GWONHAK LEE

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Ph.D. candidate, QCTC Lab, Department of Nano Science and Technology, Sungkyunkwan University

PROFILE

- Ph.D. candidate in Nanoscience and Technology at Sungkyunkwan University (expected Feb. 2026) specializing in quantum algorithms for early fault-tolerant quantum computing (EFTQC), with a focus on rigorous error analysis, resource predictability, and practical applicability.

- Research expertise includes quantum Krylov subspace diagonalization, quantum phase estimation, and quantum signal processing, with demonstrated contributions to theoretical modeling, provable algorithm design, and implementation in quantum chemistry simulation frameworks.

- Former Technical Manager at Qunova Computing, leading R&D on quantum software development and simulation platforms. Proficient in Python-based scientific computing, numerical analysis, and high-performance algorithm optimization.

Keywords: Quantum computing/algorithms, quantum computational chemistry, numerical analysis, early fault tolerance, Krylov methods

EDUCATION AND CAREER

Ph.D. in Nanoscience and Technology   Feb 2022 - (Feb 2026)
Sungkyunkwan University   *Suwon, Republic of Korea*
Advisor: Prof. Joonsuk Huh
Thesis: *Improving Reliability of Quantum Krylov Subspace Diagonalization: Error Reduction and Performance Analysis*
GPA: 4.29/4.5

- Conducting research on theoretical quantum algorithms and chemistry simulation, with a focus on **early fault-tolerant quantum computing**.
- Critically analyzing practical and non-asymptotic aspects of quantum algorithms, including ill-conditioning.
- Performing precise error analysis and developing error reduction techniques for **quantum Krylov subspace diagonalization** [J3].
- Designing quantum algorithms inspired by theories from electronic signal processing [JP2].
- Developing mappings from matrix function evaluation problems to Ising Hamiltonians [JP1].
- Equipped with an advanced mathematical foundation essential for quantum information theory.
- Delivered seminar talks [C2] and presented at international [C5, C9] and domestic [C1, C3, C4, C8, C10] conferences.
- Contributed to the patents related to quantum algorithms [P1, P2].
- Developing a Python toolkit, *Openfermion Expansion (ofex)*, to support quantum algorithm research. Full source available on GitHub.

Visiting Graduate Student   Jun 2023 - Dec 2023
Dept. of Chemistry, University of Toronto   *Toronto, Ontario, Canada*
Advisor: Prof. Artur F. Izmaylov

- Developed error mitigation techniques for the quantum Krylov subspace diagonalization method [J1].
- Presented related research in a departmental seminar [C6] and at a conference [C7].

Technical Manager   Feb 2021 - Feb 2022
Qunova Computing (link)   *Daejeon, Republic of Korea*

- Quantum start-up focused on developing quantum software and framework, with a focus on quantum chemistry simulation.
- Led R&D on quantum chemistry simulation and related software solutions.
- Built a framework for fragmented molecular orbital method, incorporating variational quantum eigensolver (VQE) as its subroutine.
- Received the Rigetti Partner Award at CDL 2021 Hackathon (Github link).
- Delivered an IBM Qiskit tutorial at the KICS Summer School on Quantum Computing [C11].

Software Engineer   Jan 2020 - Dec 2020
Looko Inc. (link)   *Daejeon, Republic of Korea*

- Start-up providing AI-based fashion styling experiences for consumers.
- Collaborated with other developers to build front-end and back-end components of a mobile service.
- Applied machine learning techniques to real-world image processing tasks.

M.S. in Electrical Engineering   Feb 2019 - Feb 2021
KAIST   *Daejeon, Republic of Korea*
Advisor: Prof. June-Koo Kevin Rhee
Thesis: *Physical and Flexible Qubit Coupled Cluster for Quantum Chemistry Simulation*
Coursework: Information Theory, Quantum Information, Statistical Learning Theory, Solid Physics
GPA: 3.98/4.3
Recipient of a full government-funded scholarship.

- Studied quantum computing and quantum chemistry simulation with a focus on noisy and intermediate-scale quantum (NISQ) algorithms.
- Collaborated with the quantum R&D team at Hyundai Motors on battery material discovery using VQE [J2],[P3].
- Presented research at domestic conference [C12, C13].

B.S. in Semiconductor System Engineering   Mar 2012 - Feb 2019
Sungkyunkwan University   *Suwon, Republic of Korea*
Coursework: Semiconductor Physics, Computer Architecture, Analog and Digital Circuit Design
Advisor: Prof. Byung-Sung Kim
GPA: 4.23/4.5
Recipient of the Samsung Electronics full scholarship.

Undergraduate Researcher   Feb 2018 - Dec 2018
RFMD Lab, Sungkyunkwan University   *Suwon, Republic of Korea*

- Developed a real-time FMCW radar signal processing system.
- Programmed FPGA and microprocessor systems for radar control and data acquisition.
- Co-authored the project *"W-Band Radar Altimeter for Drones"* [J4].

Internship   Jan 2017 - Feb 2017
Samsung Electronics, Device Solutions Division   *Yongin, Republic of Korea*

- Participated in power management IC (PMIC) development and performance analysis.

PUBLISHED JOURNAL ARTICLES

[1] Gwonhak Lee et al. "Efficient strategies for reducing sampling error in quantum Krylov subspace diagonalization". In: *Digital Discovery* 4 (4 Oct. 2025), pp. 954–969. DOI: 10.1039/D4DD00321G. URL: http://dx.doi.org/10.1039/D4DD00321G.

[2] Kyungmin Kim et al. "Variational quantum eigensolver for closed-shell molecules with non-bosonic corrections". In: *Phys. Chem. Chem. Phys.* 26 (10 Feb. 2024), pp. 8390–8396. DOI: 10.1039/D3CP05570A. URL: http://dx.doi.org/10.1039/D3CP05570A.

[3] Gwonhak Lee, Dongkeun Lee, and Joonsuk Huh. "Sampling Error Analysis in Quantum Krylov Subspace Diagonalization". In: *Quantum* 8 (Sept. 2024), p. 1477. ISSN: 2521-327X. DOI: 10.22331/q-2024-09-19-1477. URL: https://doi.org/10.22331/q-2024-09-19-1477.

[4] Yong-Seok Lee et al. "W-Band Radar Altimeter for Drones". In: *The Journal of Korean Institute of Electromagnetic Engineering and Science* 30.4 (2019), pp. 314–319. DOI: 10.5515/KJKIEES.2019.30.4.314. URL: https://doi.org/10.5515/KJKIEES.2019.30.4.314.

ARTICLES IN PREPARATION

[1] Gwonhak Lee, Minhyeok Kang, and Joonsuk Huh. "Quantum Circuit Representation of Matrix Functions: Permanent, Hafnian and Loop-hafnian". Manuscript in preparation. 2025.

[2] Gwonhak Lee et al. "Efficient Initial State Preparation through Filter Functions". Manuscript in preparation. 2025.

PATENT

[1] Gwonhak Lee and Joonsuk Huh. "Apparatus and Method for Autocorrelation Function Estimation in Early Fault-Tolerant Quantum Computing". Patent 10-2025-0108356 (Republic of Korea). 2025.

[2] Kyeongan Park, Gwonhak Lee, and Joonsuk Huh. "Apparatus and Method for Moment-Based Probability Density Function Estimation". Patent 10-2025-0079604 (Republic of Korea). 2025.

[3] Woomin Kyoung et al. "Quantum computer and quantum state simulation method using same". Patent US20230141618A1 (United States). May 2023.

CONFERENCE AND SEMINAR

[1] Gwonhak Lee et al. *Efficient Initial State Preparation through Filter Functions.* Talk presented at the Quantum Information Society of Korea (QISK) 2025 Conference. Oral presentation, Busan, Korea. **Received Best Presentation Award**. Feb. 2025.

[2] Gwonhak Lee. *Early Fault-Tolerant Quantum Algorithms and Quantum Krylov Subspace Diagonalization.* Talk presented at Quantum Information Workshop, organized by the Korea Institute for Advanced Study. Seoul, Korea. Sept. 2024.

[3] Gwonhak Lee et al. *Reduction of Sampling Error in Quantum Krylov Subspace Diagonalization.* Talk presented at the Optical Society of Korea (OSK) 2024 Conference. Oral presentation, Suwon, Korea. Feb. 2024.

[4] Gwonhak Lee et al. *Reduction of Sampling Error in Quantum Krylov Subspace Diagonalization.* Talk presented at the Quantum Information Society of Korea (QISK) 2024 Conference. Poster presentation, Busan, Korea. Apr. 2024.

[5] Gwonhak Lee et al. *Reduction of Sampling Error in Quantum Krylov Subspace Diagonalization.* Talk presented at the Quantum Techniques in Machine Learning (QTML) 2022 Conference. Poster presentation, Melbourne, Australia. Nov. 2024.

[6] Gwonhak Lee. *Measurement Problem in Quantum Subspace Diagonalization.* Seminar presented at a monthly quantum joint meeting in University of Toronto. Oct. 2023.

[7] Gwonhak Lee et al. *Reduction of Sampling Error in Quantum Krylov Subspace Diagonalization.* Talk presented at the Symposium on Chemical Physics (SCP) 2023. Poster presentation, Waterloo, Ontario, Canada. Nov. 2023.

[8] Gwonhak Lee, You Kyoung Chung, and Joonsuk Huh. *A Chemistry Application of Krylov Subspace Diagonalization based on Quantum Power Method.* Talk presented at the International Conference on Quantum Computing (ICQC) 2022. Poster presentation, Seoul, South Korea. **Received Best Presentation Award**. June 2022.

[9] Gwonhak Lee, You Kyoung Chung, and Joonsuk Huh. *A Chemistry Application of Quantum Krylov Subspace Diagonalization and Mitigation of the Finite Sampling Noise.* Talk presented at the Quantum Techniques in Machine Learning (QTML) 2022 Conference. Poster presentation, Naples, Italy. Nov. 2022.

[10] Gwonhak Lee, You Kyoung Chung, and Joonsuk Huh. *Estimation of Singlet-Triplet Gaps in Benzene Using Quantum Krylov Subspace Algorithm.* Talk presented at the Optics and Photonics Conference (OPC) 2022. Oral presentation, Jeju, South Korea. July 2022.

[11] Gwonhak Lee. *Tutorial on IBM Qiskit.* Tutorial presented at the 6th Summer School on Quantum Communication and Computing, organized by the Korean Institute of Communications and Information Sciences (KICS). Online event. Tutorial materials available at https://github.com/snow0369/qiskit_tutorial_2021_summerschool. Aug. 2021.

[12] Gwonhak Lee and June-Koo Kevin Rhee. *Physical Qubit Coupled Cluster for Quantum Chemistry Simulation.* Talk presented at the Korean Institute of Communications and Information Sciences (KICS) 2021 Winter Conference. Oral presentation, Pyeongchang, South Korea. Feb. 2021.

[13] Gwonhak Lee and June-Koo Kevin Rhee. *Singlet Unitary Coupled Cluster for Variational Quantum Chemistry Simulation.* Talk presented at the Korean Institute of Communications and Information Sciences (KICS) 2020 Summer Conference. Oral presentation, Pyeongchang, South Korea. Aug. 2020.

SKILLS

Language	Python, C/C++, Verilog/VHDL, Matlab
Theory and Subject	Quantum Algorithms, Quantum Chemistry, Numerical Methods, Function Analysis, High-dimensional Probability Theory
Technical Skills	Quantum Computer Programming (Qiskit, Pennylane), Machine Learning, Signal Processing