# High Purcell Factor Generation of Coherent On-Chip Single Photons

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In this work we use a novel double π-pulse resonance fluorescence (DPRF) technique to demonstrate a record-short radiative lifetime ($T_1$) of 22.7 ps for a QD-nanocavity system [1]. A waveguide efficiently coupled to the cavity (~41 %) allows our device to function as a near-ideal *on-chip* single photon source (SPS) exhibiting high purity and indistinguishability. Both experiments and simulations probe the photon statistics of the emission. In particular, we find that the pulse duration ($\tau_L$) and separation ($T_{rep}$) are both critical for high SPS performance.

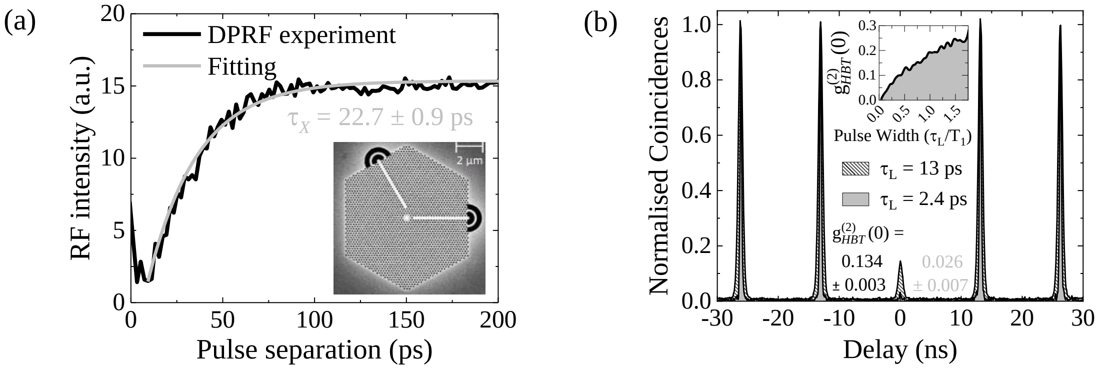

Figure 1: (a) DPRF signal versus pulse separation. An exponential fit (grey line) gives $T_1$ = 22.7 ps. Inset: SEM image of an H1 PhCC coupled to W1 waveguides. (b) Hanbury Brown & Twiss second-order correlation function ($g^{(2)}_{HBT}(t)$) measurements of single photon purity for $\tau_L$ = 13 ps (hatched fill) and $\tau_L$ = 2.4 ps (solid grey fill). Inset: Simulated $g^{(2)}_{HBT}(0)$ as a function of $\tau_L/T_1$.

Fig. 1 (a) illustrates a DPRF measurement of $T_1$ = 22.7 ps when the QD is resonant with the cavity mode. As the separation between the π-pulses is scanned, the RF signal recovers exponentially with $T_1$. If the pulse separation is too short, the second pulse arrives before radiative recombination occurs and instead drives a coherent rotation to the ground state with no emission, setting a lower bound on $T_{rep}$. Simulations show that at $T_{rep} = 5T_1$ the probability of emitting two subsequent single photons is 99.3 % of its maximum value, indicating the potential to drive the source at excitation repetition rates approaching 10 GHz. As well as determining the source brightness, this also determines the delay required for demultiplexing subsequent photons. For our device, $5T_1$ is sufficiently short for on-chip delay lines, paving the way to on-chip multiplexing for fully-integrated quantum optical circuits.

The influence of pulse duration is simulated in the inset to Fig. 1 (b). When $\tau_L$ is comparable to $T_1$, there is a significant probability that radiative recombination occurs during the pulse and that the QD may then be re-excited by the same pulse. This multi-photon emission rapidly degrades the single photon purity ($g^{(2)}_{HBT}(0)$). In agreement with this interpretation, Fig. 1 (b) shows a reduction in $g^{(2)}_{HBT}(0)$ from 0.134 to 0.026 by reducing $\tau_L$ from 13 ps to 2.4 ps. Hong-Ou-Mandel (HOM) measurements show that the raw two photon interference (TPI) visibility is also degraded by the same mechanism when increasing $\tau_L$. These measurements also reveal the existence of a modest degradation of TPI visibility on a timescale of tens of nanoseconds, attributed to spectral wandering due to charge fluctuations at nearby interfaces. For $\tau_L$ = 2.4 ps and using a relatively broad grating spectral filter, TPI visibilities > 90 % are achieved on a timescale in which 20 photons may be emitted, underlining the potential of the system as a platform for fully-integrated on-chip quantum optics.

## References

[1] F. Liu, A. J. Brash, J. O'Hara et al. *arXiv:1706.04422* (2017)