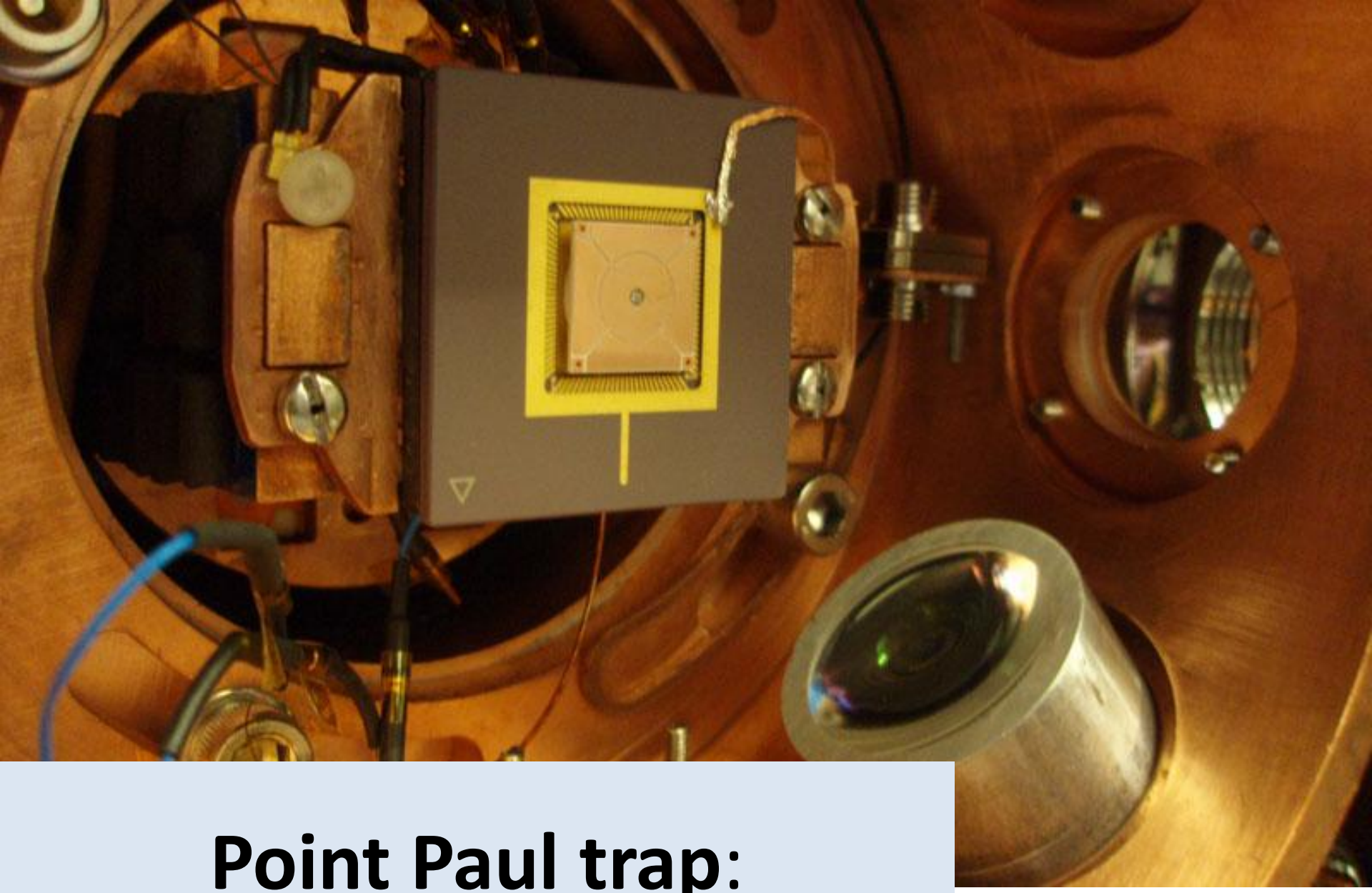

Point Paul trap:

Fiber integration and height variation

Tony Hyun Kim
Chuang group, MIT

Topics to be discussed

1. Ion trap design (“point Paul trap”) for optical fiber integration
   - Perturbation of trapping fields?
   - Effect of dielectric beneath the ion?

2. *In situ* variation of ion distance to electrodes

3. Outlook
   - Point Paul trap ideal for systematic study of anomalous heating

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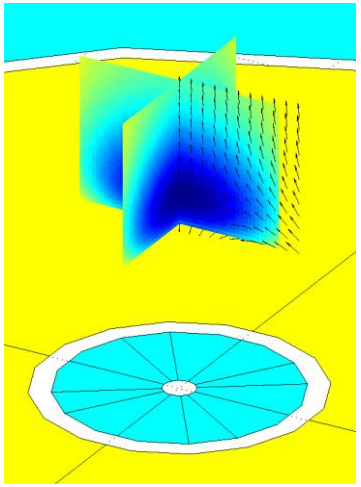
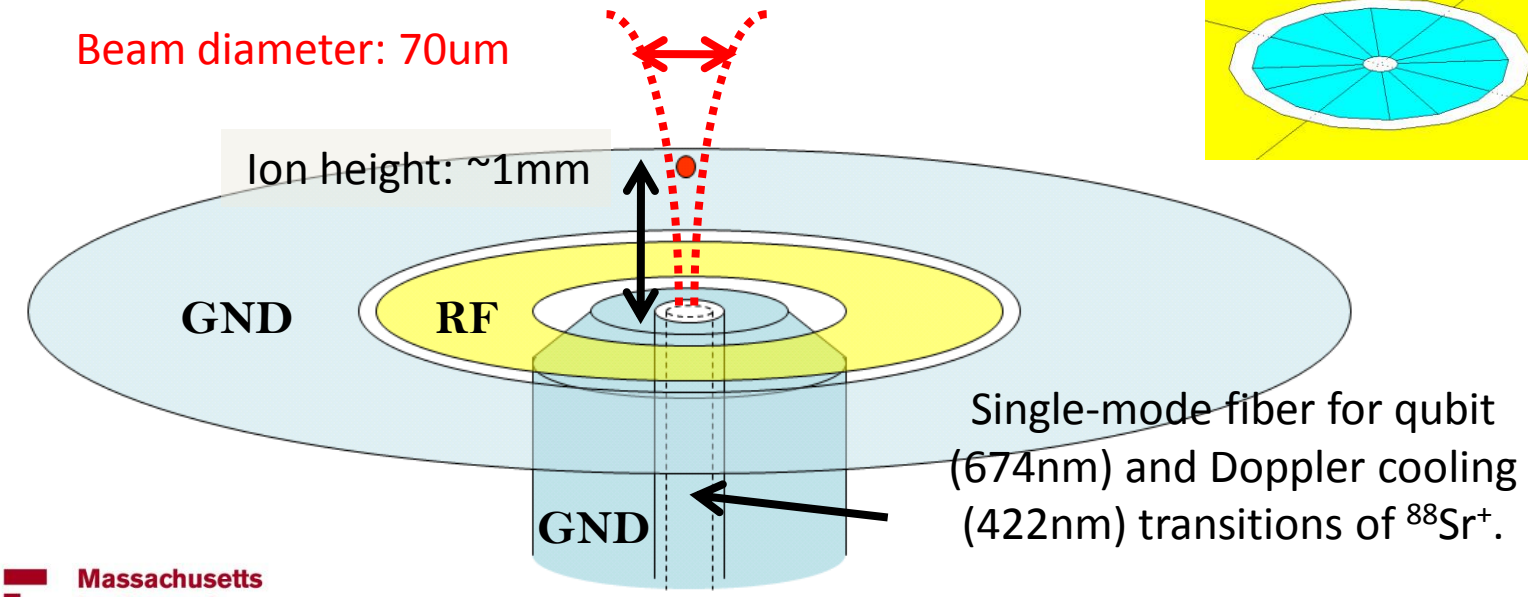
Fiber-integrated point Paul trap

- Idea: cylindrically symmetric surface-electrode trap with integrated optical fiber on axis
- Issues:
  - Perturbation of trapping fields
  - Trap assembly
  - Ion positioning relative to fiber





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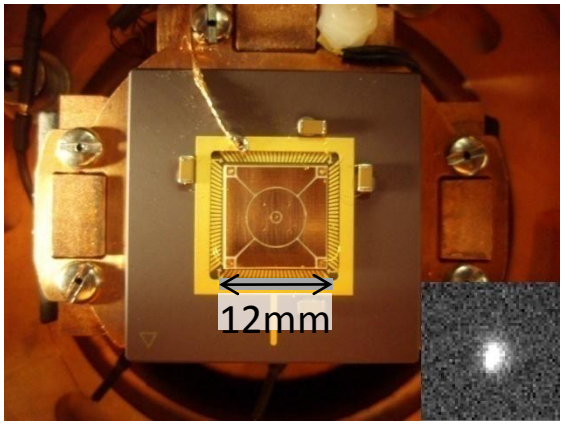
Basic point Paul trap

- Ion confinement through single RF
  - No DC fields required for trapping
- Analytic formulas for all trapping parameters
  - Can optimize different parameters (e.g. trap depth, etc)
- Typical RF drive 300V, 8MHz
  - 200meV trap depth
  - ~0.5MHz trap frequency



Kim, Herskind, Kim, Kim and Chuang. Accepted PRA. arXiv/1008.1603 (2010)

Basic Point Paul trap: Characterization

- Ion confinement through single RF
  - No DC fields required for trapping
- Analytic formulas for all trapping parameters
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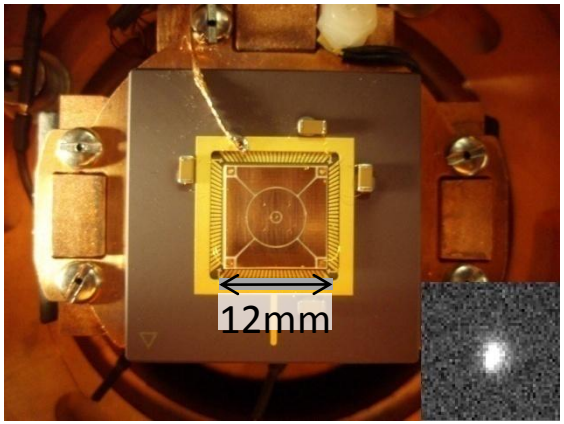
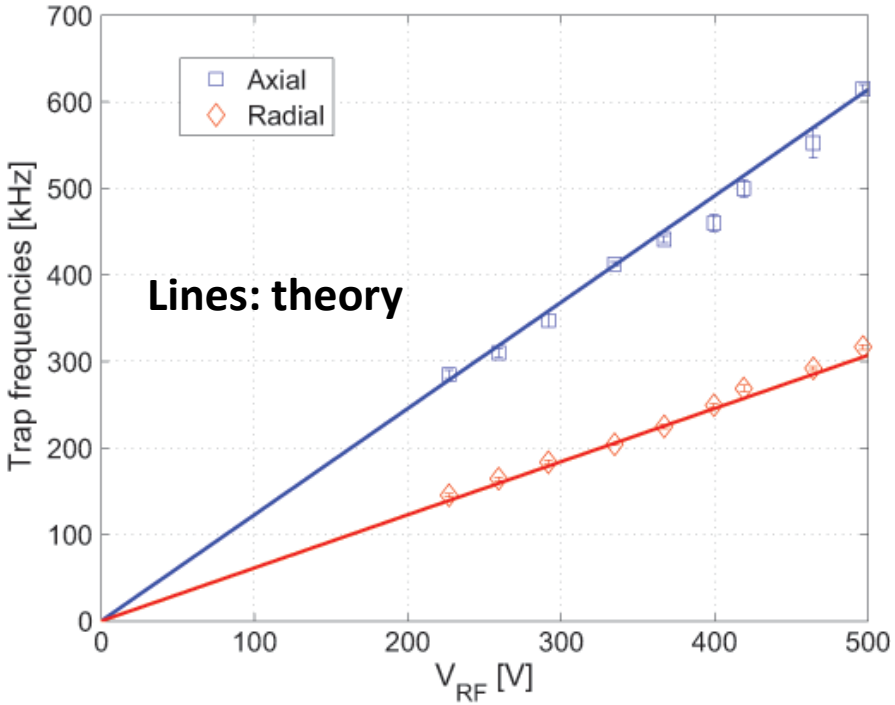
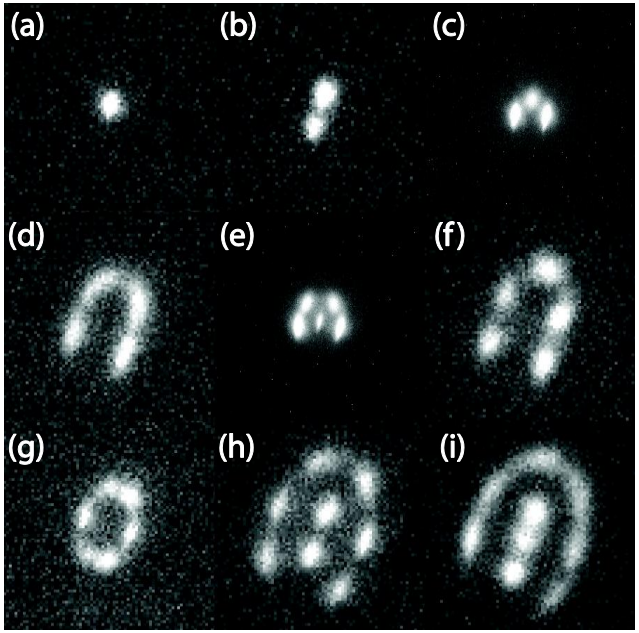


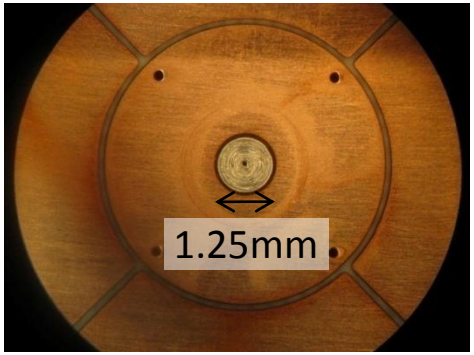




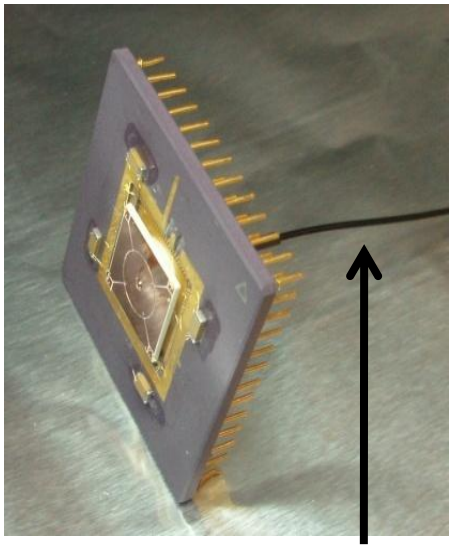
(Each panel: 40um×40um)

Fiber-integrated trap: Fabrication

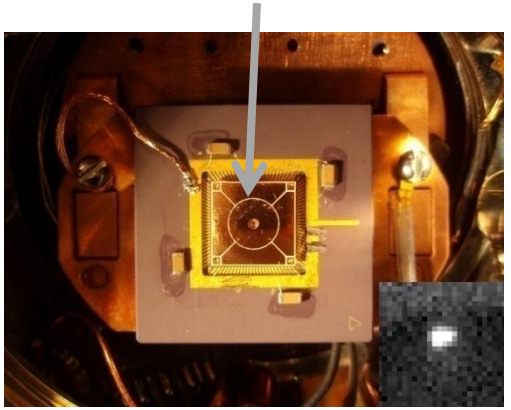
- Fiber and optical ferrule (stainless) polished as in conventional fiber connectorization.
- Macroscopic assembly at ~25um precision.



- Different fabrication options considered, such as:
  - Metallization of ceramic optical ferrule.
  - Self-aligned fab process by exposing PR through fiber itself.



Fiber introduced through the center of innermost electrode (actually an optical ferrule).



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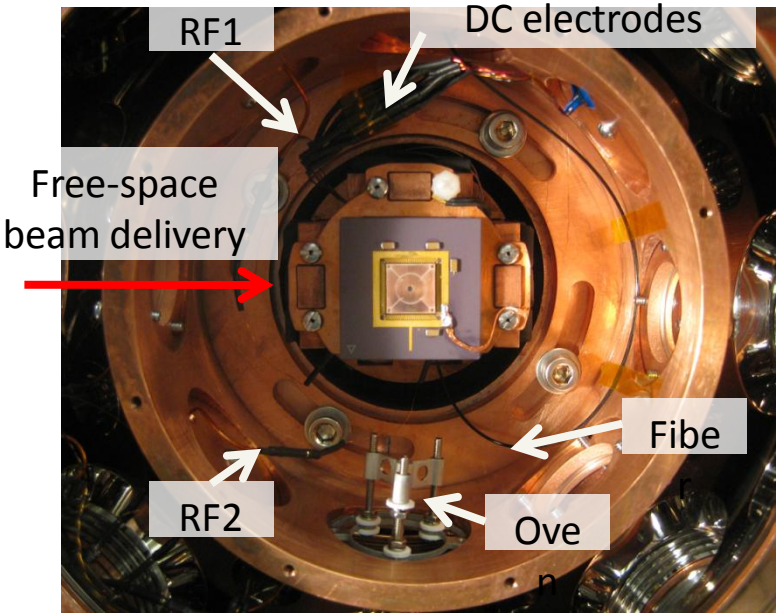
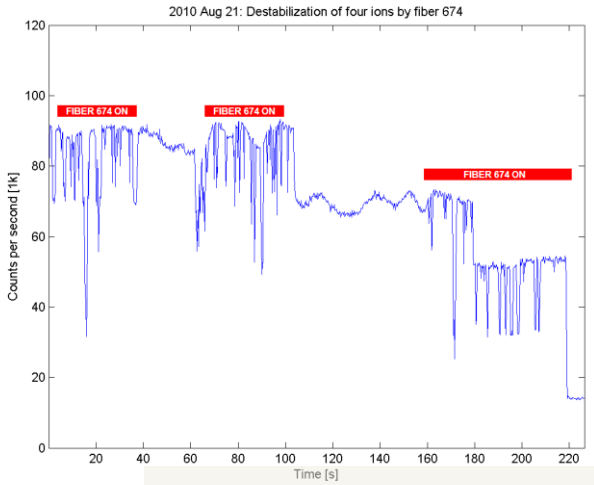
Fiber-integrated trap: Prelim results

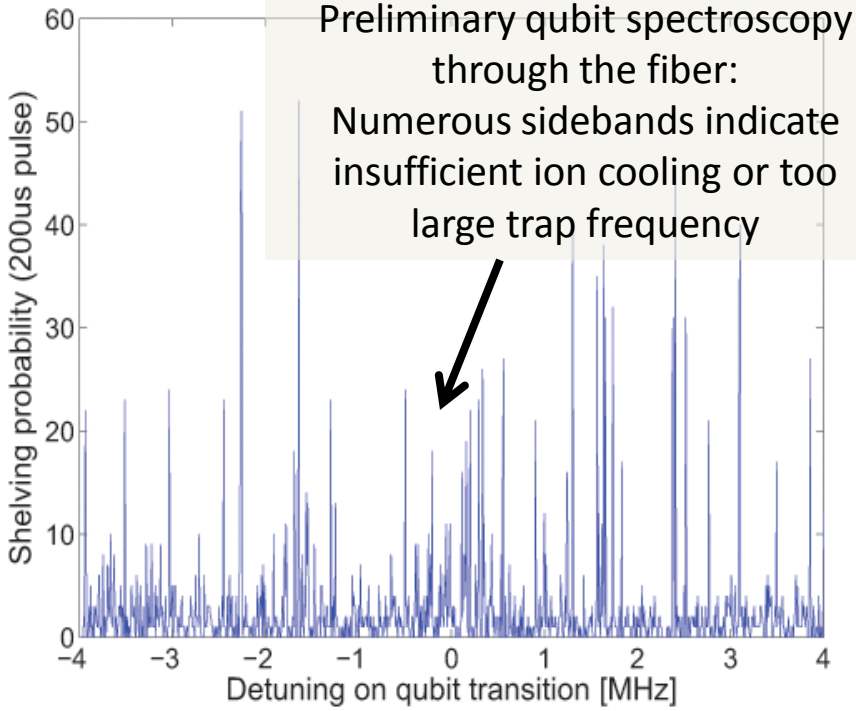
- Basic fiber-ion overlap observed in shelving of trapped ions
- Improvements expected by miniaturization of trap, i.e. to increase trap frequencies (LD regime)



40K chamber (5” diameter) of cryostat.
Trap mount is at ~10K

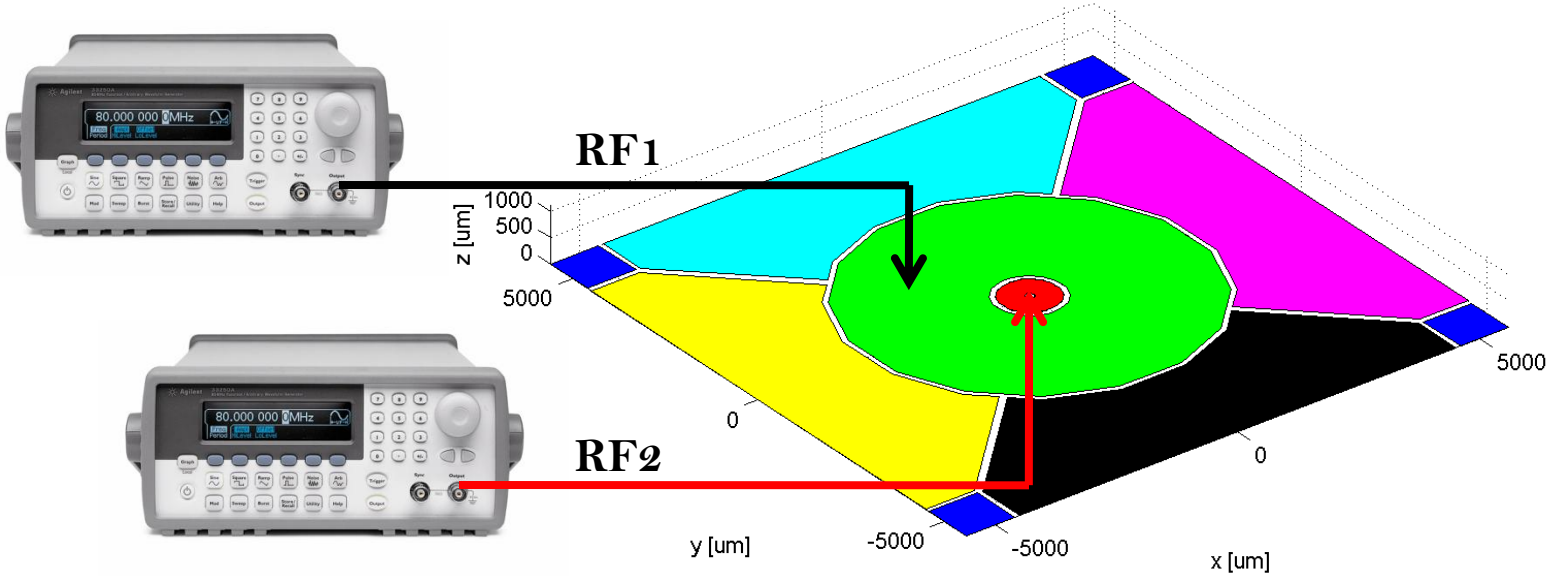


Preliminary qubit spectroscopy through the fiber:
Numerous sidebands indicate insufficient ion cooling or too large trap frequency



Height variation in point Paul trap

- Idea: RF confinement without DC fields allows for more complicated drive schemes
- Implication:
  - Order of magnitude variation in ion height *in situ* is possible
  - More generally, ion can be positioned with respect to trap.



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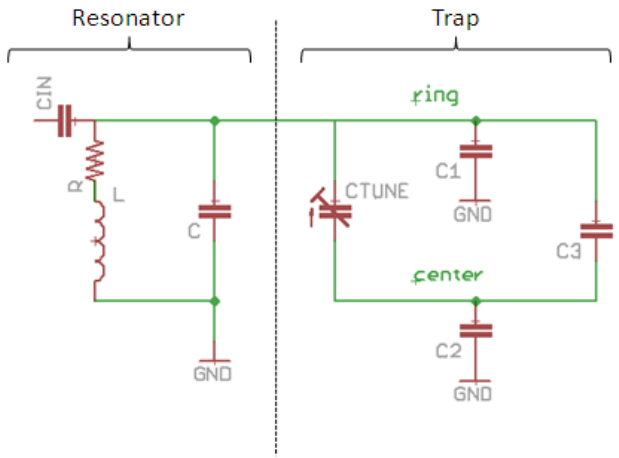
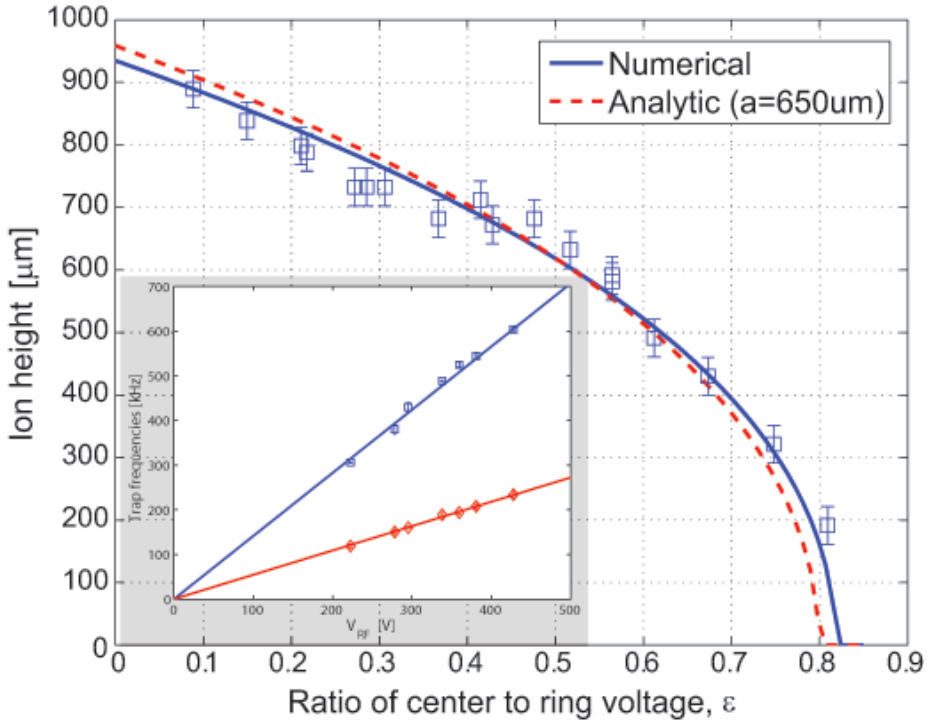
Height variation in point Paul trap

- Applying second RF on the center electrode translates the quadrupole node vertically.
  - Implementation with single trimcap
  - Works with both ferrule and PCB



- Height variation compared against analytic theory and numerical simulations



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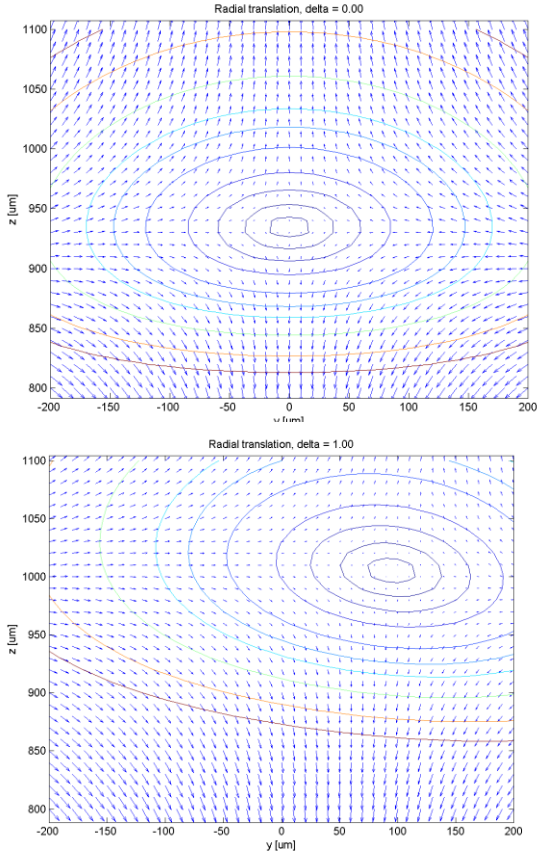
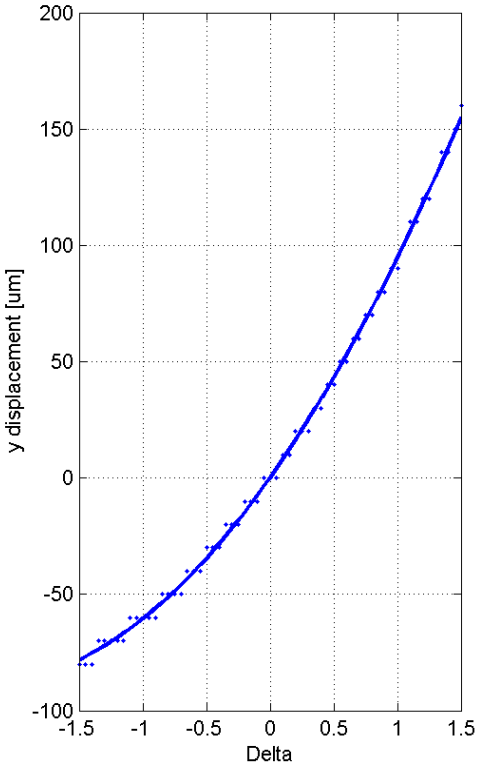
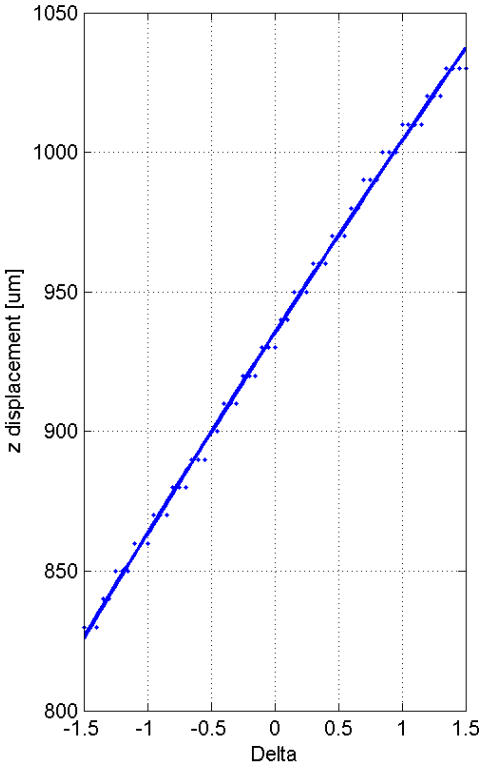
Ion positioning

- In general, applying RF to side electrodes will also translate the ion.
  - 1:1 ring:side voltage ratio moves ion radially ~100um
  - Immediate application in ion-fiber overlap control







Summary and Outlook

1. Fiber integration gives access to a typically inaccessible axis of a surface-electrode ion trap.
2. Point Paul traps allows *in situ* variation of ion height by almost an order of magnitude in a single trap.

Summary and Outlook

1. Fiber integration gives access to a typically inaccessible axis of a surface-electrode ion trap.
2. Point Paul traps allows *in situ* variation of ion height by almost an order of magnitude in a single trap.

Ingredients for a systematic study of anomalous ion heating

- What is the correct scaling law for ion heating as a function of distance to trap surface?
- How does anomalous heating effect the ion motion normal to the trap and parallel to the trap?

The point Paul trap is an ideal system in which to study these questions…

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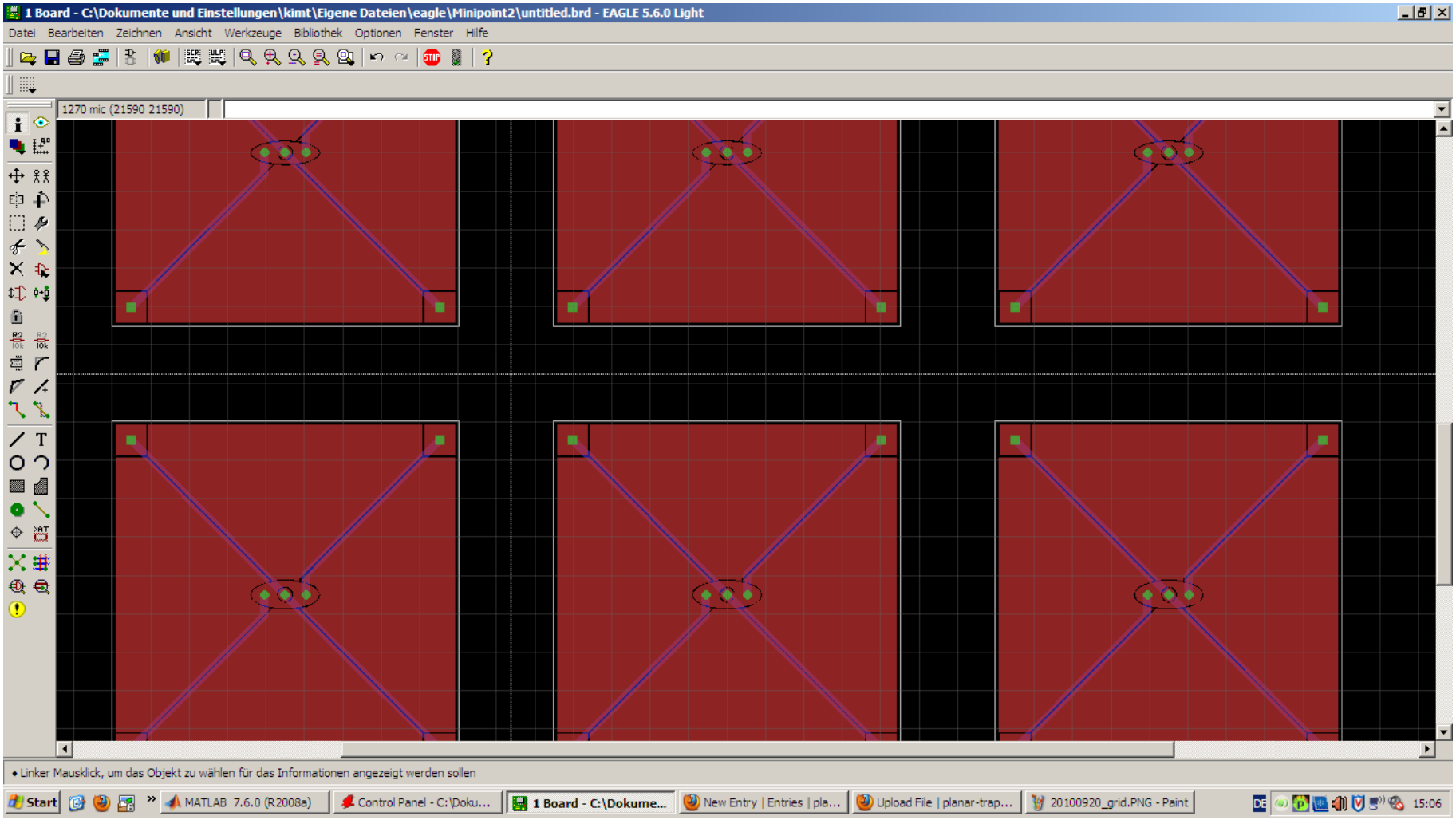
Next up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