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Organisations

Postdoc, Department of Photonics Engineering  
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VIP

Nanophotonics Theory and Signal Processing  
30/01/2014 → 15/02/2016 Former  
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Publications:

Driving-induced population trapping and linewidth narrowing via the quantum Zeno effect
We investigate the suppression of spontaneous emission from a driven three-level system embedded in an optical cavity  
via a manifestation of the quantum Zeno effect. Strong resonant coupling of the lower two levels to an external optical field  
results in a decrease of the decay rate of the third upper level. We show that this effect has observable consequences in  
the form of emission spectra with subnatural linewidths, which should be measurable using, for example, quantum dot- 
cavity systems in currently obtainable parameter regimes, and may find use in applications requiring the control of single- 
photon arrival times and wave-packet extent. These results suggest an underappreciated link between the Zeno effect,  
dressed states, and Purcell enhancement.

General information
State: Published  
Organisations: Department of Photonics Engineering, Nanophotonics Theory and Signal Processing, Technical University  
of Denmark  
Authors: Christensen, C. N. (Ekstern), Iles-Smith, J. (Intern), Petersen, T. S. (Ekstern), Mørk, J. (Intern), McCutcheon, D.  
P. S. (Intern)  
Number of pages: 5  
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Web of Science (2017): Indexed yes
Scopus rating (2016): CiteScore 2.25 SJR 1.482 SNIP 0.985  
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Web of Science (2016): Indexed yes
Scopus rating (2015): SJR 1.747 SNIP 1.008 CiteScore 2.06  
Web of Science (2015): Impact factor 2.765  
Web of Science (2015): Indexed yes
Scopus rating (2014): SJR 2.201 SNIP 1.163 CiteScore 2.46  
Web of Science (2014): Indexed yes
Scopus rating (2013): SJR 2.305 SNIP 1.166 CiteScore 2.86  
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
Scopus rating (2012): SJR 2.519 SNIP 1.231 CiteScore 2.81
Intrinsic and environmental effects on the interference properties of a high-performance quantum dot single-photon source

We report a joint experimental and theoretical study of the interference properties of a single-photon source based on an In(Ga)As quantum dot embedded in a quasiplanar GaAs microcavity. Using resonant laser excitation with a pulse separation of 2 ns, we find near-perfect interference of the emitted photons, and a corresponding indistinguishability of $I = (99.6 \pm 0.4 - 1.4)\%$. For larger pulse separations, quasiresonant excitation conditions, increasing pump power, or with increasing temperature, the interference contrast is progressively and notably reduced. We present a systematic study of the relevant dephasing mechanisms and explain our results in the framework of a microscopic model of our system. For strictly resonant excitation, we show that photon indistinguishability is independent of pump power, but strongly influenced by virtual phonon-assisted processes which are not evident in excitonic Rabi oscillations.

General information
State: Published
Organisations: Department of Photonics Engineering, Nanophotonics Theory and Signal Processing, University of Würzburg, University of Science and Technology of China
Authors: Gerhardt, S. (Ekstern), Iles-Smith, J. (Intern), McCutcheon, D. (Intern), He, Y. (Ekstern), Unsleber, S. (Ekstern), Betzold, S. (Ekstern), Gregersen, N. (Intern), Mørk, J. (Intern), Höfling, S. (Ekstern), Schneider, C. (Ekstern)
Number of pages: 10
Publication date: 2018
Main Research Area: Technical/natural sciences
A broadband tapered nanocavity for efficient nonclassical light emission

We present the design of a tapered nanocavity, obtained by sandwiching a photonic wire section between a planar gold reflector and a few-period Bragg mirror integrated into the tapered wire. Thanks to its ultrasmall mode volume ($0.71 \lambda^3/n^3$), this hybrid nanocavity largely enhances the spontaneous emission rate of an embedded quantum dot (Purcell factor: 6), while offering a wide operation bandwidth (full-width half-maximum: 20 nm). In addition, the top tapered section shapes the cavity far-field emission into a very directive output beam, with a Gaussian spatial profile. For realistic taper dimensions, a total outcoupling efficiency to a Gaussian beam of 0.8 is predicted. Envisioned applications include bright sources of non-classical states of light, such as widely tunable sources of indistinguishable single photons and polarization-entangled photon pairs.
The photonic nanowire single-photon source design approach allows for efficient broadband coupling between a quantum dot and a 1D photonic environment. In this work, we introduce weak cavity effects to the design by implementing a distributed Bragg reflector in the inverted taper. This leads to broadband enhancement of the photon emission rate with a Purcell factor of 6 over a full-width half-maximum range of 20 nm while maintaining a total outcoupling efficiency of 0.8 to a Gaussian profile.
Fundamental Limits to Coherent Scattering and Photon Coalescence from Solid-State Quantum Emitters [arXiv]

The desire to produce high-quality single photons for applications in quantum information science has lead to renewed interest in exploring solid-state emitters in the weak excitation regime. Under these conditions it is expected that photons are coherently scattered, and so benefit from a substantial suppression of detrimental interactions between the source and its phonon environment. Nevertheless, we demonstrate here that this reasoning is incomplete, and phonon interactions continue to play a crucial role in determining solid-state emission characteristics even for very weak excitation. We find that the sideband resulting from non-Markovian relaxation of the phonon environment leads to a fundamental limit to the fraction of coherently scattered light and to the visibility of two-photon coalescence at weak driving, both of which are absent for atomic systems or within simpler Markovian treatments.
Modelling exciton–phonon interactions in optically driven quantum dots: Topical Review

We provide a self-contained review of master equation approaches to modelling phonon effects in optically driven self-assembled quantum dots. Coupling of the (quasi) two-level excitonic system to phonons leads to dissipation and dephasing, the rates of which depend on the excitation conditions, intrinsic properties of the QD sample, and its temperature. We describe several techniques, which include weak-coupling master equations that are perturbative in the exciton–phonon coupling, as well as those based on the polaron transformation that can remain valid for strong phonon interactions. We additionally consider the role of phonons in altering the optical emission characteristics of quantum dot devices, outlining how we must modify standard quantum optics treatments to account for the presence of the solid-state environment.

General information

State: Published
Organisations: Department of Photonics Engineering, Nanophotonics Theory and Signal Processing, University of Manchester
Authors: Nazir, A. (Ekstern), McCutcheon, D. (Intern)
Number of pages: 26
Publication date: 2016
Optical signatures of non-Markovian behavior in open quantum systems

We derive an extension to the quantum regression theorem which facilitates the calculation of two-time correlation functions and emission spectra for systems undergoing non-Markovian evolution. The derivation exploits projection operator techniques, with which we obtain explicit equations of motion for the correlation functions, making only a second-order expansion in the system-environment coupling strength and invoking the Born approximation at a fixed initial time. The results are used to investigate a driven semiconductor quantum dot coupled to an acoustic phonon bath, where we find the non-Markovian nature of the dynamics has observable signatures in the form of phonon sidebands in the resonance fluorescence emission spectrum. Furthermore, we use recently developed non-Markovianity measures to demonstrate an associated flow of information from the phonon bath back into the quantum dot exciton system.

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Organisations: Department of Photonics Engineering
Authors: McCutcheon, D. (Intern)
Number of pages: 7
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Web of Science (2016): Indexed yes
Scopus rating (2015): SJR 1.747 SNIP 1.008 CiteScore 2.06
Web of Science (2015): Impact factor 2.765
Few-photon Non-linearities in Nanophotonic Devices for Quantum Information Technology

In this thesis we investigate few-photon non-linearities in all-optical, on-chip circuits, and we discuss their possible applications in devices of interest for quantum information technology, such as conditional two-photon gates and single-photon sources. In order to propose efficient devices, it is crucial to fully understand the non-equilibrium dynamics of strongly interacting photons. Employing both numerical and analytical approaches we map out the full scattering dynamics for two photons scattering on a two-level emitter in a one-dimensional waveguide. The strongest non-linear interaction arise when the emitter is excited the most, which occurs for incoming photon pulses with a spectral bandwidth comparable to the emitter linewidth. For two identical, counter-propagating photons, the emitter works as a non-linear beam splitter, as the emitter induces strong directional correlations between the scattered photons. Even though the non-linearity also alters the pulse spectrum due to a four-wave mixing process, we demonstrate that input pulses with a Gaussian spectrum can be mapped to the output with up to 80 % fidelity. Using two identical two-level emitters, we propose a setup for a deterministic controlled-phase gate, which preserves the properties of the two incoming photons with almost 80 %, limited by spectral changes induced by the non-linearity and phase modulations upon scattering. Another setup for a controlled-
phase operation is suggested with two coupled ring resonators exploiting a strong second-order material non-linearity. By dynamically trapping the first of two temporally separated photons in the non-linear resonator, the scattering of the second photon is altered. Due to the trapping, the undesired aforementioned non-linear effects are avoided, but the gate performance is now limited by the capturing process. Semiconductor quantum dots (QDs) are promising for realizing few-photon non-linearities in solid-state implementations, although coupling to phonon modes in the surrounding lattice have significant influence on the dynamics. By accounting for the commonly neglected asymmetry between the electron and hole wavefunction in the QD, we show how the phonon-assisted transition rate to a slightly detuned optical mode may be suppressed. This is achieved by properly matching the electrical carrier confinement with the deformation potential interaction, where the suppression only occurs in materials where the deformation potential interaction shifts the electron and hole bands in the same direction. We demonstrate also how the phonon-induced effects may be altered by placing the QD inside an infinite slab, where the confinement of the phonons is modified instead. For a slab thickness below ~70 nm, the bulk description of the phonon modes may be insufficient. The QD decay rate may be strongly increased or decreased, depending on how the detuning between the QD and the optical mode matches the phonon modes in the slab.

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Organisations: Department of Photonics Engineering, Nanophotonics Theory and Signal Processing
Authors: Nysteen, A. (Intern), Mørk, J. (Intern), Kristensen, P. T. (Intern), McCutcheon, D. (Intern), Nielsen, P. K. (Intern)
Number of pages: 172
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Highly indistinguishable photons from a QD-microcavity with a large Purcell-factor
We demonstrate the emission of highly indistinguishable photons from a quasi-resonantly pumped coupled quantum dot-microcavity system operating in the weak coupling regime. Furthermore we model the degree of indistinguishability with our novel microscopic theory.

General information
State: Published
Organisations: Department of Photonics Engineering, Nanophotonics Theory and Signal Processing, Department of Micro- and Nanotechnology, University of Wurzburg
Authors: Unsleber, S. (Ekstern), McCutcheon, D. (Intern), Dambach, M. (Ekstern), Lermer, M. (Ekstern), Gregersen, N. (Intern), Hofling, S. (Ekstern), Mørk, J. (Intern), Schneider, C. (Ekstern), Kamp, M. (Ekstern)
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Integrated optics, micro-optics, microcavities, optical couplers, optical pumping, quantum dots, quantum optics, General Topics for Engineers, Photonics and Electrooptics, highly indistinguishable photons, indistinguishability, large Purcell-factor, microscopic theory, Optical interferometry, Optical refraction, Optical variables control, photon emission, Photonics, QD-microcavity, Quantum dot lasers, Quantum dots, quasiresonantly pumped coupled quantum dot-microcavity system, Semiconductor device measurement, weak coupling regime
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Observation of resonance fluorescence and the Mollow triplet from a coherently driven site-controlled quantum dot

Resonant excitation of solid state quantum emitters has the potential to deterministically excite a localized exciton while ensuring a maximally coherent emission. In this work, we demonstrate the coherent coupling of an exciton localized in a lithographically positioned, site-controlled semiconductor quantum dot to an external resonant laser field. For strong continuous-wave driving we observe the characteristic Mollow triplet and analyze the Rabi splitting and sideband widths as a function of driving strength and temperature. The sideband widths increase linearly with temperature and the square of the driving strength, which we explain via coupling of the exciton to longitudinal acoustic phonons. We also find an increase of the Rabi splitting with temperature, which indicates a temperature induced delocalization of the excitonic wave function resulting in an increase of the oscillator strength. Finally, we demonstrate coherent control of the exciton excited state population via pulsed resonant excitation and observe a damping of the Rabi oscillations with increasing pulse area, which is consistent with our exciton-photon coupling model. We believe that our work outlines the possibility to implement fully scalable platforms of solid state quantum emitters. The latter is one of the key prerequisites for more advanced, integrated nanophotonic quantum circuits.

Scattering of two photons on a quantum emitter in a one-dimensional waveguide: exact dynamics and induced correlations
We develop a wavefunction approach to describe the scattering of two photons on a quantum emitter embedded in a one-dimensional waveguide. Our method allows us to calculate the exact dynamics of the complete system at all times, as well as the transmission properties of the emitter. We show that the nonlinearity of the emitter with respect to incoming photons depends strongly on the emitter excitation and the spectral shape of the incoming pulses, resulting in transmission of the photons which depends crucially on their separation and width. In addition, for counter-propagating pulses, we analyze the induced level of quantum correlations in the scattered state, and we show that the emitter behaves as a nonlinear beam-splitter when the spectral width of the photon pulses is similar to the emitter decay rate.

**General information**

State: Published  
Organisations: Department of Photonics Engineering, Nanophotonics Theory and Signal Processing  
Authors: Nysteen, A. (Intern), Kristensen, P. T. (Intern), McCutcheon, D. (Intern), Nielsen, P. K. (Intern), Mørk, J. (Intern)  
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Scopus rating (2017): CiteScore 3.28 SJR 1.653 SNIP 1.102  
Web of Science (2017): Impact factor 3.579  
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BFI (2016): BFI-level 2  
Scopus rating (2016): CiteScore 2.97 SJR 2.183 SNIP 1.173  
Web of Science (2016): Impact factor 3.786  
Web of Science (2016): Indexed yes  
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Scopus rating (2015): SJR 2.33 SNIP 1.157 CiteScore 2.8  
Web of Science (2015): Impact factor 3.57  
Web of Science (2015): Indexed yes  
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Web of Science (2014): Indexed yes  
BFI (2013): BFI-level 2  
Scopus rating (2013): SJR 2.87 SNIP 1.352 CiteScore 2.77  
Web of Science (2013): Impact factor 3.671  
ISI indexed (2013): ISI indexed yes  
Web of Science (2013): Indexed yes  
BFI (2012): BFI-level 2  
Scopus rating (2012): SJR 3.368 SNIP 1.517 CiteScore 3.4  
Web of Science (2012): Impact factor 4.063  
ISI indexed (2012): ISI indexed yes  
Web of Science (2012): Indexed yes  
BFI (2011): BFI-level 2  
Scopus rating (2011): SJR 3.489 SNIP 1.626 CiteScore 3.99  
Web of Science (2011): Impact factor 4.177  
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Web of Science (2011): Indexed yes  
BFI (2010): BFI-level 2  
Scopus rating (2010): SJR 3.405 SNIP 1.415
We analytically treat the scattering of two counterpropagating photons on a two-level emitter embedded in an optical waveguide. We find that the nonlinearity of the emitter can give rise to significant pulse-dependent directional correlations in the scattered photonic state, which could be quantified via a reduction in coincidence clicks in a Hong–Ou–Mandel measurement setup, analogous to a linear beam splitter. Changes to the spectra and phase of the scattered photons, however, would lead to reduced interference with other photons when implemented in a larger optical circuit. We introduce suitable fidelity measures which account for these changes and find that high values can still be achieved even when accounting for all properties of the scattered photonic state.

**Strong nonlinearity-induced correlations for counterpropagating photons scattering on a two-level emitter**

We analytically treat the scattering of two counterpropagating photons on a two-level emitter embedded in an optical waveguide. We find that the nonlinearity of the emitter can give rise to significant pulse-dependent directional correlations in the scattered photonic state, which could be quantified via a reduction in coincidence clicks in a Hong–Ou–Mandel measurement setup, analogous to a linear beam splitter. Changes to the spectra and phase of the scattered photons, however, would lead to reduced interference with other photons when implemented in a larger optical circuit. We introduce suitable fidelity measures which account for these changes and find that high values can still be achieved even when accounting for all properties of the scattered photonic state.

**General information**

State: Published
Organisations: Department of Photonics Engineering, Nanophotonics Theory and Signal Processing
Authors: Nysteen, A. (Intern), McCutcheon, D. (Intern), Mørk, J. (Intern)
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Web of Science (2015): Impact factor 2.765
Web of Science (2015): Indexed yes
Scopus rating (2014): SJR 2.201 SNIP 1.163 CiteScore 2.46
Web of Science (2014): Indexed yes
Scopus rating (2013): SJR 2.305 SNIP 1.166 CiteScore 2.86
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
Scopus rating (2012): SJR 2.519 SNIP 1.231 CiteScore 2.81
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
Scopus rating (2011): SJR 2.316 SNIP 1.252 CiteScore 2.79
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
Scopus rating (2010): SJR 2.4 SNIP 1.211
Web of Science (2010): Indexed yes
Scopus rating (2009): SJR 2.469 SNIP 1.346
Web of Science (2009): Indexed yes
Scopus rating (2008): SJR 2.536 SNIP 1.231
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 2.524 SNIP 1.203
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 1.834 SNIP 0.968
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 1.394 SNIP 0.806
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 1.473 SNIP 0.714
Web of Science (2004): Indexed yes
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Web of Science (2003): Indexed yes
Scopus rating (2002): SJR 2.066 SNIP 1.098
Web of Science (2002): Indexed yes
Scopus rating (2001): SJR 1.949 SNIP 1.356
Web of Science (2001): Indexed yes
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Web of Science (2000): Indexed yes
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Two-photon interference from a quantum dot-microcavity: Persistent pure-dephasing and suppression of time-jitter

We demonstrate the emission of highly indistinguishable photons from a quasi-resonantly pumped coupled quantum dot–microcavity system operating in the regime of cavity quantum electrodynamics. Changing the sample temperature allows us to vary the quantum dot–cavity detuning and, on spectral resonance, we observe a threefold improvement in the Hong-Ou-Mandel interference visibility, reaching values in excess of 80%. Our measurements off-resonance allow us to investigate varying Purcell enhancements, and to probe the dephasing environment at different temperatures and energy scales. By comparison with our microscopic model, we are able to identify pure dephasing and not time jitter as the dominating source of imperfections in our system.

General information
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Authors: Unsleber, S. (Ekstern), McCutcheon, D. (Intern), Dambach, M. (Ekstern), Lermer, M. (Ekstern), Gregersen, N. (Intern), Hofling, S. (Ekstern), Mørk, J. (Intern), Schneider, C. (Ekstern), Kamp, M. (Ekstern)
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Main Research Area: Technical/natural sciences

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BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 3.44 SJR 1.604 SNIP 1.04
Web of Science (2017): Impact factor 3.813
Web of Science (2017): Indexed yes
Scopus rating (2016): CiteScore 3.16 SJR 2.339 SNIP 1.151
Web of Science (2016): Impact factor 3.836
Web of Science (2016): Indexed yes
Scopus rating (2015): SJR 2.377 SNIP 1.13 CiteScore 2.8
Web of Science (2015): Impact factor 3.718
Web of Science (2015): Indexed yes
Scopus rating (2014): SJR 2.762 SNIP 1.316 CiteScore 3.3
Web of Science (2014): Impact factor 3.736
Web of Science (2014): Indexed yes
Scopus rating (2013): SJR 2.813 SNIP 1.326 CiteScore 3.55
Web of Science (2013): Impact factor 3.664
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
Scopus rating (2012): SJR 3.173 SNIP 1.378 CiteScore 3.57
Web of Science (2012): Impact factor 3.767
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
Scopus rating (2011): SJR 3.326 SNIP 1.423 CiteScore 3.61
Web of Science (2011): Impact factor 3.691
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
Scopus rating (2010): SJR 3.318 SNIP 1.447
Web of Science (2010): Impact factor 3.774
Web of Science (2010): Indexed yes
Two-photon interference from a quantum dot-microcavity: Persistent pure-dephasing and suppression of time-jitter

We demonstrate the emission of highly indistinguishable photons from a quasiresonantly pumped coupled quantum dot–microcavity system operating in the regime of cavity quantum electrodynamics. Changing the sample temperature allows us to vary the quantum dot–cavity detuning, and on spectral resonance we observe a three-fold improvement in the Hong–Ou–Mandel interference visibility, reaching values in excess of 80%. By comparison with our microscopic model, we are able to identify pure-dephasing and not time-jitter as the dominating source of imperfections in our system.

General information
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Organisations: Department of Photonics Engineering, Nanophotonics Theory and Signal Processing, University of Würzburg, Universität Würzburg
Authors: Unsleber, S. (Ekstern), McCutcheon, D. (Intern), Dambach, M. (Ekstern), Lermer, M. (Ekstern), Gregersen, N. (Intern), Hofing, S. (Ekstern), Schneider, C. (Ekstern), Kamp, M. (Ekstern)
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Main Research Area: Technical/natural sciences
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Source-ID: 110307131
Publication: Research - peer-review › Paper – Annual report year: 2015

Error Distributions on Large Entangled States with Non-Markovian Dynamics

We investigate the distribution of errors on a computationally useful entangled state generated via the repeated emission from an emitter undergoing strongly non-Markovian evolution. For emitter-environment coupling of pure-dephasing form, we show that the probability of a particular pattern of errors occurs has a bound of Markovian form, and thus, accuracy threshold theorems based on Markovian models should be just as effective. Beyond the pure-dephasing assumption, though complicated error structures can arise, they can still be qualitatively bounded by a Markovian error model.

General information
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Organisations: Department of Photonics Engineering, Nanophotonics Theory and Signal Processing, Technion-Israel Institute of Technology, Imperial College London
Indistinguishable photons from a quantum dot–cavity system: competing roles of timing-jitter and pure-dephasing

General information
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Organisations: Department of Photonics Engineering, Nanophotonics Theory and Signal Processing, University of Wurzburg
Authors: McCutcheon, D. (Intern), Gregersen, N. (Intern), Mørk, J. (Intern), Unsleben, S. (Ekstern), Dambach, M. (Ekstern), Lermer, M. (Ekstern), Höfling, S. (Ekstern), Schneider, C. (Ekstern), Kamp, M. (Ekstern)
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Indistinguishable single photons generated by quantum dots in adiabatic micropillar cavities

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Authors: Unsleber, S. (Ekstern), McCutcheon, D. (Intern), Dambach, M. (Ekstern), Lermer, M. (Ekstern), Gregersen, N. (Intern), Höfling, S. (Ekstern), Mørk, J. (Intern), Schneider, C. (Ekstern), Kamp, M. (Ekstern)
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Temperature-Dependent Mollow Triplet Spectra from a Single Quantum Dot: Rabi Frequency Renormalization and Sideband Linewidth Insensitivity

We investigate temperature-dependent resonance fluorescence spectra obtained from a single self-assembled quantum dot. A decrease of the Mollow triplet sideband splitting is observed with increasing temperature, an effect we attribute to a phonon-induced renormalization of the driven dot Rabi frequency. We also present first evidence for a nonperturbative regime of phonon coupling, in which the expected linear increase in sideband linewidth as a function of temperature is canceled by the corresponding reduction in Rabi frequency. These results indicate that dephasing in semiconductor quantum dots may be less sensitive to changes in temperature than expected from a standard weak-coupling analysis of phonon effects.
Two-photon interference from a quantum dot-microcavity: Persistent pure-dephasing and suppression of time-jitter

General information
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Authors: Unsleber, S. (Ekstern), McCutcheon, D. (Intern), Dambach, M. (Ekstern), Lermer, M. (Ekstern), Gregersen, N. (Intern), Hofling, S. (Ekstern), Merk, J. (Intern), Schneider, C. (Ekstern), Kamp, M. (Ekstern)
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Projects:

Nanophotonic devices for quantum information technology
Department of Photonics Engineering
Period: 15/02/2012 → 18/06/2015
Number of participants: 8
Phd Student:
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**Financing sources**
Source: Internal funding (public)
Name of research programme: Institut stipendie (DTU)

**Relations**
Publications:
**Few-photon Non-linearities in Nanophotonic Devices for Quantum Information Technology**
Project: PhD