

# Patrick J. Coles

Scientist 2, T-4 Division, Los Alamos National Laboratory

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## Research Directions

Quantum computing, quantum machine learning, quantum cryptography  
quantum information theory, quantum optics, quantum foundations.

## Academic Positions and Education

**Los Alamos National Laboratory** **2017 – Present**

Staff Scientist, Level 2, T-4 Division

**University of Waterloo** **2014 – 2017**

Institute for Quantum Computing, Department of Physics  
Postdoctoral Researcher

**National University of Singapore** **2012 – 2014**

Centre for Quantum Technologies  
Postdoctoral Researcher

**Carnegie Mellon University** **2008 – 2012**

Department of Physics  
Postdoctoral Researcher

**University of California, Berkeley** **2002 – 2008**

Department of Chemical Engineering  
Ph.D., *NSF Fellow*

**University of Cambridge** **2001 – 2002**

Department of Biochemistry  
M.Phil., *Churchill Fellow*  
(only 11 Churchill Scholarships awarded annually)

**Case Western Reserve University** **1997 – 2001**

B.S., Chemical Engineering  
GPA: 4.0 (maximum possible GPA: 4.0)

## Research Experience

**Los Alamos National Laboratory** **2017 – Present**

Quantum Computing Algorithms  
- Evolving quantum algorithms with machine learning  
- Quantum Neural Networks

**University of Waterloo (Postdoctoral research)****2014 – 2017**

Quantum key distribution (QKD):

- Constructing a security proof framework for arbitrary QKD protocols
- Developing numerical methods for computing the secret key rate
- Collaborating with experimentalists on continuous variable and time-bin QKD

Quantum computing: randomized benchmarking in the presence of non-Markovian noise

*Advisor: Norbert Lütkenhaus, Professor***National University of Singapore (Postdoctoral research)****2012 – 2014**

Quantum optics: visibility-distinguishability tradeoffs in interferometers

Quantum information technologies: quantum key distribution, quantum networks, superdense coding

Quantum information theory: entanglement and Heisenberg's uncertainty principle

*Advisor: Stephanie Wehner, Associate Professor***Carnegie Mellon University (Postdoctoral research)****2008 – 2012**

Decoherence: Unifying the theory of decoherence. Modeling decoherence in simple physical systems.

Uncertainty principle: Reformulating the uncertainty principle to be useful for quantum cryptography.

Quantum correlations: Analyzing the utility of non-classical correlations for information processing.

*Advisor: Robert Griffiths\*, Otto Stern University Professor of Physics**\*Inventor of the Consistent Histories approach to quantum mechanics***UC Berkeley (Doctoral thesis research)****2002 – 2008**

Thesis title: "Model for optically-induced nuclear spin polarization in Gallium Arsenide"

Theoretical and experimental studies of laser-induced nuclear spin alignment in semiconductors.

Experimental techniques: radiofrequency electronics, NMR, laser optics, cryogenics, vacuum.

Theoretical areas: solid-state physics, coherent spin dynamics and spin thermodynamics.

*Advisor: Jeffrey Reimer, Chair of Chemical Engineering Department, Schlinger Distinguished Professor***University of Cambridge (Masters thesis research)****2001 – 2002**

Determined the 3-D structure of DNA-binding protein using Nuclear Magnetic Resonance (NMR).

*Advisor: Jean Thomas, Professor***Carnegie Mellon University (Summer project)****Summer 2001**

Optical measurement of surface forces, using Total Internal Reflection Microscopy (TIRM)

*Advisor: Dennis Prieve, Gulf Professor of Chemical Engineering, Inventor of TIRM***Case Western Reserve University (Undergrad. Research)****1999 – 2001**

Computer modeling of interactions between protein receptors and pharmaceuticals.

*Advisors: Professor Menachem Shoham and Professor Bryan Roth***SOFTWARE DEVELOPMENT****University of Waterloo**

Led a team of students in developing the first software for calculating key rates of quantum key distribution (QKD) protocols. The software is a Graphical User Interface based in Matlab. It is publicly

available at our website:

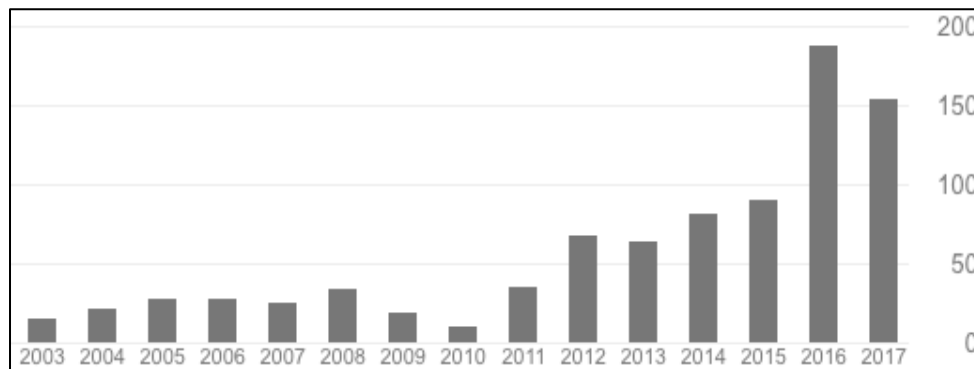
<https://lutkenhausgroup.wordpress.com/qkd-software/>

## Publications

### Citations

Total: 889, h-index: 15

(from Google Scholar, accessed on Oct. 10, 2017)



### Review article

28. **P. J. Coles**, M. Berta, M. Tomamichel, S. Wehner  
Entropic uncertainty relations and their applications  
*Reviews of Modern Physics*.89: 015002. (2017).  
<https://journals.aps.org/rmp/abstract/10.1103/RevModPhys.89.015002>

### Peer-reviewed articles

27. F. Rozpedek, J. Kaniewski, **P. J. Coles**, S. Wehner  
Quantum preparation uncertainty and lack of information  
*New Journal of Physics*. 19: 023038. (2017)  
<http://iopscience.iop.org/article/10.1088/1367-2630/aa5d64/meta;jsessionid=720C9852D43866FED1E2F373404D076F.ip-10-40-2-120>
26. **P. J. Coles**, E. M. Metodiev, N. Lütkenhaus  
Numerical approach for unstructured quantum key distribution  
*Nature Communications*. 7: 11712. (2016)  
<http://www.nature.com/ncomms/2016/160520/ncomms11712/full/ncomms11712.html>
25. **P. J. Coles**  
Entropic framework for wave-particle duality in multi-path interferometers  
*Physical Review A*. 93: 062111. (2016)  
<http://journals.aps.org/pr/abstract/10.1103/PhysRevA.93.062111>

24. C. Pfister, N. Lütkenhaus, S. Wehner, **P. J. Coles**  
Sifting attacks in finite-size quantum key distribution  
*New Journal of Physics*. 18: 053001. (2016)  
<http://iopscience.iop.org/article/10.1088/1367-2630/18/5/053001/meta>
23. D. B. S. Soh, C. Brif, **P. J. Coles**, N. Lütkenhaus, R. M. Camacho, J. Urayama, M. Sarovar  
Self-referenced continuous-variable quantum key distribution protocol  
*Physical Review X*. 5: 041010. (2015)  
<https://journals.aps.org/prx/abstract/10.1103/PhysRevX.5.041010>
22. **P. J. Coles** and F. Furrer  
State-dependent approach to entropic measurement-disturbance relations  
*Physics Letters A*. 379: 105-112. (2015)  
<http://www.sciencedirect.com/science/article/pii/S0375960114011098>
21. **P. J. Coles**, J. Kaniewski, S. Wehner  
Equivalence of wave-particle duality to entropic uncertainty  
*Nature Communications*. 5: 5814. (2014)  
<http://www.nature.com/doi/10.1038/ncomms6814>
20. M. Berta, **P. J. Coles**, S. Wehner  
Entanglement-assisted guessing of complementary measurement outcomes  
*Physical Review A*. 90: 062127. (2014)  
<http://link.aps.org/doi/10.1103/PhysRevA.90.062127>
19. **P. J. Coles** and M. Piani  
Complementary sequential measurements generate entanglement  
*Physical Review A: Rapid Communications*. 89: 010302(R). (2014) **Selected for Editors' Suggestion**  
<http://link.aps.org/doi/10.1103/PhysRevA.89.010302>
18. **P. J. Coles** and M. Piani  
Improved entropic uncertainty relations and information exclusion relations  
*Physical Review A*. 89: 022112. (2014)  
<http://link.aps.org/doi/10.1103/PhysRevA.89.022112>
17. **P. J. Coles**  
Role of complementarity in superdense coding  
*Physical Review A*. 88: 062317. (2013)  
<http://link.aps.org/doi/10.1103/PhysRevA.88.062317>
16. **P. J. Coles**  
Collapse of the quantum correlation hierarchy links entropic uncertainty to entanglement creation  
*Physical Review A*. 86: 062334. (2012)  
<http://link.aps.org/doi/10.1103/PhysRevA.86.062334>

15. **P. J. Coles**, V. Gheorghiu, R. Griffiths  
Collisional decoherence of tunneling molecules: a consistent histories treatment  
*Physical Review A*. 86: 042111. (2012)  
<http://link.aps.org/doi/10.1103/PhysRevA.86.042111>
14. **P. J. Coles**, R. Colbeck, L. Yu, M. Zwolak  
Uncertainty relations from simple entropic properties  
*Physical Review Letters*. 108: 210405. (2012)  
<http://link.aps.org/doi/10.1103/PhysRevLett.108.210405>
13. **P. J. Coles**  
Unification of different views of decoherence and discord  
*Physical Review A*. 85: 042103. (2012)  
<http://link.aps.org/doi/10.1103/PhysRevA.85.042103>
12. **P. J. Coles**, L. Yu, V. Gheorghiu, R. Griffiths  
Information-theoretic treatment of tripartite systems and quantum channels  
*Physical Review A*. 83: 062338. (2011)  
<http://link.aps.org/doi/10.1103/PhysRevA.83.062338>
11. J. King, **P. J. Coles**, J. Reimer  
Optical polarization of  $^{13}\text{C}$  nuclei in diamond through nitrogen vacancy centers  
*Physical Review B*. 81: 073201. (2010)  
<http://link.aps.org/doi/10.1103/PhysRevB.81.073201>
10. B. Li, **P. J. Coles**, J. Reimer, P. Dawson, C. Meriles  
Optical pumping of nuclear spin magnetization in GaAs/AlAs quantum wells of variable electron density  
*Solid State Communications*. 150: 450-453. (2010)  
<http://www.sciencedirect.com/science/article/pii/S0038109809007558>
9. **P. J. Coles**  
Helicity asymmetry of optically pumped NMR spectra in GaAs  
*Physical Review B*. 78: 033201. (2008)  
<http://journals.aps.org/prb/abstract/10.1103/PhysRevB.78.033201>
8. **P. J. Coles** and J. Reimer  
Penetration depth model for optical alignment of nuclear spins in GaAs.  
*Physical Review B*. 76: 174440. (2007)  
<http://journals.aps.org/prb/abstract/10.1103/PhysRevB.76.174440>
7. A. Paravastu, **P. J. Coles**, J. Reimer, T. Ladd, R. Maxwell  
Photocurrent-modulated optical nuclear polarization in bulk GaAs  
*Applied Physics Letters*, 87: 232109. (2005)  
<http://scitation.aip.org/content/aip/journal/apl/87/23/10.1063/1.2140484>

6. T. Ali, **P. J. Coles**, T. Stevens, K. Stott, J. Thomas  
Two homologous domains of similar structure but different stability in the yeast linker histone, Hho1P  
*Journal of Molecular Biology*, 338:139. (2004)  
<http://www.sciencedirect.com/science/article/pii/S0022283604002232>
5. M. Thibonnier, **P. J. Coles**, A. Thibonnier, and M. Shoham  
Molecular Pharmacology and Modeling of Vasopressin Receptors  
*Progress in Brain Research*, 139:179-96. (2002)  
<http://www.sciencedirect.com/science/article/pii/S0079612302390162>
4. M. Thibonnier, **P. J. Coles**, A. Thibonnier, and M. Shoham  
The Basic and Clinical Pharmacology of Nonpeptide Vasopressin Receptor Antagonists  
*Annual Review of Pharmacology and Toxicology*, 41:175-202. (2001)  
<http://www.annualreviews.org/doi/abs/10.1146/annurev.pharmtox.41.1.175>
3. M. Thibonnier, **P. J. Coles**, D. Conarty, C. Plesnicher, and M. Shoham  
Molecular model of agonist and nonpeptide antagonist binding to the human V<sub>1</sub> vascular vasopressin receptor  
*Journal of Pharmacology and Experimental Therapeutics*, 294:195-203. (2000)  
<http://jpet.aspetjournals.org/content/294/1/195.short>

### **Preprints**

2. **P. J. Coles**, L. Yu, M. Zwolak  
Relative entropy derivation of the uncertainty principle with quantum side information  
arXiv:1105.4865. (2011)  
<http://arxiv.org/abs/1105.4865>
1. **P. J. Coles**  
Non-negative discord strengthens the subadditivity of quantum entropy functions  
arXiv:1101.1717. (2011)  
<http://arxiv.org/abs/1101.1717>

## Media Coverage

### Quantum key distribution

- Science Daily  
<https://www.sciencedaily.com/releases/2016/05/160523104817.htm>
- Phys.org  
<http://phys.org/news/2016-05-secret-unbreakable-key.html>
- Scientific Computing  
<http://www.scientificcomputing.com/news/2016/05/computing-secret-unbreakable-key>
- ECN  
<http://www.ecnmag.com/news/2016/05/computing-secret-unbreakable-key>
- EurekAlert!  
[http://www.eurekalert.org/pub\\_releases/2016-05/uow-cas052016.php](http://www.eurekalert.org/pub_releases/2016-05/uow-cas052016.php)
- University of Waterloo  
<https://uwaterloo.ca/news/news/computing-secret-unbreakable-key>

### Wave-particle duality

- Huffington Post  
[http://www.huffingtonpost.com/2014/12/24/quantum-physics-easier-to-understand\\_n\\_6370570.html](http://www.huffingtonpost.com/2014/12/24/quantum-physics-easier-to-understand_n_6370570.html)
- Ten of the biggest science and technology stories of 2014 (phys.org)  
<http://phys.org/news/2014-12-ten-biggest-science-technology-stories.html>
- Asian Scientist  
<http://www.asianscientist.com/2014/12/in-the-lab/bridging-mysteries-heart-quantum-physics/>
- University of Waterloo  
<https://uwaterloo.ca/stories/quantum-physics-breakthrough-scientists-solve-100-year-old>
- Motherboard Vice  
[http://motherboard.vice.com/en\\_us/read/how-digital-information-unifies-quantum-mechanics](http://motherboard.vice.com/en_us/read/how-digital-information-unifies-quantum-mechanics)
- Phys.org  
<http://phys.org/news/2014-12-quantum-physics-complicated.html>
- From Quarks to Quasars  
<http://www.fromquarkstoquasars.com/particle-wave-duality-quantum-uncertainty-principle-united/>
- EurekAlert! [http://www.eurekalert.org/pub\\_releases/2014-12/cfqf-qpj121814.php](http://www.eurekalert.org/pub_releases/2014-12/cfqf-qpj121814.php)
- International Business Times  
<http://www.ibtimes.co.uk/quantum-physics-just-got-less-complicated-rosetta-stone-breakthrough-1480238>
- Controlled Environments  
<http://www.cemag.us/news/2014/12/making-quantum-physics-less-complicated>
- Opli [http://www.opli.net/opli\\_magazine/eo/2014/quantum-physics-just-got-less-complicated-dec-news/](http://www.opli.net/opli_magazine/eo/2014/quantum-physics-just-got-less-complicated-dec-news/)
- Science Daily <http://www.sciencedaily.com/releases/2014/12/141219085153.htm>
- Nanowerk <http://www.nanowerk.com/nanotechnology-news/newsid=38529.php>
- (e) Science News  
<http://esciencenews.com/articles/2014/12/19/quantum.physics.just.got.less.complicated>
- R&D Magazine <http://www.rdmag.com/news/2014/12/quantum-physics-just-got-less-complicated>
- Laboratory Equipment <http://www.laboratoryequipment.com/news/2014/12/good-news-quantum-physics-just-got-less-complicated>

## Visiting Research Invitations

**Sandia National Laboratory** **Feb. 2015**

Continuous-variable quantum key distribution  
*Host: Mohan Sarovar, Researcher*

**ETH Zurich** **Oct. 2013**

Quantum information resource theories  
*Host: Joe Renes, Researcher*

**University of Waterloo** **Jun. 2012**

Entanglement and the uncertainty principle  
*Host: Marco Piani, Assistant Professor*

**Perimeter Institute for Theoretical Physics** **Jun. 2011**

General framework for proving uncertainty relations  
*Host: Roger Colbeck, Assistant Professor*

**Los Alamos National Laboratory** **Feb. 2011**

Correlations in quantum systems  
*Host: Michael Zwolak, Assistant Professor*

## Invited Talks

**SPIE Conference on Quantum Communication** **Aug. 2016**

San Diego, USA  
"Unstructured quantum key distribution"

**Workshop on Beyond I.I.D. in Information Theory** **July 2016**

Barcelona, Spain  
"Entropic uncertainty relations and their applications"

**Quantum Foundations Seminar** **Nov. 2014**

Perimeter Institute for Theoretical Physics, Canada  
"Equivalence of wave-particle duality to entropic uncertainty"

**Quantum Lunch Seminar** **Feb. 2011**

Los Alamos National Lab, USA  
"Diagrammatic approach to Consistent Histories"

**Quantum Lunch Seminar** **Nov. 2010**

Los Alamos National Lab, USA  
"Information-theoretic treatment of tripartite systems and quantum channels"

**Quantum Coherence and Decoherence Workshop** **Sep. 2010**

Benasque, Spain



“Information-theoretic treatment of tripartite systems and quantum channels”

**UC Berkeley, Dept. of Chemical Engineering Colloquium    Apr. 2007**

Berkeley, USA

“Laser-Induced Nuclear Spin Alignment in GaAs”

## Honors

### Research Award

- Best-poster-award at the largest international conference on quantum cryptography (QCRYPT) in 2012

### Referee Award

- Outstanding Reviewer for the journal *Physics Letters A*, awarded in 2015

### Graduate Fellowships

- Churchill Fellowship  
(11 awarded nationwide annually, for US students to pursue a Masters Degree at Cambridge)
- National Science Foundation Graduate Fellowship
- NDSEG Fellowship from the Department of Defense (Declined due to NSF Fellowship)
- University of California, Berkeley Fellowship (Declined due to Churchill Fellowship)

### Undergraduate Scholarships

- Society for Analytical Chemists of Pittsburgh (SACP) \$16,000 College Scholarship  
(This \$16,000 scholarship was awarded based on my score on the annual ACS high-school chemistry exam.)
- Case Western Alumni Scholarship
- Case Western Presidential Scholarship
- Zeta Beta Tau Fraternity 4.0 Scholarship

### Undergraduate Awards

- AIChE (American Institute of Chemical Engineers) Research Award
- Bahnsen Award: achievement in Chemical Engineering and outstanding design and research projects
- Case Alumni Prize: senior with best academic record in the Case School of Engineering
- Outstanding Junior Award of the Case School of Engineering
- Outstanding Sophomore Award of the Case School of Engineering
- Kilpatrick Award: senior varsity athlete with highest GPA
- UAA All-Academic (1998 – 2001)
- NSCAA/Adidas Scholar Athlete - Honorable Mention (1999)
- Tau Beta Pi Honor Society (HS), Mortar Board HS, Gamma Sigma Alpha HS, Golden Key HS

## Teaching Experience

### University of Waterloo

- Lecturer on quantum information theory: Developed and taught a special topics course on quantum information theory, offered to graduate students in June 2016.
- Lecturer at the Undergraduate School for Experimental Quantum Information Processing (USEQIP), from 2015 to present.
- Mentored three undergraduate students and two graduate students on quantum optics and quantum information research projects.

### National University of Singapore

- Mentored graduate and undergraduate students on quantum information research projects.

### Carnegie Mellon University

- Lecturer on Quantum Optics: Developed and taught a graduate course, the first quantum optics course ever offered at Carnegie Mellon. Topics covered included field quantization, field states, characteristic functions, field-atom interaction, spontaneous emission, open systems, quantum jumps, lasers, experimental paradigms, Casimir's effect, optical devices (beam splitters, interferometers, detectors), quantum information, and optical tests of quantum foundations.

### University of California, Berkeley

- Graduate Student Instructor: Chemical Engineering 162 - Process Dynamics and Control.
- Graduate Student Instructor: Chemical Engineering 137 - Transport Laboratory

### Case Western Reserve University

- Supplemental Instructor: Organic Chemistry I and II.

## Additional Experience

### Machine Learning and Neural Networks

- Certification in Machine Learning course offered by Coursera, Stanford University (Dec. 2016).
- Certification in Neural Networks course offered by Coursera, University of Toronto (March 2017).

### Conference Organizer

- Organizing committee member for the largest international conference on quantum cryptography (QCRYPT), hosted by National University of Singapore in 2012.

### Referee

- Referee for Physical Review Letters, IEEE Transactions on Information Theory, Physical Review A, New Journal of Physics, International Journal of Quantum Information, Quantum Information Processing, Scientific Reports, Physical Letters A, and Journal of Physics A.

## REFERENCES

### **Robert Griffiths**

Otto Stern University Professor of Physics  
Department of Physics  
Carnegie Mellon University  
Phone: 4122682765  
Email: [rgrif@andrew.cmu.edu](mailto:rgrif@andrew.cmu.edu)  
Relationship: Postdoc advisor

### **Norbert Lutkenhaus**

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Relationship: Postdoc advisor

### **Stephanie Wehner**

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Relationship: Postdoc advisor