Characterization of single photon frequency comb generated by stimulated parametric down conversion

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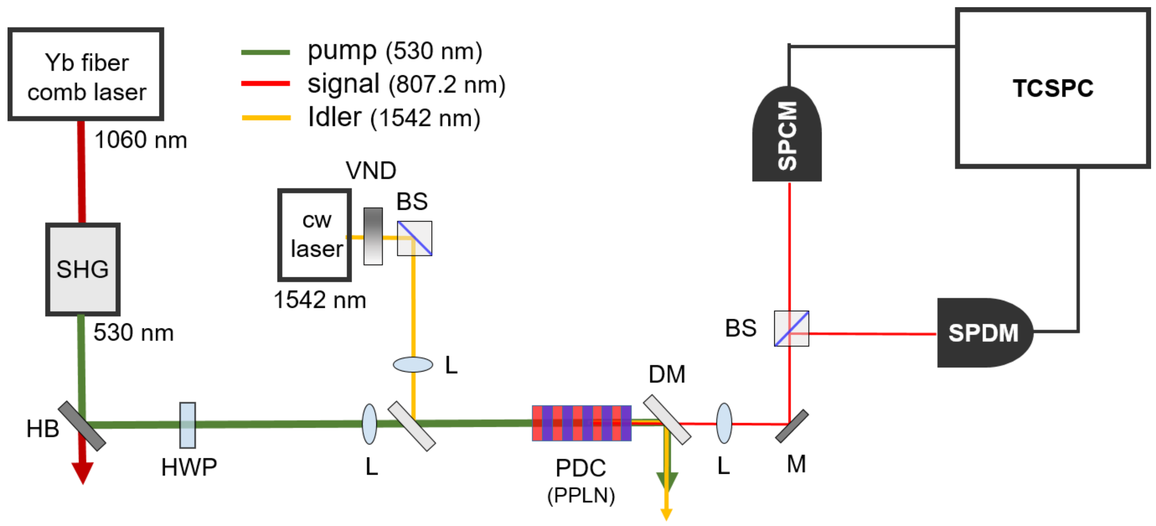
Abstract

Recently, we demonstrated frequency comb single-photon interferometry in an unheralded manner, which provided an attractive platform for quantum technological development. In this work, the characteristics and the second order correlation functions of the generated signal photons obtained by one nonlinear crystal were estimated by measuring the RF spectrum and the time-tagged data of TCSPC. The generated signal photons with unique properties were investigated by measuring the optical bandwidth and the linewidth of individual comb tooth. Furthermore, because there was continuous wave ultra-narrow seed laser for stimulated parametric down conversion (StPDC), the second order correlation functions ($g^{(2)}(\tau)$) were obtained as a function of seed power with the unheralded way.

Experimental set-up



frequency comb technology + quantum optical measurement

the single-photon emission efficiency is very low

the multi-photon generation can be ignored

By making the photon statistics of the idler fields indistinguishable, a coherent laser at the idler field frequency was injected without heralding idler detection

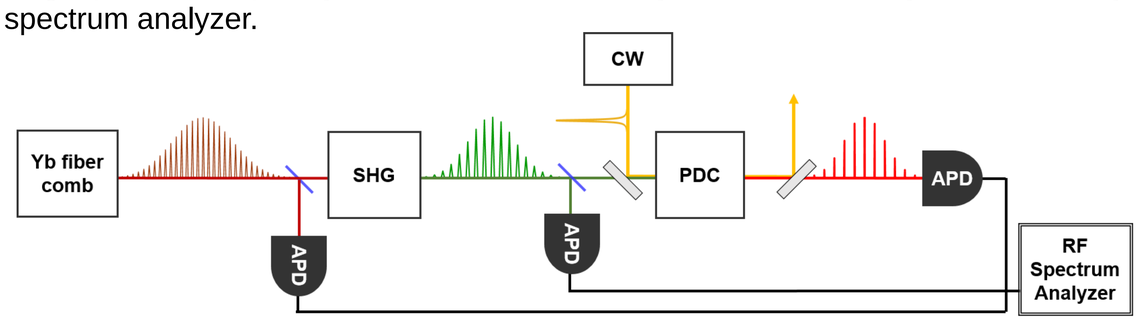
RF spectrum analyzer the characteristics of signal photons

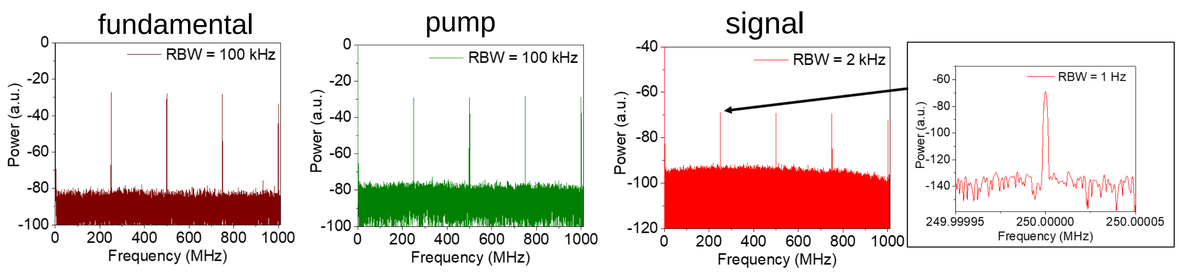
HBT measurement the second order correlation function ($g^{(2)}(\tau)$)

quantum imaging and spectroscopy with undetected photons

Frequency comb structure of signal photons

To confirm the comb structure of signal photon generated by StPDC in frequency domain, the optical bandwidth and the linewidth of individual comb tooth of the signal single-photon frequency comb from PPLN crystal were directly measured by RF spectrum analyzer.



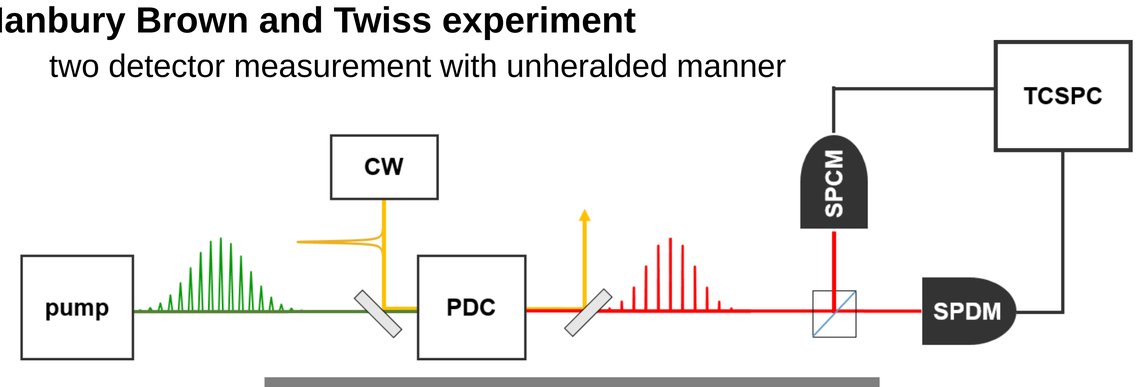


The measured optical linewidth was measured to be 1 Hz, which was five orders of magnitude narrower than that of the pump frequency comb (~200 kHz). It is induced by the stimulated emission process in the StPDC crystal with our exceptionally narrow (1Hz) CW seed laser.

$g^{(2)}$ function measurement

Hanbury Brown and Twiss experiment

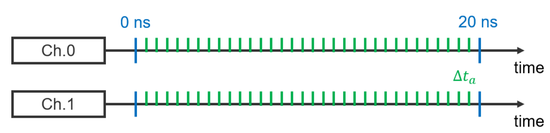
two detector measurement with unheralded manner



the second order correlation function

$$g^2(\tau) = \frac{\langle I(t_1)\cdot I(t_1+\tau)\rangle}{\langle I(t_1)\rangle\langle I(t_1+\tau)\rangle} \Rightarrow g^2(\tau=0) \approx \alpha = \frac{\eta_1\eta_2 P_{12}}{\eta_1 P_1 \eta_2 P_2} = \frac{P_{12}}{P_1 P_2}$$

1. relative arrival time in specific period



$$P_1 = R_1\Delta t = \left(\frac{N_1}{\Delta T}\right)\Delta t$$

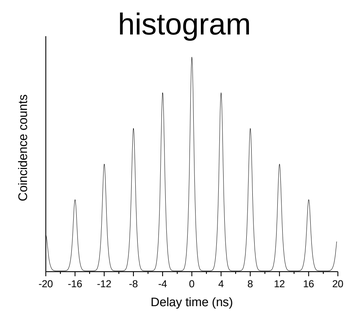
$$P_2 = R_2\Delta t = \left(\frac{N_2}{\Delta T}\right)\Delta t$$

$$P_{12} = R_{12}\Delta t = \left(\frac{N_{12}}{\Delta T}\right)\Delta t$$

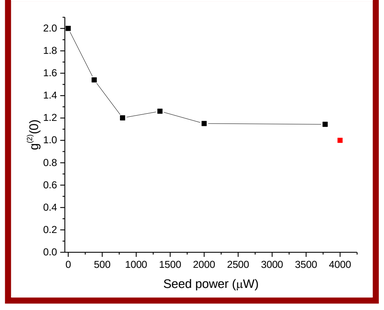
$$g^2(\tau) = \frac{N_{12}}{N_1 N_2}\left(\frac{\Delta T}{\Delta t}\right)$$

$$\boldsymbol{g^2(\tau) = \frac{N_{12}(\tau)\times P(\tau)}{N_1 \times P(\tau)\times N_2 \times P(\tau)}\left(\frac{\Delta T}{\Delta t}\right)}$$

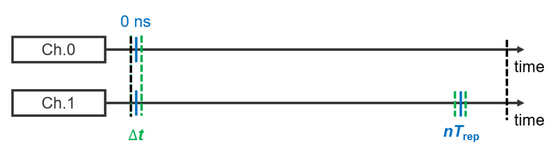
histogram



seed power dependence



2. absolute arrival time in measurement time

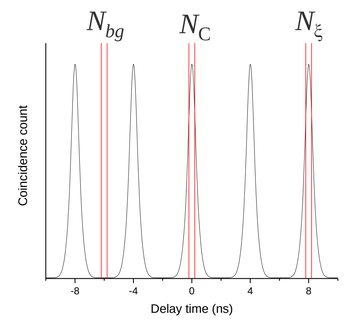


$$N_C - N_{bg}$$

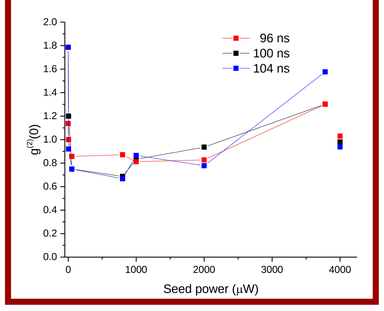
$$\alpha_{exp} = \frac{N_C - N_{bg}}{N_\xi - N_{bg}}$$

$$N_C = \sum_{i=-k_\omega/2}^{k_\omega/2} N_i \qquad N_\xi = \sum_{i=T-k_\omega/2}^{T+k_\omega/2} N_i$$

background coincidences (N_{bg})
true coincidences (N_C)
accidental coincidences (N_ξ)
the number of bins (k_ω) corresponding to the chosen coincidence window ω



seed power dependence



the second order correlation functions were measured by the Hanbury Brown and Twiss experiment. Although our single photon source could not be detected by heralded configuration, because of our CW seed laser, the two detectors measurement of signal photons was applied to estimate the second order correlation function. As observing the $g^{(2)}(0)$ of signal photons depended on the injection of seed laser, we investigate the properties of single party of two mode squeezed coherent state. The time-tagged data were measured as a function of the power of seed laser. In this respect, the estimated values of $g^{(2)}(0)$ were shown the dependence on the power of seed laser, which suggested that the properties of detected photons could be changed by seed laser **from coherent state to squeezed vacuum state.**

Acknowledgements

This work was supported by IBS-R023-D1