Seok-Hyung Lee

PERSONAL INFORMATION

- **Address**: 320B, Physics Building, Physics Rd, Camperdown, NSW 2050, Australia
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- **Google Scholar**: https://scholar.google.com/citations?user=NURGJAwAAAAJ
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EMPLOYMENT

Mar 2023 – Present | **Postdoctoral Associate** | **University of Sydney**

Group: Quantum Theory Group, School of Physics
Location: Sydney, New South Wales, Australia
Mentor: Prof. Stephen D. Bartlett

EDUCATION

Mar 2017 – Feb 2023 | **Ph. D. in Physics** | **Seoul National University**

Group: Center for Macroscopic Quantum Control, Department of Physics and Astronomy
Location: Seoul, Republic of Korea
Advisor: Prof. Hyunseok Jeong
Thesis: Universal Resource-Efficient Topological Measurement-Based Quantum Computing (Awarded the *BK Excellent Thesis Award*)
GPA: 3.93 / 4.30

Mar 2013 – Feb 2017 | **Bachelor in Physics** | **Seoul National University**

Location: Seoul, Republic of Korea
GPA: 3.89 / 4.30 (*Graduated with Honours)*

RESEARCH INTERESTS

My research primarily focuses on **developing and optimising resource-efficient, fault-tolerant quantum computing strategies** through quantum error correction. This includes areas such as decoding, logical operations, magic state preparation, syndrome extraction, and code construction. I am also particularly interested in **photonic platforms**.

During my postdoc at the University of Sydney, I have explored **2D color codes** by designing a high-performance decoding algorithm and efficient magic state distillation schemes. In my Ph.D., I investigated **measurement-based quantum computing with photonic qubits**, addressing challenges like photon loss and non-deterministic entangling operations.

In the long term, I aim to develop strategies that **bridge the gap between theory and experimental implementation**. My goal is to construct practical, integrated schemes that can be directly applied to real quantum hardware, ensuring they remain generalisable to suit evolving architectures.

SKILLS

- Experienced in Python programming
  - Data analysis with NumPy, SciPy, and pandas
  - Graph analysis with NetworkX and igraph
  - QEC libraries such as Stim (Clifford circuit simulation) and PyMatching (decoding)
  - Package development

MENTORSHIP

- **(2024)** *Andrew Li,* Honours Student at The University of Sydney
  Role: Supervisor
  Thesis: *Decoding twist defects on the color code*
  Summary: Twist defects can be used to define logical qubits in color codes, but corresponding decoding strategies have yet to be developed. We design a decoding algorithm for a triangular color code with a pair of twist defects, demonstrating a threshold comparable to that of a standard triangular color code.

PUBLICATIONS

2025

- SHL, A. Li, and S. D. Bartlett,
  Color code decoder with improved scaling for correcting circuit-level noise, Quantum 9, 1609 (2025).

2024

- **[Magazine]** SHL,
  색 부호를 활용한 결함허용 양자컴퓨팅 (Fault-Tolerant Quantum Computing with the Color Code), 물리학과 첨단기술 (Physics and High Technology) 33, 17 (2024).

- **[Preprint]** SHL, F. Thomsen, N. Fazio, B. J. Brown, S. D. Bartlett,
  Low-overhead magic state distillation with color codes, arXiv:2409.07707 (2024).

- J. Lee, N. Kang, SHL, H. Jeong, L. Jiang, and S.-W. Lee,
  Fault-Tolerant Quantum Computation by Hybrid Qubits with Bosonic Cat Code and Single Photons, PRX Quantum 5, 030322 (2024).

2023

- SHL and H. Jeong,
  Graph-theoretical optimization of fusion-based graph state generation, Quantum 7, 1212 (2023).

- **[Conference]** H. Jeong, SHL, S. Omkar, Y. S. Teo,
  Highly fault-tolerant quantum computing using both discrete and continuous variables of light, in Optica Quantum 2.0 Conference and Exhibition (Optica Publishing Group, 2023) p. QTu4A.6.

- SHL, S. Omkar, Y. S. Teo, and H. Jeong,
  Parity-encoding-based quantum computing with Bayesian error tracking, npj Quantum Inf. 9, 39 (2023).

- Y. S. Teo, S. Shin, H. Kwon, SHL, and H. Jeong,
  Virtual distillation with noise dilution, Phys. Rev. A 107, 022608 (2023).

2022

- S. Omkar, SHL, Y. S. Teo, S.-W. Lee, and H. Jeong,
  All-photonic architecture for scalable quantum computing with Greenberger-Horne-Zeilinger States, PRX Quantum 3, 030309 (2022).
- SHL and H. Jeong,
  Universal hardware-efficient topological measurement-based quantum computation via color-code-based cluster states, Phys. Rev. Research 4, 013010 (2022).

2021

- SHL, S.-W. Lee, and H. Jeong,
  Loss-tolerant concatenated Bell-state measurement with encoded coherent-state qubits for long-range quantum communication, Phys. Rev. Research 3, 043205 (2021).

2020

- S. Choi, SHL, and H. Jeong,
  Teleportation of a multiphoton qubit using hybrid entanglement with a loss-tolerant carrier qubit, Phys. Rev. A 102, 012424 (2020).

SOFTWARE DEVELOPMENTS

- *ConcatMatching*: Python package implementing the generalised concatenated matching decoder for decoding arbitrary stabiliser codes (2024),
  https://github.com/seokhyung-lee/ConcatMatching
- *color-code-stim*: Python module for simulating and decoding color code circuits (2024),
  https://github.com/seokhyung-lee/color-code-stim
- *OptGraphState*: Python package for graph-theoretical optimization of fusion-based graph state generation (2023),
  https://github.com/seokhyung-lee/OptGraphState

PATENTS

- H. Jeong, SHL, Y. S. Teo, S. Omkar,
  METHOD AND APPARATUS FOR LINEAR OPTICAL QUANTUM COMPUTING,
  US Patent, App. 18/075327 (2024) & KR Patent, App. 1020220120561 (2024)

PRESENTATIONS

Contributed conference talks

- **[Long talk]** *Color code decoder with improved scaling for correcting circuit-level noise*,
  24th Asian Quantum Information Science Conference, Sapporo, Japan (26.08.2024)
- *Linear optical quantum computing tolerant to non-ideal fusions and photon losses*,
  15th Asia Pacific Physics Conference, Gyeongju, Republic of Korea, online (24.08.2022)
- *Loss-tolerant optical measurement-based quantum computing with incomplete fusion operations*,
  Optics and Photonics Congress 2022, Jeju, Republic of Korea (03.07.2022)

- *Universal hardware-efficient topological measurement-based quantum computation via color-code-based cluster states*,
  33rd Optical Society of Korea Winter Conference, Daejeon, Republic of Korea (17.02.2022)

Invited talks

- *Towards resource-efficient fault-tolerant quantum computing with error correction,*
  SKKU Seminar, Qcenter, Sungkyunkwan University, Suwon, Republic of Korea (02.01.2025)
- *Low-overhead magic state distillation with color codes,*
  KAIST Seminar, Korea Advanced Institute of Science and Technology (KAIST), Daejeon, Republic of Korea (23.12.2024)
- *Low-overhead magic state distillation with color codes*,
  Joint PsiQuantum-USYD Workshop, University of Sydney, Sydney, Australia (25.09.2024)
- *Graph-theoretical optimization of fusion-based graph state generation*,
  Foxconn Quantum Computing Center Weekly Seminar, Hon Hai Quantum Computing Research Center, Taipei, Taiwan, online (17.05.2024)
- **[Tutorial Series]** *Toward Fault-tolerant Photonic Quantum Computing*,
  SAIT Seminar, Samsung Advanced Institute of Technology, Suwon, Republic of Korea (Part 1: 18.04.2024, Part 2: 05.06.2024 online, Part 3: 12.07.2024 online)
- *Color code decoder with improved scaling for correcting circuit-level noise*,
  CMQC Seminar, Center for Macroscopic Quantum Control, Seoul National University, Seoul, Republic of Korea (15.04.2024)
- *Color code decoder with improved scaling for correcting circuit-level noise*,
  KIST Seminar, Center for Quantum Information, Korea Institute of Science and Technology, Seoul, Republic of Korea (11.04.2024)
- *Color code decoder with improved scaling for correcting circuit-level noise*,
  KIAS Seminar, School of Computational Sciences, Korea Institute for Advanced Study, Seoul, Republic of Korea (09.04.2024)
- *Color code decoder with improved scaling for correcting circuit-level noise*,
  Coogee'24 Sydney Quantum Information Theory Workshop, Sydney, Australia (03.04.2024)
- *Low-overhead Lattice-surgery-based Quantum Computing with the Color Code*,
  QST Seminar, Research Institute of Mathematics, Seoul National University, Seoul, Republic of Korea (15.03.2024)
- *Pauli-product-measurement-based Quantum Computing with Two-dimensional Color Codes*,
  CMQC Seminar, Center for Macroscopic Quantum Control, Seoul National University, Seoul, Republic of Korea (04.09.2023)
- *Parity-encoding-based linear-optical quantum computing with graph-theoretical optimization of cluster state generation*,
  KIST Workshop on Quantum Information Theory 2022, Center for Quantum Information, Korea Institute of Science and Technology, Seoul, Republic of Korea (19.12.2022)
- *Parity-encoding-based linear-optical quantum computing with Bayesian error tracking*,
  Quantum Information Science Strategy, KOFST 2022 BrainLink X-Lab Day, Yeosu, Republic of Korea (15.12.2022)
- *Universal hardware-efficient topological measurement-based quantum computing via color-code-based cluster states*,

KIST Seminar, Center for Quantum Information, Korea Institute of Science and Technology, Seoul, Republic of Korea (30.05.2022)

- *Universal resource-efficient topological measurement-based quantum computation via color-code-based cluster states*,
  QST Seminar, Research Institute of Mathematics, Seoul National University, Seoul, Republic of Korea (12.11.2021)

Posters

- *Low-Overhead Magic State Distillation with Color Codes,*
  EQUS 2024 Annual Workshop, Noosa Heads, QLD, Australia (11.12.2024)
- *Low-Overhead Lattice-Surgery-Based Quantum Computing with the Color Code,*
  Quantum Information Processing 2024, Taipei, Taiwan (16.01.2024)
- *Low-Overhead Lattice-Surgery-Based Quantum Computing with the Color Code*,
  EQUS 2023 Annual Workshop, Perth, WA, Australia (21.11.2023)
- *Graph-theoretical optimization of fusion-based graph state generation*,
  6th International Conference on Quantum Error Correction (QEC23), Sydney, NSW, Australia (31.10.2023)
- *Graph-theoretical optimization of fusion-based graph state generation*,
  Asian Quantum Information Science Conference 2023, Seoul, Republic of Korea (31.08.2023)
- *Parity-encoding-based linear optical quantum computing with graph-theoretical optimization*,
  Bolder Boulder Quantum Workshop 2023, Boulder, Colorado, USA (20.06.2023)
- *Loss-tolerant all-optical quantum computing architecture using parity-state-encoded multiphoton qubits*,
  Quantum Information Processing 2023, Ghent, Belgium (06.02.2023)
- *Loss-tolerant multiphoton-qubit-based linear optical quantum computation with nonideal fusions*,
  Single Photon Workshop 2022, Seoul, Republic of Korea (03.11.2022)
- *Loss-tolerant linear optical quantum computation with non-ideal fusion operations*,
  5th Quantum Information Conference, Seoul, Republic of Korea (28.06.2022)
- **[Awarded]** *Universal resource-efficient topological measurement-based quantum computation via color-code-based cluster states,*
  21st Asian Quantum Information Science Conference, Tokyo, Japan, online (02.09.2021)
- *Loss-tolerant concatenated Bell-state measurement with coherent-state qubits,*
  20th Asian Quantum Information Science Conference, Sydney, Australia, online (08.12.2020)

AWARDS

- *BK Excellent Thesis Award*
  by Department of Physics and Astronomy, Seoul National University (24.02.2023)
- *Best Student Poster Award*
  in 21st Asian Quantum Information Science Conference (04.09.2021)
- *Graduated with Honours*
  by Department of Physics and Astronomy, Seoul National University (24.02.2017)

CONTRIBUTIONS

- I am an active reviewer of the following journals: *Quantum*, *PRX Quantum*, *Physical Review Letters*, *Physical Review A, Quantum Information Processing,* and *IEEE Transactions on Network Science and Engineering*.
- I am a member of the scientific organising committee for **Coogee'25 (Sydney Quantum Information Theory Workshop)**, scheduled to take place from 10 to 13 February 2025 in Coogee, Sydney.