Single ion detection on a planar chip trap

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Application Note

Introduction

The goal of the experiment is to link two trapped ions via a transmission line coherently. An oscillating trapped ion induces oscillating image charges in the trap electrodes. If this current is sent to the electrodes of a second trap, it influences the motion of ions within the second trap. For this we trap single calcium ions in a linear planar Paul trap. Narrow-band laser light at 397 nm excites the $S_{1/2} \rightarrow P_{1/2}$ transition and the fluorescence can be detected with an Andor iXon DV885-LC-VP camera.

Experimental setup

In the trap, single calcium ions are conned 800 µm above the trap surface in ultra high vacuum. With a piezo translation stage a wire can be brought close to the ions (< 100µm) to study the interaction between the wire and the ion(s). The trap consists of copper electrodes plated onto an epoxy substrate (see Fig. 2). About 100 µW of detection laser light at 397 nm focussed to 50 µm travel parallel to the chip surface. Fluorescence is collected with a objective (numerical aperture of 0.28, F-number of 1.72, magnification of 25) placed 6 cm above the trap. This light is then sent through two interference filters to a DV885-LC-VP iXon camera from Andor.

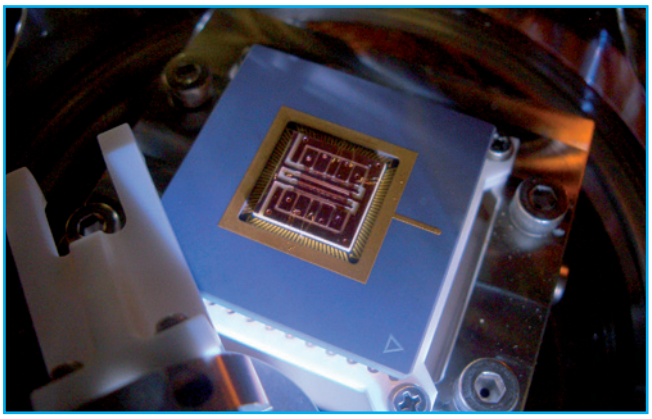

Figure 1: View into the vacuum chamber onto the trap. The center electrode is held at ground, while a voltage of 500 V oscillating at 10 MHz is supplied to the neighboring electrdodes, leading to trapping in the plane perpendicular to the trap axis. Appropriate DC-voltages on the segments on the outside side provide connement along the trap axis.

Detection of single ions

Ions are created via photoionisation from a neutral atomic calcium beam inside the trap. Success is monitored via irradiating the trap center with the detection light and collecting the fluorescence onto the camera. If the trap parameters are set correctly, the ion is rapidly cooled and forms a bright spot. Typically, we chose exposure times of 200 ms and an EM gain of 3000.

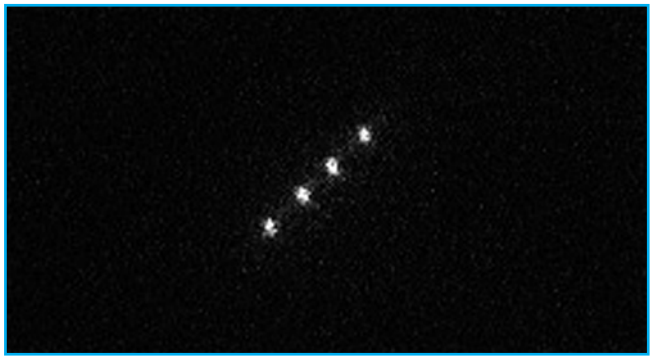

Figure 2: Fluorescence from a string of four calcium ions. The exposure time was 300 ms and the EM-gain was set to 3500. The distance between neighboring ions is about 10 µs

Using the camera instead of an avalanche photodiode or a photomultiplier tube has several advantages:

- Easy spatial filtering of the light. A problem in single ion detection is stray light caused especially from the detection light (light of other sources usually can be efficiently suppressed with interference filters). For planar traps this situation is aggravated as the ions are trapped close to the electrodes. In order to handle this, spatial filtering is employed, i.e. light from only of a certain region of interest is analysed. Using a camera, a large area can easily be observed at the same time, while still providing optimal spatial filtering. This is particulary important if ions are moved back and forth across the chip trap.
- The spatial information available from the camera allows also for detecting unambiguously the crystalisation process. In addition, the fluorescence of the ions in an ion string can be monitored individually. Thus ions of a different species (or in a different quantum state) can be easily detected by voids in the light emitted by the crystal.
- Robustness against large intensities. During the alignment process, the detection laser might hit a trap electrode. This can harm and even destroy photodetectors. However, it is desirable to monitor the alignment procedure. The EMCCD technology, on the other hand, is relatively robust and thus allows for monitoring the alignment procedure.

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