

# Nikolas P. Breuckmann

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UCLQ Fellow at University College London

## Education

- 2013–2017 **Ph.D. Physics**, RWTH Aachen University, Thesis: Homological Quantum Codes Beyond the Toric Code, supervised by Prof. Barbara Terhal.
- 2010–2013 **M.Sc. Physics**, RWTH Aachen University, Thesis: From Quantum Circuits to Hamiltonians - Analysis of a Multi-Time Construction for QMA, supervised by Prof. Barbara Terhal.
- 2009–2011 **B.Sc. Mathematics**, RWTH Aachen University, Thesis: Logical and Algorithmical Aspects of Rank Notions over Rings, supervised by Prof. Erich Grädel.
- 2008–2010 **B.Sc. Physics**, RWTH Aachen University, Thesis: Quantum Subsystem Codes - Their Theory and Use, supervised by Prof. Barbara Terhal.

## Grants & Awards

- UCLQ Post-Doctoral Research Fellowship in Quantum Technologies [£235,640 in funds] (2017)
- HPC project of 1.3 million core-hours at the RWTH Compute Cluster to simulate the performance of quantum fault-tolerance schemes (2016)
- IOP Journal of Physics A: Highlights of 2014, for “Space-Time Circuit-to-Hamiltonian Construction and its Applications” (2014)
- Travel grant to visit the conference QStart at Hebrew University Jerusalem [€1,000 in funds] (2013)

## Industry Experience

I deferred my UCLQ fellowship for a year to work full-time as an employee at PsiQuantum, a start-up working on silicon-photon quantum computation based in Palo Alto. I was hired as “Quantum Architect” in the fault-tolerance team.

## Publications

- N. P. Breuckmann and B. M. Terhal, “Space-Time Circuit-to-Hamiltonian Construction and its Applications,” *IOP Journal of Physics A: Mathematical and Theoretical*, vol. 47, no. 19, p. 195304, 2014.
- N. P. Breuckmann and B. M. Terhal, “Constructions and Noise Threshold of Hyperbolic Surface Codes,” *IEEE Transactions on Information Theory*, vol. 62, no. 6, pp. 3731-3744, 2016.
- N. P. Breuckmann, K. Duivenvoorden, D. Michels, and B. M. Terhal, “Local Decoders for the 2D and 4D Toric Code,” *Quantum Information and Computation*, vol. 17, no. 3-4, 2017.
- N. P. Breuckmann, C. Vuillot, E. Campbell, A. Krishna and B. M. Terhal, “Hyperbolic and Semi-Hyperbolic Codes for Quantum Storage,” *IOP Quantum Science and Technology*, vol. 2, no. 3, 2017.
- N. P. Breuckmann and X. Ni, “Scalable Neural Network Decoders for Higher-Dimensional Quantum Codes,” *QUANTUM*, vol. 2, 68-92, 2018.
- J. Conrad, C. Chamberland, N. P. Breuckmann and B. M. Terhal, “The Small Stellated Dodecahedron Code and Friends”, *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 376(2123), 20170323, 2018.

- K. Duivenvoorden, N. P. Breuckmann and B. M. Terhal, “A Renormalization-Group Decoder for 4D Toric Codes,” *IEEE Transactions on Information Theory*, vol. 65 (4), 2545-2562, 2019.
- C. Vuillot and N. P. Breuckmann, “Quantum Pin Codes,” arXiv:1906.11394, submitted to IEEE ToI
- N. P. Breuckmann, B. Placke and A. Roy, “Critical Properties of the Ising Model on the Hyperbolic Plane,” *APS Physical Review E*, vol. 101 (2), 022124, 2020.
- H. Chen, M. Vasmer, N. P. Breuckmann, E. Grant, “Machine learning logical gates for quantum error correction,” arXiv:1912.10063, submitted to NPJ Quantum Information
- N. P. Breuckmann and V. Londe, “Single-Shot Decoding of Linear Rate LDPC Quantum Codes with High Performance,” arXiv:2001.03568, submitted to IEEE ToI

## Talks

★ indicates talk given by a co-author

### Invited talks

- QUID Summer School, ETH Zurich (2019), 3 hour lecture series on “Quantum Error Correction”
- UCLQ Industry Event (2019) - “The Present and Future of Quantum Error Correction”
- Cleary, Gottlieb, Steen & Hamilton (2018) - “Introduction to Quantum Computation”
- Freiburg University (2016), lecture series “Algebra, Number Theory and Algebraic Geometry” - “Applications of Homology in Quantum Fault-Tolerance”

### Contributed conference talks

- QEC (2019) on “Single-Shot-Decoding with High Thresholds in LDPC Quantum Codes with Constant Encoding Rate”
- ★ QEC (2019) on “Quantum Pin Codes”
- APS March Meeting (2019) on “The Ising Model in Curved Geometries”
- ★ QEC (2017) on “Performance of (Semi-)Hyperbolic Surface Codes for Quantum Storage”
- Fault-Tolerant Quantum Technologies (2016) on “Local Decoders in 2D and 4D”

### Seminar talks

- Delft University of Technology (2020) on “Single-Shot Decoding of Linear Rate LDPC Quantum Codes with High Performance”
- University of Sydney (2019) on “Single-Shot Decoding of Linear Rate LDPC Quantum Codes with High Performance”
- University of Technology Sydney (2019) on “Single-Shot Decoding of Linear Rate LDPC Quantum Codes with High Performance”
- Technische Universität München (2017) on “Homological Quantum Codes Beyond the Surface Code”
- Freie Universität Berlin (2017) on “Performance of Semi-Hyperbolic Surface Codes for Quantum Storage”

- Perimeter Institute (2015) on “Constructions and Noise Threshold of Hyperbolic Surface Codes”

## Posters

- QIP 2018 on “Decoding Higher-Dimensional Quantum Codes with Neural Networks”
- QIP 2017 on “Local Decoders for the 2D and 4D Toric Code”
- QIP 2017 on “Performance of (Semi-)Hyperbolic Surface Codes for Quantum Storage”
- TQC 2016 on “Systematic Construction of Color Codes in any Dimension”
- QIP 2014 on “Space-Time Circuit-to-Hamiltonian Construction and Its Applications”

## Student supervision

I am currently co-supervising a PhD student in quantum error correction. In the past I have co-supervised two Bachelor projects and an M.Res. project related to my work:

- Friederike Metz, B.Sc. thesis project: “Space-Time Circuit-To-Hamiltonian Construction Applied to MERA Circuits” (2015)
- Jonathan Conrad, B.Sc. thesis project: “Parity Check Schedules for Hyperbolic Surface Codes” (2017)
- Oscar Higgot, M.Res. thesis project: “Decoding two-dimensional topological quantum codes with reliability-based belief propagation” (2019)
- Oscar Higgot, Ph.D. thesis project: “Low-overhead quantum fault-tolerance using hypergraph product codes” (2019-now)

## Teaching

- Institute for Mathematical Foundations of Computer Science April - August 2010  
Teaching assistant for the course “Mathematical Logic”, grading of homework and exams, presenting solutions to students in weekly seminars
- Institute for Mathematical Foundations of Computer Science April - August 2011  
Teaching assistant for the course “Mathematical Logic”, grading of homework and exams, presenting solutions to students in weekly seminars
- Institute for Quantum Information April - August 2013  
Teaching assistant for the course “Quantum Information”, grading of homework and exams, presenting solutions to students in weekly seminars
- Institute for Quantum Information April - August 2014  
Senior teaching assistant for the course “Introduction to Theoretical Physics”, designing homework problem sets and solutions, organizing weekly seminars, designing two exams with sample solutions, organizing exams
- Institute for Quantum Information April - August 2015  
Senior teaching assistant for the course “Introduction to Theoretical Physics”, designing homework problem sets and solutions, organizing weekly seminars, designing two exams with sample solutions, organizing exams
- Institute for Quantum Information October 2015 - February 2016  
Teaching assistant for the course “Quantum Error Correction”, preparing some of the lectures and writing lecture notes

- Institute for Quantum Information

April - August 2016

Senior teaching assistant for the course “Introduction to Theoretical Physics”, designing homework problem sets and solutions, organizing weekly seminars, designing two exams with sample solutions, organizing exams

## Refereeing

**Journals:** Physical Review X, Physical Review A, IEEE Transactions on Information Theory, IEEE Transactions on Computers, QUANTUM, IOP Quantum Science and Technology, AMS Mathematical Reviews, Annales de l’Institut Henri Poincaré D Combinatorics

**Conferences:** IEEE, Quantum Information Processing (QIP)

## Outreach

I have given a talk to lawyers at the law firm Cleary, Gottlieb, Steen & Hamilton on Quantum Computation in view of UK legislation on mergers and acquisitions of quantum technologies companies based in the UK. The contents were published in the journal “European Competition Law Review” under the title “Is quantum computing a national security threat?.”

I have given a presentation titled “The Present and Future of Quantum Error Correction” at the UCLQ Industry Event aimed towards members of the press and industry.