MOTion Apparatus Design Considerations

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RF Trap

The dimensions of the RF trap probably matter:

- for smaller traps, the deviations from the ideal quadrupole might become important
- during extraction into the TOFMS, smaller traps might lead to larger deflections of ions perpendicular to the direction of extraction

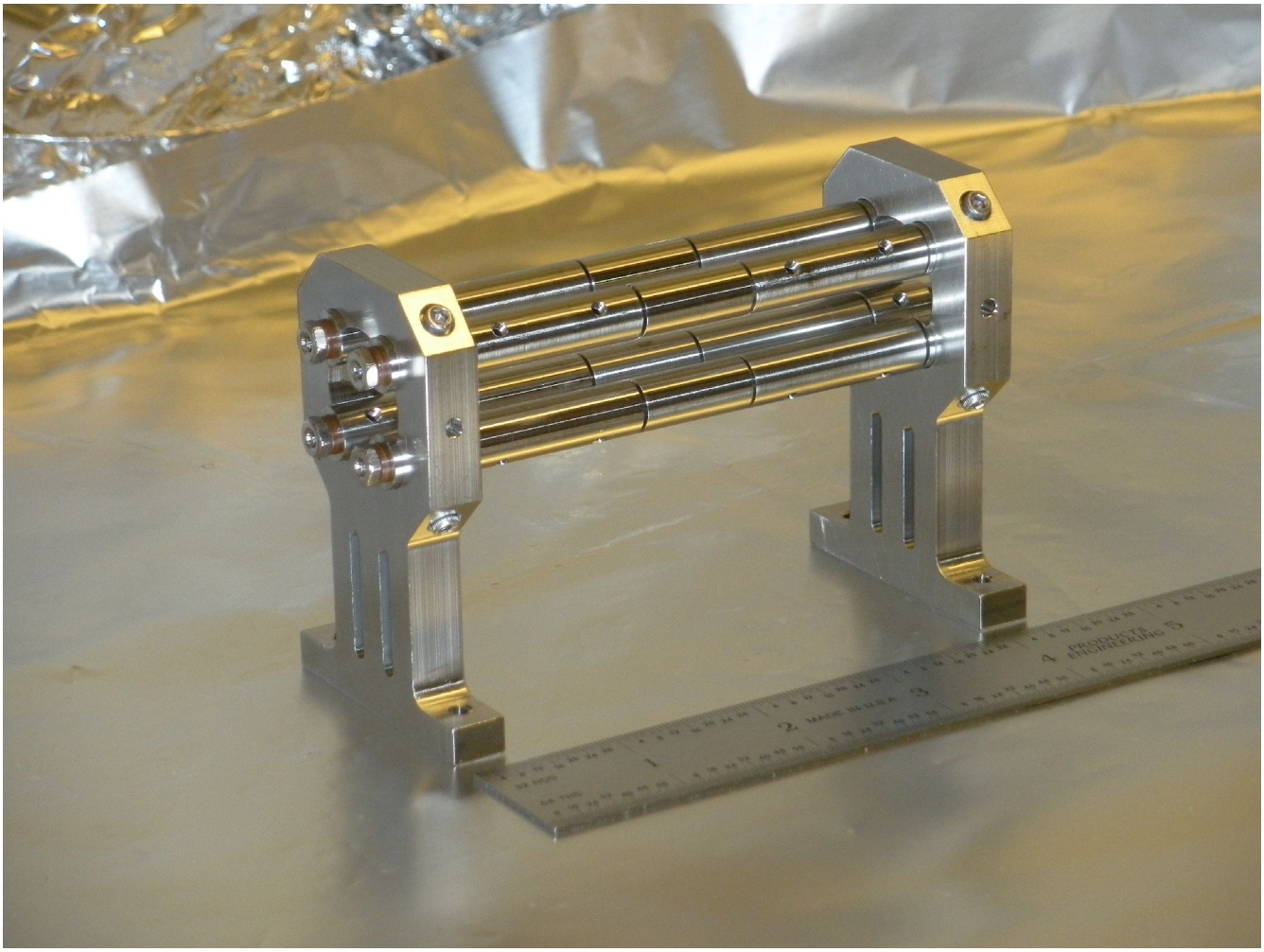

Illustration 1: RF trap design in MOTion trap version 2 at UCLA

The trap is a segmented RF trap, such that the outer segments can have an additional DC voltage for axial confinement of the ions. This design requires 8 to 12 copies of the drive electronics and a lot of matching of all these 8 to 12 circuits.

For future designs, it is strongly recommended to use an RF trap with external (DC-only) endcap electrodes and non-segmented rods. For that, only 4 copies of the drive electronics will be required,

which is the minimum. **Each rod must be wired up separately to the air-side** for use as a TOFMS, because the front rods (closer to the TOF drift tube) have a smaller HV for TOF extraction than the rear rods; however, the RF is applied to diagonally opposing rods. As such, the pairs (RF voltage, TOF HV) for all the rods are pairwise different requiring their own drive electronics. (Each drive unit can only provide exactly one pair of such voltages.)

TOFMS Drift Tube and Einzel Lenses

The TOFMS has two Einzel lenses. In our design, the inner cylindrical part that the high voltage is applied to, is hidden within the two outer, grounded pieces.

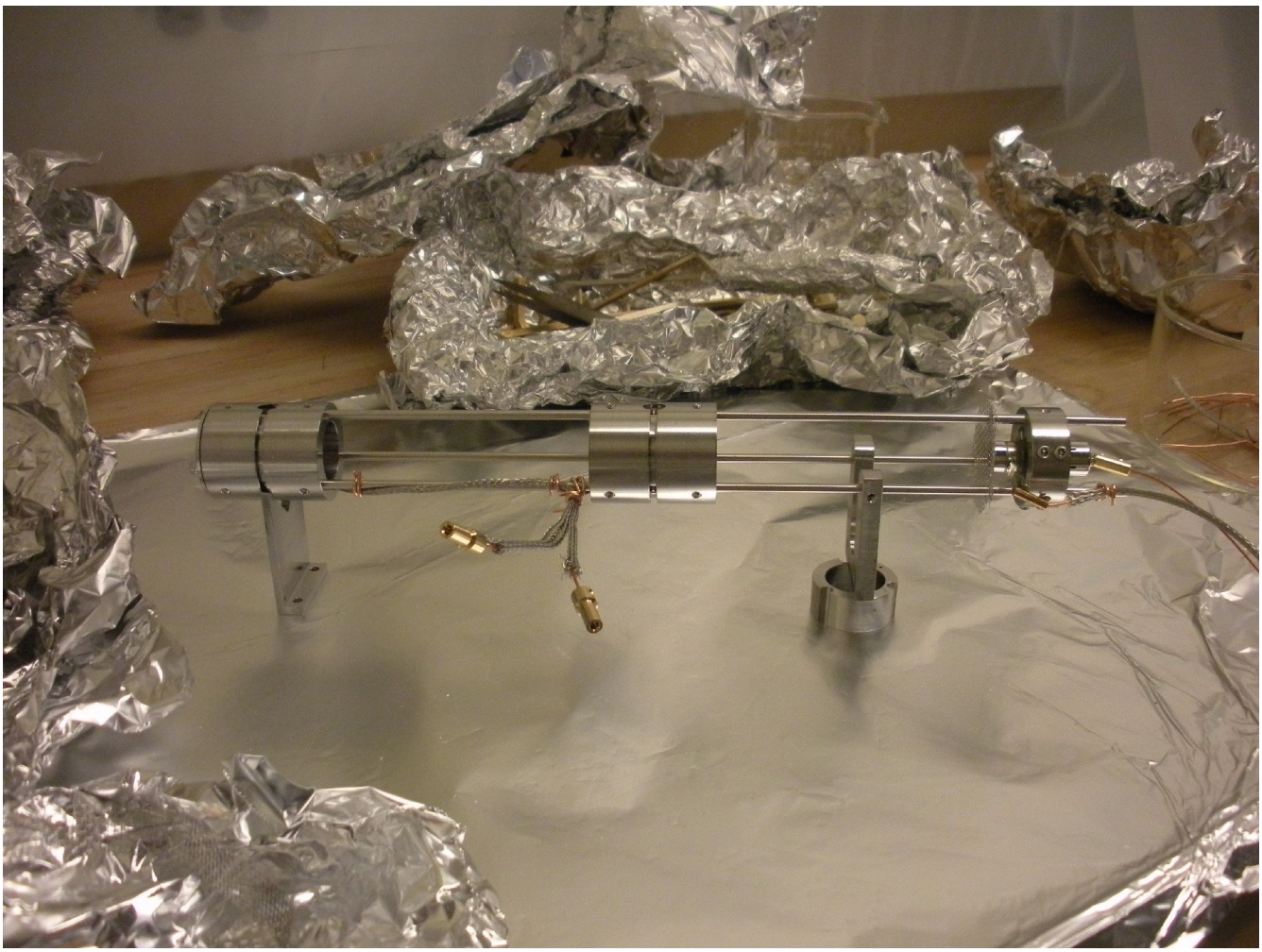

Illustration 2: TOFMS drift tube during assembly. The structure will be inserted into a (grounded) CF nipple of the vacuum chamber.

Also, there is a grounded skimmer (= aperture) in front of the first Einzel lens, which defines the entrance to the TOF drift tube. The distance of RF trap center to skimmer matters. The exact maths are in the original Wiley-McLaren paper (see references below); as a rough estimate, the ratio should be

$$\frac{\text{RF trap center to "end" of the RF trap}}{\text{"end" of RF trap to skimmer}} \sim \frac{1}{1} \quad \text{, but} \quad \frac{1}{2} \quad \text{as in the current system works fine too.}$$

(The "end" of the RF trap denotes the point roughly in the middle between the two rods facing the

TOFMS.)

More details on simulations (ion trajectories, HV extraction voltages, etc.) can be found in Steven Schowalter's paper, whose RF trap and TOFMS have very similar dimensions.

While our design uses a channeltron (on the right-hand side in the figure, shielded by the grounded stainless steel mesh) for ion detection, future designs will likely use a microchannel plate (MCP). An MCP promises higher detection efficiency (due to larger area) and maybe even better mass resolution, as the device is "flat" as compared to the elongated channeltron.

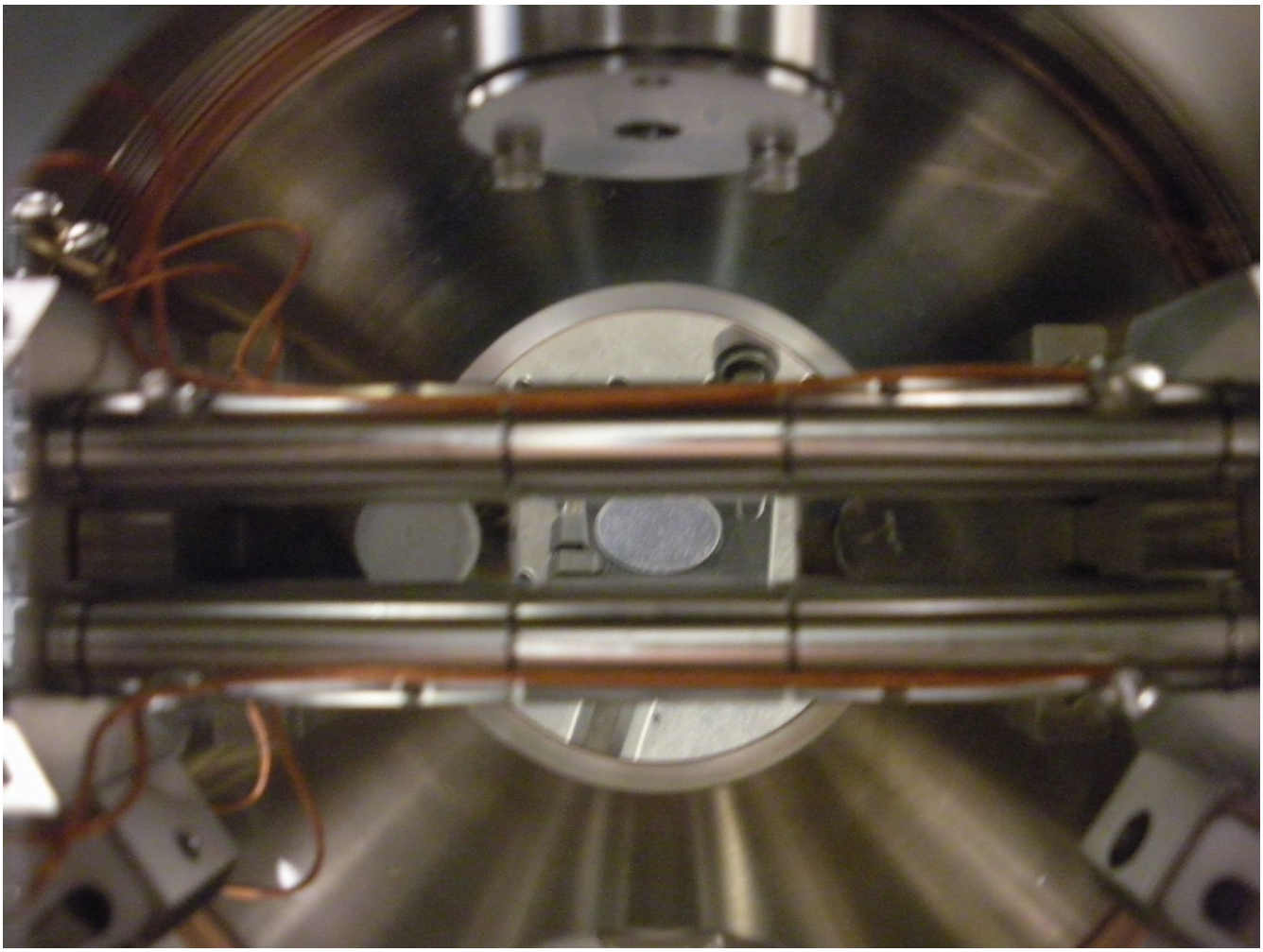

Illustration 3: Top view of RF trap structure and skimmer of TOFMS drift tube. Note the distance between RF trap and skimmer. Here, it the first Einzel lens is slightly further back than it ideally should be due to geometrical constraints imposed by the laser beams for the MOT.

Wiring Considerations

The wires in the vacuum chamber should be as short as possible, loops or closeness to grounded parts should be avoided (and, of course, unshielded wires should be used). All the wires for the RF trap rods should be as equal and symmetric as possible. This is important to keep the capacitance and inductance as low and equal as possible.

We are using four Lesker EFT0143052 feedthroughs for driving our trap (3 of the 4 wires are used of

each feedthrough, the 4th one is not connected). On the air side, a hat-like mount is attached to the feedthrough. The "hat" is put on the feedthrough and together they are screwed down using the screws for sealing the CF port. **That means this mount has to be assembled at the time the feedthrough is mounted to the chamber, i.e., before pumping/baking the chamber.** The "hat" is used to securely mount a printed-circuit board serving both as

- an adapter between feedthrough wires and cables going to the drive electronics and
- a measuring probe, because the PCB contains a pickup structure that makes ~1..3% of the actual RF signal at the rod available for inspection with a scope.

For future purposes it is probably best to go with two 2-wire feedthroughs to keep the capacitance as low as possible. Diagonally opposing rods of the RF trap should be wired up to the same feedthrough to prevent cross-talk, when operating the RF trap asymmetrically (with RF on only two rods and the other rods grounded).

The little round PCBs (with the SMB connectors on one side) have MillMax 0492-0-15-15-13-14-04-0 receptacles on the other side, which slide on the wires of the feedthrough. It is advisable to get some receptacles (e.g., as samples from MillMax) for the assembly of the vacuum chamber, such that the wires of the feedthroughs can be shortened on the air side to the right length. The length of the wires has to allow the surface of the receptacle that touches the PCB to be slightly below the surface of the "hat" that touches the PCB. (= You don't want the wire of the feedthrough to feel any force when you screw down the PCB to the "hat".)

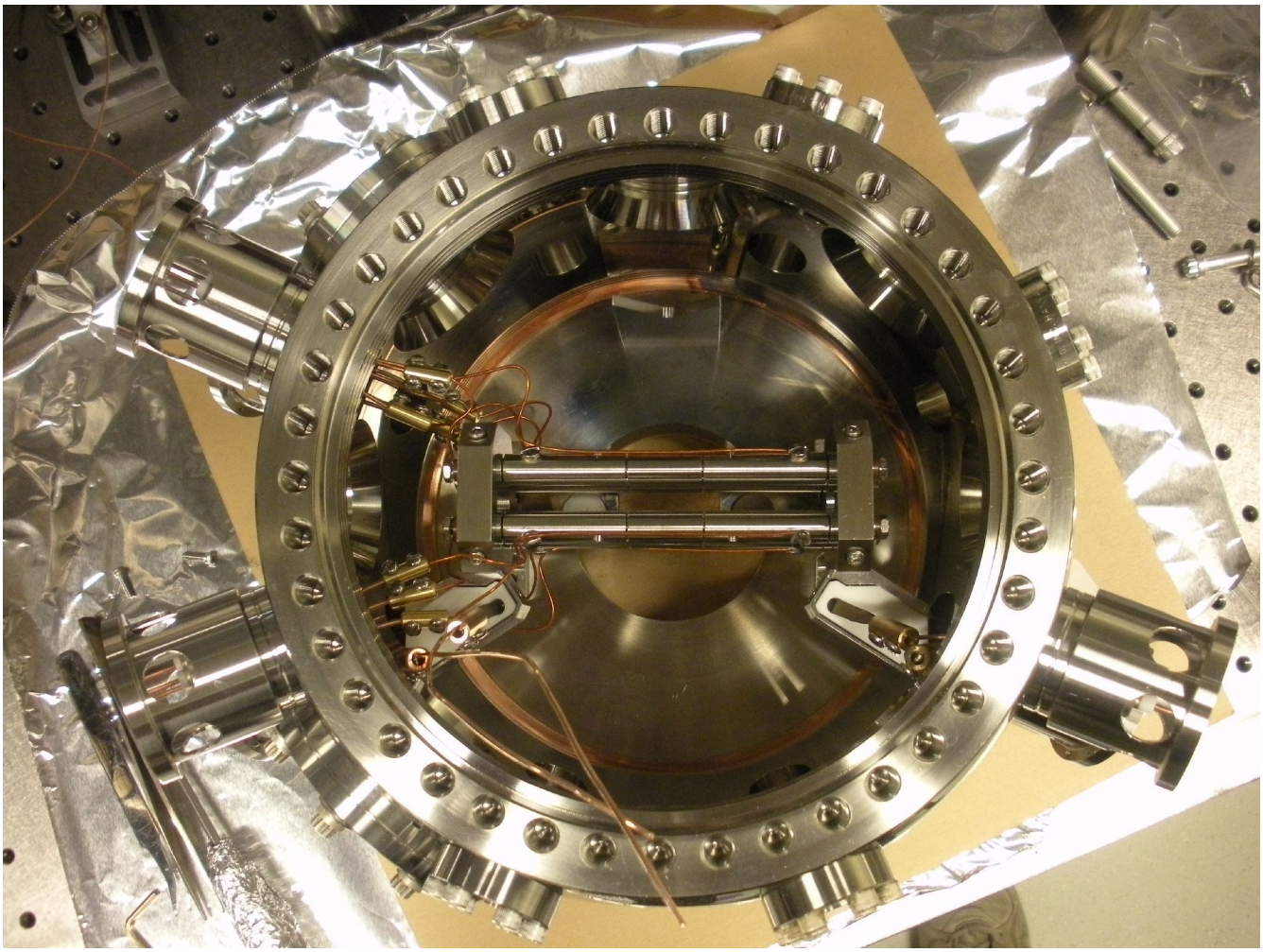

Illustration 4: Wiring of the RF trap electrodes inside the vacuum chamber. While wires may be close to electrodes with same RF/HV voltages, there should be a gap between wires and grounded parts. The hat-like mounting structures can be seen on the air-side of the chamber.

Illustration 5: PCB mounted on "hat" with cables having the RF drive voltage and pickup signals, respectively.

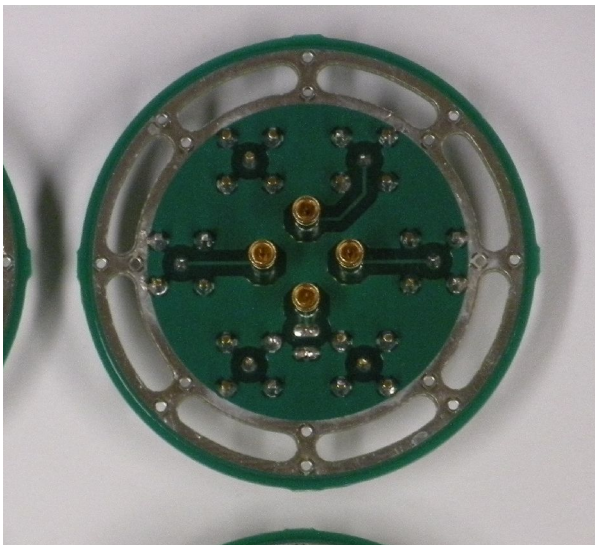

Illustration 6: Bottom view of PCB for "hat" with MillMax receptacles visible.

Further Reading

- **Current MOTion trap electronics:** Schneider et al.: arXiv 1507.00035 (http://arxiv.org/abs/1507.00035)
- **Laser-cooling-assisted mass spectrometry** with current setup: Schneider et al.: Phys. Rev. Appl. 2, 034013 (2014) (http://link.aps.org/doi/10.1103/PhysRevApplied.2.034013)
- **Previous RF trap with TOFMS** (without laser cooling or MOT): Schowalter et al.: Rev. Sci. Instrum. 83, 043103 (2012) (http://dx.doi.org/10.1063/1.3700216)
- **Original Wiley-McLaren TOFMS:** Wiley and McLaren: Rev. Sci. Instrum. 26, 1150-1157 (1955) (http://dx.doi.org/10.1063/1.1715212)