Spatiotemporal mode isolation in SPDC using a pulse-pumped triply resonant cavity

Chenqi Qian, Rory Hatfield, Thomas Cumming, Rob Gardner, Mengbo Long, Steve Kolthammer

Blackett Laboratory, Department of Physics, Imperial College London,

Prince Consort Rd, London, SW7 2AZ, United Kingdom

Delivering highly squeezed light in an isolated temporal mode to single-mode fibre networks is a key requirement for myriad quantum photonic applications. High levels of squeezing have primarily been achieved using cavity-enhanced or guided-wave SPDC with continuous-wave pumping, while temporal mode purity has required broadband, pulsed pumping. Combining these concepts has enabled high modal purity of single-mode squeezing from a doubly resonant cavity, where spectral filtering is used to attenuate contributions from other cavity longitudinal modes [1]. In our work, we extend this concept to two-mode squeezing in a triply resonant cavity [2]. For this arrangement, we leverage birefringence to suppress unwanted cavity longitudinal modes and demonstrate that temporal mode purity is controlled by the pump pulse duration.

We present a plano-concave resonator built from a coated KTP crystal, poled for type-II PDC, and a separate mirror on a piezoelectric mount. Cavity resonances for a pump field at 780 nm and cross-polarized frequency-degenerate signal and idler fields at 1560 nm have respective linewidths of 200 MHz and 120 MHz and corresponding finesses of 74 and 140. Simultaneous resonance of a unique set of cavity modes for the three fields is achieved via control of the crystal temperature and mirror position. Contributions from other pairs of cavity modes for the signal and idler fields, including higher-order transverse spatial modes, are suppressed due to the cavity geometry and birefringence, following a similar use of dispersion [3]. Temporal mode isolation in SPDC is achieved by using a pump resonance linewidth and pulse bandwidth greater than the signal and idler resonance linewidths.

To quantify the multimode character of the SPDC, we measure the marginal second-order intensity autocorrelation $g^{(2)}$ and joint temporal intensity of the two fields, showing how these depend on a pump duration varying from 50 to 1 ns. These data show an effective mode number varying from 7 to 1.3, in agreement with theoretical expectations. These findings align with recent work in a doubly resonant monolithic cavity without a resonant pump field [4].

Funding acknowledgement
C.Q., R.H. and T.C. are supported by the UK Engineering and Physical Sciences Research Council (EPSRC) Doctoral Training Partnership. S.K. is supported by the EPSRC UK Quantum Technologies Programme grant EP/Z53318X/1.

**chenqi.qian19@imperial.ac.uk*

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