Controlling frequency correlations and biphoton statistics in a semiconductor photonic chip

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Nonclassical states of light are key components in quantum information science; in this domain, the maturity of semiconductor technology offers high potential in terms of ultra-compact devices including the generation, manipulation and detection of photonic quantum bits. Among the different resources under development, on-chip entangled photon sources play a central role for applications spanning quantum communications, computing and metrology [1]. The technological maturity and optoelectronic capabilities of III-V materials make them an ideal platform to develop integrated quantum light sources. In particular, employing a transverse pump geometry enables a high control on the frequency correlations of the emitted states, hardly achievable in a collinear geometry [2].
In this work, we demonstrate that tailoring the spatial profile of the pump beam in intensity and phase enables the control of the frequency correlations and the symmetry properties of the spectral wavefunction, without post-manipulation. Fig. 1b reports the joint spectrum of the biphoton state emitted by an AlGaAs ridge waveguide under transverse pump illumination, measured through stimulated emission tomography [3]. Using a spatial light modulator, we add a phase shift between the two halves of the pump beam, leading to a progressive splitting of the joint spectrum into two distinct lobes as the amplitude of the phase shift increases. These results enable the study of new effects linked to the parity control of the biphoton wavefunction. For example, Fig 1c) reports the simulation of the result expected in a Hong-Ou-Mandel experiment performed with the biphoton states presented in Fig 1b). The coincidence probabilities feature a clear change from a bunching behavior, typical of bosonic statistics, to an anti-bunching behavior, typical of fermionic statistics. These findings, confirmed by preliminary experimental results, open interesting perspectives for the utilization of our platform to perform quantum simulation of fermionic and bosonic statistics by simple frequency correlation engineering of photon pairs [4].

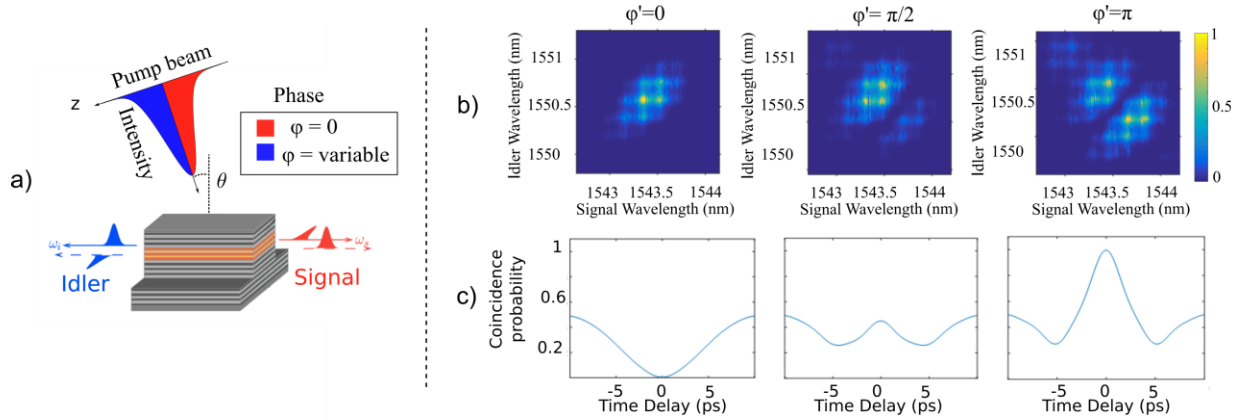

Figure 1: a) Sketch of the working principle of the device under transverse pump illumination; b) experimentally measured joint spectrum for different values of the phase shift imposed to the pump beam; c) numerical simulations showing the corresponding two-photon interference expected in a Hong-Ou-Mandel experiment.

References

[1] A. Orieux et al., "Semiconductors devices for entangled photons generation: a review", Rep. Prog. Phys. 80, 076001 (2017).
[2] X. Caillet et al., "A semiconductor source of counterpropagating twin photons: A versatile device allowing the control of the two-photon state", Journal of Modern Optics (2009).
[3] A. Eckstein et al., "High-resolution spectral characterization of two photon states via classical measurements", Laser and Photonics Reviews (2014).
[4] S. Francesconi et al., in preparation.