Generation and manipulation of hyper-entangled frequency combs in an AlGaAs chip

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The development of miniaturized chips for the generation, manipulation and detection of entangled states of light is one of the key issue on the way towards a large diffusion of quantum information technologies. Among different platforms AlGaAs presents a strong case for integrability thanks to its compliance with electrical injection, allowing to monolithically integrate active and passive components [1], and to its large electro-optic effect that can be exploited for the manipulation of photonic states. In these last years, a growing attention has been devoted to increasing the dimensionality of quantum entanglement as a means to enable high-capacity and robust quantum information protocols [2]. An interesting way to achieve a large Hilbert space is by using hyperentangled states where each degree of freedom can be expanded in more than two dimensions. This allows to dispose of high dimensional states and to use one of the entangled degree of freedom to control the other(s), thus leading to the engineering of a large variety of quantum states. In this work we present an AlGaAs waveguide emitting hyper-entangled photon pairs displaying a frequency comb-like spectrum through spontaneous parametric down conversion. We demonstrate, using a Hong-Ou-Mandel setup, that the fine tuning of the pump frequency controls the biphoton spatial wavefunction to obtain either bosonic or fermionic symmetry. Our source emits two-photon states in the telecom range at room temperature with a generation rate of 2,37 MHz and a SNR up to 5×10^4. The dispersion properties of the devices, combined to energy and momentum conservation, lead to the generation of photon pairs which are hyper-entangled in polarization and frequency. Moreover, the facets reflectivity creates a Fabry-Perot cavity, thus leading to a comb-like spectrum spanning several tens of nanometers. Figure 1 (a) shows a zoom of the measured joint spectral intensity presenting a strong frequency anti-correlation with peaks spaced of around 20 GHz. In Figure 1 (b, c, d) we present the results of a Hong-Ou-Mandel experiment around the zero-time delay (b) and for a time delay corresponding to the half of the cavity roundtrip (c, d). The central dip has a visibility of 85% and a width corresponding to a biphoton bandwidth of around 150nm; this excludes the generation of a frequency-correlated classical mixed state or of a quantum-classical mixed state. In Fig 1c-d, we show how the fine tuning of the pump frequency switches the interference signal form bunching (c) to anti-bunching (d) [3]. These results demonstrate the ability of our chip to generate and manipulate hyper-entangled high-dimensional entangled states and open the way to its utilisation in a large variety of quantum information protocols.

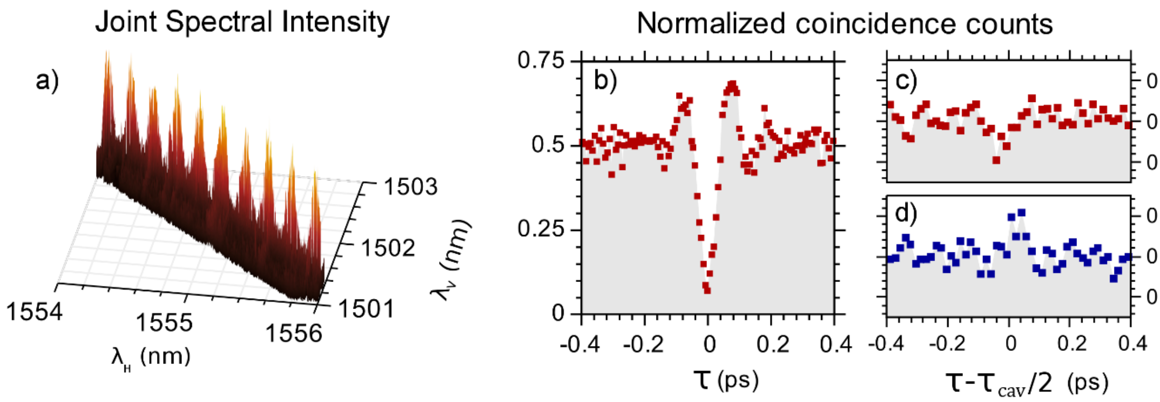

Figure 1: Characterization of the biphoton state emitted by our device: measurements of the Joint Spectral Intensity (a), HOM interference at zero delay (b) and for a time delay corresponding to the half of the cavity roundtrip for two different values of the pump beam frequency (c,d).

References

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