Quantum non-linear optics with a quantum dot in a nano-photonic waveguide: Influence of the Fano effect on photon statistics

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The Fano effect arises due to interference between a resonant scattering process and a background continuum. We demonstrate this effect in the transmission of a single-mode nano-photonic waveguide containing a single quantum dot (QD). We show control of the transmitted-photon statistics as a function of detuning between the QD resonance and a coherent probe laser, and measure a system-record bunching of 2.22±0.08 at the point of minimum waveguide transmission.

Our device consists of a single QD located in a slow light photonic crystal waveguide connected to input and output nanobeam waveguides (Fig. 1a). Typically, a QD in such a waveguide acts as a reflective element for resonant single photons [1]. In our current device, strong reflection at waveguide interfaces leads to Fabry-Perot modes in the waveguide, i.e. a background continuum. We therefore observe a Fano lineshape in transmission (line, Fig. 1b). At the transmission minimum (normalized transmission ~0.4), strong bunching of the transmitted laser field is observed, due to preferential reflection of single photons by the QD and the transmission of two-photon bound states (points, Fig. 1b, and Fig. 1c). Conversely, antibunching of the field is observed near the transmission maximum (normalized transmission ~1.6), as single photons are preferentially transmitted and two photon states reflected (Fig. 1d). This is the first experimental demonstration of the tuning of photon statistics using a QD and Fano resonance.

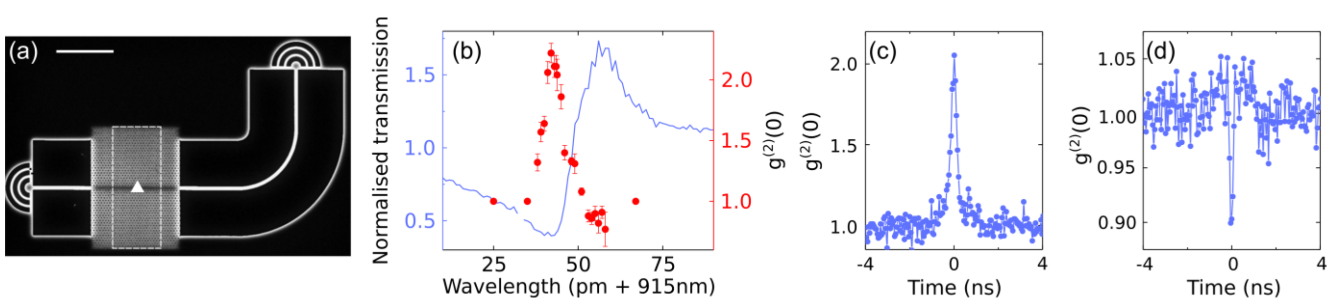

Fig. 1. (a) Scanning electron microscope image of the device. The QD (triangle) is embedded in a GaAs slow light photonic crystal waveguide (PhCWG - dashed rectangle). Nanobeam waveguides on either side of the PhCWG are terminated with Bragg grating couplers for light in- and out-coupling. Scale bar 5µm. (b) Normalised waveguide transmission (line) and second order autocorrelation at zero time delay (points) as a function of wavelength. (c) Second order autocorrelation at a probe wavelength of 915.042nm, showing bunching of 2.22±0.08. (d) Second order autocorrelation at a probe wavelength of 915.053nm, showing antibunching of 0.88±0.05.

References

[1] D. Hallett et al., Optica 5, 5 644 (2018)