Experimental quantum position verification: practical challenges and single-photon correlations

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Bibliography

[1] Chandran, N., Goyal, V., Moriarty, R. & Ostrovsky, R. Position Based Cryptography. In Halevi, S. (ed.) *Advances in Cryptology - CRYPTO 2009*, 391 (Springer, Berlin, Heidelberg, 2009).

[2] Beausoleil, R. G., Kent, A., Spiller, T. P. & Munro, W. J. Tagging Systems (2006).

[3] Kent, A. Quantum Tagging for Tags Containing Secret Classical Data. *Phys. Rev. A* **84**, 022335 (2011).

[4] Kent, A., Munro, W. J. & Spiller, T. P. Quantum Tagging: Authenticating Location via Quantum Information and Relativistic Signaling Constraints. *Phys. Rev. A* **84**, 012326 (2011).

[5] Lau, H.-K. & Lo, H.-K. Insecurity of Position-Based Quantum-Cryptography Protocols against Entanglement Attacks. *Phys. Rev. A* **83**, 012322 (2011).

[6] Malaney, R. A. Location-Dependent Communications Using Quantum Entanglement. *Phys. Rev. A* **81**, 042319 (2010).

[7] Malaney, R. A. Quantum Location Verification in Noisy Channels. In *2010 IEEE Global Telecommunications Conference GLOBECOM 2010*, 1 (2010). arXiv: `1004.4689`.

[8] Qi, B. & Siopsis, G. Loss-Tolerant Position-Based Quantum Cryptography. *Phys. Rev. A* **91**, 042337 (2015).

[9] Ribeiro, J. & Grosshans, F. A Tight Lower Bound for the BB84-states Quantum-Position-Verification Protocol (2015). arXiv: `1504.07171`.

[10] Unruh, D. Quantum Position Verification in the Random Oracle Model. In Garay, J. A. & Gennaro, R. (eds.) *Advances in Cryptology – CRYPTO 2014*, 1 (Springer Berlin Heidelberg, Berlin, Heidelberg, 2014).

[11] Tomamichel, M., Fehr, S., Kaniewski, J. & Wehner, S. A Monogamy-of-Entanglement Game with Applications to Device-Independent Quantum Cryptography. *New J. Phys.* **15**, 103002 (2013).

[12] Lim, C. C. W. *et al.* Loss-Tolerant Quantum Secure Positioning with Weak Laser Sources. *Phys. Rev. A* **94**, 032315 (2016).

[13] Gao, F., Liu, B. & Wen, Q.-Y. Enhanced No-Go Theorem for Quantum Position Verification (2013). arXiv: `1305.4254`.

[14] Buhrman, H., Fehr, S., Schaffner, C. & Speelman, F. The Garden-Hose Model. In *Proceedings of the 4th Conference on Innovations in Theoretical Computer Science*, 145 (ACM, Berkeley California USA, 2013).

[15] Buhrman, H. *et al.* Position-Based Quantum Cryptography: Impossibility and Constructions. *SIAM J. Comput.* **43**, 150 (2014).

[16] Chakraborty, K. & Leverrier, A. Practical Position-Based Quantum Cryptography. *Phys. Rev. A* **92**, 052304 (2015).

[17] Allerstorfer, R., Buhrman, H., Speelman, F. & Lunel, P. V. On the Role of Quantum Communication and Loss in Attacks on Quantum Position Verification (2022). arXiv: `2208.04341`.

[18] Allerstorfer, R., Buhrman, H., Speelman, F. & Lunel, P. V. Towards Practical and Error-Robust Quantum Position Verification (2022). arXiv: `2106.12911`.

[19] Allerstorfer, R. *et al.* Making Existing Quantum Position Verification Protocols Secure Against Arbitrary Transmission Loss (2023). arXiv: `2312.12614`.

[20] Allerstorfer, R., Buhrman, H., May, A., Speelman, F. & Verduyn Lunel, P. Relating Non-Local Quantum Computation to Information Theoretic Cryptography. *Quantum* **8**, 1387 (2024).

[21] Amer, O. *et al.* Certified Randomness Implies Secure Classical Position-Verification (2024). arXiv: `2410.03982`.

[22] Asadi, V., Cleve, R., Culf, E. & May, A. Linear Gate Bounds against Natural Functions for Position-Verification (2024). arXiv: `2402.18648`.

[23] Bluhm, A., Christandl, M. & Speelman, F. A Single-Qubit Position Verification Protocol That Is Secure against Multi-Qubit Attacks. *Nat. Phys.* **18**, 623 (2022).

[24] Cowperthwaite, G., Kent, A. & Pitalua-Garcia, D. Towards a Proof-of-Principle Experimental Demonstration of Quantum Position Verification: Working Notes (2023). arXiv: `2309.10070`.

[25] Cree, J. & May, A. Code-Routing: A New Attack on Position Verification. *Quantum* **7**, 1079 (2023).

[26] Escolà-Farràs, L. & Speelman, F. Single-Qubit Loss-Tolerant Quantum Position Verification Protocol Secure against Entangled Attackers. *Phys. Rev. Lett.* **131**, 140802 (2023).

[27] Escolà-Farràs, L., Palais, L. C. & Speelman, F. A Quantum Cloning Game with Applications to Quantum Position Verification (2024). arXiv: `2410.22157`.

[28] Escolà-Farràs, L. & Speelman, F. Quantum Position Verification in One Shot: Parallel Repetition of the f-BB84 and f-Routing Protocols (2025). arXiv: `2503.09544`.

[29] Escolà-Farràs, L. & Speelman, F. Lossy-and-Constrained Extended Non-Local Games with Applications to Quantum Cryptography. *Quantum* **9**, 1712 (2025). arXiv: `2405.13717`.

[30] George, I., Allerstorfer, R., Lunel, P. V. & Chitambar, E. Orthogonality Broadcasting and Quantum Position Verification (2024). arXiv: `2311.00677`.

[31] Junge, M., Kubicki, A. M., Palazuelos, C. & Pérez-García, D. Geometry of Banach Spaces: A New Route Towards Position Based Cryptography. *Commun. Math. Phys.* **394**, 625 (2022).

[32] Liu, J., Liu, Q. & Qian, L. Beating Classical Impossibility of Position Verification (2022). arXiv: `2109.07517`.

[33] May, A. Quantum Tasks in Holography. *J. High Energy Phys.* **2019**, 233 (2019).

[34] Miller, C. A. & Alnawakhtha, Y. Perfect Cheating Is Impossible for Single-Qubit Position Verification (2024). arXiv: `2406.20022`.

[35] Olivo, A., Chabaud, U., Chailloux, A. & Grosshans, F. Breaking Simple Quantum Position Verification Protocols with Little Entanglement (2020). arXiv: `2007.15808`.

[36] Bennett, C. H. & Brassard, G. Quantum Cryptography: Public Key Distribution and Coin Tossing. *Theor. Comput. Sci.* **560**, 7 (2014).

[37] Hong, C. K., Ou, Z. Y. & Mandel, L. Measurement of Subpicosecond Time Intervals between Two Photons by Interference. *Phys. Rev. Lett.* **59**, 2044 (1987).

[38] Garcia-Escartin, J. C. & Chamorro-Posada, P. Swap Test and Hong-Ou-Mandel Effect Are Equivalent. *Phys. Rev. A* **87**, 052330 (2013).

[39] Poletti, F. *et al.* Towards High-Capacity Fibre-Optic Communications at the Speed of Light in Vacuum. *Nat. Photonics* **7**, 279 (2013).

[40] Antesberger, M. *et al.* Distribution of Telecom Entangled Photons through a 7.7 Km Antiresonant Hollow-Core Fiber. *Opt. Quantum* **2**, 173 (2024).

[41] Petrovich, M. *et al.* Broadband Optical Fibre with an Attenuation Lower than 0.1 Decibel per Kilometre. *Nat. Photonics* 1 (2025).

[42] Damask, J. N. *Polarization optics in telecommunications*. No. 101 in Springer series in optical sciences (Springer, New York, 2005).

[43] Jozsa, R. Fidelity for Mixed Quantum States. *Journal of Modern Optics* **41**, 2315 (1994).

[44] Ren, Z. B., Robert, Ph. & Paratte, P.-A. Temperature Dependence of Bend- and Twist-Induced Birefringence in a Low-Birefringence Fiber. *Opt. Lett.* **13**, 62 (1988).

[45] Rodimin, V. *et al.* Impact of Polarization Mode Dispersion on Entangled Photon Distribution (2025). arXiv: `2408.01754`.

[46] Poole, C. & Wagner, R. Phenomenological Approach to Polarisation Dispersion in Long Single-Mode Fibres. *Electron. Lett.* **22**, 1029 (1986).

[47] Jopson, R., Nelson, L. & Kogelnik, H. Measurement of Second-Order Polarization-Mode Dispersion Vectors in Optical Fibers. *IEEE Photonics Technol. Lett.* **11**, 1153 (1999).

[48] Dong, H. *et al.* Generalized Mueller Matrix Method for Polarization Mode Dispersion Measurement in a System with Polarization-Dependent Loss or Gain. *Opt. Express* **14**, 5067 (2006).

[49] Brodsky, M., Frigo, N. J., Boroditsky, M. & Tur, M. Polarization Mode Dispersion of Installed Fibers. *J. Lightwave Technol.* **24**, 4584 (2006).

[50] Hakki, B. Polarization Mode Dispersion in a Single Mode Fiber. *J.Lightwave Technol.* **14**, 2202 (1996).

[51] Galtarossa, A., Gianello, G., Someda, C. & Schiano, M. In-Field Comparison among Polarization-Mode-Dispersion Measurement Techniques. *J. Lightwave Technol.* **14**, 42 (1996).

[52] Heffner, B. Automated Measurement of Polarization Mode Dispersion Using Jones Matrix Eigenanalysis. *IEEE Photonics Technol. Lett.* **4**, 1066 (1992).

[53] Poole, C. D. Measurement of Polarization-Mode Dispersion in Single-Mode Fibers with Random Mode Coupling. *Opt. Lett.* **14**, 523 (1989).

[54] Rashleigh, S. C. & Ulrich, R. Polarization Mode Dispersion in Single-Mode Fibers. *Opt. Lett.* **3**, 60 (1978).

[55] Czegledi, C. B., Karlsson, M., Agrell, E. & Johannisson, P. Polarization Drift Channel Model for Coherent Fibre-Optic Systems. *Sci. Rep.* **6**, 21217 (2016).

[56] Ramos, M. F., Pinto, A. N. & Silva, N. A. Polarization Based Discrete Variables Quantum Key Distribution via Conjugated Homodyne Detection. *Sci. Rep.* **12**, 6135 (2022).

[57] Maring, N. *et al.* A Versatile Single-Photon-Based Quantum Computing Platform. *Nat. Photonics* **18**, 603 (2024).

[58] Li, Y.-H. *et al.* Free-Space and Fiber-Integrated Measurement-Device-Independent Quantum Key Distribution under High Background Noise. *Phys. Rev. Lett.* **131**, 100802 (2023).

[59] Semenenko, H., Sibson, P., Thompson, M. G. & Erven, C. Interference between Independent Photonic Integrated Devices for Quantum Key Distribution. *Opt. Lett.* **44**, 275 (2019).

[60] Santori, C., Fattal, D., Vučković, J., Solomon, G. S. & Yamamoto, Y. Indistinguishable Photons from a Single-Photon Device. *Nature* **419**, 594 (2002).

[61] Patel, R. B. *et al.* Quantum Interference of Electrically Generated Single Photons from a Quantum Dot. *Nanotechnology* **21**, 274011 (2010).

[62] Patel, R. B. *et al.* Postselective Two-Photon Interference from a Continuous Nonclassical Stream of Photons Emitted by a Quantum Dot. *Phys. Rev. Lett.* **100**, 207405 (2008).

[63] Proux, R. *et al.* Measuring the Photon Coalescence Time Window in the Continuous-Wave Regime for Resonantly Driven Semiconductor Quantum Dots. *Phys. Rev. Lett.* **114**, 067401 (2015).

[64] Wenniger, I. M. d. B. *et al.* Quantum Interferences and Gates with Emitter-Based Coherent Photon Sources. *Optica Quantum* **2**, 404 (2024). arXiv: `2401.01187`.

[65] Ates, S. *et al.* Post-Selected Indistinguishable Photons from the Resonance Fluorescence of a Single Quantum Dot in a Microcavity. *Phys. Rev. Lett.* **103**, 167402 (2009).

[66] Tomm, N. *et al.* A Bright and Fast Source of Coherent Single Photons. *Nat. Nanotechnol.* **16**, 399 (2021).

[67] Ding, X. *et al.* High-Efficiency Single-Photon Source above the Loss-Tolerant Threshold for Efficient Linear Optical Quantum Computing. *Nat. Photonics* **19**, 387 (2025).

[68] Wenniger, I. M. d. B. *Impact of Photon-Number Coherence on the Performance and Energetics of Quantum Optics Protocols.* Ph.D. thesis, Université Paris-Saclay (2023).

[69] Loredo, J. C. *et al.* Generation of Non-Classical Light in a Photon-Number Superposition. *Nat. Photonics* **13**, 803 (2019).

[70] Wein, S. C. *et al.* Photon-Number Entanglement Generated by Sequential Excitation of a Two-Level Atom. *Nat. Photonics* **16**, 374 (2022).

[71] Steindl, P. *et al.* Artificial Coherent States of Light by Multiphoton Interference in a Single-Photon Stream. *Phys. Rev. Lett.* **126**, 143601 (2021).

[72] Poortvliet, M. *et al.* Picosecond Laser Pulses for Quantum Dot–Microcavity-Based Single-Photon Generation by Cascaded Electro-Optic Modulation of a Narrow-Linewidth Laser. *Phys. Rev. Appl.* **23**, 014017 (2025).

[73] Paudel, U. *et al.* Generation of Frequency Sidebands on Single Photons with Indistinguishability from Quantum Dots. *Phys. Rev. A* **98**, 011802 (2018).

[74] Zhai, L. *et al.* Quantum Interference of Identical Photons from Remote GaAs Quantum Dots. *Nat. Nanotechnol.* **17**, 829 (2022).

[75] Somaschi, N. *et al.* Near-Optimal Single-Photon Sources in the Solid State. *Nat. Photonics* **10**, 340 (2016).

[76] Thomas, F. S. *et al.* Spectroscopy of the Local Density of States in Nanowires Using Integrated Quantum Dots. *Phys. Rev. B* **104**, 115415 (2021).

[77] Snijders, H. J. *et al.* Observation of the Unconventional Photon Blockade. *Phys. Rev. Lett.* **121**, 043601 (2018).

[78] Steindl, P. *et al.* Cross-Polarization-Extinction Enhancement and Spin-Orbit Coupling of Light for Quantum-Dot Cavity Quantum Electrodynamics Spectroscopy. *Phys. Rev. Appl.* **19**, 064082 (2023).

[79] Steindl, P. *et al.* Resonant Two-Laser Spin-State Spectroscopy of a Negatively Charged Quantum-Dot–Microcavity System with a Cold Permanent Magnet. *Phys. Rev. Appl.* **20**, 014026 (2023).

[80] Istrati, D. *et al.* Sequential Generation of Linear Cluster States from a Single Photon Emitter. *Nat. Commun.* **11**, 5501 (2020).

[81] Guichard, V. *et al.* Monitoring the Generation of Photonic Linear Cluster States with Partial Measurements (2025). arXiv: `2505.01929`.

[82] Bienfang, J. *et al.* Single-Photon Sources and Detectors Dictionary. Tech. Rep., National Institute of Standards and Technology (U.S.) (2023).

[83] Couteau, C. Spontaneous Parametric Down-Conversion. *Contemp. Phys.* **59**, 291 (2018).

[84] Eisaman, M. D., Fan, J., Migdall, A. & Polyakov, S. V. Invited Review Article: Single-photon Sources and Detectors. *Rev. Sci. Instrum.* **82**, 071101 (2011).

[85] Wang, H. *et al.* Bright Heralded Single-Photon Source Saturating Theoretical Single-photon Purity. *Laser Photonics Rev.* **19**, 2401420 (2025). arXiv: `2404.03236`.

[86] Loredo, J. C. *et al.* Scalable Performance in Solid-State Single-Photon Sources. *Optica* **3**, 433 (2016).

[87] Lenzini, F. *et al.* Active Demultiplexing of Single Photons from a Solid-State Source. *Laser Photonics Rev.* **11**, 1600297 (2017).

[88] Wang, H. *et al.* High-Efficiency Multiphoton Boson Sampling. *Nat. Photonics* **11**, 361 (2017).

[89] Kanneworff, K. *et al.* Towards Experimental Demonstration of Quantum Position Verification Using Single Photons. *Quantum Sci. Technol.* **10**, 045004 (2025).

[90] Soref, R. Tutorial: Integrated-photonic Switching Structures. *APL Photonics* **3**, 021101 (2018).

[91] Errando-Herranz, C. *et al.* MEMS for Photonic Integrated Circuits. *IEEE J. Sel. Top. Quantum Electron.* **26**, 1 (2020).

[92] Wooten, E. *et al.* A Review of Lithium Niobate Modulators for Fiber-Optic Communications Systems. *IEEE J. Sel. Top. Quantum Electron.* **6**, 69 (2000).

[93] Chen, X., Lin, J. & Wang, K. A Review of Silicon-Based Integrated Optical Switches. *Laser Photonics Rev.* **17**, 2200571 (2023).

[94] Müller, H. Fast High-Voltage Amplifiers for Driving Electro-Optic Modulators. *Rev. Sci. Instrum.* **76**, 084701 (2005).

[95] Dryazgov, M. *et al.* Resource-Efficient Low-Loss Four-Channel Active Demultiplexer for Single Photons. *Opt. Quantum* **1**, 14 (2023).

[96] Antón, C. *et al.* Interfacing Scalable Photonic Platforms: Solid-State Based Multi-Photon Interference in a Reconfigurable Glass Chip. *Optica* **6**, 1471 (2019).

[97] Münzberg, J. *et al.* Fast and Efficient Demultiplexing of Single Photons from a Quantum Dot with Resonantly Enhanced Electro-Optic Modulators. *APL Photonics* **7**, 070802 (2022).

[98] Hansen, L. M. *et al.* Single-Active-Element Demultiplexed Multi-Photon Source. *Opt. Quantum* **1**, 1 (2023).

[99] Hummel, T. *et al.* Efficient Demultiplexed Single-Photon Source with a Quantum Dot Coupled to a Nanophotonic Waveguide. *Appl. Phys. Lett.* **115**, 021102 (2019).

[100] Ollivier, H. *et al.* Hong-Ou-Mandel Interference with Imperfect Single Photon Sources. *Phys. Rev. Lett.* **126**, 063602 (2021).

[101] Brassard, G. The Conundrum of Secure Positioning. *Nature* **479**, 307 (2011).

[102] Das, S. & Siopsis, G. Practically Secure Quantum Position Verification. *New J. Phys.* **23**, 063069 (2021).

[103] Escolà-Farràs, L. & Speelman, F. Lossy-and-Constrained Extended Non-Local Games with Applications to Cryptography: BC, QKD and QPV (2024). arXiv: `2405.13717`.

[104] González-Ruiz, E. M., Bjerlin, J., Sandberg, O. A. D. & Sørensen, A. S. Two-Photon Correlations and Hong-Ou-Mandel Visibility from an Imperfect Single-Photon Source. *Phys. Rev. Appl.* **23**, 054063 (2025).