

Armanpreet Pannu

Postdoctoral Fellow at The University of Toronto

📍 Toronto, Canada | ✉ arman.pannu@mail.utoronto.ca | 🎓 Google Scholar | 🔗 LinkedIn

RESEARCH PROFILE

I am a theoretical quantum researcher working at the intersection of quantum optics, information theory, and mathematical physics. My research asks when quantum resources provide a meaningful advantage under realistic conditions such as background noise, signal loss, and limited energy.

- **Quantum sensing and imaging:** developing protocols for detecting and locating weakly reflecting objects in noisy environments.
- **High-dimensional and multi-photon entanglement:** studying how the structure of entangled light can improve performance and resilience to loss.
- **Foundations of quantum advantage:** identifying which improvements are fundamental and which depend on idealized assumptions or particular implementations.

SELECTED RESEARCH HIGHLIGHTS

- Showed that high-dimensional Bell states can provide robust quantum-illumination advantages across low-, intermediate-, and high-noise regimes, extending the usefulness of discrete-variable approaches beyond their previously understood limits.
- Demonstrated theoretically that high-dimensional entanglement combined with sequential detection can drive target-finding error toward zero at finite transmitted energy for the model studied.
- Introduced a multi-photon entangled state whose useful correlation structure can largely survive signal attenuation, providing a building block for loss-prone photonic applications.

EDUCATION

Doctorate of Philosophy, Electrical and Computer Engineering <i>University of Toronto</i> Thesis: "Quantum-Enhanced Sensing with Discrete-Variable Entangled States"	2020 - 2025 <i>Toronto, Canada</i>
Doctorate of Philosophy*, Mathematics <i>University of Toronto</i> <i>*Candidacy achieved; program discontinued following the passing of my advisor.</i>	2018 - 2020 <i>Toronto, Canada</i>
Masters of Science, Mathematics <i>University of Toronto</i> Research project: "Motivic Structure of Feynman Graphs in the Grothendieck Ring"	2017 - 2018 <i>Toronto, Canada</i>
Honours Bachelors of Science (with high distinction), Mathematics and Physics <i>University of Toronto</i>	2013 - 2017 <i>Toronto, Canada</i>

SCHOLARLY CONTRIBUTIONS

Journal Contributions:

1. **Armanpreet Pannu**, Amr S. Helmy and Hesham El Gamal. Toward error-free quantum target finding: When sequential detection meets high-dimensional entanglement. *Physical Review A.*, **112**:L030602 (2025)
URL: <https://doi.org/10.1103/jqx6-5hcc>
2. **Armanpreet Pannu**, Amr S. Helmy and Hesham El Gamal. Quantum illumination with high-dimensional Bell states. *Physical Review A (Editors' Suggestion)*, **110**:L050603 (2024)
URL: <https://doi.org/10.1103/PhysRevA.110.L050603>

Books:

1. Francis Dawson and **Armanpreet Pannu**. *Introduction to Mathematical Physics*. Kendall Hunt Publishing Group, first edition, 506 pages (2026). A practical, intuition-led treatment of multivariable calculus for physics and engineering students.

Conference Proceedings:

1. Zhizhong Yan, Armanpreet Pannu, Amr S. Helmy. Two-dimensional quantum imaging from a single photon detector over kilometre-scale fibre. *Proc. SPIE 14033, Three-Dimensional Imaging, Visualization, and Display 2026, 1403307* (Jun 2026)
URL: <https://doi.org/10.1117/12.3094213>
2. **Armanpreet Pannu**, Amr S. Helmy, and Hesham El Gamal. Achieving Unbounded Quantum Advantage in Sensing with High-Dimensional Bell States. *Proceedings of the Conference on Lasers and Electro-Optics (CLEO) 2025, Optica Publishing Group / IEEE Xplore*. (May 2025)
URL: https://doi.org/10.1364/CLEO_FS.2025.FF120_5
3. Zhizhong Yan, **Armanpreet Pannu**, and Amr S. Helmy. Quantum-Enhanced Imaging Using Temporal Correlation and Non-Local Dispersion Over Long-Haul Fiber Link. *Proceedings of the Conference on Lasers and Electro-Optics (CLEO) 2025, Postdeadline Session V, Optica Publishing Group / IEEE Xplore*. (May 2025)
URL: https://doi.org/10.1364/CLEO_AT.2025.PD104_1
4. **Armanpreet Pannu**, Amr S. Helmy, and Hesham El Gamal. A novel multi-photon entangled state with enhanced resilience to path loss. *2024 IEEE International Symposium on Information Theory Workshops (ISIT-W)*. (2024)
URL: <https://ieeexplore.ieee.org/document/10591773>

TALKS AND PRESENTATIONS

Invited Talks

1. “Quantum-Enhanced LiDAR,” University of Toronto Robotics Association (UTRA) Hackathon, Toronto, Canada, January 2025.

Conference Presentations

1. “Achieving Unbounded Quantum Advantage in Sensing with High-Dimensional Bell States,” CLEO 2025, Long Beach, California.
2. “Quantum-Enhanced Imaging Using Temporal Correlation and Non-Local Dispersion Over Long-Haul Fiber Link,” CLEO 2025, Long Beach, California.

Other Presentations

1. “Multi-Photon Maximally Entangled States,” Quantum-Enhanced Sensing and Imaging (QuEnSI) Consortium Annual Meeting, Ottawa, Canada, 2024. (Presented on behalf of Professor Helmy’s research group)
2. “Unbounded Quantum Advantage in Sensing with High-Dimensional Bell States,” Quantum-Enhanced Sensing and Imaging (QuEnSI) Consortium Annual Meeting, Montreal, Canada, 2025. (Presented on behalf of Professor Helmy’s research group)

RESEARCH EXPERIENCE

Postdoctoral Fellow, University of Toronto

Sep 2025 - present

Edward S Rogers Department of Electrical and Computer Engineering

Supervisor: Professor Amr S. Helmy

- Investigating the fundamental information-theoretic limits of quantum enhancement in sensing
- Designing and analyzing theoretical protocols to maximize quantum advantage under real-world constraints

Visiting Research Associate, The University of Sydney

Jan 2024 - Apr 2024

School of Electrical and Information Engineering

Supervisor: Professor Hesham El Gamal

- Developed a multi-photon generalization of Bell states to address various single-photon limitations

Ph.D. Student, University of Toronto

May 2020 - May 2025

Edward S Rogers Department of Electrical and Computer Engineering

Supervisor: Professor Amr S. Helmy

- Worked on developing theoretical tools and frameworks for quantum sensing with discrete variable Bell states.
- Worked on designing and implementing imaging methods that leverage entanglement to enhance noise resilience.

Ph.D. Student, University of Toronto

Jan 2019 - Dec 2019

Department of Mathematics

Supervisor: Professor Peter Wittek and Professor Henry Yuen

- Worked on machine learning with quantum computers.
- Studied the relationship between tensor network methods in many-body quantum physics and machine learning.
- Investigated the PAC learnability of tensor network quantum states such as matrix product states.

Masters Student, University of Toronto

May 2018 - Aug 2018

Department of Mathematics

Supervisor: Professor Matilde Marcolli

- Worked on using motivic theory from algebraic geometry to describe Feynman graphs in quantum field theory.
- Studied the structure of melonic Feynman graphs in the Grothendieck Ring.

Undergraduate Research Assistant, University of Toronto

May 2015 - Aug 2017

Department of Physics

Toronto, Canada

- Several research projects across multiple labs and disciplines:
 - **Ocean Physics** (*with Professor Nicolas Grisouard*): Ran simulation in Fortran to discover conditions that contribute to the formation of solitons and tsunamis in the ocean.
 - **Photonics** (*with Professor Amr S. Helmy*): Analyzed photon correlations in waveguide arrays analytically and using Mathematica aiding in the design of integrated photonic chips.
 - **Particle Accelerators** (*with Professor Robert Orr*): Designed two methods to test and improve the performance of SRF particle accelerator cavities at TRIUMF national laboratories.
 - **Particle Physics**: (*with Professor Pierre Savard*) Analyzed datasets from the large hadron collider using machine learning tools in Python and C++ to verify the discovery of the Higgs Boson.

- All projects funded by either NSERC USRA or Physics SURF awards

TEACHING EXPERIENCE

Course Instructor

University of Toronto

Jan 2020 - Present

Toronto, Canada

- Taught courses in both math and engineering departments:
 - MAT 234 (Differential Equations) - *Winter 2026*
 - MAT 136 (Calculus II) - *Winter 2026*
 - MAT 187 (Calculus II for Engineering) - *Winter 2025, Summer 2025*
 - MAT 291 (Introduction to Mathematical Physics) - *Fall 2021, 2022, 2023, 2024*
 - MAT 237 (Multivariable Calculus with Proofs) - *Summer 2020, 2022, 2023, 2025, 2026*
 - MATA 37 (Calculus II for Physical Sciences) - *Winter 2020*
- Designed lesson plans, delivered lectures, and created evaluation material.
- Managed classroom logistics for smooth course operations.
- Led and supervised teams of 5-15 teaching assistants.

Head Teaching Assistant

University of Toronto

Sep 2019 - Apr 2023

Toronto, Canada

- Involved as Head TA for first year engineering math courses:
 - MAT 186 (Calculus I for Engineering) - *2020*
 - MAT 187 (Calculus II for Engineering) - *2020, 2021, 2022, 2023*
- Contributed to curriculum development by designing worksheets and field-specific problems.
- Trained teams of TAs and facilitated transition to flipped classroom and active learning.
- Created rubrics and supervised teams of graders to ensure consistent and high-quality grading.

Teaching Assistant

University of Toronto

Sep 2015 - Apr 2022

Toronto, Canada

- Taught several courses (most with multiple appointments), covering a wide array of subjects:
 - ECE 110 (Electricity Fundamentals)
 - MAT 235 (Multivariable Calculus)
 - MAT 237 (Multivariable Calculus with proofs)
 - MAT 257 (Analysis II)
 - MAT 185 (Linear Algebra for Eng Sci)
 - MAT 334 (Complex Variables)
 - MAT 327 (Introduction to Topology)
 - MAT 292 (Differential Equations for Eng Sci)
 - IFP 050 (Reading and Writings in Mathematics)
 - PUMP II (Preparing for University Mathematics)

STUDENT SUPERVISION

(All students officially supervised by Prof. Amr S. Helmy; I served as day-to-day supervisor)

1. Aryan Jain, Undergraduate Student, Sep 2025 – Aug 2026
2. Mayalakshmi Kolangatt, Ph.D. Student, Sep 2024 – Jan 2026
3. Dixshant Shree Gamal, Undergraduate Student, May 2023 – Jul 2024
Project: *Using Machine Learning for Long Range Optical Communication*

PROFESSIONAL SERVICE

- Reviewer for Physical Review A (PRA)
- Reviewer for International Journal of Quantum Information (IJQI)

AWARDS AND HONOURS

Research Awards:

NSERC Undergraduate Summer Research Award	2017
NSERC Undergraduate Summer Research Award	2016
U of T Physics Summer Undergraduate Research Fellowship	2015

Academic Awards:

Ontario Graduate Scholarship	2024
Queen Elizabeth II Graduate Scholarship (x3)	2021-2023
Edward S. Rogers Sr. Graduate Scholarship (x4)	2020-2024
Malcolm Slingsby Robertson Fellowship in Mathematics	2019
New College Council In-Course Scholarship	2016
Rhea V. Scott Scholarship	2015
University of Toronto President's Entrance Scholarship	2013