

Cover Page



Universiteit Leiden



The handle <http://hdl.handle.net/1887/67538> holds various files of this Leiden University dissertation.

**Author:** Snijders, H.J.

**Title:** Quantum dot microcavity control of photon statistics

**Issue Date:** 2018-12-20

# Bibliography

- [1] Reiserer, A. & Rempe, G. Cavity-based quantum networks with single atoms and optical photons. *Reviews of Modern Physics* **87**, 1379 (2015).
- [2] Somaschi, N., Giesz, V., De Santis, L., Loredo, J. C., Almeida, M. P., Hornecker, G., Portalupi, S. L., Grange, T., Antón, C., Demory, J., Gómez, C., Sagnes, I., Lanzillotti-Kimura, N. D., Lemaître, A., Auffeves, A., White, A. G., Lanco, L. & Senellart, P. Near-optimal single-photon sources in the solid state. *Nature Photonics* **10**, 340 (2016).
- [3] Ding, X., He, Y., Duan, Z.-C., Gregersen, N., Chen, M.-C., Unsleber, S., Maier, S., Schneider, C., Kamp, M., Höfling, S., Lu, C.-Y. & Pan, J.-W. On-Demand Single Photons with High Extraction Efficiency and Near-Unity Indistinguishability from a Resonantly Driven Quantum Dot in a Micropillar. *Physical Review Letters* **116**, 020401 (2016).
- [4] Snijders, H., Frey, J. A., Norman, J., Post, V. P., Gossard, A. C., Bowers, J. E., van Exter, M. P., Löffler, W. & Bouwmeester, D. Fiber-Coupled Cavity-QED Source of Identical Single Photons. *Physical Review Applied* **9**, 031002 (2018).
- [5] Snijders, H., Frey, J. A., Norman, J., Bakker, M. P., Langman, E. C., Gossard, A., Bowers, J. E., Van Exter, M. P., Bouwmeester, D. & Löffler, W. Purification of a single-photon nonlinearity. *Nature Communications* **7**, 12578 (2016).
- [6] Leonard, D., Krishnamurthy, M., Reaves, C. M., Denbaars, S. P. & Petroff, P. M. Direct formation of quantum-sized dots from uniform coherent islands of InGaAs on GaAs surfaces. *Applied Physics Letters* **63**, 3203 (1993).
- [7] Coldren, L., Corzine, S. & Milan Mašanović. *Diode Lasers and Photonic Integrated Circuits* (John Wiley & Sons, 2012), second edn.
- [8] Park, Y., Choe, J.-S. & Jeon, H. Design, fabrication, and micro-reflectance measurement of a GaAs/AlAs-oxide antireflection film. *Journal of the Korean Physical Society* **40** (2002).
- [9] Santori, C., Fattal, D., Vučković, J., Solomon, G. S. & Yamamoto, Y. Indistinguishable photons from a single-photon device. *Nature* **419**, 594 (2002).
- [10] Gerry, C. C. & Knight Peter L. *Introductory Quantum Optics* (Cambridge University Press, 2005), 3rd editio edn.

- [11] Duan, L.-M. & Monroe, C. Colloquium: Quantum networks with trapped ions. *Reviews of Modern Physics* **82**, 1209 (2010).
- [12] Gisin, N., Ribordy, G., Tittel, W. & Zbinden, H. Quantum cryptography. *Reviews of Modern Physics* **74**, 145 (2002).
- [13] Nielsen, M. & Chuang, I. *Quantum Computation and Quantum Information*, vol. 1 (Cambridge University Press, 2000).
- [14] Enk, S. J. v., Cirac, J. I. & Zoller, P. Photonic Channels for Quantum Communication. *Science* **279**, 205 (1998).
- [15] Jaynes, E. & Cummings, F. Comparison of quantum and semiclassical radiation theories with application to the beam maser. *Proc. IEEE* **51**, 89 (1963).
- [16] Tang, J., Geng, W. & Xu, X. Quantum interference induced photon blockade in a coupled single quantum dot-cavity system. *Scientific reports* **5**, 9252 (2015).
- [17] Loo, V., Arnold, C., Gazzano, O., Lemaitre, A., Sagnes, I., Krebs, O., Voisin, P., Senellart, P. & Lanco, L. Optical nonlinearity with few-photon pulses using a quantum dot-pillar cavity device. *Physical Review Letters* **109**, 166806 (2013).
- [18] Lien, Y.-H., Barontini, G., Scheucher, M., Mergenthaler, M., Goldwin, J. & Hinds, E. A. Observing coherence effects in an overdamped quantum system. *Nature Communications* **7**, 13933 (2016).
- [19] Waks, E. & Vuckovic, J. Dipole Induced Transparency in Drop-Filter Cavity-Waveguide Systems. *Physical Review Letters* **96**, 153601 (2006).
- [20] Armen, M. a. & Mabuchi, H. Low-lying bifurcations in cavity quantum electrodynamics. *Physical Review A* **73**, 063801 (2006).
- [21] Imamoglu, A., Schmidt, H., Woods, G. & Deutsch, M. Strongly Interacting Photons in a Nonlinear Cavity. *Physical Review Letters* **79**, 1467 (1997).
- [22] Kimble, H. J. The quantum internet. *Nature* **453**, 1023 (2008).
- [23] Loudon, R. *The Quantum Theory of Light (Oxford Science publications)* (Oxford University Press, USA, 1973), 3rd ed edn.
- [24] Auffèves-Garnier, A., Simon, C., Gérard, J.-M. & Poizat, J.-P. Giant optical nonlinearity induced by a single two-level system interacting with a cavity in the Purcell regime. *Physical Review A* **75**, 053823 (2007).
- [25] Braak, D., Chen, Q.-H., Batchelor, M. T. & Solano, E. Semi-classical and quantum Rabi models: in celebration of 80 years. *Journal of Physics A: Mathematical and Theoretical* **49**, 300301 (2016).
- [26] Bakker, M. P., Barve, A. V., Ruytenberg, T., Löffler, W., Coldren, L. A., Bouwmeester, D. & Van Exter, M. P. Polarization degenerate solid-state cavity quantum electrodynamics. *Physical Review B* **91**, 115319 (2015).

- [27] Bonato, C., Ding, D., Gudat, J., Thon, S., Kim, H., Petroff, P. M., van Exter, M. P. & Bouwmeester, D. Tuning micropillar cavity birefringence by laser induced surface defects. *Applied Physics Letters* **95**, 251104 (2009).
- [28] Frey, J. A., Snijders, H. J., Norman, J., Gossard, A. C., Bowers, J. E., Löffler, W. & Bouwmeester, D. Electro-optic polarization tuning of microcavities with a single quantum dot. *Optics Letters* **43**, 4280 (2018).
- [29] Antón, C., Hilaire, P., Kessler, C. A., Demory, J., Gómez, C., Lemaître, A., Sagnes, I., Lanzillotti-Kimura, N. D., Krebs, O., Somaschi, N., Senellart, P. & Lanco, L. Tomography of the optical polarization rotation induced by a single quantum dot in a cavity. *Optica* **4**, 1326 (2017).
- [30] He, Y.-M., Wang, H., Gerhardt, S., Winkler, K., Jurkat, J., Yu, Y., Chen, M.-C., Ding, X., Chen, S., Qian, J., Li, J.-P., Wang, L.-J., Huo, Y.-H., Yu, S., Lu, C.-Y. & Pan, J.-W. Polarized indistinguishable single photons from a quantum dot in an elliptical micropillar. *arXiv:1809.10992* (2018).
- [31] Warburton, R. J. Single spins in self-assembled quantum dots. *Nature Materials* **12**, 483 (2013).
- [32] Fowles, G. *Introduction to Modern Optics* (Dover Publications, New York, 1989), 2nd edn.
- [33] Bayer, M., Ortner, G., Stern, O., Kuther, A., Gorbunov, A. A., Forchel, A., Hawrylak, P., Fafard, S., Hinzer, K., Reinecke, T. L., Walck, S. N., Reithmaier, J. P., Klopff, F. & Schäfer, F. Fine structure of neutral and charged excitons in self-assembled In(Ga)As/(Al)GaAs quantum dots. *Physical Review B* **65**, 195315 (2002).
- [34] Ismail, N., Kores, C. C., Geskus, D. & Pollnau, M. Fabry-Pérot resonator: spectral line shapes, generic and related Airy distributions, linewidths, finesses, and performance at low or frequency-dependent reflectivity. *Optics Express* **24**, 16366 (2016).
- [35] Proux, R., Maragkou, M., Baudin, E., Voisin, C., Roussignol, P. & Diederichs, C. Measuring the Photon Coalescence Time Window in the Continuous-Wave Regime for Resonantly Driven Semiconductor Quantum Dots. *Physical Review Letters* **114**, 067401 (2015).
- [36] Matthiesen, C., Vamivakas, A. N. & Atatüre, M. Subnatural Linewidth Single Photons from a Quantum Dot. *Physical Review Letters* **108**, 093602 (2012).
- [37] Johansson, J., Nation, P. & Nori, F. QuTiP: An open-source Python framework for the dynamics of open quantum systems. *Computer Physics Communications* **183**, 1760 (2012).
- [38] Johansson, J. R., Nation, P. D. & Nori, F. QuTiP 2: A Python framework for the dynamics of open quantum systems. *Computer Physics Communications* **184**, 1234 (2013).

- [39] Larson, J. Absence of Vacuum Induced Berry Phases without the Rotating Wave Approximation in Cavity QED. *Physical Review Letters* **108**, 033601 (2012).
- [40] Michler, P. *Single Quantum Dots. Fundamentals, Applications, and New concepts* (Springer, 2011), topics in edn.
- [41] Schliwa, A., Winkelkemper, M. & Bimberg, D. Impact of size, shape, and composition on piezoelectric effects and electronic properties of InGaAs quantum dots. *Physical Review B* **76**, 205324 (2007).
- [42] van Kesteren, H. W., Cosman, E. C., van der Poel, W. A. J. A. & Foxon, C. T. Fine structure of excitons in type-II GaAs/AlAs quantum wells. *Physical Review B* **41**, 5283 (1990).
- [43] Bayer, M., Stern, O., Kuther, A. & Forchel, A. Spectroscopic study of dark excitons in InGaAs self-assembled quantum dots by a magnetic-field-induced symmetry breaking. *Physical Review B* **61**, 7273 (2000).
- [44] Löffler, W. *Electrical preparation of spin-polarized electrons in semiconductor quantum dots*. Ph.D. thesis, University of Karlsruhe, Karlsruhe (2008).
- [45] Xu, X., Wu, Y., Sun, B., Huang, Q., Cheng, J., Steel, D. G., Bracker, A. S., Gammon, D., Emary, C. & Sham, L. J. Fast spin state initialization in a singly charged InAs-GaAs quantum dot by optical cooling. *Physical review letters* **99**, 097401 (2007).
- [46] Cortez, S., Krebs, O., Laurent, S., Senes, M., Marie, X., Voisin, P., Ferreira, R., Bastard, G., Gérard, J.-M. & Amand, T. Optically Driven Spin Memory in  $n$ -Doped InAs-GaAs Quantum Dots. *Physical Review Letters* **89**, 207401 (2002).
- [47] Hu, C. Y., Munro, W. J., O'Brien, J. L. & Rarity, J. G. Proposed entanglement beam splitter using a quantum-dot spin in a double-sided optical microcavity. *Physical Review B* **80**, 205326 (2009).
- [48] Atatüre, M. Quantum-Dot Spin-State Preparation with Near-Unity Fidelity. *Science* **312**, 551 (2006).
- [49] Stockill, R., Le Gall, C., Matthiesen, C., Huthmacher, L., Clarke, E., Hugues, M. & Atatüre, M. Quantum dot spin coherence governed by a strained nuclear environment. *Nature Communications* **7**, 12745 (2016).
- [50] Bechtold, A., Li, F., Müller, K., Simmet, T., Ardel, P. L., Finley, J. J. & Sinitsyn, N. A. Quantum Effects in Higher-Order Correlators of a Quantum-Dot Spin Qubit. *Physical Review Letters* **117**, 1 (2016).
- [51] Huthmacher, L., Stockill, R., Clarke, E., Hugues, M., Le Gall, C. & Atatüre, M. Coherence of a dynamically decoupled quantum-dot hole spin. *Physical Review B* **97** (2018).
- [52] Minář, J., Söyler, Ş. G. & Lesanovsky, I. Non-equilibrium dynamics of a nonlinear Jaynes–Cummings model in cavity arrays. *New Journal of Physics* **18**, 053035 (2016).

- [53] Lugiato, L. A., Mandel, P. & Narducci, L. M. Adiabatic elimination in nonlinear dynamical systems. *Physical Review A* **29**, 1438 (1984).
- [54] Bonato, C., Haupt, F., Oemrawsingh, S. S. R., Gudat, J., Ding, D., van Exter, M. P. & Bouwmeester, D. CNOT and Bell-state analysis in the weak-coupling cavity QED regime. *Physical Review Letters* **104**, 160503 (2010).
- [55] Imamoglu, A., Awschalom, D. D., Burkard, G., DiVincenzo, D. P., Loss, D., Sherwin, M. & Small, A. Quantum Information Processing Using Quantum Dot Spins and Cavity QED. *Physical Review Letters* **83**, 4204 (1999).
- [56] Kubanek, A., Ourjoumtsev, A., Schuster, I., Koch, M., Pinkse, P. W. H., Murr, K. & Rempe, G. Two-Photon Gateway in One-Atom Cavity Quantum Electrodynamics. *Physical Review Letters* **101**, 203602 (2008).
- [57] Birnbaum, K. M., Boca, A., Miller, R., Boozer, A. D., Northup, T. E. & Kimble, H. J. Photon blockade in an optical cavity with one trapped atom. *Nature* **436**, 87 (2005).
- [58] Dayan, B., Parkins, A. S., Aoki, T., Ostby, E. P., Vahala, K. J. & Kimble, H. J. A Photon Turnstile Dynamically Regulated by One Atom. *Science* **319**, 1062 (2008).
- [59] Schuster, I., Kubanek, A., Fuhrmanek, A., Puppe, T., Pinkse, P. W. H., Murr, K. & Rempe, G. Nonlinear spectroscopy of photons bound to one atom. *Nature Physics* **4**, 382 (2008).
- [60] Kasprzak, J., Reitzenstein, S., Muljarov, E. A., Kistner, C., Schneider, C., Strauss, M., Höfling, S., Forchel, A. & Langbein, W. Up on the Jaynes–Cummings ladder of a quantum-dot/microcavity system. *Nature Materials* **9**, 304 (2010).
- [61] Faraon, A., Majumdar, A. & Vučković, J. Generation of nonclassical states of light via photon blockade in optical nanocavities. *Physical Review A* **81**, 033838 (2010).
- [62] Faraon, A., Fushman, I., Englund, D., Stoltz, N., Petroff, P. & Vučković, J. Coherent generation of non-classical light on a chip via photon-induced tunnelling and blockade. *Nature Physics* **4**, 859 (2008).
- [63] Muñoz, C. S., Del Valle, E., Tudela, A. G., Müller, K., Lichtmannecker, S., Kaniber, M., Tejedor, C., Finley, J. J. & Laussy, F. P. Emitters of N-photon bundles. *Nature Photonics* **8**, 550 (2014).
- [64] del Valle, E., Gonzalez-Tudela, A., Laussy, F. P., Tejedor, C. & Hartmann, M. J. Theory of Frequency-Filtered and Time-Resolved N-Photon Correlations. *Physical Review Letters* **109**, 183601 (2012).
- [65] Majumdar, A., Bajcsy, M. & Vučković, J. Probing the ladder of dressed states and nonclassical light generation in quantum-dot–cavity QED. *Physical Review A* **85**, 041801 (2012).
- [66] Müller, K., Rundquist, A., Fischer, K. A., Sarmiento, T., Lagoudakis, K. G., Ke-laïta, Y. A., Sánchez Muñoz, C., Del Valle, E., Laussy, F. P. & Vučković, J. Coherent generation of nonclassical light on chip via detuned photon blockade. *Physical Review Letters* **114**, 233601 (2014).

- [67] Reinhard, A., Volz, T., Winger, M., Badolato, A., Hennessy, K. J., Hu, E. L. & Imamoglu, A. Strongly correlated photons on a chip. *Nature Photonics* **6**, 93 (2012).
- [68] Rundquist, A., Bajcsy, M., Majumdar, A., Sarmiento, T., Fischer, K., Lagoudakis, K. G., Buckley, S., Piggott, A. Y. & Vučković, J. Nonclassical higher-order photon correlations with a quantum dot strongly coupled to a photonic-crystal nanocavity. *Physical Review A* **90**, 023846 (2014).
- [69] McNeil, K. J. & Walls, D. F. Possibility of observing enhanced photon bunching from two photon emission. *Physics Letters A* **51**, 233 (1975).
- [70] Yoshie, T., Scherer, A., Hendrickson, J., Khitrova, G., Gibbs, H. M., Rupper, G., Ell, C., Shchekin, O. B. & Deppe, D. G. Vacuum Rabi splitting with a single quantum dot in a photonic crystal nanocavity. *Nature* **432**, 200 (2004).
- [71] Reithmaier, J. P., Sek, G., Löffler, A., Hofmann, C., Kuhn, S., Reitzenstein, S., Keldysh, L. V., Kulakovskii, V. D., Reinecke, T. L. & Forchel, A. Strong coupling in a single quantum dot-semiconductor microcavity system. *Nature* **432**, 197 (2004).
- [72] Arnold, C., Demory, J., Loo, V., Lemaître, A., Sagnes, I., Glazov, M., Krebs, O., Voisin, P., Senellart, P. & Lanco, L. Macroscopic rotation of photon polarization induced by a single spin. *Nature Communications* **6**, 6236 (2015).
- [73] Strauf, S., Stoltz, N. G., Rakher, M. T., Coldren, L. A., Petroff, P. M. & Bouwmeester, D. High-frequency single-photon source with polarization control. *Nature Photonics* **1**, 704 (2007).
- [74] Bakker, M. P., Barve, A. V., Zhan, A., Coldren, L. A., van Exter, M. P. & Bouwmeester, D. Polarization degenerate micropillars fabricated by designing elliptical oxide apertures. *Applied Physics Letters* **104**, 151109 (2014).
- [75] Coldren, L. A., Thibeault, B. J., Hegblom, E. R., Thompson, G. B. & Scott, J. W. Dielectric apertures as intracavity lenses in vertical-cavity lasers. *Applied Physics Letters* **68**, 313 (1996).
- [76] Gardiner, C. & Zoller, P. *Quantum Noise* (Springer, 2004).
- [77] Carmichael, H. J. Photon Antibunching and Squeezing for a Single Atom in a Resonant Cavity. *Physical Review Letters* **55**, 2790 (1985).
- [78] Rice, P. R. & Carmichael, H. J. Single-atom cavity-enhanced absorption. I. Photon statistics in the bad-cavity limit. *IEEE Journal of Quantum Electronics* **24**, 1351 (1988).
- [79] Vogel, W. Homodyne correlation measurements with weak local oscillators. *Physical Review A* **51**, 4160 (1995).
- [80] Schulte, C. H. H., Hansom, J., Jones, A. E., Matthiesen, C., Le Gall, C. & Atatüre, M. Quadrature squeezed photons from a two-level system. *Nature* **525**, 222 (2015).

- [81] Giesz, V., Somaschi, N., Hornecker, G., Grange, T., Reznichenko, B., De Santis, L., Demory, J., Gomez, C., Sagnes, I., Lemaître, A., Krebs, O., Lanzillotti-Kimura, N. D., Lanco, L., Auffèves, A. & Senellart, P. Coherent manipulation of a solid-state artificial atom with few photons. *Nature Communications* **7** (2016).
- [82] Laussy, F. P., del Valle, E., Schrapp, M., Laucht, A. & Finley, J. J. Climbing the Jaynes - Cummings ladder by photon counting. *Journal of Nanophotonics* **6**, 061803 (2012).
- [83] Illes, E., Roy, C. & Hughes, S. Spectral multiphoton effects and quantum anharmonicities in dissipative cavity-QED systems via off-resonant coherent excitation. *Optica* **2**, 689 (2015).
- [84] Snijders, H. J., Frey, J. A., Norman, J., Flayac, H., Savona, V., Gossard, A. C., Bowers, J. E., van Exter, M. P., Bouwmeester, D. & Löffler, W. Observation of the Unconventional Photon Blockade. *Physical Review Letters* **121**, 043601 (2018).
- [85] Milburn, G. J. Quantum optical Fredkin gate. *Physical Review Letters* **62**, 2124 (1989).
- [86] Senellart, P., Solomon, G. & White, A. High-performance semiconductor quantum-dot single-photon sources. *Nature Nanotechnology* **12**, 1026 (2017).
- [87] Lang, C., Bozyigit, D., Eichler, C., Steffen, L., Fink, J. M., Abdumalikov, A. A., Baur, M., Filipp, S., Da Silva, M. P., Blais, A. & Wallraff, A. Observation of resonant photon blockade at microwave frequencies using correlation function measurements. *Physical Review Letters* **106** (2011).
- [88] Hoffman, A. J., Srinivasan, S. J., Schmidt, S., Spietz, L., Aumentado, J., Türeci, H. E. & Houck, A. A. Dispersive photon blockade in a superconducting circuit. *Physical Review Letters* **107** (2011).
- [89] Dousse, A., Lanco, L., Suffczyński, J., Semenova, E., Miard, A., Lemaître, A., Sagnes, I., Roblin, C., Bloch, J. & Senellart, P. Controlled Light-Matter Coupling for a Single Quantum Dot Embedded in a Pillar Microcavity Using Far-Field Optical Lithography. *Physical Review Letters* **101** (2008).
- [90] Santis, L. D., Antón, C., Reznichenko, B., Somaschi, N., Coppola, G., Senellart, J., Gómez, C., Lemaître, A., Sagnes, I., White, A. G., Lanco, L., Auffèves, A. & Senellart, P. A solid-state single-photon filter. *Nature Nanotechnology* **12**, 663 (2017).
- [91] Bamba, M., Imamoğlu, A., Carusotto, I. & Ciuti, C. Origin of strong photon antibunching in weakly nonlinear photonic molecules. *Physical Review A* **83**, 021802 (2011).
- [92] Liew, T. C. H. & Savona, V. Single Photons from Coupled Quantum Modes. *Physical Review Letters* **104**, 183601 (2010).
- [93] Flayac, H. & Savona, V. Unconventional photon blockade. *Physical Review A* **96**, 053810 (2017).



- [94] Flayac, H. & Savona, V. Input-output theory of the unconventional photon blockade. *Physical Review A* **88**, 033836 (2013).
- [95] Liew, T. C. H. & Savona, V. Single photons from coupled quantum modes : supplementary information. *Physical Review Letters* **2**, 1 (2010).
- [96] Gerace, D. & Savona, V. Unconventional photon blockade in doubly resonant microcavities with second-order nonlinearity. *Physical Review A* **89** (2014).
- [97] Majumdar, A., Bajcsy, M., Rundquist, A. & Vučković, J. Loss-Enabled Sub-Poissonian Light Generation in a Bimodal Nanocavity. *Physical Review Letters* **108**, 183601 (2012).
- [98] Verger, A., Ciuti, C. & Carusotto, I. Polariton quantum blockade in a photonic dot. *Physical Review B - Condensed Matter and Materials Physics* **73** (2006).
- [99] Wang, C., Liu, Y.-X. Y.-L., Wu, R. & Liu, Y.-X. Y.-L. Phase-modulated photon antibunching in a two-level system coupled to two cavities. *Physical Review A* **96**, 013818 (2017).
- [100] Lemonde, M.-A., Didier, N. & Clerk, A. A. Antibunching and unconventional photon blockade with Gaussian squeezed states. *Physical Review A* **90**, 063824 (2014).
- [101] Vaneph, C., Morvan, A., Aiello, G., Féchant, M., Aprili, M., Gabelli, J. & Estève, J. Observation of the Unconventional Photon Blockade in the Microwave Domain. *Physical Review Letters* **121**, 043602 (2018).
- [102] Flayac, H. & Savona, V. Single photons from dissipation in coupled cavities. *Physical Review A - Atomic, Molecular, and Optical Physics* **94**, 1 (2016).
- [103] Vogel, W. Squeezing and anomalous moments in resonance fluorescence. *Physical Review Letters* **67**, 2450 (1991).
- [104] Kim, J., Benson, O., Kan, H. & Yamamoto, Y. A single-photon turnstile device. *Nature* **397**, 500 (1999).
- [105] Knill, E., Laflamme, R. & Milburn, G. J. A scheme for efficient quantum computation with linear optics. *Nature* **409**, 46 (2001).
- [106] Kok, P., Munro, W. J., Nemoto, K., Ralph, T. C., Dowling, J. P. & Milburn, G. J. Linear optical quantum computing with photonic qubits. *Reviews of Modern Physics* **79**, 135 (2007).
- [107] Varnava, M., Browne, D. E. & Rudolph, T. How Good Must Single Photon Sources and Detectors Be for Efficient Linear Optical Quantum Computation? *Physical Review Letters* **100**, 060502 (2008).
- [108] O'Brien, J. L., Furusawa, A. & Vučković, J. Photonic quantum technologies. *Nature Photonics* **3**, 687 (2009).
- [109] Aspuru-Guzik, A. & Walther, P. Photonic quantum simulators. *Nature Physics* **8**, 285 (2012).

- [110] He, Y.-M., Liu, J., Maier, S., Emmerling, M., Gerhardt, S., Davanço, M., Srinivasan, K., Schneider, C. & Höfling, S. Deterministic implementation of a bright, on-demand single-photon source with near-unity indistinguishability via quantum dot imaging. *Optica* **4**, 802 (2017).
- [111] Gazzano, O., Michaelis de Vasconcellos, S., Arnold, C., Nowak, A., Galopin, E., Sagnes, I., Lanco, L., Lemaître, A. & Senellart, P. Bright solid-state sources of indistinguishable single photons. *Nature Communications* **4**, 1425 (2013).
- [112] Aharonovich, I., Englund, D. & Toth, M. Solid-state single-photon emitters. *Nature Photonics* **10**, 631 (2016).
- [113] Burek, M. J., Meuwly, C., Evans, R. E., Bhaskar, M. K., Sipahigil, A., Meesala, S., MacHielse, B., Sukachev, D. D., Nguyen, C. T., Pacheco, J. L., Bielejec, E., Lukin, M. D. & Lončar, M. Fiber-coupled diamond quantum nanophotonic interface. *Physical Review Applied* **8**, 024026 (2017).
- [114] Barz, S., Cronenberg, G., Zeilinger, A. & Walther, P. Heralded generation of entangled photon pairs. *Nature Photonics* **4**, 553 (2010).
- [115] Eisaman, M. D., Fan, J., Migdall, A., Polyakov, S. V. & Fan, J. Invited Review Article: Single-photon sources and detectors. *Review of Scientific Instruments* **82**, 071101 (2011).
- [116] Takemoto, K., Nambu, Y., Miyazawa, T., Sakuma, Y., Yamamoto, T., Yorozu, S. & Arakawa, Y. Quantum key distribution over 120 km using ultrahigh purity single-photon source and superconducting single-photon detectors. *Scientific Reports* **5**, 14383 (2015).
- [117] Kuhn, A., Hennrich, M. & Rempe, G. Deterministic Single-Photon Source for Distributed Quantum Networking. *Physical Review Letters* **89**, 067901 (2002).
- [118] Higginbottom, D. B., Slodička, L., Araneda, G., Lachman, L., Filip, R., Hennrich, M. & Blatt, R. Pure single photons from a trapped atom source. *New Journal of Physics* **18**, 093038 (2016).
- [119] Hennessy, K., Badolato, A., Winger, M., Gerace, D., Atatüre, M., Gulde, S., Fält, S., Hu, E. L. & Imamoglu, A. Quantum nature of a strongly coupled single quantum dot–cavity system. *Nature* **445**, 896 (2007).
- [120] Bennett, A. J., Lee, J. P., Ellis, D. J. P., Farrer, I., Ritchie, D. A. & Shields, A. J. A semiconductor photon-sorter. *Nature Nanotechnology* **11**, 857 (2016).
- [121] Rogers, L. J., Jahnke, K. D., Teraji, T., Marseglia, L., Müller, C., Naydenov, B., Schaufert, H., Kranz, C., Isoya, J., McGuinness, L. P. & Jelezko, F. Multiple intrinsically identical single-photon emitters in the solid state. *Nature Communications* **5**, 4739 (2014).
- [122] Sipahigil, A., Jahnke, K., Rogers, L., Teraji, T., Isoya, J., Zibrov, A., Jelezko, F. & Lukin, M. Indistinguishable Photons from Separated Silicon-Vacancy Centers in Diamond. *Physical Review Letters* **113**, 113602 (2014).

- [123] Davanco, M., Liu, J., Sapienza, L., Zhang, C. Z., De Miranda Cardoso, J. V., Verma, V., Mirin, R., Nam, S. W., Liu, L. & Srinivasan, K. Heterogeneous integration for on-chip quantum photonic circuits with single quantum dot devices. *Nature Communications* **8**, 889 (2017).
- [124] Haupt, F., Oemrawsingh, S. S. R., Thon, S. M., Kim, H., Kleckner, D., Ding, D., Suntrup III, D. J., Petroff, P. M. & Bouwmeester, D. Fiber-connectorized micropillar cavities. *Applied Physics Letters* **97**, 131113 (2010).
- [125] Schlehahn, A., Fischbach, S., Schmidt, R., Kaganskiy, A., Strittmatter, A., Rodt, S., Heindel, T. & Reitzenstein, S. A stand-alone fiber-coupled single-photon source. *Scientific Reports* **8**, 1340 (2018).
- [126] Muller, A., Flagg, E. B., Metcalfe, M., Lawall, J. & Solomon, G. S. Coupling an epitaxial quantum dot to a fiber-based external-mirror microcavity. *Applied Physics Letters* **95**, 173101 (2009).
- [127] Greuter, L., Starosielec, S., Kuhlmann, A. V. & Warburton, R. J. Towards high-cooperativity strong coupling of a quantum dot in a tunable microcavity. *Physical Review B* **92**, 045302 (2015).
- [128] Bonato, C., Gudat, J., de Vries, K., Thon, S. M., Kim, H., Petroff, P. M., van Exter, M. P. & Bouwmeester, D. Optical modes in oxide-apertured micropillar cavities. *Optics Letters* **37**, 4678 (2012).
- [129] Ghatak, K. & Thyagarajan, A. *An introduction to fiber optics* (Cambridge University Press, 1998).
- [130] Bakker, M. P., Snijders, H., Löffler, W., Barve, A. V., Coldren, L. A., Bouwmeester, D. & van Exter, M. P. Homodyne detection of coherence and phase shift of a quantum dot in a cavity. *Optics Letters* **40**, 3173 (2015).
- [131] Kroutvar, M., Ducommun, Y., Heiss, D., Bichler, M., Schuh, D., Abstreiter, G. & Finley, J. J. Optically programmable electron spin memory using semiconductor quantum dots. *Nature* **432**, 81 (2004).