Dr Norbert Matthias Linke

Personal data

Address:	St Timothy's School	Office:	+1 (301) 405-6105
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	Stevenson, MD 21153	E-Mail:	linke@umd.edu
	USA	Web:	linkelab.umd.edu
Born:	20th March 1983 in Munich, Germany	Citizenship:	German

Research positions

01/2019 – present: Assistant Professor or Physics and Fellow of the Joint Quantum Institute, University of Maryland, College Park, MD, USA

07/2017 – 12/2018: Faculty Research Scientist, Trapped ion quantum information group, Joint Quantum Institute, University of Maryland (Prof. C. Monroe), MD, USA

02/2015 – 06/2017: Post-doctoral Research Associate, Trapped ion quantum information group, Joint Quantum Institute, University of Maryland (Prof. C. Monroe), MD, USA

10/2012 – 12/2014: Post-doctoral Research Assistant, Ion trap group, Department of Physics, University of Oxford (Prof. D. M. Lucas), UK

Education

2008 – 2012: **University of Oxford, UK, D.Phil. in Atomic & Laser Physics**
Dissertation: "*Background-free detection and mixed-species crystals in micro- and macroscopic ion-traps for scalable QIP.*" supervisor: Prof. D. M. Lucas

2002 – 2008: **University of Ulm, Germany, Diplom in Physics (grade 1.1, range 1.0-4.0)**
Diploma Thesis (1.0): "*Cold ion crystals in a segmented Paul trap as a deterministic source of single ions.*" supervisor: Prof. F. Schmidt-Kaler

University of Ulm, Germany, Bachelor in Philosophy (B.A.) (1.3)
Bachelor Thesis (1.3): "*Pyrrhonian Scepticism.*" supervisor: Prof. M. Kober

1993 – 2002: **Secondary school: Ludwigsgymnasium München, Germany, Abitur (1.4)**

Publications

(30.) "*Variational Generation of Thermofield Double States and Critical Ground States with a Quantum Computer,*" D. Zhu, S. Johri, N. M. Linke, K. A. Landsman, N. H. Nguyen, C. H. Alderete, A. Y. Matsuura, T. H. Hsieh, C. Monroe, preprint arXiv:1906.02699 (2019).

(29.) „*Noise reduction using past causal cones in variational quantum algorithms,*" O. Shehab, I. H. Kim, N. H. Nguyen, K. A. Landsman, Cinthia H. Alderete, Daiwei Zhu, C. Monroe, and Norbert M. Linke, preprint arXiv:1906.00476 (2019).

(28.) "*Two-qubit entangling gates within arbitrarily long chains of trapped ions,*" K. A. Landsman, Y. Wu, P. H. Leung, D. Zhu, N. M. Linke, K. R. Brown, L.-M. Duan, C. Monroe, preprint arXiv:1905.10421 (2019).

(27.) "*Toward convergence of effective field theory simulations on digital quantum computers*," O. Shehab, K. A. Landsman, Y. Nam, D. Zhu, N. M. Linke, M. J. Keesan, R. C. Pooser, C. Monroe, preprint arXiv:1904.04338 (2019).

(26.) "*Training of Quantum Circuits on a Hybrid Quantum Computer,*" D. Zhu, N. M. Linke, M. Benedetti, K. A. Landsman, N. H. Nguyen, C. H. Alderete, A. Perdomo-Ortiz, N. Korda, A. Garfoot, C. Brecque, L. Egan, O. Perdomo, and C. Monroe, accepted at Science Advances, preprint arXiv:1812.08862 (2018).

25. "*Full-Stack, Real-System Quantum Computer Studies: Architectural Comparisons and Design Insights,*" P. Murali, N. M. Linke, M. Martonosi, A. J. Abhari, N. H. Nguyen, C. H. Alderete, 46th International Symposium on Computer Architecture (ISCA '19), arXiv:1905.11349 (2019).

24. "*Parallel Entangling Operations on a Universal Ion Trap Quantum Computer,*" C. Figgatt, A. Ostrander, N. M. Linke, K. A Landsman, D. Zhu, D. Maslov, C. Monroe; Nature (in print) https://www.nature.com/articles/s41586-019-1427-5, (2019).

23. "*Validating and Certifying Stabilizer States,*" A. Kalev, A. Kyrillidis, N. M. Linke; **Phys. Rev. A 99**, 042337 (2019).

22. "*Verified Quantum Information Scrambling,*" K. A Landsman, C. Figgatt, T. Schuster, N. M. Linke, B. Yoshida, N. Y. Yao, C. Monroe; **Nature 567**, 61-65 (2019).

21. "*Measuring the Renyi entropy of a two-site Fermi-Hubbard model on a trapped ion quantum computer,*" N. M. Linke, S. Johri, C. Figgatt, K. A. Landsman, C. Monroe, **Phys. Rev. A 98**, 052334 (2018).

20. "*Machine Learning Assisted Readout of Trapped Ion Qubits,*" A. Seif, K. A. Landsman, N. M. Linke, C. Figgatt, C. Monroe, and M. Hafezi, **J. Phys. B: At. Mol. Opt. Phys. 51**, 174006 (2018).

19. "*Demonstration of a Bayesian Quantum Game on an Ion Trap Quantum Computer,*" N. Solmeyer, N. M. Linke, C. Figgatt, K. A. Landsman, R. Balu, G. Siopsis, C. Monroe, **Quantum Sci. Tech. 3**, 045002 (2018).

18. "*Observation of Hopping and Blockade of Bosons in a Trapped Ion Spin Chain,*" S. Debnath, N. M. Linke, S.-T. Wang, C. Figgatt, K. A. Landsman, L.-M. Duan, C. Monroe; **Phys. Rev. Lett. 120**, 073001 (2018), Editor's Suggestion.

17. "*Robust two-qubit gates in a linear ion crystal using a frequency-modulated drive force,*" P.-H. Leung, K. A. Landsman, C. Figgatt, N. M. Linke, C. Monroe, K. R. Brown, **Phys. Rev. Lett.**, **120**, 020501 (2018).

16. "*Complete 3-qubit Grover search on a programmable quantum computer,*" C. Figgatt, D. Maslov, K. A. Landsman, N. M. Linke, S. Debnath, C. Monroe; **Nat. Communs. 8**, 1918 (2017).

15. "*Fault tolerant quantum error detection,*" N. M. Linke, M. Gutierrez, K. A. Landsman, C. Figgatt, S. Debnath, K. R. Brown, C. Monroe; **Sci. Adv. 3**, 10 (2017).

14. "*Experimental comparison of two quantum computing architectures,*" N. M. Linke, D. Maslov, M. Roetteler, S. Debnath, C. Figgatt, K. A. Landsman, K. Wright, C. Monroe; **Proc. Natl. Acad. Sci. 114**, 13 (2017).

13. "*High-fidelity spatial addressing of Ca-43 qubits using near-field microwave control,*" D. P. L. Aude Craik, N. M. Linke, M. A. Sepiol, T. P. Harty, C. J. Ballance, D. N. Stacey, A. M. Steane, D. M. Lucas, D. T. C. Allcock; **Phys. Rev. A 95**, 022337 (2017).

12. "*Demonstration of a small programmable quantum computer with atomic qubits,*" S. Debnath, N. M. Linke, C. Figgatt, K. A. Landsman, K. Wright, C. Monroe; **Nature 536**, 63 (2016), cover story.

11. "*High-fidelity quantum logic gates using trapped-ion hyperfine qubits,*" C. J. Ballance, T. P. Harty, N. M. Linke, M. A. Sepiol, D. M. Lucas; **Phys. Rev. Lett. 117**, 060504 (2016).

10. "*Hybrid quantum logic and a test of Bell's inequality using two different atomic species,*" C. J. Ballance, V. M. Schäfer, J. P. Home, D. J. Szwer, S. C. Webster, D. T. C. Allcock, N. M. Linke, T. P. Harty, D. P. L. Aude Craik, D. N. Stacey, A. M. Steane, D. M. Lucas; **Nature 528**, 384 (2015).

9. "*High-fidelity preparation, gates, memory and readout of a trapped-ion quantum bit,*" T. P. Harty, D. T. C. Allcock, C. J. Ballance, L. Guidoni, H. A. Janacek, N. M. Linke, D. N. Stacey, D. M. Lucas; **Phys. Rev. Lett. 113**, 220501 (2014).

8. "*Injection locking of two frequency-doubled lasers with 3.2 GHz offset for driving Raman transitions with low photon scattering in $^{43}Ca^+$,*" N. M. Linke, C.J. Ballance, D. M. Lucas; **Opt. Lett. 38**, 5087 (2013).

7. "*Microwave control electrodes for scalable, parallel, single-qubit operations in a surface-electrode ion trap,*" D. P. L. Aude Craik, N. M. Linke, T. P. Harty, C. J. Ballance, D. M. Lucas, A. M. Steane, D. T. C. Allcock; **Appl. Phys. B 114**, 3 (2013).

6. "*A microfabricated ion trap with integrated microwave circuitry,*" D. T. C. Allcock, T. P. Harty, C. J. Ballance, B. C. Keitch, N. M. Linke, D. N. Stacey, D. M. Lucas; **Appl. Phys. Lett. 102**, 044103 (2013).

5. "*Background-free detection of trapped ions,*" N. M. Linke, D. T. C. Allcock, D. J. Szwer, C. J. Ballance, T. P. Harty, H. A. Janacek, D. N. Stacey, A. M. Steane and D. M. Lucas; **Appl. Phys. B 107**, 1175 (2012).

4. "*Heating rate and electrode charging measurements in a scalable, microfabricated, surface-electrode ion trap,*" D. T. C. Allcock, T. P. Harty, H. A. Janacek, N. M. Linke, C. J.Ballance, A. M. Steane, D. M. Lucas, R. L. Jarecki Jr., S. D. Habermehl, M. G. Blain, D. Stick, D. L. Moehring; **Appl. Phys. B 107**, 913 (2012).

3. "*Implementation of a symmetric surface electrode ion trap with field compensation using a modulated Raman effect,*" D. T. C. Allcock, J. A. Sherman, D. N. Stacey, A. H. Burrell, M. J. Curtis, G. Imreh, N. M. Linke, D. J. Szwer, S. C. Webster, A. M. Steane, D. M. Lucas; **New J. Phys. 12** 053026 (2010).

2. "*Optimized focusing ion optics for an ultracold deterministic single ion source targeting nm resolution,*" R. Fickler, W. Schnitzler, N. M. Linke, F. Schmidt-Kaler, K. Singer; **J. Mod. Opt. 56**, 2061 (2009).

1. "*Deterministic Ultracold Ion Source targeting the Heisenberg Limit,*" W. Schnitzler, N. M. Linke, R. Fickler, J. Meijer, F. Schmidt-Kaler, and K. Singer; **Phys. Rev. Lett. 102**, 070501 (2009).

Grants awarded

Research community activities

Peer-reviewed publications for:
  Nature, Nature Communications, Quantum Science and Technology, Applied Physics B,
  Annals of Physics

Grant review:
  NSERC (Canada) Discovery Grant

Conferences:
  Co-chair and main organizer: 2nd North American Conference on Trapped Ions,
                  nacti2019.umd.edu, UMD College Park, MD, July 2019

  Session Chair: DPG Frühjahrstagung 2019, Rostock, Germany, March 2019

  Session Chair: DAMOP 2018, Fort Lauderdale, FL, May 2018

  Conference trip organization: QuAMP 2010, University of Oxford, UK, August 2010

Talks and Seminars

"Quantum-classical hybrid circuits with trapped ions," 2nd North American Conference on Trapped
Ions (NACTI), University of Maryland, College Park, MD (Jul. 2019) – **invited**.

"Quantum circuit training with trapped ions," CLEO/Europe-EQEC conference, Munich, Germany
(Jun. 2019) – **contributed**.

"A programmable trapped-ion quantum computer – first applications in HEP," workshop on
QIS/HEP, Aspen Center for Physics, Aspen, CO (May. 2019) – **invited**.

"Quantum information scrambling and hybrid machine learning with trapped ions," QCQC meeting,
Department of Chemistry, Emory University, Atlanta, GA (May. 2019) – **invited**.

"A programmable trapped-ion quantum computer," 695. WE-Heraeus-Seminar, Engineering a
Scalable Quantum Information Processor, Physikzentrum, Bad Honnef, Germany (Apr. 2019) –
invited.

"A quantum computer based on trapped ions," colloquium talk, George Washington University,
Department of Mathematics, Washington, DC (Apr. 2019) – **invited**.

"Quantum information scrambling and hybrid machine learning with trapped ions," seminar talk,
Oak Ridge National Laboratory, Oak Ridge, TN (Apr. 2019) – **invited**.

"Quantum information scrambling and hybrid machine learning with trapped ions," DPG
Frühjahrstagung, Rostock, Germany (Mar. 2019) – **invited**.

"Trapped-ion Applications and Quantum Operations," JQI Seminar, University of Maryland, College
Park, MD (Feb. 2019) – **invited**.

"Quantum information scrambling and hybrid machine learning with trapped ions," Physics of
Quantum Electronics conference (PQE), Snowbird, UT (Jan. 2019) – **invited**.

"A programmable quantum computer based on trapped ions," Software-tailored architecture for
quantum co-design (STAQ) kick-off meeting, Duke University, Durham, NC (Dec. 2018) –
contributed.

"A quantum computer based on trapped ions," Annual Meeting of the Mid-Atlantic Section of the American Physical Society (APS), University of Maryland, College Park, MD (Nov. 2018) – **invited**.

"Quantum simulators with large ion numbers - how to make them - what to learn from them," Trapped Charged Particles (TCP) conference, Traverse City, MI (Sept. 2018) – **invited**.

"Quantum machine learning with trapped ions," Quantum Machine Learning (QML) conference, Joint Center for Quantum Information and Computer Science (QuICS), University of Maryland, College Park, MD (Sept. 2018) – **invited**.

"Quantum games on a trapped-ion quantum computer," Quantum Algorithms Workshop, Army Research Laboratory (ARL), Adelphi, MD (Sept. 2018) – **invited**.

"Hardware for universal quantum computers – a programmable trapped-ion machine," IEEE Quantum Computing Summit, Georgia Institute of Technology, Atlanta, GA (Aug. 2018) – **invited**.

"A programmable quantum computer based on trapped ions," given 11 times on a tour of European research groups at the University of Oxford, UK, the Universities of Ulm, Saarbrücken, Freiburg, Mainz, Siegen, and Hannover, Germany, at ETH Zürich, Switzerland, at the University of Innsbruck, Austria, at the Physikalisch-Technische Bundesanstalt (PTB), Braunschweig, Germany, at Aix-Marseille Université, Marseilles, France, and at the Max Planck Institute for Quantum Optics, Garching, Germany (Jun./Jul. 2018) – **contributed**.

"Quantum simulation with trapped atomic ions," 2D Quantum Metamaterials Workshop, National Institute of Science and Technology (NIST), Gaithersburg, MD (Apr. 2018) – **invited**.

"A Trapped-Ion Quantum Computer," LPS Seminar, Laboratory of Physical Sciences, National Security Agency and University of Maryland, College Park, MD (Apr. 2018) – **invited**.

"Phonon Hopping and Blockade with Trapped Ions," JQI-QuICS-CMTC Seminar, Department of Physics, University of Maryland, College Park, MD (Mar. 2018) – **invited**.

"Quantum Algorithms with Trapped Ions," QCMC conference, Louisiana State University, Baton Rouge, LA (Mar. 2018) – **invited**.

"A Programmable Quantum Computer based on Trapped Ions," Physics seminar, Department of Physics, University of Maryland, UMD, MD (Mar. 2018) – **invited**.

"A Programmable Quantum Computer based on Trapped Ions," Physics seminar, Department of Physics, University of Oregon, Eugene, OR (Feb. 2018) – **invited**.

"A Programmable Quantum Computer based on Trapped Ions," Physics seminar, Department of Physics, University of Virginia, Charlottesville, VA (Feb. 2018) – **invited**.

"A Programmable Quantum Computer based on Trapped Ions," Physics seminar, Department of Physics, Penn State University, University Park, PA (Jan. 2018) – **invited**.

"Trapped-Ion Quantum Information," Physics of the Universe Summit, SpaceX and CalTech, Hawthorne and Pasadena, CA (Jan. 2018) – **invited**.

"Quantum Algorithms on a Programmable Quantum Computer based on Trapped Ions," Quantum Physics Seminar, Department of Physics, UC Berkeley, Berkeley, CA (Oct. 2017) – **invited**.

"Fault-Tolerant Quantum Error Detection with Trapped Ions," Quantum Error Correction (QEC) conference, College Park, MD (Sept. 2017) – **invited**.

"Fault-Tolerant Error Detection on a Programmable Ion Trap Quantum Computer," 1st North American Conference on Trapped Ions (NACTI), NIST, Boulder, CO (Aug. 2017) – **invited**.

"Comparing the Architectures of the First Programmable Quantum Computers," CLEO/Europe-EQEC conference, Munich, Germany (Jun. 2017) – **contributed**.

"Fault-Tolerant Encoding of a Logical Qubit," APS Division of Atomic, Molecular and Optical Physics (DAMOP) conference, Sacramento, CA (Jun. 2017) – **contributed**.

"Quantum Computing with Trapped Ions," Southeast Quantum Computing Workshop, Department of Physics, University of Georgia, Athens, GA (May. 2017) – **invited**.

"Scaling Up and Networking the Ion Trap Quantum Computer," Graduate Class on Quantum Information, Department of Electrical Engineering, Princeton University, Princeton, NJ (Apr. 2017) – **invited**.

"A Programmable Quantum Computer Module Based on Trapped ions," Quantum Colloquium, Department of Electrical Engineering, Princeton University, Princeton, NJ (Apr. 2017) – **invited**.

"Quantum Algorithms on a Programmable Ion Trap Quantum Computer," IEEE Baltimore Colloquium on Quantum Computing, American Center for Physics, College Park, MD (Oct. 2016) – **invited**.

"Quantum Algorithms on a Programmable Ion Trap Quantum Computer," JQI seminar, University of Maryland, College Park, MD (Oct. 2016) – **invited**.

"Quantum Algorithms and Error Detection a Programmable Ion Trap Quantum Computer," JQI-QuICS-CMTC seminar, University of Maryland, College Park, MD (Sept. 2016) – **contributed**.

"Quantum Algorithms on a Programmable Ion Trap Quantum Computer," European Conference on Trapped Ions (4th ECTI), Hot Topic talk, Arosa, Switzerland (Aug. 2016) – **invited**.

"Non-nearest-neighbor gate in a linear ion chain," Ion storage group talk, National Institute of Standards and Technology (NIST), Boulder, CO (Aug. 2015) – **contributed**.

"High Fidelity Qubit Operations with $^{43}Ca^+$," QUANTUM seminar, Institut für Physik, Universität Mainz, Germany (Nov. 2014) – **invited**.

"Trapped Ion Quantum Technologies at Oxford," Frontiers in Quantum Technologies doctoral training center, Imperial College, London, UK (Jan. 2014) – **contributed**.

"Oxford ion trap group overview," Ion Traps for Tomorrow's Applications (IOTA) workshop, COST network, Heidelberg, Germany (May 2011) – **contributed**.

Poster Presentations

"Quantum Algorithm Demonstrations on a Programmable Quantum Computer," European Conference on Trapped Ions (4th ECTI), Arosa, Switzerland (2016).

"Quantum Algorithm Demonstrations on a Fully Reconfigurable Ion Trap Quantum Computer," Southwest Quantum Information and Technology workshop (18th SquInT), Albuquerque, NM (2015).

"Fault-tolerant microwave addressing of trapped ions," European Conference on Trapped Ions (3rd ECTI), Schloss Waldthausen, Germany (2014).

"Two-qubit entangling gates in $^{43}Ca^+$ and $^{40}Ca^+$," Techniques for Trapped Ions workshop (IonTech 2), COST network, Paris, France (2013).

"*Laser cleaning and background-free detection in microfabricated ion traps,*" International Conference on Atomic Physics (23rd ICAP), Paris, France (2012).

"High-fidelity multi-qubit EMCCD readout and microfabricated ion traps for QIP," International conference on Quantum Information Processing and Communication (QIPC), Rome, Italy (2009).

Popular Press

accounts of research covered by:

ABC (Aus.), David Ignatius, Electronics Weekly, Endgadget, FAZ, The Inquirer, The Irish Independent, Nature, Nature Podcast, New Scientist, pro-physik.de, Science, Science News, Sci-News, SciTechDaily, Superconductor Week, The Wall Street Journal, phys.org, Welt der Physik, Wired

Teaching experience

01/2014 – 12/2014:	Stipendiary Lecturer in Physics, teaching 1st year Electricity and Magnetism, Mechanics and Special Relativity, Linear Optics and Circuits, Hertford College, University of Oxford, UK
10/2013 – 06/2014:	Tutor for Atomic, Molecular and Laser Physics (3rd year), St. Hilda's College, University of Oxford, UK
10/2012 – 09/2013:	Stipendiary Lecturer in Physics, teaching Mechanics and Special Relativity (1st year), Quantum Mechanics (2nd year) and Atomic, Molecular and Laser Physics (3rd year), Brasenose College, Oxford, UK
10/2010 – 06/2014:	Tutor for Atomic, Molecular and Laser Physics (3rd year), Mansfield College, University of Oxford, UK
04/2010 – 06/2010:	Demonstrator on the Physics Practical Course in Condensed Matter (3rd year) and Thermal Physics (2nd year), University of Oxford, UK
10/2009 – 06/2012	Demonstrator on the Physics Practical Course in General Physics (1st year), University of Oxford
10/2007 – 02/2008:	Tutor for Circuit Theory (2nd year), University of Ulm, Germany
04/2007 – 07/2007:	Tutor for Optics (1st year), University of Ulm, Germany
10/2006 – 02/2007:	Tutor for Mechanics and Thermal Physics (1st year), University of Ulm, Germany
04/2006 – 07/2006:	Tutor for year Linear Algebra (1st year), University of Ulm, Germany
10/2004 – 02/2006:	Grader for Higher Mathematics for Physicists (1st and 2nd year), University of Ulm, Germany

Fellowships/Awards

2019:	Fellow of the Joint Quantum Institute of the University of Maryland and the National Institute for Standards and Technology, College, Park, MD

2015:	Engineering and Physical Sciences Research Council (EPSRC) U.K. National Science Photo of the Year competition, overall winner together with D. P. L. Aude Craik
2008:	Wykeham Scholarship, New College, University of Oxford, UK

Outreach activities

2016-2017:	Advisor for the International Young Physicists' Tournament (IYPT) club, St. Timothy's School, Stevenson, MD
2015:	Maryland Day (university open day), laboratory tour guide, University of Maryland, College Park, MD
2015:	*"Science is Fun"*, physics-based whole school assembly with explosive experimental demonstrations, St. Timothy's School, Stevenson, MD
2014:	*"Atoms and Light,"* presentation on spectroscopy, Balliol College Oxford outreach program, The John Warner School, Hoddesdon, UK
2012:	Development day for physics high school teachers, Physics Practical Course, University of Oxford, Oxford, UK