Harnessing a Novel Ultracold-Atom Platform for Quantum Simulations and Information Processing

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Making use of the massive parallelism inherent in many quantum physics phenomena, the emergent and ever evolving field of Quantum Information Science seeks to create and control quantum-based technological platforms that are slated to revolutionize the information processing, computation and communication technologies, and which can provide novel approaches to quantum computing, quantum simulation, quantum sensing, and metrology.

Our project aims to exploit the versatility of a novel ultracold atomic system to develop a dedicated and universal platform to probe fundamental emergent phenomena through quantum simulations, and to explore its capabilities for information processing beyond those of existing classical computers. The project combines the experimental capabilities of Prof. Dominik Schneble's ultracold quantum systems laboratory with the expertise in theoretical quantum information and computation and theoretical cold atom physics of Prof. Tzu-Chieh Wei's group. By adapting the concepts of universal simulators to a recently developed ultracold-atom platform, we aim, as a long-term goal, to tackle important issues of fundamental physics and quantum information science and technology. In particular, we plan to theoretically search for and then experimentally realize novel many-body quantum phases out of equilibrium and in the presence of engineered system-bath couplings, and to tune our ultracold atomic quantum simulator to act as a dedicated quantum processor for the realization of quantum circuits, where ultracold-atom systems have the advantage of having many identical quantum bits available. Theoretical constructs of circuits that enable demonstration of computation beyond existing computer power will guide the development of ultracold-atom circuits for such realizations.

The project will foster a new experiment-theory collaboration at Stony Brook and help to develop a competitive position for projected funding from federal agencies in connection with the National Quantum Initiative Act of 2018.