Morgan W. Mitchell

CONTACT INFORMATION

ICFO - The Institute of Photonic Sciences
Av. Carl Friedrich Gauss, 3
08860 Castelldefels (Barcelona)
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PERSONAL

Citizen of USA, resident of Spain since 2004, married to an Italian.

EXPERTISE

Experimental quantum sensing with hot, cold, and ultra-cold atoms, generation and use of non-classical light in quantum sensing. Miniaturization of atomic quantum sensors. Optical magnetometry, use of quantum non-demolition measurement and spin squeezing in atomic clocks. Quantum optics.

EDUCATION

Ph.D. in Physics. **University of California at Berkeley** **June 1999**
Dynamics of photon-photon scattering in rubidium vapor. Advisor: R. Y. Chiao

M.A. in Physics, **University of California at Berkeley** **June 1993**

B.A. in Physics with High Honors. **Swarthmore College** **May 1990**

RESEARCH EXPERIENCE

ICFO - The Institute of Photonic Sciences, Castelldefels (Barcelona), Spain
ICREA Professor at ICFO - Quantum Optics **Oct 2011 to present**
Group Leader - Atomic Quantum Optics **July 2004 to Oct 2011**

Group of Aephraim Steinberg, University of Toronto
Research Associate **July 2002 – June 2004**

Group of Serge Haroche, Laboratoire Kastler-Brossel, ENS
Post-doctoral researcher **July 1999 – June 2000**

TEACHING EXPERIENCE

ICFO, Barcelona, Spain
Professor of Quantum Optics **July 2004 – present**

- Master and Ph.D. courses on experimental quantum sensing and q. optics.
- Supervision of 23 Ph.D. theses, 14 Master theses, 16 undergraduates.

Reed College, Portland, Oregon
Visiting Assistant Professor **July 2000 – June 2002**

- Undergraduate teaching and curriculum development.

MAIN RESEARCH AREAS

Atomic quantum sensing : Quantum limits of field sensing. Protocols for generation and use of optical and spin squeezing in scenarios of practical importance. Optical magnetometry. Miniaturized atomic sensors for magnetoencephalography. Sensing with ultracold gases. Back-action evasion in optical magnetometers and optical lattice atomic clocks.

Extreme entanglement generation : Entanglement generation in macroscopic systems of atoms and photons. Entanglement quantification. Laboratory probes of entanglement in dense atomic media.

Quantum randomness and local realism : Metrological approach to quantum randomness, including rigorous methods for quantum randomness quantification, use in loophole-free Bell tests, Bell test methodology.

Publication summary

As of June 2024, 141 refereed publications, including 2 Reviews of Modern Physics, 6 Nature, 1 PNAS, 28 Physical Review Letters, 1 Physical Review X, 2 Nature Photonics, 1 Nature Physics, 3 Nature Communications, 1 Optica, 2 Applied Physics Letters, 1 Quantum, 4 Physical Review Applied, 2 J. Phys. Chem. Lett., 1 Reports in Progress in Physics, 10 New Journal of Physics, 13 Optics Express, 7 Optics Letters, 27 Physical Review A. "h-index" 46 (Scopus), 56 (Google). Citations in 2023: 1074 (Scopus) 1916 (Google).

Selected high-visibility publications

[1] **M. W. Mitchell** and S. Palacios Alvarez. Colloquium: Quantum limits to the energy resolution of magnetic field sensors. *Rev. Mod. Phys.*, **92**, 021001 (2020)

[2] S. P. Alvarez, P. Gomez, S. Coop, R. Zamora-Zamora, C. Mazzinghi, and **M. W. Mitchell**. Single-domain Bose condensate magnetometer achieves energy resolution per bandwidth below $\hbar$. *Proceedings of the National Academy of Sciences*, **119**, e2115339119 (2022)

[3] G. Colangelo, F. M. Ciurana, L. C. Bianchet, R. J. Sewell, and **M. W. Mitchell**. Simultaneous tracking of spin angle and amplitude beyond classical limits. *Nature*, **543**, 525 (2017)

[4] M. Napolitano, M. Koschorreck, B. Dubost, N. Behbood, R. J. Sewell, and **M. W. Mitchell**. Interaction-based quantum metrology showing scaling beyond the Heisenberg limit. *Nature*, **471**, 486 (2011)

[5] **M. W. Mitchell**, J. S. Lundeen, and A. M. Steinberg. Super-resolving phase measurements with a multiphoton entangled state. *Nature*, **429**, 161 (2004)

[6] C. Troullinou, R. Jiménez-Martínez, J. Kong, V. G. Lucivero, and **M. W. Mitchell**. Squeezed-light enhancement and backaction evasion in a high sensitivity optically pumped magnetometer. *Phys. Rev. Lett.*, **127**, 193601 (2021)

[7] J. Kong, R. Jiménez-Martínez, C. Troullinou, V. G. Lucivero, G. Tóth, and **M. W. Mitchell**. Measurement-induced, spatially-extended entanglement in a hot, strongly-interacting atomic system. *Nature Communications*, **11**, 2415 (2020)

[8] D. Braun, G. Adesso, F. Benatti, R. Floreanini, U. Marzolino, **M. W. Mitchell**, and S. Pirandola. Quantum-enhanced measurements without entanglement. *Rev. Mod. Phys.*, **90**, 035006 (2018)

[9] F. Wolfgramm, C. Vitelli, F. A. Beduini, N. Godbout, and **M. W. Mitchell**. Entanglement-enhanced probing of a delicate material system. *Nat Photon*, **7**, 28 (2013)

[10] R. J. Sewell, M. Koschorreck, M. Napolitano, B. Dubost, N. Behbood, and **M. W. Mitchell**. Magnetic sensitivity beyond the projection noise limit by spin squeezing. *Phys. Rev. Lett.*, **109**, 253605 (2012)

Selected invited talks

Institut d'Optique 2010, ICOLS 2011, DAMOP 2011, NIST Boulder 2011, MPQ 2011, Stuttgart 2011, Niels Bohr Institute 2011 & 2012, ICAP 2012, QCMC 2012, Royal Society 2012, Innsbruck 2012, Cambridge 2012, Toronto 2012, Stanford 2012, Arizona 2012, Heidelberg 2012, Quantum Optics 2012, IQIS 2013, ECAMP 2013, Vienna 2013, NIST Gaithersburg 2013, IQOQI 2014, Quantum Optics 2014, Buenos Aires 2014, Geneva 2015, QuantumRandom 2015, Heraeus 2015 & 2016, YQI 2016, SQUINT 2016, RAQM 2016, La Sapienza 2016, Quantum Optics 2016, INRIM 2017, BQIT 2017, Photonics Ireland 2017, ICQT 2017, QCrypt 2017, Institut d'Optique 2017, IQEC 2018, Harvard & MIT 2018, Singapore 2018, Heidelberg 2018, Quantum Optics IX 2018, Quantum Sensing and Magnetometry 2019, Quantum Metrology and Physics Beyond the Standard Model 2019, Quantum 2019, CLEO 2019, CQM 2019, IFCS-EFTF 2019, DAMOP 2020, APS March Meeting 2020, IQF 2020, Photonics North 2021, EGAS 2021, LIMQUET 2021, DPG 2021, WOPM 2021, Photonics West 2022, Quantum Science Implementations 2022, MoSaiQC 2022, Spanish Royal Academy 2023, CEWQO 2023, Quantum 2023.

Research leadership

Coordinator of QuantumCAT, the quantum technologies emergent community in Catalonia, in which participate all major research groups in the topic.

Workpackage leader "Micro-fabricated optically pumped magnetometers" for Quantum Technologies Flagship project MACQSIMAL.

Group leader, "Cavity-Enhanced Quantum Optical Clocks," (QuantERA project), "Ultra-stable optical oscillators from quantum coherent and entangled systems"

In 2016, I initiated the BIG Bell Test Collaboration to perform tests of local realism using human input. I recruited leading quantum optics groups from Europe (A. Acín, H. de Riedmatten, F. Sciarrino, S. Tanzilli, A. Wallraff, H. Weinfurter, A. Zeilinger), from Asia/Australia (J.-W. Pan, G. Pryde, A. White), and from the Americas (M. Larotonda, S.-W. Nam, G. Xavier). In 2016 the project generated $>$ 200 print and online media articles, attracted $>$ 100,000 citizen participants, performed 13 experiments on five continents, and closed for the first time the "freedom-of-choice" loophole (publised in Nature in 2018 [39]).

Leader of randomness generation for loophole-free Bell tests: 1) groups of Ronald Hanson, Stephanie Wehner and Tim Taminiau, TU Delft, Netherlands [60]. 2) group of Anton Zeilinger, IQOQI Vienna, Austria [58]. 3) group of Sae Woo Nam, NIST Boulder, USA [57]. 4) device-independent protocols in the NIST Randomness Beacon programme.

Selected competitive funding last 12 years

ERC Advanced Grant Field-SEER	2400 k€
Spanish PRTR Quantum Sensor Networks	700 k€
European Defense Fund ADEQUADE	700 k€
EIC Transition Optically pumped magnetometers for magnetoencephalography	400 k€
Quantum Technologies Emergent Community in Catalonia (coordinator)	4000 k€
Quantum Technologies Flagship MACQSIMAL	560 k€
FET Launchpad UVALITH	100 k€
EMPIR USOQS	50 k€
QuantERA QClocks	150 k€
ERC Proof-of-Concept Grant, ERIDIAN	150 k€
ERC Proof-of-Concept Grant, MAMBO	150 k€
ERC Starting Grant, "Atomic Quantum Metrology"	1400 k€
EC Horizon 2020, "Quantum Simulation of Insulators and Conductors"	400 k€

Professional Service

Lecturer: Quantum Technology Training for Policymakers, 2023

NSF Quantum Leap Challenge Institutes evaluation panelist, 2023

ERC Advanced Grant evaluation panelist 2019-20, deputy panel chair 2021-22 & 2023-24

German DFG Review Panels (Transregio) 2020-2021

NSF Quantum Leap Challenge Institutes Expert Evaluator, 2020

Expert Referee for ERC Starting, ERC Consolidator, ERC Advanced and ERC Synergy Grants, Spanish ANEP, French ANR, Austrian FWF, Polish OSF, Australian ARC, Canadian NSERC, US NSF, Swiss SNSF, German DFG.

Referee for Nature, Science, Nature Physics, Nature Photonics, Nature Communications, PNAS, Physical Review Letters, Optics Express, Optics Letters, New Journal of Physics, Physical Review A, Journal of Physics B, American Journal of Physics.

Local organizing committee, ICAP Barcelona 2014–18

CLEO/QELS Programme committees "Q. Science, Engineering and Technology" 2010–11 "Fundamental Science 1: Q. Optics of Atoms, Molecules and Solids" 2012–14, Organizer, OSA symposium on Quantum Simulators, 2013

Editorial Advisory Board *Quantum Measurements and Quantum Metrology* (Journal).

Ph.D. thesis committees for Niels Bohr Institute, Institut d'Optique, LENS, ICFO, Autonomous University of Barcelona, Autonomous University of Madrid, Aarhus University, École Normale Supérieure, Jagiellionian University.

Patent families

"Ultrafast quantum random number generation process and system therefore," US9218160B2
"Process for quantum random number generation in a multimode laser cavity," US9710230B2
"Method for physical random number generation using a vertical cavity surface emitting laser," US11631964B2
"Monolithic Frequency Converter," US10007170B2
"A cell for an optically-pumped atomic magnetic gradiometer, an optically-pumped atomic magnetic gradiometer, and a system comprising the gradiometer and a microscopy system," European Patent Application No. 21382888
"An atomic vapor cell, an integrated atomic/photonic device and apparatus comprising the atomic vapor cell, and a method for fabricating an atomic vapor cell," European Patent Application No. 22382127

Companies founded

QuSide Technologies S.L. Quantum randomness generation and optical quantum technologies. Incorporated 2017. 40 employees in 2024.

Popular articles

[1] R. J. Sewell and **M. W. Mitchell**. Collaboration and precision in quantum measurement. *Physics Today*, **64**, 72 (2011)

[2] M. Napolitano, M. Koschorreck, B. Dubost, N. Behbood, R. Sewell, and M. Mitchell. Quantum optics and the "Heisenberg limit" of measurement. *Opt. Photon. News*, **22**, 40 (2011)

[3] R. J. Sewell and **M. W. Mitchell**. コラボで上がる測定精度. *Parity (Japanese Physics Magazine)*, **27**, 50 (2012)

[4] C. Abellán, W. Amaya, and **M. W. Mitchell**. Un test de Bell sin escapatorias. *Investigación y Ciencia (Spanish edition of Scientific American)*, **472**, 10 (2016)

Press coverage

La Vanguardia 20 February 2012 & 4 March, 2012, El Pais 25 March, 2011, Physics World 24 March, 2011, QueQuiCom (Catalan television) 2014 Horizon Magazine 2014, Scientific American 2014, Le Scienze 2014 Science News 2015 Muy Interesante 2015, Phys.org 2015, FQXi 2015, Physics World 2015, Le Monde 2015, New Scientist 2015, Nature 2015, Science 2015, Forbes 2015, New York Times 2015 Neue Zuricher Zeitung 2016 El País 2016 La Repubblica 2016 PBS Newshour 2016 Il Sole 24 Ore 2016 El Mundo 2016 Sverige Radio 2016 Tele Basel 2016 Nature News 2017 El Periodico 2017 La Vanguardia 2017 APS Physics Central 2017 Chemistry World 2017 Scientific American 2017 CORDIS 2017 El País 2018 Wired 2018 MIT Technology Review 2018 The New Yorker 2018 Forbes 2019 Physics World 2020a, 2020b, 2020c Medium 2020 La Vanguardia 2020 Nature Communications 2021 Scientific American 2022 Wired 2022 El Periodico 2023 El País 2023 Optics and Photonics News 2023

Awards and recognition

European Research Council Advanced Grant	2023
ERC Public Engagement with Research Award (finalist)	2022
Physics World Quantum Highlights	2020
Nature Communications Quantum Highlights	2020
Best publication at Kavli Institute of Nanoscience Delft	2016
Paul Ehrenfest Best Paper Award for Quantum Foundations	2016
Nature (journal) "Editor's Choice" (first position)	2015
Science (journal) "Breakthrough of the year" top ten	2015
Optics and Photonics News "Optics in 2015"	2015
Vanguardia de la Ciencia (top research result in any field in Spain, first runner-up)	2012
European Research Council Starting Grant	2011
Optics and Photonics News "Year in Review"	2011
Laser Focus World Commendation for Excellence in Technical Communications	2007
Consolider Ingenio 2010	2005
Physics World "Highlights of the year"	2004
National Science Foundation Fellowship	1991-1994
Hertz Foundation Fellowship (declined)	1990
Phi Beta Kappa	1990

Languages

English (native), Spanish, Italian, French, Catalan

Publications of Morgan W. Mitchell

Publication summary

As of June 2024, 141 refereed publications, including 2 Reviews of Modern Physics, 6 Nature, 1 PNAS, 28 Physical Review Letters, 1 Physical Review X, 2 Nature Photonics, 1 Nature Physics, 3 Nature Communications, 1 Optica, 2 Applied Physics Letters, 1 Quantum, 4 Physical Review Applied, 2 J. Phys. Chem. Lett., 1 Reports in Progress in Physics, 10 New Journal of Physics, 13 Optics Express, 7 Optics Letters, 27 Physical Review A. "h-index" 46 (Scopus), 56 (Google). Citations in 2023: 1074 (Scopus) 1916 (Google).

Books

[1] A. Predojevic and **M. W. Mitchell**. *Engineering the Atom-Photon Interaction: Controlling Fundamental Processes with Photons, Atoms and Solids*. Nano-Optics and Nanophotonics. Springer International Publishing, 2015.

Book chapters

[1] **M. W. Mitchell**. Generation, characterization and use of atom-resonant indistinguishable photon pairs. In A. Predojević and **M. W. Mitchell**, editors, *Engineering the Atom-Photon Interaction: Controlling Fundamental Processes with Photons, Atoms and Solids*, Nano-Optics and Nanophotonics. Springer International Publishing, 2015.

Peer-reviewed journal articles

[1] K. Mouloudakis, J. Kong, A. Sierant, E. Arkin, M. Hernández Ruiz, R. Jiménez-Martínez, and **M. W. Mitchell**. Anomalous noise spectra in a spin-exchange-relaxation-free alkali-metal vapor. *Phys. Rev. A*, **109**, L040802 (2024)

[2] M. Hernández Ruiz, Y. Ma, H. Medhat, C. Mazzinghi, V. G. Lucivero, and **M. W. Mitchell**. Cavity-enhanced detection of spin polarization in a microfabricated atomic vapor cell. *Phys. Rev. Appl.*, **21**, 064014 (2024)

[3] M. Lipka, A. Sierant, C. Troullinou, and **M. W. Mitchell**. Multiparameter quantum sensing and magnetic communication with a hybrid dc and rf optically pumped magnetometer. *Phys. Rev. Appl.*, **21**, 034054 (2024)

[4] K. Mouloudakis, et al. Interspecies spin-noise correlations in hot atomic vapors. *Phys. Rev. A*, **108**, 052822 (2023)

[5] C. Troullinou, V. G. Lucivero, and **M. W. Mitchell**. Quantum-enhanced magnetometry at optimal number density. *Phys. Rev. Lett.*, **131**, 133602 (2023)

[6] S. Storz, et al. Loophole-free Bell inequality violation with superconducting circuits. *Nature*, **617**, 265 (2023)

[7] K. Mouloudakis, S. Bodenstedt, M. Azagra, **M. W. Mitchell**, I. Marco-Rius, and M. C. D. Tayler. Real-time polarimetry of hyperpolarized ^{13}C nuclear spins using an atomic magnetometer. *The Journal of Physical Chemistry Letters*, **14**, 1192 (2023)

[8] S. Abend, et al. Technology roadmap for cold-atoms based quantum inertial sensor in space. *AVS Quantum Science*, **5**, 019201 (2023)

[9] L. C. Bianchet, N. Alves, L. Zarraoa, T. Lamich, V. Prakash, and **M. W. Mitchell**. Quantum jump spectroscopy of a single neutral atom for precise subwavelength intensity measurements. *Phys. Rev. Research*, **4**, L042026 (2022)

[10] S. Bodenstedt, **M. W. Mitchell**, and M. C. D. Tayler. Meridional composite pulses for low-field magnetic resonance. *Phys. Rev. A*, **106**, 033102 (2022)

[11] V. G. Lucivero, A. Zanoni, G. Corrielli, R. Osellame, and **M. W. Mitchell**. Laser-written vapor cells for chip-scale atomic sensing and spectroscopy. *Opt. Express*, **30**, 27149 (2022)

[12] M. C. D. Tayler, K. Mouloudakis, R. Zetter, D. Hunter, V. G. Lucivero, S. Bodenstedt, L. Parkkonen, and **M. W. Mitchell**. Miniature biplanar coils for alkali-metal-vapor magnetometry. *Phys. Rev. Applied*, **18**, 014036 (2022)

[13] D. B. Orenes, R. J. Sewell, J. Lodewyck, and **M. W. Mitchell**. Improving short-term stability in optical lattice clocks by quantum nondemolition measurement. *Phys. Rev. Lett.*, **128**, 153201 (2022)

[14] E. Aybar, A. Niezgoda, S. S. Mirkhalaf, **M. W. Mitchell**, D. Benedicto Orenes, and E. Witkowska. Critical quantum thermometry and its feasibility in spin systems. *Quantum*, **6**, 808 (2022)

[15] K. Mouloudakis, G. Vasilakis, V. G. Lucivero, J. Kong, I. K. Kominis, and **M. W. Mitchell**. Effects of spin-exchange collisions on the fluctuation spectra of hot alkali-metal vapors. *Phys. Rev. A*, **106**, 023112 (2022)

[16] S. P. Alvarez, P. Gomez, S. Coop, R. Zamora-Zamora, C. Mazzinghi, and **M. W. Mitchell**. Single-domain Bose condensate magnetometer achieves energy resolution per bandwidth below $\hbar$. *Proceedings of the National Academy of Sciences*, **119**, e2115339119 (2022)

[17] W. Du, et al. SU(2)-in-SU(1,1) nested interferometer for high sensitivity, loss-tolerant quantum metrology. *Phys. Rev. Lett.*, **128**, 033601 (2022)

[18] S. Bodenstedt, D. Moll, S. Glöggler, **M. W. Mitchell**, and M. C. D. Tayler. Decoupling of Spin Decoherence Paths near Zero Magnetic Field. *J. Phys. Chem. Lett.*, **13**, 98 (2022)

[19] C. Mazzinghi, D. B. Orenes, P. Gomez, V. G. Lucivero, E. Aybar, S. Gugnani, and **M. W. Mitchell**. Cavity-enhanced polarization rotation measurements for low-disturbance probing of atoms. *Opt. Express*, **29**, 40854 (2021)

[20] C. Troullinou, R. Jiménez-Martínez, J. Kong, V. G. Lucivero, and **M. W. Mitchell**. Squeezed-light enhancement and backaction evasion in a high sensitivity optically pumped magnetometer. *Phys. Rev. Lett.*, **127**, 193601 (2021)

[21] L. C. Bianchet, N. Alves, L. Zarraoa, N. Bruno, and **M. W. Mitchell**. Manipulating and measuring single atoms in the Maltese cross geometry. *Open Research Europe*, **1**, 102 (2021)

[22] D. Goncalves, **M. W. Mitchell**, and D. E. Chang. Unconventional quantum correlations of light emitted by a single atom in free space. *Phys. Rev. A*, **104**, 013724 (2021)

[23] V. Prakash, A. Sierant, and **M. W. Mitchell**. Autoheterodyne characterization of narrow-band photon pairs. *Phys. Rev. Lett.*, **127**, 043601 (2021)

[24] S. Bodenstedt, **M. W. Mitchell**, and M. C. D. Tayler. Fast-field-cycling ultralow-field nuclear magnetic relaxation dispersion. *Nature Communications*, **12**, 4041 (2021)

[25] S. S. Mirkhalaf, D. Benedicto Orenes, **M. W. Mitchell**, and E. Witkowska. Criticality-enhanced quantum sensing in ferromagnetic Bose-Einstein condensates: Role of readout measurement and detection noise. *Phys. Rev. A*, **103**, 023317 (2021)

[26] L. K. Shalm, et al. Device-independent randomness expansion with entangled photons. *Nature Physics*, **17**, 452 (2021)

[27] J. Kong, R. Jiménez-Martínez, C. Troullinou, V. G. Lucivero, G. Tóth, and **M. W. Mitchell**. Measurement-induced, spatially-extended entanglement in a hot, strongly-interacting atomic system. *Nature Communications*, **11**, 2415 (2020)

[28] P. Gomez, F. Martin, C. Mazzinghi, D. Benedicto Orenes, S. Palacios, and **M. W. Mitchell**. Bose-einstein condensate comagnetometer. *Phys. Rev. Lett.*, **124**, 170401 (2020)

[29] **M. W. Mitchell** and S. Palacios Alvarez. Colloquium: Quantum limits to the energy resolution of magnetic field sensors. *Rev. Mod. Phys.*, **92**, 021001 (2020)

[30] **M. W. Mitchell**. Scale-invariant spin dynamics and the quantum limits of field sensing. *New Journal of Physics*, **22**, 053041 (2020)

[31] Y. Zhang, et al. Experimental low-latency device-independent quantum randomness. *Phys. Rev. Lett.*, **124**, 010505 (2020)

[32] V. Prakash, L. C. Bianchet, M. T. Cuairan, P. Gomez, N. Bruno, and **M. W. Mitchell**. Narrowband photon pairs with independent frequency tuning for quantum light-matter interactions. *Optics Express*, **27**, 38463 (2019)

[33] P. Gomez, C. Mazzinghi, F. Martin, S. Coop, S. Palacios, and **M. W. Mitchell**. Interferometric measurement of interhyperfine scattering lengths in $^{87}\mathrm{Rb}$. *Phys. Rev. A*, **100**, 032704 (2019)

[34] N. Bruno, L. C. Bianchet, V. Prakash, N. Li, N. Alves, and **M. W. Mitchell**. Maltese cross coupling to individual cold atoms in free space. *Opt. Express*, **27**, 31042 (2019)

[35] Y. Liu, et al. Experimental measurement-dependent local Bell test with human free will. *Phys. Rev. A*, **99**, 022115 (2019)

[36] M. Rudé, C. Abellán, A. Capdevila, D. Domenech, **M. W. Mitchell**, W. Amaya, and V. Pruneri. Interferometric photodetection in silicon photonics for phase diffusion quantum entropy sources. *Optics Express*, **26**, 31957 (2018)

[37] R. Jiménez-Martínez, J. Kołodyński, C. Troullinou, V. G. Lucivero, J. Kong, and **M. W. Mitchell**. Signal tracking beyond the time resolution of an atomic sensor by Kalman filtering. *Phys. Rev. Lett.*, **120**, 040503 (2018)

[38] D. Braun, G. Adesso, F. Benatti, R. Floreanini, U. Marzolino, **M. W. Mitchell**, and S. Pirandola. Quantum-enhanced measurements without entanglement. *Rev. Mod. Phys.*, **90**, 035006 (2018)

[39] C. Abellán, et al. Challenging local realism with human choices. *Nature*, **557**, 212 (2018)

[40] S. Palacios, S. Coop, P. Gomez, T. Vanderbruggen, Y. N. M. de Escobar, M. Jasperse, and **M. W. Mitchell**. Multi-second magnetic coherence in a single domain spinor bose–einstein condensate. *New Journal of Physics*, **20**, 053008 (2018)

[41] J. A. Zielińska and **M. W. Mitchell**. Atom-resonant squeezed light from a tunable monolithic ppRKTP parametric amplifier. *Opt. Lett.*, **43**, 643 (2018)

[42] G. Vitagliano, G. Colangelo, F. Martin Ciurana, **M. W. Mitchell**, R. J. Sewell, and G. Tóth. Entanglement and extreme planar spin squeezing. *Phys. Rev. A*, **97**, 020301 (2018)

[43] M. N. Bera, A. Acín, M. Kuś, **M. W. Mitchell**, and M. Lewenstein. Randomness in quantum mechanics: philosophy, physics and technology. *Reports on Progress in Physics*, **80**, 124001 (2017)

[44] S. Coop, S. Palacios, P. Gomez, Y. N. M. de Escobar, T. Vanderbruggen, and **M. W. Mitchell**. Floquet theory for atomic light-shift engineering with near-resonant polychromatic fields. *Optics Express*, **25**, 32550 (2017)

[45] F. Martin Ciurana, G. Colangelo, L. Slodička, R. J. Sewell, and **M. W. Mitchell**. Entanglement-enhanced radio-frequency field detection and waveform sensing. *Phys. Rev. Lett.*, **119**, 043603 (2017)

[46] G. Colangelo, F. Martin Ciurana, G. Puentes, **M. W. Mitchell**, and R. J. Sewell. Entanglement-enhanced phase estimation without prior phase information. *Phys. Rev. Lett.*, **118**, 233603 (2017)

[47] G. Colangelo, F. M. Ciurana, L. C. Bianchet, R. J. Sewell, and **M. W. Mitchell**. Simultaneous tracking of spin angle and amplitude beyond classical limits. *Nature*, **543**, 525 (2017)

[48] J. A. Zielińska and **M. W. Mitchell**. Self-tuning optical resonator. *Optics Letters*, **42**, 5298 (2017)

[49] V. G. Lucivero, A. Dimic, J. Kong, R. Jiménez-Martínez, and **M. W. Mitchell**. Sensitivity, quantum limits, and quantum enhancement of noise spectroscopies. *Phys. Rev. A*, **95**, 041803(R) (2017)

[50] J. A. Zielińska, A. Zukauskas, C. Canalias, M. A. Noyan, and **M. W. Mitchell**. Fully-resonant, tunable, monolithic frequency conversion as a coherent UVA source. *Optics Express*, **25**, 1142 (2017)

[51] **M. W. Mitchell**. Number-unconstrained quantum sensing. *Quantum Science and Technology*, **2**, 044005 (2017)

[52] C. Abellan, W. Amaya, D. Domenech, P. Muñoz, J. Capmany, S. Longhi, **M. W. Mitchell**, and V. Pruneri. Quantum entropy source on an InP photonic integrated circuit for random number generation. *Optica*, **3**, 989 (2016)

[53] F. M. Ciurana, G. Colangelo, R. J. Sewell, and **M. W. Mitchell**. Real-time shot-noise-limited differential photodetection for atomic quantum control. *Opt. Lett.*, **41**, 2946 (2016)

[54] V. G. Lucivero, R. Jiménez-Martínez, J. Kong, and **M. W. Mitchell**. Squeezed-light spin noise spectroscopy. *Phys. Rev. A*, **93**, 053802 (2016)

[55] J. Kofler, M. Giustina, J.-A. Larsson, and **M. W. Mitchell**. Requirements for a loophole-free photonic Bell test using imperfect setting generators. *Phys. Rev. A*, **93**, 032115 (2016)

[56] C. Abellán, W. Amaya, D. Mitrani, V. Pruneri, and **M. W. Mitchell**. Generation of fresh and pure random numbers for loophole-free Bell tests. *Phys. Rev. Lett.*, **115**, 250403 (2015)

[57] L. K. Shalm, et al. Strong loophole-free test of local realism. *Phys. Rev. Lett.*, **115**, 250402 (2015)

[58] M. Giustina, et al. Significant-loophole-free test of Bell's theorem with entangled photons. *Phys. Rev. Lett.*, **115**, 250401 (2015)

[59] C. Budroni, G. Vitagliano, G. Colangelo, R. J. Sewell, O. Gühne, G. Tóth, and **M. W. Mitchell**. Quantum nondemolition measurement enables macroscopic Leggett-Garg tests. *Phys. Rev. Lett.*, **115**, 200403 (2015)

[60] B. Hensen, et al. Loophole-free Bell inequality violation using electron spins separated by 1.3 kilometres. *Nature*, **526**, 682 (2015)

[61] T. Vanderbruggen, S. P. Álvarez, S. Coop, N. M. de Escobar, and **M. W. Mitchell**. Spontaneous PT symmetry breaking of a ferromagnetic superfluid in a gradient field. *Europhys Lett*, **111**, 66001 (2015)

[62] Y. N. M. de Escobar, S. P. Álvarez, S. Coop, T. Vanderbruggen, K. T. Kaczmarek, and **M. W. Mitchell**. Absolute frequency references at 1529 and 1560 nm using modulation transfer spectroscopy. *Opt. Lett.*, **40**, 4731 (2015)

[63] J. Kong, V. G. Lucivero, R. Jiménez-Martínez, Ricardo, and **M. W. Mitchell**. Long-term laser frequency stabilization using fiber interferometers. *Rev. Sci. Instrum.*, **86**, 073104 (2015)

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