Establishing a Shared Quantum Lab for Research and Education in Quantum Information Science and Engineering at the University of Wyoming

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Amount Requested: **$50,000.00**

Project Description:

Overview: The Department of Physics & Astronomy and the Center for Quantum Information Science and Engineering (C-QISE) propose to establish a shared "Quantum Device and Quantum Bit (Qubit) Measurement Lab" (Quantum Lab) in Rooms 4 & 6 of Physical Sciences Building (PS 4 & 6) to support the research and education in QISE at the University of Wyoming (UW). The Quantum Lab is planned to house the state-of-the-art facilities designed to facilitate cutting-edge research for quantum materials and devices under extreme conditions. The core equipment is a dilution refrigerator with a base temperature of ~ 10 mK and a superconducting solenoid magnet with magnetic fields up to 14 T. The Quantum Lab will also incorporate hardware and electronic instruments from leading companies (including Keysight Technologies, Quantum Machines, and Stanford Research Systems), permitting simultaneous direct current and radio frequency measurements. The *key features and capabilities* of the Quantum Lab include 1) superconducting qubit testbed; 2) spin and charge transport measurements; 3) thermal transport and thermal Hall effect measurements; 4) microwave resonance spectroscopy and 5) *in situ* strain manipulation. The *objective* of this project is to renovate PS 4 & 6 to establish the proposed Quantum Lab.

Critical Need: UW has recognized immense opportunities presented by QISE. To capitalize on these opportunities, UW has established the C-QISE and prioritized quantum science and technology research and education, aiming to become a regional leader in this field. For instance, in 2022, we secured a five-year, $5 million NSF ExpandQISE grant dedicated to building research and education capacity in QISE at UW. Following that achievement, the university received an NSF Regional Innovation Engine Development Award in 2023 led by Montana State University ($ 1M), aimed at building a regional quantum supply ecosystem in rural areas of Montana, Wyoming, and Idaho. Furthermore, UW has just established a Master's degree (School of Computing) and a minor at the undergraduate level (Department of Physics & Astronomy) in QISE. These significant efforts underscore the university's commitment to advancing quantum science and technology. However, currently, there are no dedicated and shared quantum labs to support these ongoing research and education activities. For instance, sub-100 mK cryogenic apparatus for studying the quantum behaviors of quantum devices and testing qubits for quantum computing applications are not available in Wyoming, representing a significant gap in the region's research and educational infrastructure for QISE. This critical lack of instrumentation has already caused delays in ongoing research projects at UW. Establishing such a shared Quantum Lab at UW is essential to bridge this infrastructure gap, support current and future research and education endeavors, and solidify UW's role as a regional leader in QISE.

Rationale: PS 4 & 6 present the optimal location for establishing the shared Quantum Lab. These rooms are situated in the basement of the Physical Sciences building, adjacent to the other Physics and Chemistry labs, providing the low-noise environment essential for quantum device measurements. Importantly, PS 4 & 6 feature a special "sinking" design that yields extra floor-to-ceiling clearance—critical for the installation of a dilution refrigerator. We note that no other rooms

in the Physical Sciences building have this necessary height, and choosing an alternative space would require significant excavation at a minimum cost of $100,000 per dilution refrigerator. Fortunately, these rooms are currently available, as the IT department has agreed to move its TV studio, and the Department Head of Physics & Astronomy has formally requested the allocation of PS 4 & 6. Furthermore, substantial efforts have been made to secure federal funding to acquire the dilution refrigerator and associated hardware and electronic instruments. For example, the team submitted an NSF MRI proposal in November 2024, requesting $1,398,566 to support the acquisition of a cryogen-free dilution refrigerator for quantum information science research and education. PS 4 & 6 would be the ideal place for housing this new system. To ensure the successful installation and operation of the system, the minimal renovations listed below are required. However, renovation costs cannot be covered by the NSF MRI project and no other funding is currently available. If selected, the renovation supported by this funding will serve as the first critical step in establishing the proposed Quantum Lab.

Renovation Plan: To accommodate the requirements of the future advanced quantum device and qubit measurement system, we propose a series of renovations to the designated laboratory space. First, the existing wall will be modified to physically separate the Gas Handling System (GHS) from the core cryostat, thereby mitigating the noise generated by the GHS and ensuring a quieter environment for sensitive measurements. Next, new piping will be installed to circulate cooling water, which is necessary to maintain the compressor at an optimal operating temperature. Finally, the laboratory's electrical infrastructure will be upgraded to meet the power requirements of both 110 V and 250 V outlets, and a dedicated "clean" ground point will be established to isolate electrical noise—an essential factor in conducting reliable electrical transport and microwave measurements on quantum devices and qubits.

Impact: Establishing the Quantum Lab will have a substantial impact on the C-QISE at UW by positioning it as a regional leader in quantum research and education. The Quantum Lab with versatile capabilities will fill a critical infrastructure gap, providing cutting-edge resources previously unavailable in the state. This lab will greatly expand training opportunities for both graduate and undergraduate students, enabling them to engage in advanced experimental quantum research and technology. It can also attract new talents to join UW and develop new research projects. It will foster interdisciplinary collaboration among physics, chemistry, electrical engineering, computer science, and materials science, catalyzing research and educational growth. By preparing a new generation of scientists and engineers with practical experience in quantum technologies and low-temperature physics offered in the shared Quantum Lab, UW will enhance its ability to attract high-caliber students and faculty.

Preparing the future workforce in QISE is critical for the sustainable growth and development of quantum science and technology. This Quantum Lab with advanced quantum device and qubits measurement systems will offer a variety of research training opportunities for postdoctoral fellows, graduate researchers, and undergraduate students. The technologies associated with instruments of the Quantum Lab encompass advanced low-temperature cooling technologies, microwave, and low-frequency measurement techniques, electrical circuit design, as well as high-precision low-noise sampling and measurements, qubit control and operation, etc. These technologies are critical for pursuing a career in quantum industries. The Quantum Lab will also serve as a key infrastructure to support UW's educational program initiative in QISE. Currently, UW is establishing a master's degree and an undergraduate minor in QISE. The research results generated in the Quantum Lab can be integrated into both new and existing courses, and new laboratory sections can be created to provide students with hands-on experience.

Budget and Budget Justification

Amount Requested: **$ 50,000.00**

Justification:
The requested funding will cover the following labor and materials/supply for the proposed renovation, including 1) modification of existing wall ($ 25,000); 2) installation of new cooling water piping ($ 10,000); 3) upgradation of electrical infrastructure ($ 10,000); and 4) creation of a dedicated "clean" electrical ground point ($ 5,000).

This budget request is based on the informal estimate conducted by Steven Fletcher. I have quoted part of his email below:

"Mechanical/Electrical/Wall Modifications: $40,000-$45,000 Floor Modification: $40,000-$50,000 If you want to be conservative in your grant application, I would allocate $100,000 to install the unit in PS25. If you can find a different, more suitable location, then allocate $50,000. Since we are now targeting Room PS 4, the floor modification is no longer necessary, and the estimated renovation cost is reduced to $50,000."

We note that the team leader has communicated with Dr. Danny Dale and Joe Rovani and got approvals to use this informal estimate for this proposal.