MIT's Undergraduate Research Opportunities Program

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Summer 2008 UROP Project at Status: Approved

Faculty Supervisor: Chuang, Isaac L. Student: Diab, Kenan S.

Project Title: Building a Simulator of Quantum Spin Models

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Term: Summer 2008
PhD Supervisor: Robert Clark
Faculty Supervisor: Isaac Chuang
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My UROP project this summer will be in the research group of Prof. Isaac Chuang in the Research Laboratory of Electronics at MIT. I will help construct a two-dimensional Paul ion trap with the intent of building a simulator of quantum spin models. Ion traps have long been known as a leading candidate for quantum information processing. Decoherence times for the relevant electronic states of the ions are exceptionally long, and the means of addressing each qubit is relatively simple. Linear ion traps and other earlier devices, however, require large, complicated three-dimensional apparatuses that scale impractically as the number of ions in the register increases. In comparison, planar ion traps hold great promise as a means of conducting large-scale quantum computing: The geometry resulting from the extra spatial dimension afforded by planar traps allows for higher ion densities and raises the motional frequencies relevant for qubit manipulation. The simple, compact structure of the trap itself makes it an ideal candidate for parallelization. This project, if successful, would be a big step forward in scientists' efforts to efficiently harness the well-known, widely publicized power of quantum information theory.

The specific nature of the project will be dictated by the difficulties that arise in the process of building the device. At the start of the UROP, the laboratory will already have built a closed-cycle helium cryostat. The problems I will work on upon beginning the project include installing the trap into the cryostat, designing the electrodes of the trap so that each individual atom is well-confined, and designing the optics required to address each ion. Along the way, I also hope to expand my theoretical knowledge of quantum mechanics, quantum information theory, and optics, as well as gain general laboratory experience. By the end of the summer, I hope to have built a Paul trap which can reliably trap ions in a regular, planar two-dimensional array. The long term goal of this project is to study phase transitions in Ising and Heisenberg spin systems. This will require addressing of individual ions and construction of appropriate lasers for the ion-ion interactions. If I continue the project after the summer, this goal may be achieved in one to two years.

I am undertaking this project to pursue my deep passion for physics. At one level, this project will be my first serious project in experimental physics. Thus, my involvement in this UROP will prepare me for 8.13 and 8.14, the experimental physics courses at MIT; more generally, it will help me begin to decide whether I would like to be a theoretical or experimental physicist. At a deeper level, this project will allow me to further explore my interests in quantum mechanics and atomic physics. By building a real, working device, I will see the elegance and beauty of these physical theories

become manifest. I am extremely excited at the opportunity of working in Prof. Chuang's research group, and I look forward to a thrilling summer of physics.