Electric Field Simulations with Segmented Field Plates

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Structure of Presentation

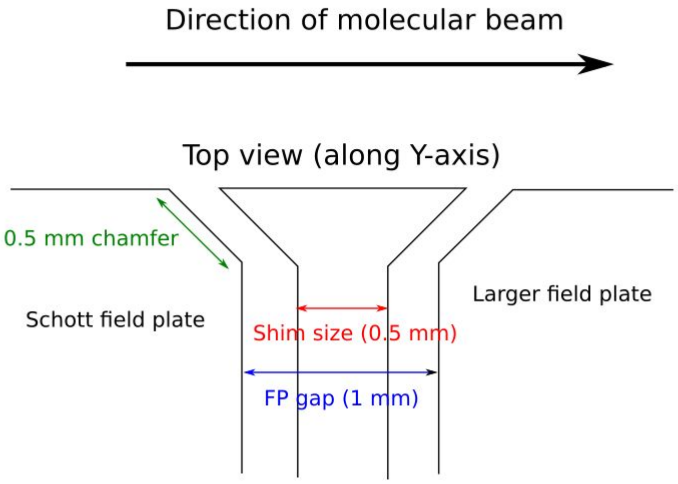
1. Experimental motivations
2. Simulation setup
3. Results
4. How to measure E-fields
5. Conclusion

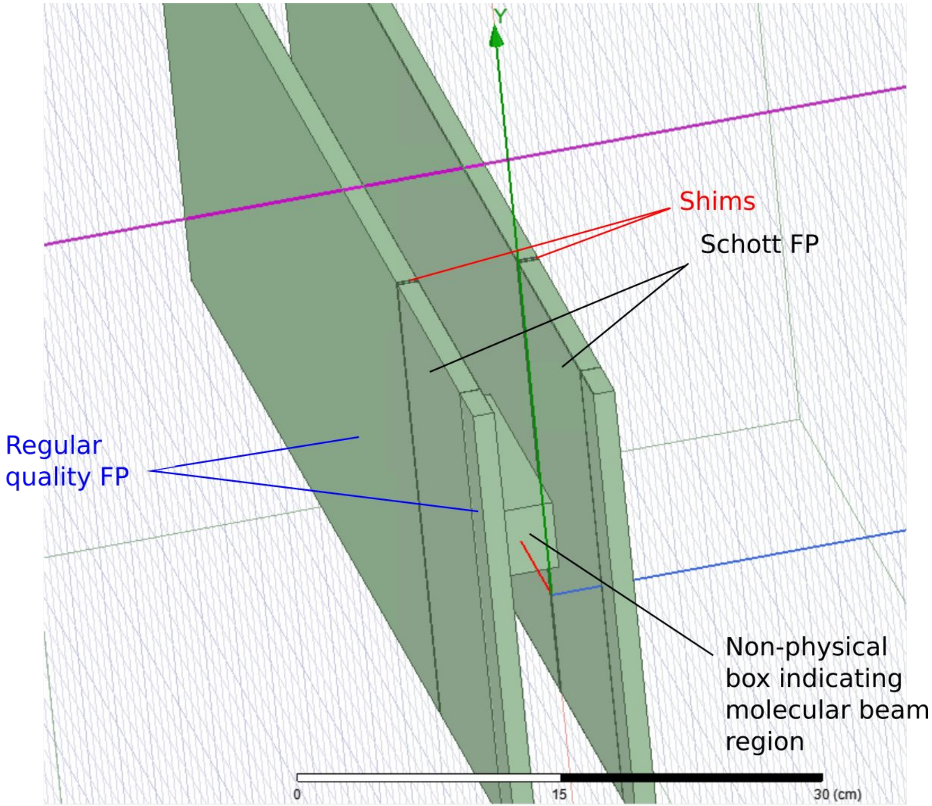
Experimental motivation

- We want to improve the quality of our field plates in ACME III in order to reduce systematics arising from polarization gradients caused by birefringence
- New FPs must be ~1 m long (length in ACME II was 43 cm)
- Schott SF57HTUltra has 200 times smaller stress birefringence, but can only be acquired in 16 x 28 cm pieces
- Plan 1: glue Schott piece to lower quality FPs, coat ITO on top
- **Plan 2: Use multiple rectangular FPs with shim electrodes to improve homogeneity (this presentation)**
- Target homogeneity (ACME II):
    - 15-20 mV/cm variation in applied E-field homogeneity (E^E)
    - 20 mV/cm E^nr gradient (East-West)

Setup of E-field simulations in ANSYS Maxwell

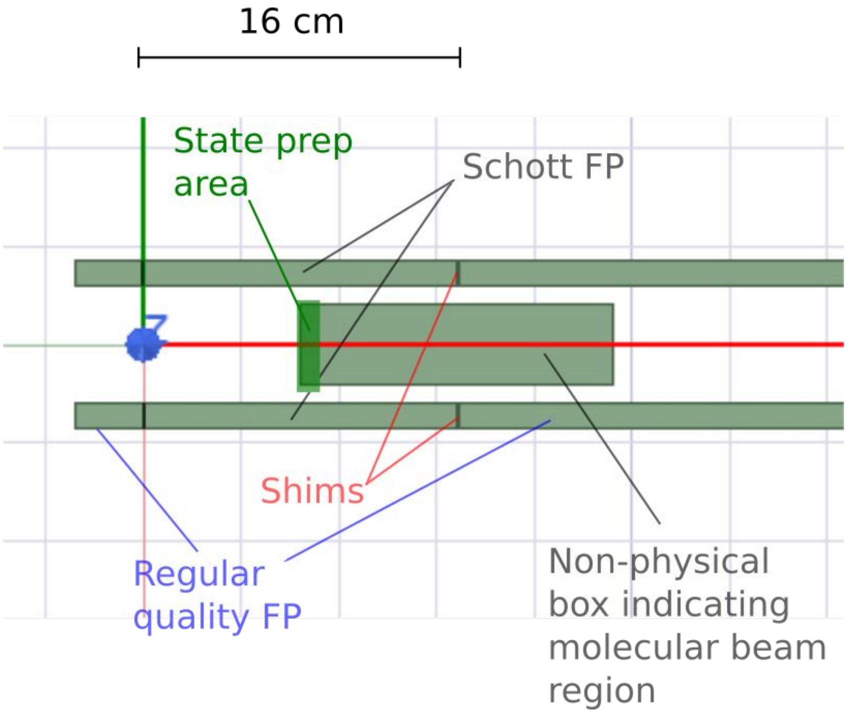
- FP-FP distance: 6 cm (E_z = 140 V/cm)
- Schott FP: 16 cm x 28 cm
- 0.5 mm chamfer



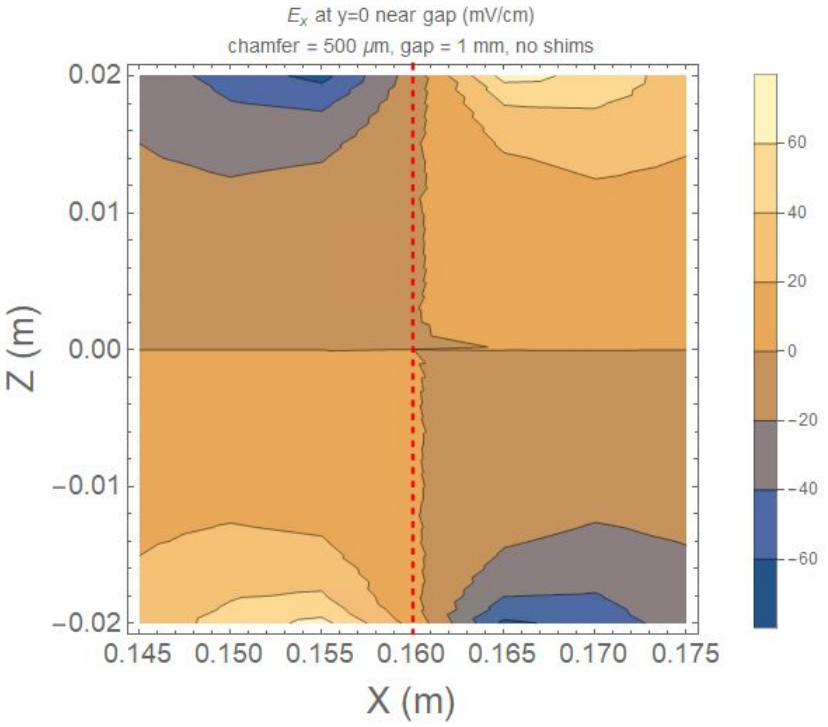


Setup of E-field simulations in ANSYS Maxwell

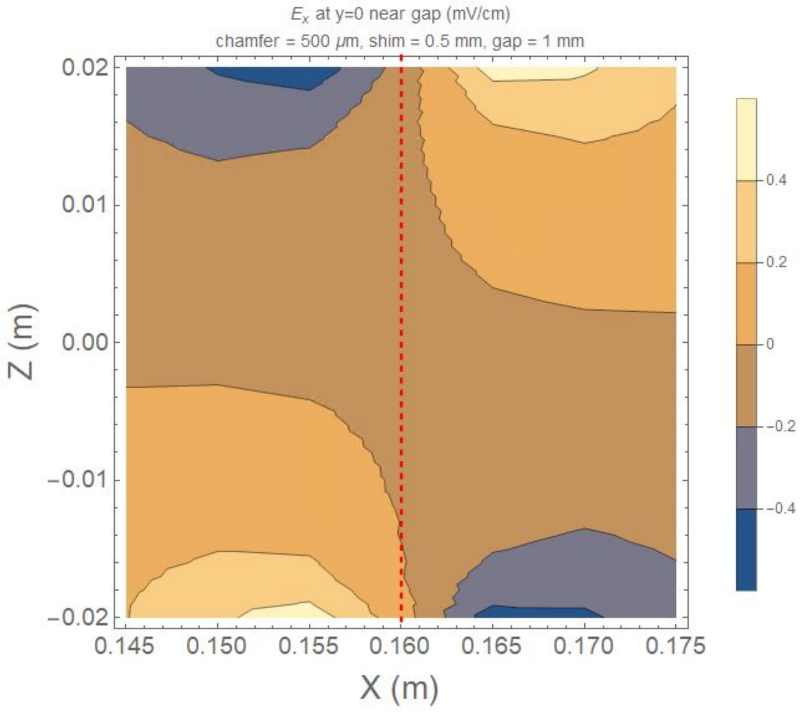
- Molecular beam size: sigma = 7 mm
  - Based on latest lens simulations
  - Recorded difference of max and min values of E_x and E_z within a 16 cm x 4.2 cm x 4.2 cm region (3 sigma)
- Ran simulation in both 3D and 2D (Y = 0)
- Accuracy: 0.1%



Sample field maps



1 mm gap, no shims



1 mm gap, 0.5 mm shim

Results

Gap size (mm)	Shim size (mm)	E_x spread (mV/cm)	E_z spread (mV/cm)
0.1	None	11	10
0.5	None	57	49
1	None	141	122
1	0.5	3.2	3.1
2	1.5	3.0	2.9
2	1	24	21
3	2.5	3.1	2.7
3	2	23	20

- Optimum shim voltage is at 420 V (same as other FPs)
- Unsurprisingly, **difference between gap size and shim size most important**
- **Able to reduce E-field inhomogeneity better than a small gap and below goal** (<15 mV/cm variation)
- 2D results also bear out this relationship, and match with 3D within a factor of 1.5-2
- Larger shim size is better for structural stability

Measuring the E-field

- Need precise method to measure E-field to be able to tune voltage of shim
- Microwave method:
  - Main method of E-field measurement in ACME II
  - Prepare molecules in H, J=1 state, knock them out to J=2 using microwaves. Efficiency of transfer depends on microwave detuning and E-field experienced. Read out remaining population in the probe region.
  - Suffers from spatial averaging (~1.6 cm) due to velocity dispersion, which will become worse in ACME III (~8 cm) because of the longer interaction region.
  - **Note that this increased spatial averaging will become an issue anyway for measurement of the E-field in ACME III**
  - Now investigating possibility of improvement by velocity selection.

Measuring the E-field

- Raman method:
  - Performed in ACME I by Paul Hess
  - Send a pair of laser beams at the region of interest to transfer molecules out of H, J=1, N=-1 to N=+1. Read out remaining population at probe region.
  - Can either send Raman beams through the FPs or between them from above.
  - Allows spatial precision (~1 mm in ACME I), but needs optical access at each region of interest.
  - Probably needed if we use shims.

Conclusion

- Simulations have shown it is theoretically possible to reduce the E-field inhomogeneity in the gaps between field plates below the goal homogeneity (<15 mV/cm) using specially designed shims.
- Need to think of way to construct, mount and align shims precisely
- Need to design vacuum chamber to allow optical access for Raman measurement of E-field to tune the voltage of the shims
- **Further research:** investigate velocity selection methods to improve quality of E-field measurements using microwaves, as well as for general velocity-dependent systematic checks