（別紙様式５）

変革を駆動する先端物理・数学プログラム（FoPM）

国外連携機関長期研修　報告書

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受入先	Pohang University of Science and Technology (POSTECH) および Korea Institute for Advanced Study (KIAS)
日程	西暦 2023 年 5 月 15 日　～　西暦 2023 年 5 月 24 日　および 西暦 2023 年 10 月 29 日　～　西暦 2023 年 11 月 1 日

For international research experience, I stayed at two research institutes in South Korea: Pohang University of Science and Technology (POSTECH) and Korea Institute for Advanced Study (KIAS). POSTECH is in Pohang, a port city located in the southeast of the Korean Peninsula, and is a relatively new university established by POSCO, a South Korean steel-making company. The campus of POSTECH is vast, and there are a lot of facilities, including a hotel where I stayed. On the other hand, KIAS is near the center of Seoul and is a research institute on theoretical physics at the Korea Advanced Institute of Science and Technology (KAIST). Each environment is comfortable for me to engage in research activity and has a lot of remarkable researchers in theoretical physics. My stay was hosted by Hee-Cheol Kim in POSTECH and Sunjin Choi in KIAS. They have been working on lower-dimensional quantum field theory called conformal field theory (CFT) and its mathematical aspects. My research topic is closely related to theirs, so this stay allowed me to discuss with leading researchers and was beneficial for the further development of my research.

During my research experience in Korea, I studied the mathematical relationship between quantum field theory and quantum information theory. The details of my activities in Korea are as follows:

① (POSTECH) Seminar on fermionic CFTs from classical error-correcting codes.
② (POSTECH) Discussion on its extension to quantum codes.
③ (KIAS) Seminar on probing supersymmetry through coding structure.
④ (KIAS) Discussion on the generalization to higher-dimensional theory.

In POSTECH, I had a seminar on my work. My research interest is the application of error correction in quantum field theory. Error correction is a framework to protect information from noise and is an indispensable technique in modern information communication. For a long time, it has been known that error correction can be applicable to construct a bosonic type of quantum field theory. My work considered a general setup of error correction and found that a fermionic quantum field theory naturally arises from classical error correction. It reveals a new relationship between error correction and quantum field theory.


Campus of POSTECH

While in POSTECH, I tried to extend my work to quantum error correction with Hee-Cheol Kim, his student Minsung Kim, and KIAS professor Kimyeong Lee. My previous paper focused on classical error correction, which does not incorporate quantum effects. When communicating with quantum information like qubits, it is necessary to introduce quantum error correction. Recently, quantum error correction has demonstrated its utility in constructing a quantum field theory. Inspired by this

development, we proceeded to extend my work to quantum error correction. We discussed the way of constructing fermionic CFTs from quantum codes and finally obtained a non-chiral type of fermionic CFTs. We also identified a class of quantum codes that can give fermionic CFTs.

In KIAS, I had a seminar on my other paper about probing supersymmetry through quantum error correction. This work utilized the fermionization technique in two dimensions, which states the equivalence between a bosonic and a fermionic theory. Via fermionization, a bosonic theory can be described by a fermionic degree of freedom. My work gave a systematic way of constructing fermionic CFTs from quantum error correction through fermionization. I also found that a special type of symmetry called supersymmetry in quantum field theory corresponds to some simple properties in quantum error correction. This work constitutes a new application of quantum codes and paves the way for the methodical search for supersymmetric quantum field theories.

After the talk at KIAS, I discussed the generalization of the correspondence in two dimensions to three-dimensional theories with Sunjin Choi, Sungjay Lee, and Takuya Okuda. In my previous works, the main goal was an application of quantum error correction to two-dimensional quantum field theory. Furthermore, it has been known that two-dimensional CFTs have a description by three-dimensional Chern-Simons theories, which are closely related to topological quantum error correcting codes. It motivates me to understand the correspondence in two dimensions from three-dimensional viewpoints. It may yield novel perspectives on the relationship between quantum error correcting codes and Chern-Simons theories. We briefly discussed the implications of the relationships by refining my work on two-dimensional theories. Additionally, we compared our analysis with the recent study about the duality structure of Chern-Simons theories with ensemble averaging of two-dimensional theories.

Lastly, I would like to express my gratitude for supporting my stay in Korea. The stay at POSTECH was supported by Hee-Cheol. At every lunch and dinner, Hee-Cheol would take me to a restaurant, and I enjoyed many tasty Korean foods. It was a precious and memorable time, and I greatly appreciate his kindness. Also, the stay at KIAS was supported by the KIAS School of Physics. Sunjin and Sungjay helped me visit KIAS and discussed it over a few days. I am grateful for their continuous support.