

Alexandre Clément

Postdoctoral researcher at Dalhousie University

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Research Interests

My research topics lie in the domain of formal methods for quantum computing, with a focus on graphical languages, a powerful theoretical tool for the description, manipulation, and optimization of quantum processes. As part of my doctoral work, I designed an optics-inspired graphical language dedicated to quantum control, and another one dedicated to realistic optical schemes that could be used in photonic quantum computers. More recently, I have shifted my focus on quantum circuits, the practical equivalent of the assembly language in quantum computing. In what I consider my most important contribution to date, I found the first complete equational theory for quantum circuits; this solved a longstanding open question in the field. The main aspects of my current research program are to develop equational theories for further important families of quantum circuits and to study these equational theories from a broader perspective, in order to provide both theoretical insights and practical applications.

Research Experience

PhD and Postdoc

- Since June 2026: Postdoc – Department of Mathematics and Statistics, Dalhousie University (Halifax, Canada)
Funded by NSERC under *Canada Impact+ Research Training Awards*
- June 2023 – May 2026: Postdoc – Université Paris-Saclay, QuaCS team of Laboratoire Méthodes Formelles (Gif-sur-Yvette, France)
- Sept. 2019 – May 2023: PhD – Université de Lorraine, Laboratoire Lorrain de Recherche en Informatique et ses Applications (Nancy, France)
Title: Graphical Languages for Quantum Control and Linear Optics
Supervised by Simon Perdrix and Emmanuel Jeandel
Defended on 16 May 2023

Research Internships

- Apr. – Aug. 2019: Laboratoire Lorrain de Recherche en Informatique et ses Applications (Nancy, France)
Introduced a graphical language for quantum control
Supervised by Simon Perdrix
- Oct. 2018 – Mar. 2019: Dalhousie University (Halifax, Canada)
Found a complete equational theory for a language closely related to quantum circuits
Supervised by Peter Selinger and Neil J. Ross
- May – July 2018: Institut de Recherche en Informatique Fondamentale (Paris, France)
Investigated the possibility of removing infinities in a model of the quantum lambda-calculus with recursion
Supervised by Michele Pagani and Benoît Valiron
- May – July 2017: Institut de Mathématiques de Marseille (Marseille, France)
Bibliographic synthesis about the cubical model of Homotopy Type Theory and the univalence axiom
Supervised by Laurent Regnier and Dimitri Ara
- May – July 2016: Institut de Mathématiques de Marseille (Marseille, France)
Bibliographic synthesis about the independence of the continuum hypothesis towards ZFC
Supervised by Laurent Regnier

Education

- 2019-2023: PhD – Université de Lorraine (Nancy, France)
- 2018-2019: Pre-PhD (research internships), as part of the École Normale Supérieure de Lyon curriculum
- 2017-2018: MSc in Mathematical Logic and Foundations of Computer Science (with honours) – Université Paris 7 Diderot (Paris, France)
- 2015-2017: BSc in Mathematics – École Normale Supérieure de Lyon (Lyon, France)
- 2012-2015: Classe préparatoire Mathématiques-Physique – Janson de Sailly (Paris, France)
- 2012: Baccalauréat (French high school graduation)

Publications

Conference Proceedings

- Alexandre Clément. “A Complete Equational Theory for Real-Clifford+CH Quantum Circuits.” In *41st Annual Symposium on Logic in Computer Science (LICS 2026)*, Lisbon, Portugal, July 2026. URL: <https://hal.science/hal-05487235>, arXiv:2602.06644, doi:10.4230/LIPIcs.LICS.2026.28.
- Alexandre Clément, Noé Delorme, and Simon Perdrix. “Minimal equational theories for quantum circuits.” In *39th Annual ACM/IEEE Symposium on Logic in Computer Science (LICS 2024)*, Tallinn, Estonia, July 2024. URL: <https://hal.science/hal-04399210>, arXiv:2311.07476, doi:10.1145/3661814.3662088.
- Alexandre Clément, Noé Delorme, Simon Perdrix, and Renaud Vilmart. “Quantum circuit completeness: Extensions and simplifications.” In *International Conference on Computer Science Logic (CSL 2024)*, Naples, Italy, February 2024. URL: <https://hal.science/hal-04016498>, arXiv:2303.03117, doi:10.4230/LIPIcs.CSL.2024.20.
- Alexandre Clément, Nicolas Heurtel, Shane Mansfield, Simon Perdrix, and Benoît Valiron. “A complete equational theory for quantum circuits.” In *38th Annual ACM/IEEE Symposium on Logic in Computer Science (LICS 2023)*, Boston, United States, June 2023. URL: <https://hal.science/hal-03926757>, arXiv:2206.10577, doi:10.1109/LICS56636.2023.10175801.
- Alexandre Clément, Nicolas Heurtel, Shane Mansfield, Simon Perdrix, and Benoît Valiron. “LO_v-calculus: A graphical language for linear optical quantum circuits.” In *47th International Symposium on Mathematical Foundations of Computer Science (MFCS 2022)*, Vienna, Austria, August 2022. URL: <https://hal.science/hal-03926660>, arXiv:2204.11787, doi:10.4230/LIPIcs.MFCS.2022.35.

- Alexandre Clément and Simon Perdrix. “Resource optimisation of coherently controlled quantum computations with the PBS-calculus.” In *47th International Symposium on Mathematical Foundations of Computer Science (MFCS 2022)*, Vienna, Austria, August 2022. URL: <https://hal.science/hal-03926639>, arXiv:2202.05260, doi:10.4230/LIPIcs.MFCS.2022.36.
- Cyril Branciard, Alexandre Clément, Mehdi Mhalla, and Simon Perdrix. “Coherent control and distinguishability of quantum channels via PBS-diagrams.” In *46th International Symposium on Mathematical Foundations of Computer Science (MFCS 2021)*, Tallinn, Estonia, August 2021. URL: <https://hal.science/hal-03325456>, arXiv:2103.02073, doi:10.4230/LIPIcs.MFCS.2021.22.
- Alexandre Clément and Simon Perdrix. “PBS-calculus: A graphical language for coherent control of quantum computations.” In *45th International Symposium on Mathematical Foundations of Computer Science (MFCS 2020)*, Prague, Czech Republic, August 2020. URL: <https://hal.science/hal-02929291>, arXiv:2002.09387, doi:10.4230/LIPIcs.MFCS.2020.24.

PhD Thesis

- Alexandre Clément. *Graphical Languages for Quantum Control and Linear Optics*. PhD thesis, Université de Lorraine, May 2023. URL: <http://www.theses.fr/2023LORR0093>.

Reviews

Conferences (subreviewer)

- LICS 2025
- QPL 2020, 2021, 2022, 2023, 2024, 2025
- TQC 2022

Journals (referee)

- Quantum (January 2025)
- LMCS (November 2024)

Talks

International Conferences

- LICS 2023, 2026
- MFCS 2020, 2021, 2022
- QPL 2020, 2021, 2026

Local Conferences and Workshops

- CMS Summer Meeting (St John, NB, Canada) – June 2026
- GT IQ annual meeting (France) – November 2019, November 2022, September 2023
- Meeting of the SoftQPro ANR project (Les-Clayes-sous-Bois, France) – November 2019

Seminars

- Dalhousie quantum group informal meeting (Halifax, Canada) – September 2026
- Visit at LIS (Marseille, France) – November 2024
- Visit at LIG (Grenoble, France) – November 2023
- QuaCS team informal seminar (Gif-sur-Yvette, France) – November 2023
- ZX-meeting (international online seminar) – June 2020, July 2021, March 2024

Student Supervision

June – Sept. 2026: BSc internship of Katie J. Keiller (Durham University)
Dalhousie University (Halifax, Canada)
Explaining and implementing a recently-introduced, lattice-based, efficient quantum circuit synthesis technique
Co-supervised together with Neil J. Ross

Sept. 2021 – Feb. 2022: BSc internship of Julien Lamiroy (École Normale Supérieure de Paris)
Laboratoire Lorrain de Recherche en Informatique et ses Applications
(Nancy, France)
Extending the PBS-calculus towards universality
Co-supervised together with Simon Perdrix