On-demand source of entangled photon-pairs using the biexciton-exciton radiative cascade

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Abstract: We show that pairs of photons resulting from the radiative cascade of the confined biexciton are maximally entangled. The measured entanglement depends on the resolution by which the time between the pair emissions is determined.
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The ability to generate entangled photons on-demand is crucial for many future applications in quantum information processing. Devices based on the biexciton-exciton radiative cascade in single semiconductor quantum dot are considered to be one of the best candidates for these applications [1-3]. The ability to deterministically excite the biexciton using its two-photon absorption resonance [4] makes this avenue even more promising. A remaining challenge, however, is the excitonic fine structure, which splits the two exciton eigenstates thus providing spectral "which-path" information on the radiative cascade and preventing the pairs of emitted photons from being polarization entangled [2].

We present a novel study of a planar microcavity embedded single semiconductor quantum dot, optically depleted and then resonantly excited on-demand by a π-area pulse to the biexciton two photon absorption resonance[4]. The resulting pairs of biexciton and exciton photons are detected by two superconducting detectors synchronized to the exciting laser pulse. By performing time resolved polarization tomography of the two emitted photons, we show that the photons remain maximally polarization entangled during the whole radiative decay.
Our measurements provide simple ways for using a single quantum dot with a non-vanishing excitonic fine structure splitting as a reliable and high fidelity source of on-demand pairs of polarization entangled photons [5].

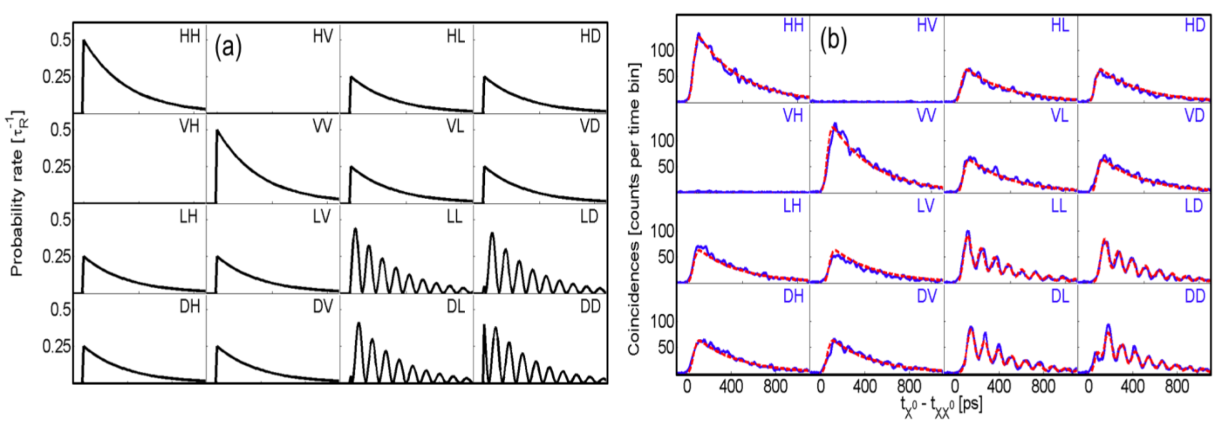

Fig. 1 Sixteen different polarization sensitive two photon detection coincidences as a function of the time difference between the detection of the first and second photon. Solid black lines in (a) represent the best fitted calculated probability rates, with the exciton radiative time (420ps) as the only fitting parameter. Solid blue lines in (b) represent the measured coincidences rates, and solid red lines in (b) represent the calculated probability rates from (a) convolved by the measured system temporal response (of full width at half maximum of 42ps). The first (second) capital letter above each curve represents the polarization on which the biexciton (exciton) photon was projected.

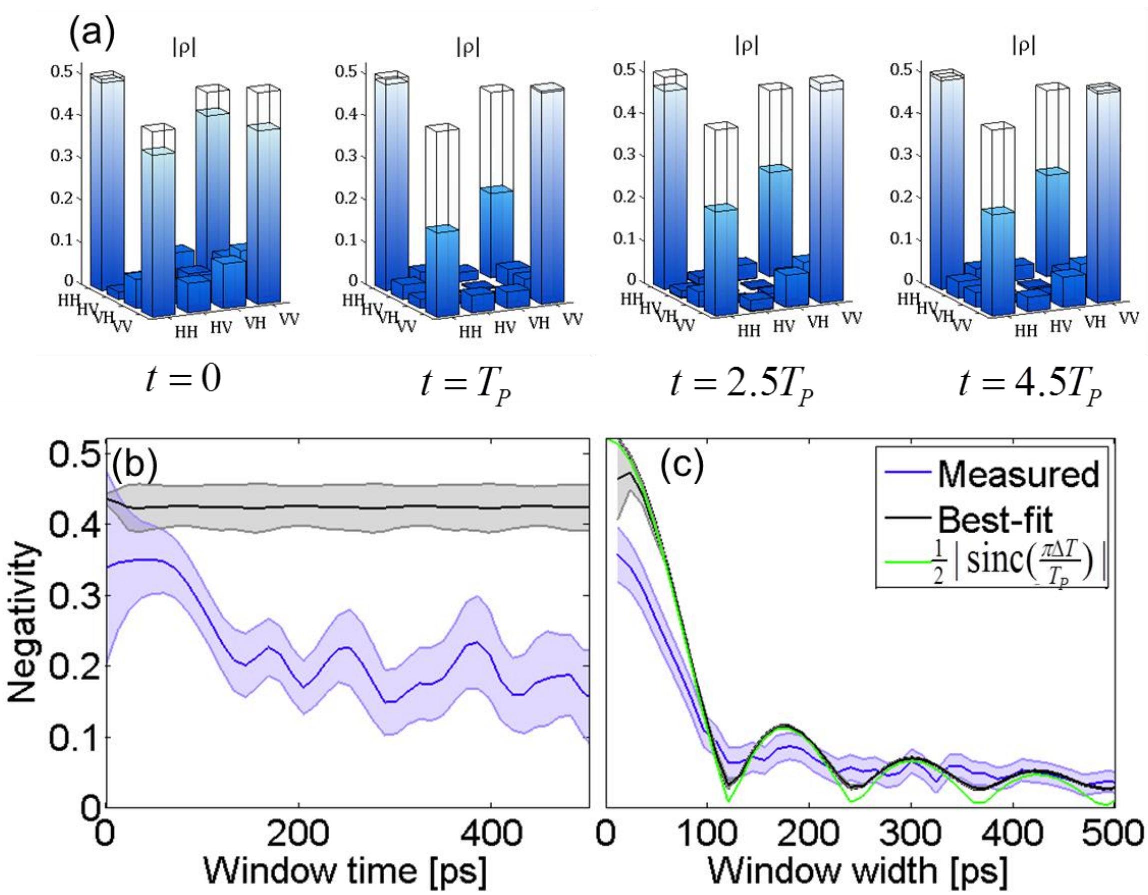

Fig. 2 (a) the absolute value of the two photon polarization density matrix for various times after the detection of the biexciton photon. Blue bars represent matrix elements obtained directly from the measured data, while empty bars represent matrix elements deduced from the fitted calculations, which consider the measured temporal response of the detectors. In both cases the temporal window width over which the data is integrated was set to ΔT =24ps. (b) The negativity of the two photon polarization density matrix as a function of the time difference between the exciton and biexciton detection times for temporal window width of ΔT =24ps. The negativity measures the degree of entanglement between the two photons and 0.5 indicates maximally entangled pair. Blue line presents the negativity deduced directly from the measured raw data. Black line presents the negativity deduced from the fitted calculations considering the system response. Shaded areas with corresponding colors represent uncertainties of one standard deviation. (c) The negativity of the two photons polarization density matrix as a function of the temporal window width, ΔT. Blue line presents the negativity deduced directly from the measured raw data. Black line presents the negativity deduced by considering the system response. The theoretical dependence, which simply yields $N\left[\rho_{2P}(\Delta T)\right]=\frac{1}{2}|\operatorname{sinc}(\pi\Delta T/T_P)|$ is represented by the green solid line. Here $N\left[\rho_{2P}\right]$ is the negativity of the measured two photons polarization density matrix and $T_P = h/\Delta = 122\text{ps}$ is the exciton precession time, h is the Planck constant and $\Delta = 34\mu\text{eV}$ is the excitonic fine structure splitting.

4. References

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