MEng Pre-proposal: Fiber-coupled Ion Trap

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1 Basic info and personal statement

The project described in this pre-proposal is my intended Course IV Master of Engineering thesis work with Prof. Isaac Chuang of the Quanta Group at the Center for Ultracold Atoms (RLE). I will begin work in the Fall 2009 semester, with a projected timeline consisting of three regular semesters, as well as Summer 2010.

My interest is in applied physics. In particular, I wish to learn about and develop useful devices that go beyond standard microelectronics based on the principle of current switching. Through this project, I plan on gaining experience in device fabrication, as well as deepening my understanding of quantum physics in the AMO (atomic, molecular, optics) context.

2 Project introduction

We pursue planar ion traps as a platform for quantum computation. These structures can trap individual atomic ions, which are then used as qubits. The distinct advantage of planar traps is that they can be fabricated via standard silicon VLSI technology. This allows for arbitrary scaling of the devices, thus fulfilling one of the

basic requirements for implementing quantum information algorithms and quantum simulations.

The manipulation of the atomic ion qubit, as well as its state readout, is achieved by atom-light interactions. However, at the moment, the coupling of the atomic qubit with the external laser remains problematic, as the trap must be carefully aligned with respect to the laser frequently. In other words, despite the scalability of planar ion traps on a chip, the readout system to interface to those qubits is extremely cumbersome to maintain. This effectively prevents large-scale planar ion devices, since it is unfeasible to address many ions at a given time.

Hence, in this project, we propose to fabricate a planar ion trap on the surface end of an optical fiber. The general structure is illustrated in Figure 1.

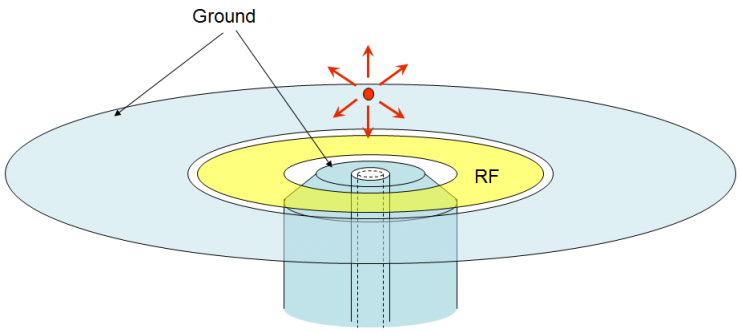

Figure 1: Schematic of the fiber-coupled ion trap. The red dot represents the trapped ion interacting with the light from the fiber below. The annular electrodes are utilized to trap the ion above the fiber.

The advantages of such a structure is that, by design, the ion is held at a precise position with respect to the light source, thereby removing the difficult alignment efforts in interfacing to the atomic qubit. Furthermore, by placing a mirror above the fiber, the trapped ion can be effectively placed in an optical cavity, thereby increasing the efficiency of atom-light coupling.

The objective of the project is to experimentally produce such a fiber ion trap,

and to verify its performance with the $^{88}Sr^{+}$ ion. In particular, a fabrication process for the trap will be designed.

3 Previous work

This project is preceded by various efforts in the Quanta Group that have direct relevance. Pearson's S.M. thesis (2006) investigated analytically the trapping potential of a planar trap shown in Fig. 1. It is predicted that singly-charged $^{88}Sr^{+}$ ions can be trapped by such a device.

In Summer 2008, a sequence of fiber planar traps for macroscopic objects (corn starch particles) were successfully constructed by Dr. Tae-hyun Kim, now a postdoc at Duke University. His work will be a very useful resource as I further develop the traps for atomic ions.