COVER PAGE

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Principal Investigator Information: Prof. Chih-Chun Chien	**Recipient Organization:** The Regents of the University of California 5200 N. Lake Rd. Merced, CA 95343-5001 Country: USA **UEI:** FFM7VPAG8P92

ACCOMPLISHMENTS

The project aims to build an interdisciplinary team of experts from the physics and computer science departments and scientists from the Lawrence Berkeley National Laboratory (LBNL) to expand the research and education capacities of quantum information science and technology (QIST) at the University of California, Merced. The team will recruit, train, and mentor graduate and undergraduate trainees to become the next generation workforce in QIST. Through research on quantum computation of exemplary chemistry and material science problems, the trainees gain hand-on experiences of quantum physics, quantum algorithms and hardware, as well as artificial intelligence and optimization. The team will enrich the QIST curriculum and connect the trainees to academic and industrial partners to explore career paths in QIST. For the recruitment, the team hosted a table in the APS Graduate School Fair and the UC Merced Bobcat Day to introduce the program to prospective students. The recruitment information was sent to all UC Merced students through the public relation office. To train and mentor the trainees, we had weekly joint meetings for the team and the trainees to help the trainees understand quantum physics and quantum computation. The trainees went through trainings to use the NRSEC supercomputer at LBNL and the IBM quantum computers to perform research. Furthermore, the PI and Co-PI have additional weekly meetings with the trainees to monitor their progress. Moreover, the UCM team brought the trainees to visit LBNL to help the trainees perform collaborative research.

Our achievements start with the successful recruitment of three graduate students and three undergraduate students interested in the program. The graduate students completed the training for using the NRSEC supercomputer at LBNL and the IBM quantum computers while the undergraduates are learning quantum physics and computer programming. The PI finished three theoretical studies relevant to the foundation of the research and published them in research journals. One trainee has performed simulations of a quantum system coupled to its environment and observed a topological phase which was predicted but thought to be impossible in a laboratory. The highly controllable quantum computer achieved such a formidable task, and the trainee wrote a research paper with the PI and the LBNL Co-PI. The graduate trainees presented their research in the 2025 APS Global Summit and attended the 2025 IEEE Quantum Week. Moreover, the graduate trainees from the physics and computer science have teamed up and worked on machine learning of quantum dynamics together. During the next period, the team will continue the recruitment to assemble a new cohort of trainees. Through the weekly joint meeting and individual meetings with the PI and Co-PI, the new trainees will gain knowledge and skills to perform artificial intelligence assisted quantum computing of physical problems related to chemistry and material science. The trainees will use the IBM quantum computers to extract the energy spectra of molecules and apply artificial intelligence to differentiate quantum correlations from dynamics. The trainees will present their research in professional conferences and workshops and publish the research when they are completed. The team will help our trainees apply for internal and external fellowships, summer or winter schools, research or internship opportunities, etc., through our connections with academic and industrial partners. The team will incorporate more QIST contents and emphases into the curriculum and prepare new courses and training opportunities for the students.

The program allows students interested in QIST to obtain the training, mentoring, and research experience to transform them into the next generation workforce in QIST. The weekly joint meeting had guests from academia and industry to show the trainees exciting opportunities in QIST. The collaborative research between the physics and computer science departments and LBNL exposed the trainees to different research culture and help them develop their career path s in QIST. The PI distributed information of fellowships, internships, research and training opportunities and encouraged the trainees to apply for those opportunities.

The weekly joint meeting and individual meetings for the trainees has accelerated the trainees to work on research in QIST. The trainees also have access to the NRSEC supercomputer at LBNL and IBM quantum computer after completing the training. Through the collaborative research under the supervision of the PI and Co-PI, the trainees started working on challenging problems with the help of quantum computers and artificial intelligence. The trainees went through the publishing process for publishing their research as journal articles and theses , and they present the results in professional conferences and workshops.

The PI has published three journal articles on the theoretical predictions relevant to the research for the trainees. One trainee has completed a research topic and submitted a research article co-authored with the PI and LBNL Co-PI. All the articles can be accessed free of charge on the online repository arXiv. The PI, Co-PI, and the trainees also presented the research in professional conferences. Moreover, the PI presented research opportunities in QIST and the program at UC Merced events to the local communities and high-school students, teachers, and counselors. We will continue the education and research efforts throughout the award period.

PRODUCTS

The products shown below include only Publications with a 'Published' status and Intellectual Properties with a 'Granted' status. Products with other statuses are not included in this report. The Revision Type indicates whether a product is New (newly added), Updated (existing product modified), or No Change (existing product reported without modifications) during the current budget period. Note that 'Updated' statuses may appear more frequently as products progress through the publishing process. All products listed have been reported for the current project period of this award.

PUBLICATIONS

Journal Article (New):
Wang, Xin; Tang, Jia-Chen; Hou, Xu-Yang; Guo, Hao; Chien, Chih-Chun, "Mixed-state geometric phases of coherent and squeezed spin states", *Physical Review B*, Volume 111, 235450, Published, 2025, DOI: https://doi.org/10.1103/98sq-16bz, OSTI Record: https://www.osti.gov/biblio/3000366.

Journal Article (New):
He, Yan; Chien, Chih-Chun, "Two-component atomic Fermi superfluid with spin-orbital coupling in thin-spherical-shell geometry", *Physical Review A*, Volume 111, 053309, Published, 2025, DOI: https://doi.org/10.1103/PhysRevA.111.053309, OSTI Record: https://www.osti.gov/biblio/3000367.

Journal Article (New):
Chien, Chih-Chun; Rittenhouse, Seth T.; Mistakidis, S. I.; Sadeghpour, H. R., "Tunable pairing with local spin-dependent Rydberg molecule potentials in an atomic Fermi superfluid", *Physical Review A*, Volume 111, 043316, Published, 2025, DOI: https://doi.org/10.1103/PhysRevA.111.043316, OSTI Record: https://www.osti.gov/biblio/3000368.

INTELLECTUAL PROPERTIES

There are no intellectual properties to report.

PARTICIPANTS AND OTHER COLLABORATING ORGANIZATIONS

The table below only contains participants who have identified an affiliation with the Awardee Institution. Participants from any associated subawards may not be included in this count.

PARTICIPANTS DETAIL

Project Role	Number of People	Total Person Months Worked
Co-Investigator	1	1
Graduate Student (Research Assistant)	3	12
Principal Investigator/Project Director	1	1
Undergraduate Student	3	3
Total Responses	**8**	**17**

PARTNERS DETAIL

There are no partners to report.

IMPACT

The project showcases the power of quantum computer as a new tool to solve challenging problems in science and engineering. Our results from the IBM quantum computers demonstrate a phenomenon deemed too difficult to perform in a typical laboratory. The success of our research lies in the highly controllable quantum hardware and the artificial intelligence assisted optimization. Our research component highlights practical usage of quantum computers on the one hand, and our education components prepares our trainees to perform research with quantum computers and artificial intelligence on the other hand. Moreover, the program attracts the attention from our students who may not heard of quantum science and technology (QIST) and transforms them into the next-generation workforce in QIST.

The framework of translating a physical problems into a quantum circuit and running it on a quantum computer can be applied to other fields in science and engineering. Our optimization of quantum computation by artificial intelligence further demonstrates the synergy between different branches of science and technology. Moreover, our studies of chemistry and material science problems by quantum computation provides examples for relevant fields to follow.

The project demonstrates an integration of local computers, supercomputers and quantum computers with software, artificial intelligence, and optimization to solve challenging problems using novel ideas and hardware. Our framework thus provides an example of multi-scale, multi-institution effort to handle science and engineering problems.

The exploding developments in QIST offer economic stimulations and growth with creations of new jobs and benefits, resembling the developments of semiconductor industry. Moreover, the project demonstrate applications of quantum computers in chemistry and material science, which in turn will find new applications in energy and healthcare sectors and benefit our daily lives.

Importantly, the program will produce a sizeable cohort of trainees well prepared for QIST research and education. Through the collaborative research with our academic, national lab, and industrial partners, the trainees are exposed to a variety of opportunities and develop their career paths in QIST. The program will prepare a group of the next-generation workforce in QIST for the insatiable needs from the academia and industry. Finally, none of the award was spent in any foreign country, and our trainees are all domestic students.