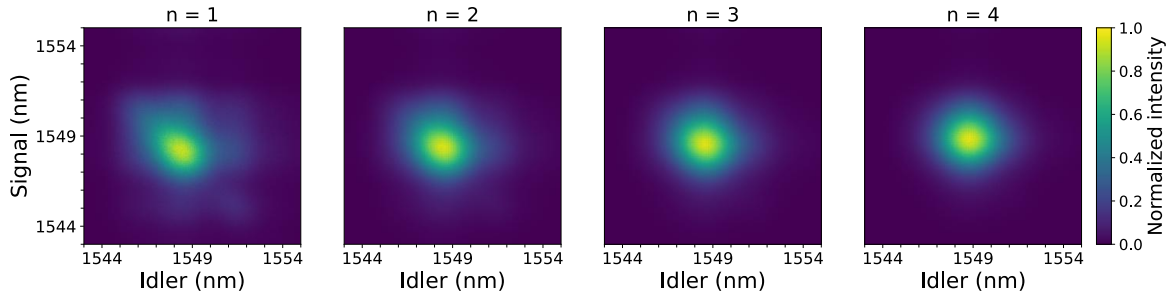

Fig. 1: *JSI of the SPDC source for n = 1, 2, 3, 4 photon events, where the spectral distribution gradually becomes narrower and more circular as the photon number n increases, leading to generation of highly pure photons. As an example, for the n = 2 case, we plot all possible combinations* i_1 - s_1, i_1 - s_2, i_2 - s_1, i_2 - s_2.

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Reference

[1] Gerrits et al., CLEO: 2014, Optica Publishing Group, paper JTu4A.35