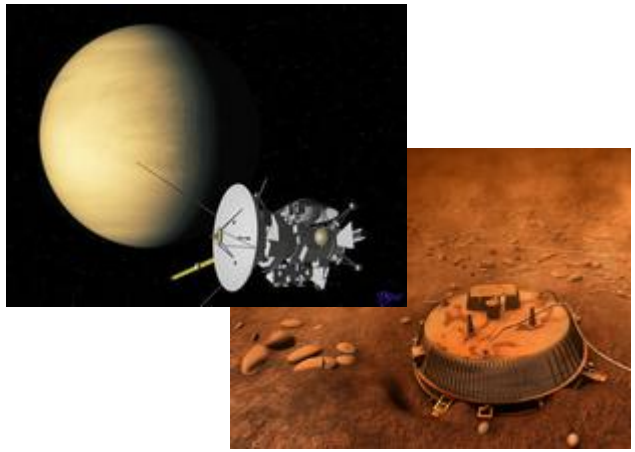
Department of Chemistry

# MEMS Assembled Ion Optical Devices: Current Technology and a Look at Advantages and Disadvantages

Guido F. Verbeck, IV

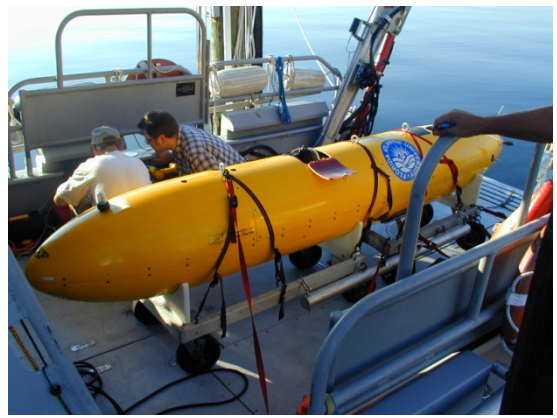
MMS
SERS
IR Imaging



http://saturn.jpl.nasa.gov

http://www.ornl.gov/sci/csd/Research_areas/ecms_rd_cbms.html

http://www.nasa.gov/missions/science/volcano.html



http://cot.marine.usf.edu/hems/underwater/pix/prep.htm

# Goals and Highlights

• The purpose of this project is to develop a mass spectrometer detector for the Micro Gas Analyzer. Ultimate goal is operation at 0.1 bar, or 76 Torr.

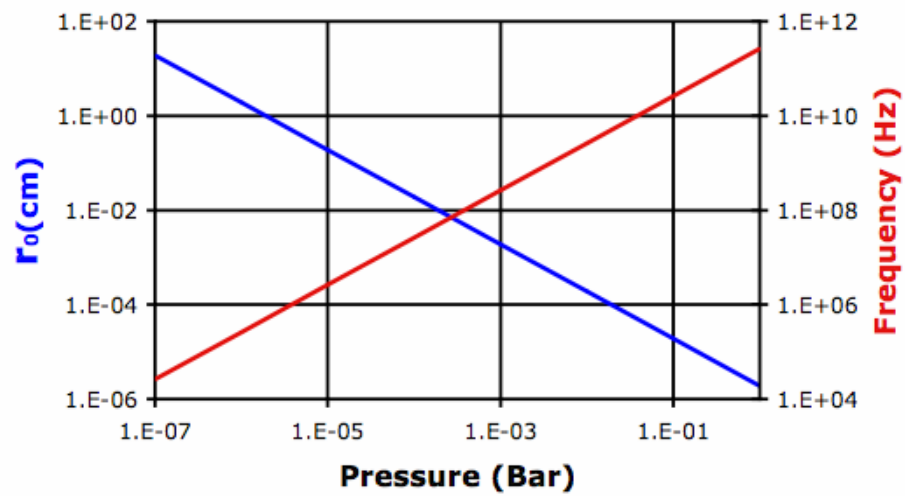
• Phase I critical milestone is operation at 1 Torr.

• Approach: use an array of microfabricated ion traps with dimensions smaller than a mean free path.

• Highlights:

  • Measurement of mass spectra at a pressure of ~ 1 Torr

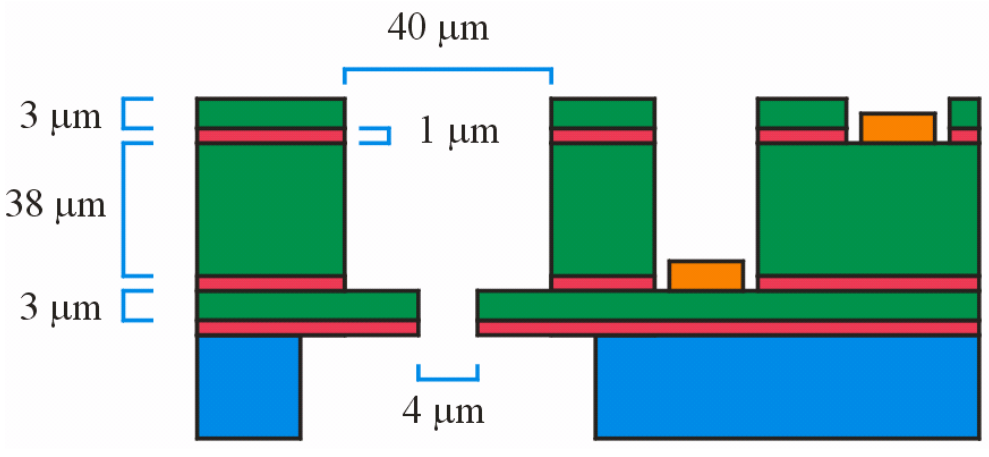
  • Observation of ion trapping in an array of microfabricated 40-μm ion traps

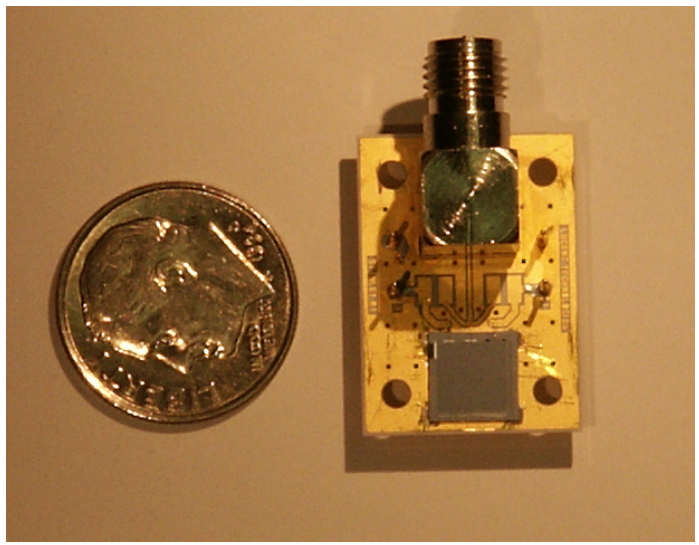


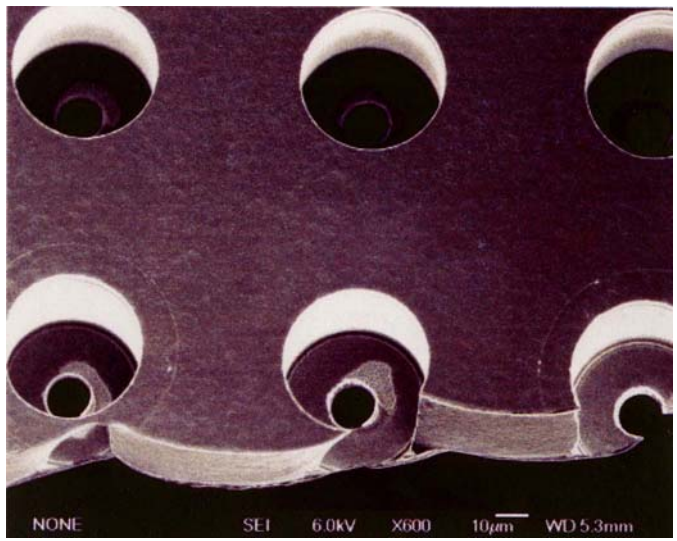

Trap radius and frequency vs pressure

- **The first generation of 40-μm polysilicon ion traps fabricated by Bell Labs**

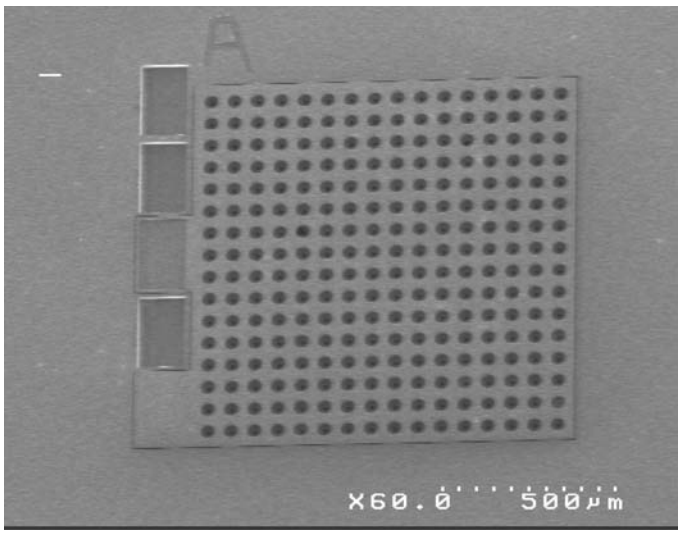
- **Rejects are being used in ionizer experiments**



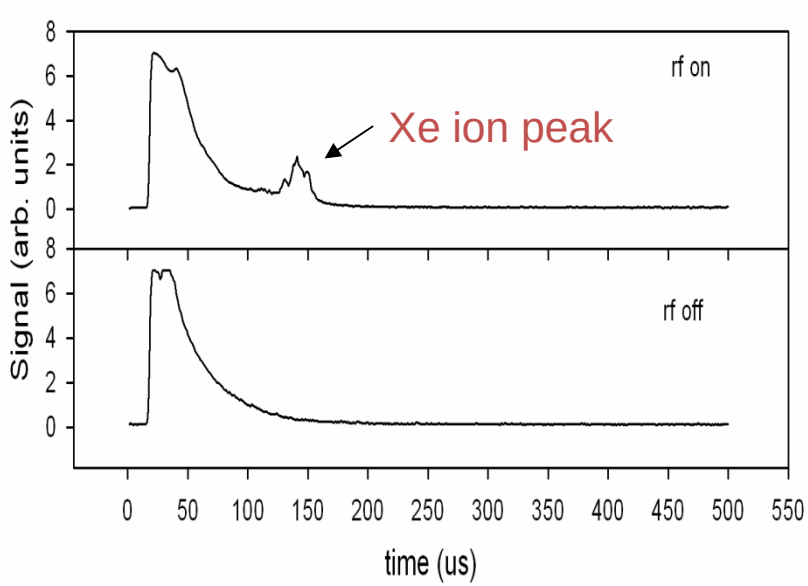





**A second generation array of 40-micrometer traps has fewer traps, lower capacitance. We can now detect trapped xenon ions at low pressure.**

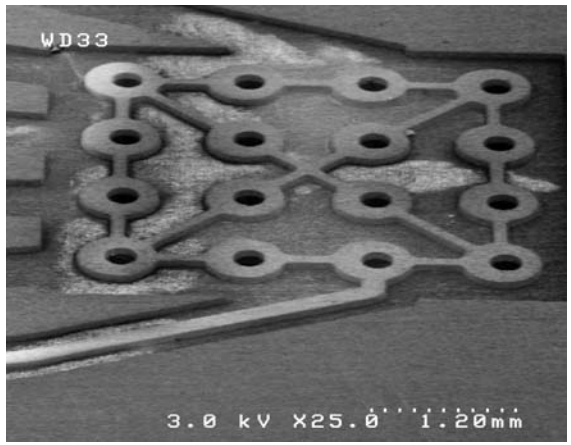



SEM image of low-capacitance array fabricated by Bell Labs

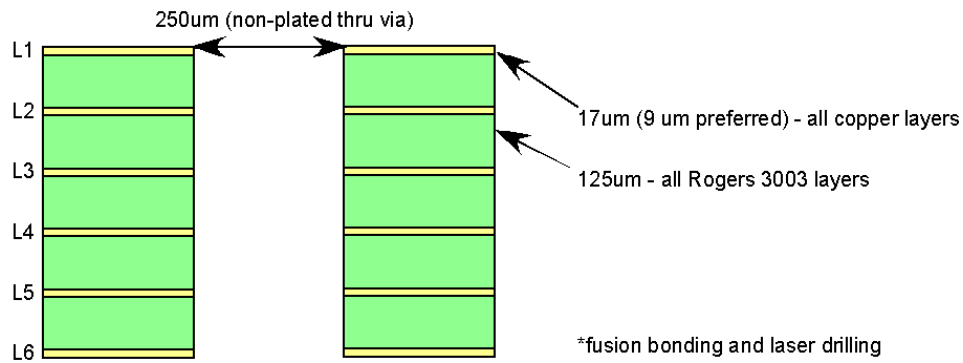



Ion signal (xenon) obtained with array at left at low helium pressure ($10^{-4}$ Torr)

**Bell Labs has fabricated a series of arrays of 250-μm diameter ion traps from micro circuit-board material. These arrays will be tested in both the ion drift experiment and the electron ionization experiment. They can be wired up as pairs of individual ion traps in series.**




SEM image of circuit-board array of 16 ion traps




Cross-section view of each non-plated thru-via

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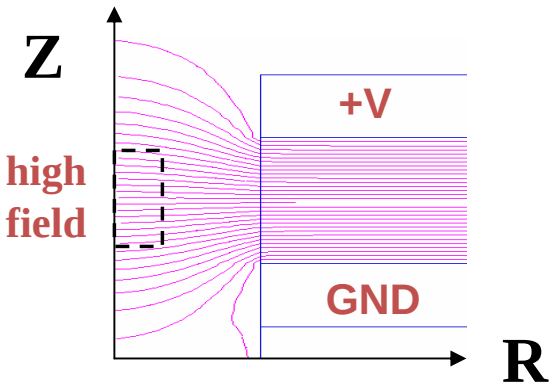
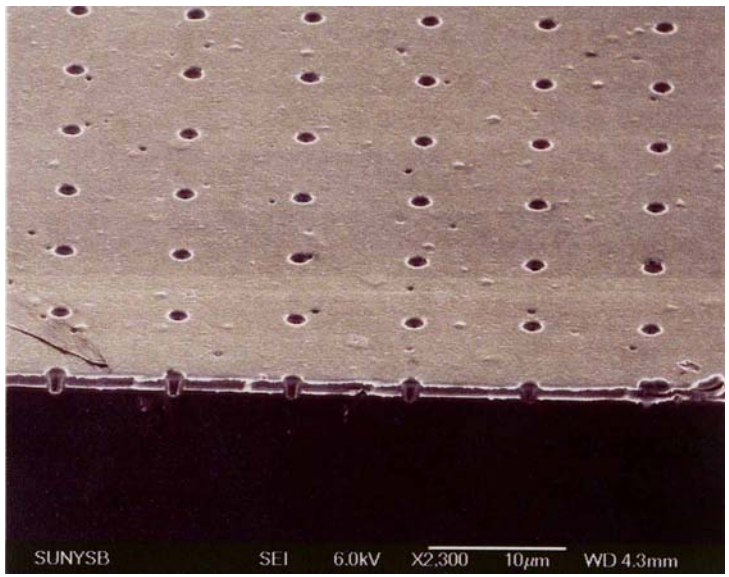
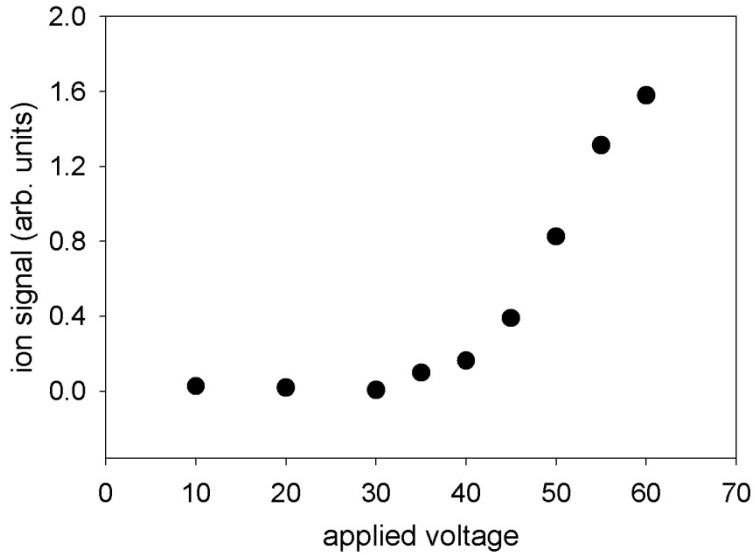
# Electric Field Ionization




0.8 and 0.3-μm microfabricated devices from Bell Labs are being tested at low pressure. We have observed ions being formed when a voltage is applied between the two electrodes.




Soft ionization array, before cavity etch




Ion generation from 0.3 μm membrane

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# SOI Process Overview

Sputtered sidewall metal

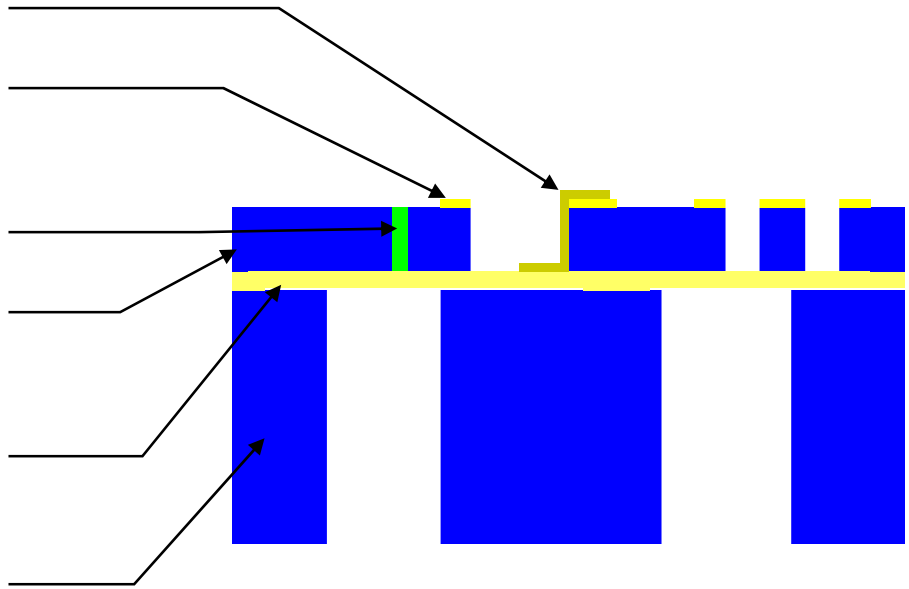
Top metal

Trench isolation

Device layer ~ 50 microns thick

Buried oxide layer ~ 2 microns thick

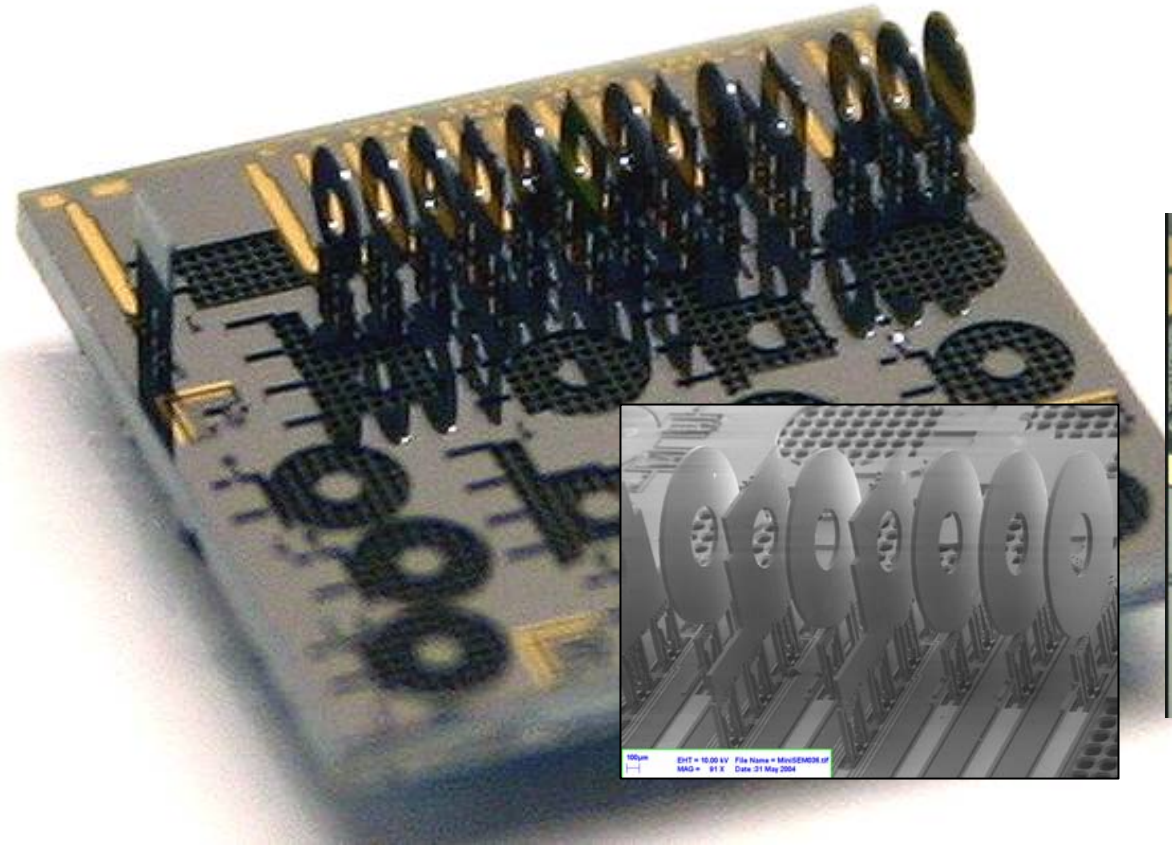
Silicon handle wafer ~ 550 microns thick



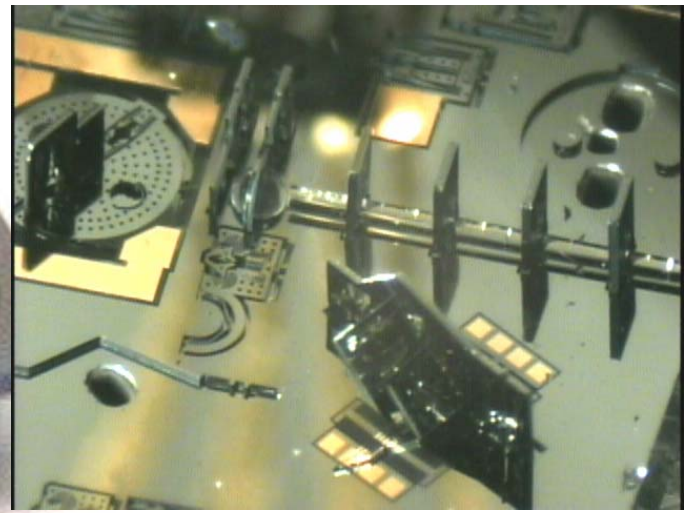
Cross section of completed wafer

zyvex®

# New Doped Silicon Micro-Electro-Mechanical System (MEMS) Methods



MEMS Microcolumn for SEM



MEMS Spectrometer

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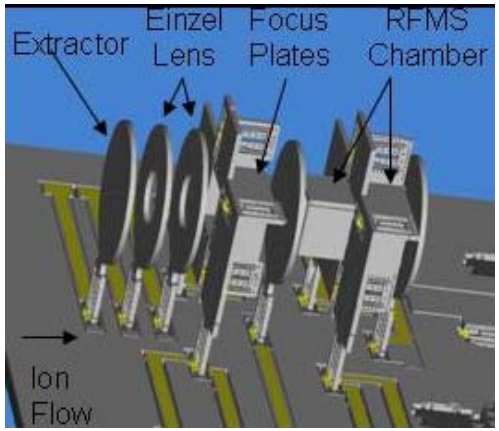
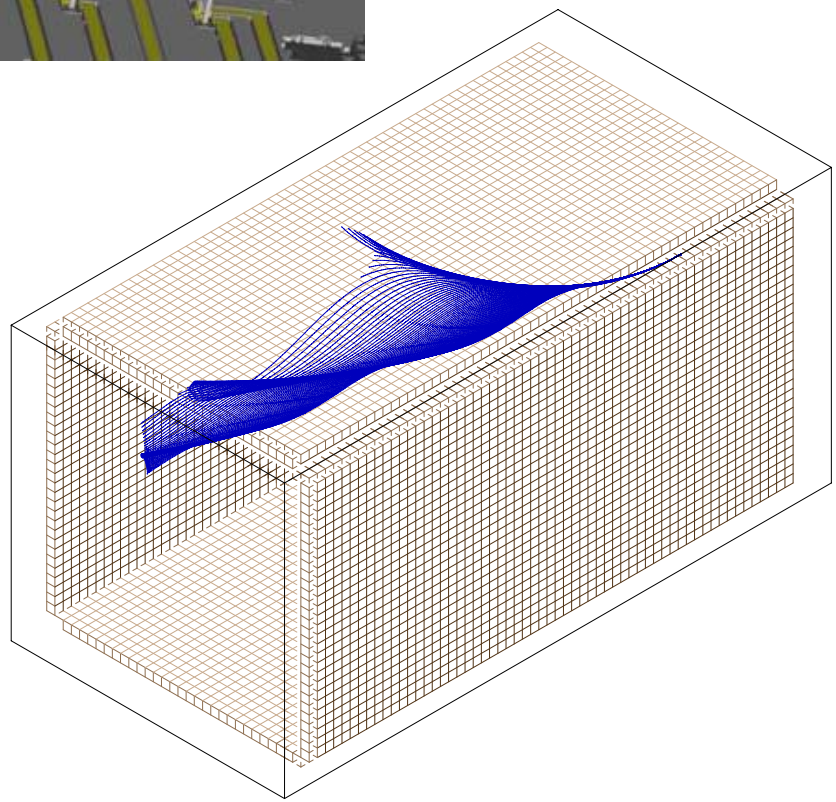
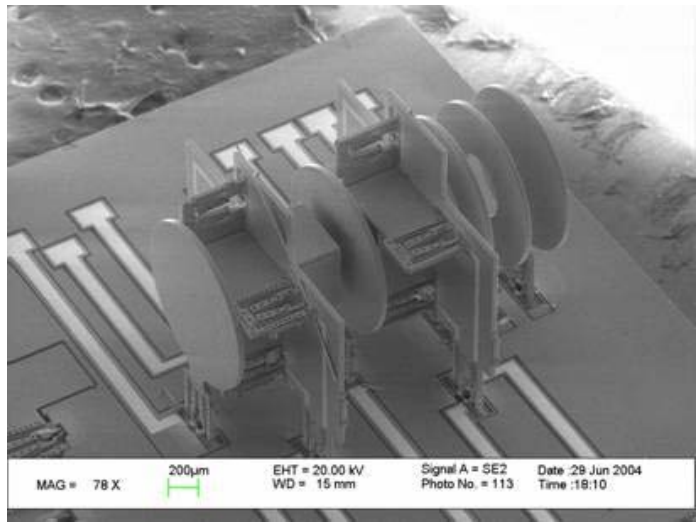



# Rotating Field MS



SimIon 7.0 Simulation: 1mmx1mmx2mm,
15V at 6MHz.




Benefit: 1. 0-300amu
2. Low Voltage Requirement

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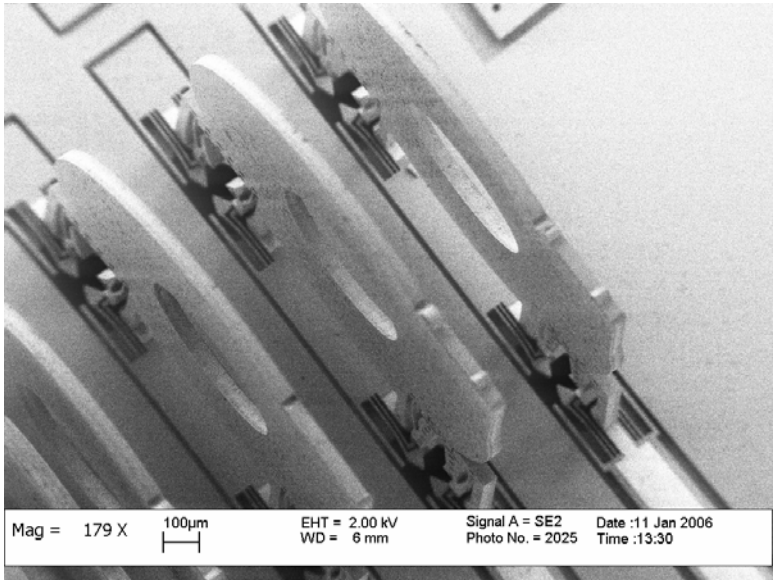
# Einzel Lens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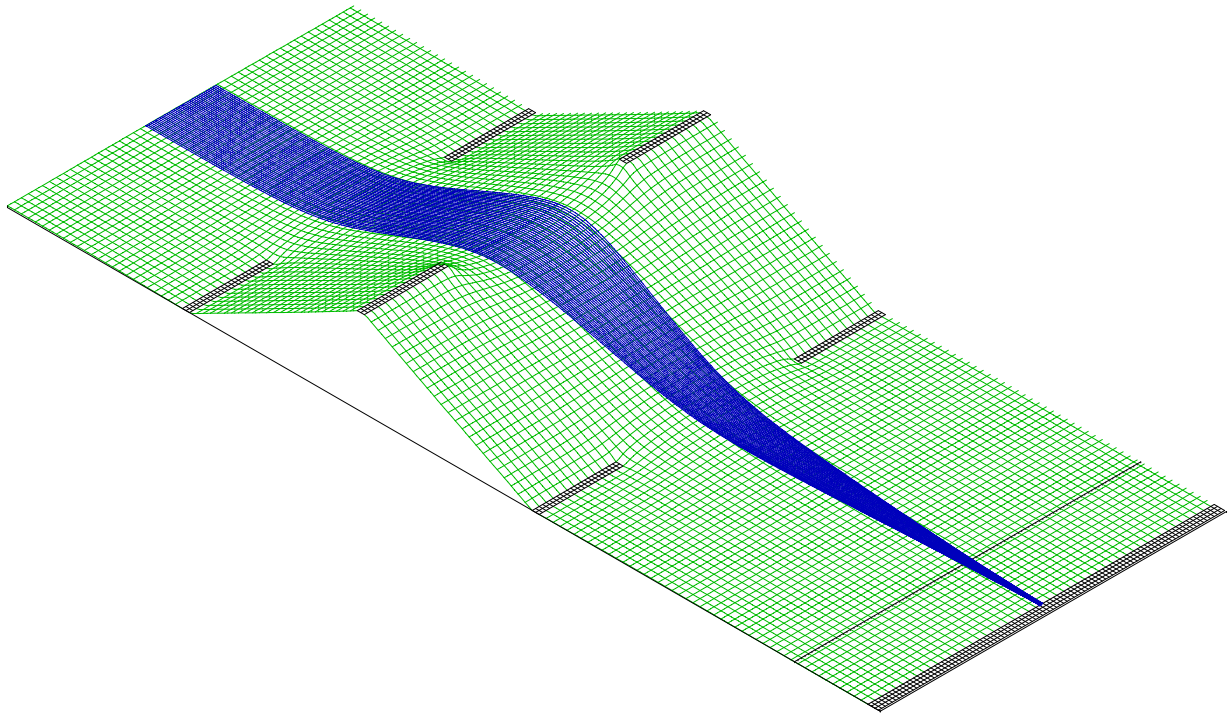
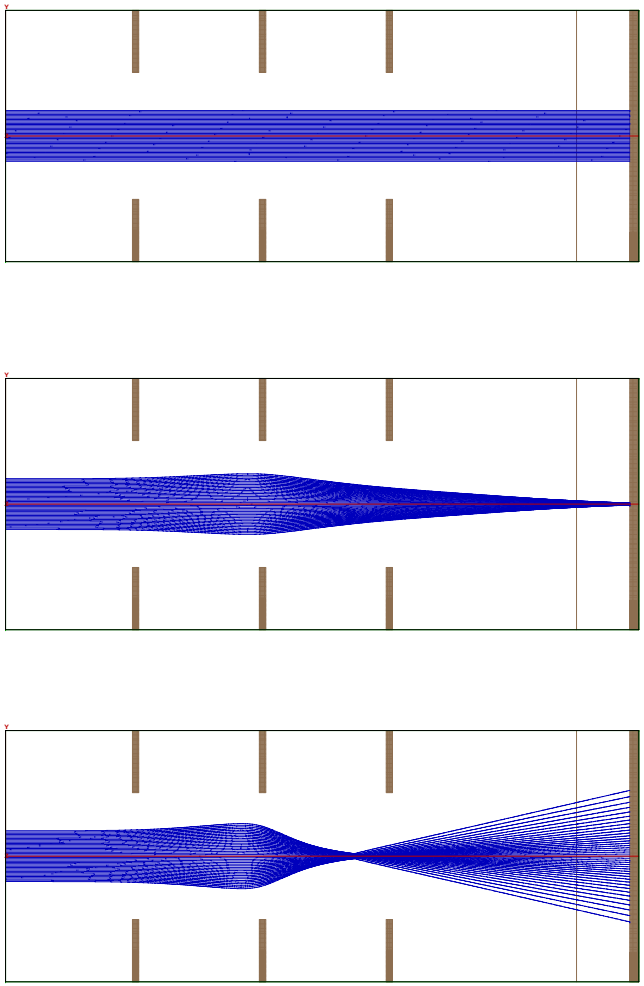
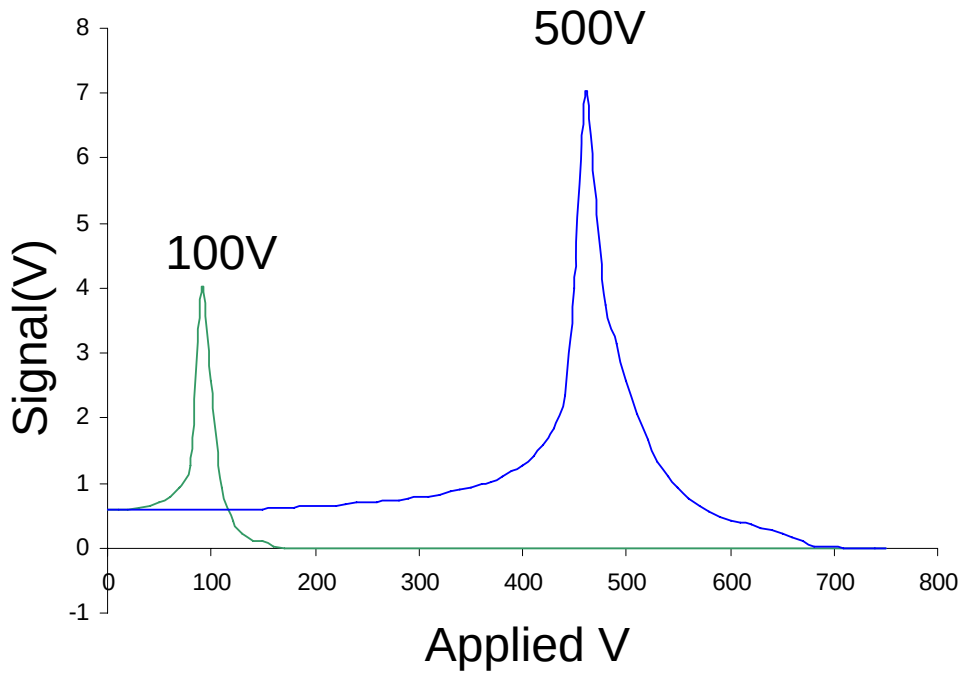
100µm
EHT = 2.00 kV
WD = 6 mm
Signal A = SE2
Photo No. = 2025
Date :11 Jan 2006
Time :13:30



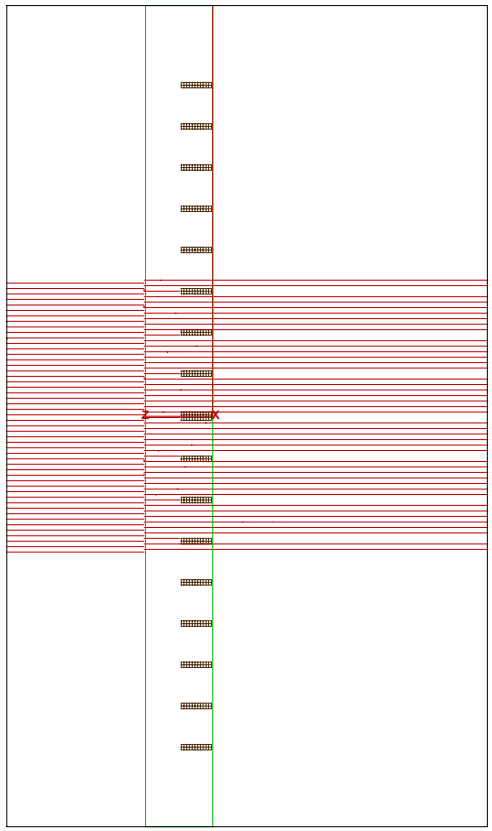
# Einzel Lens



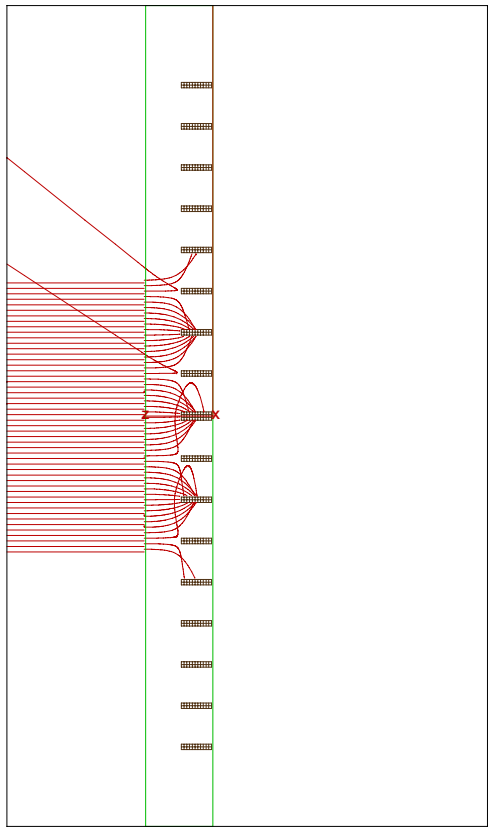

500V
100V
Signal(V)
Applied V
8
7
6
5
4
3
2
1
0
-1
0
100
200
300
400
500
600
700
800

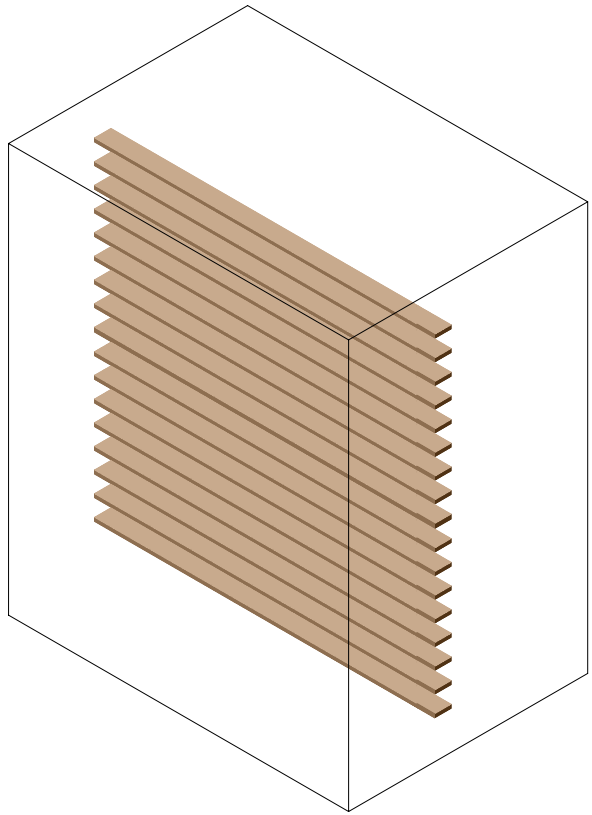
# Bradbury-Nielsen Gate

60V, 60V Gate



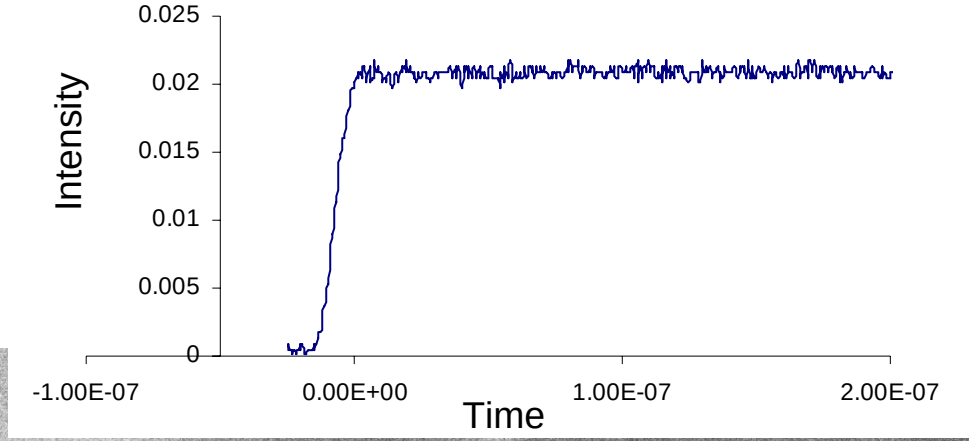
60V, 30V Gate

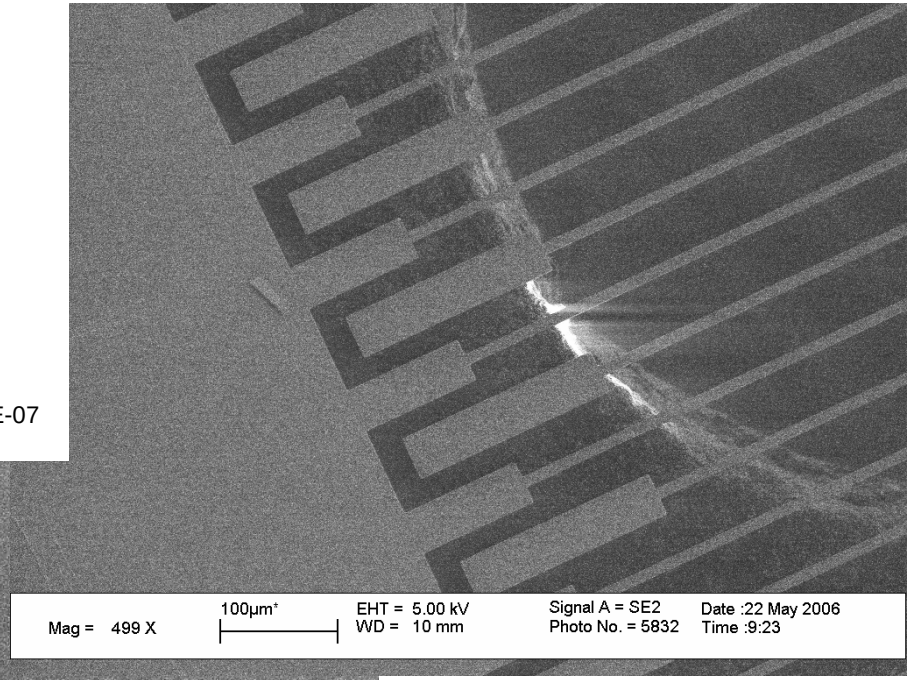


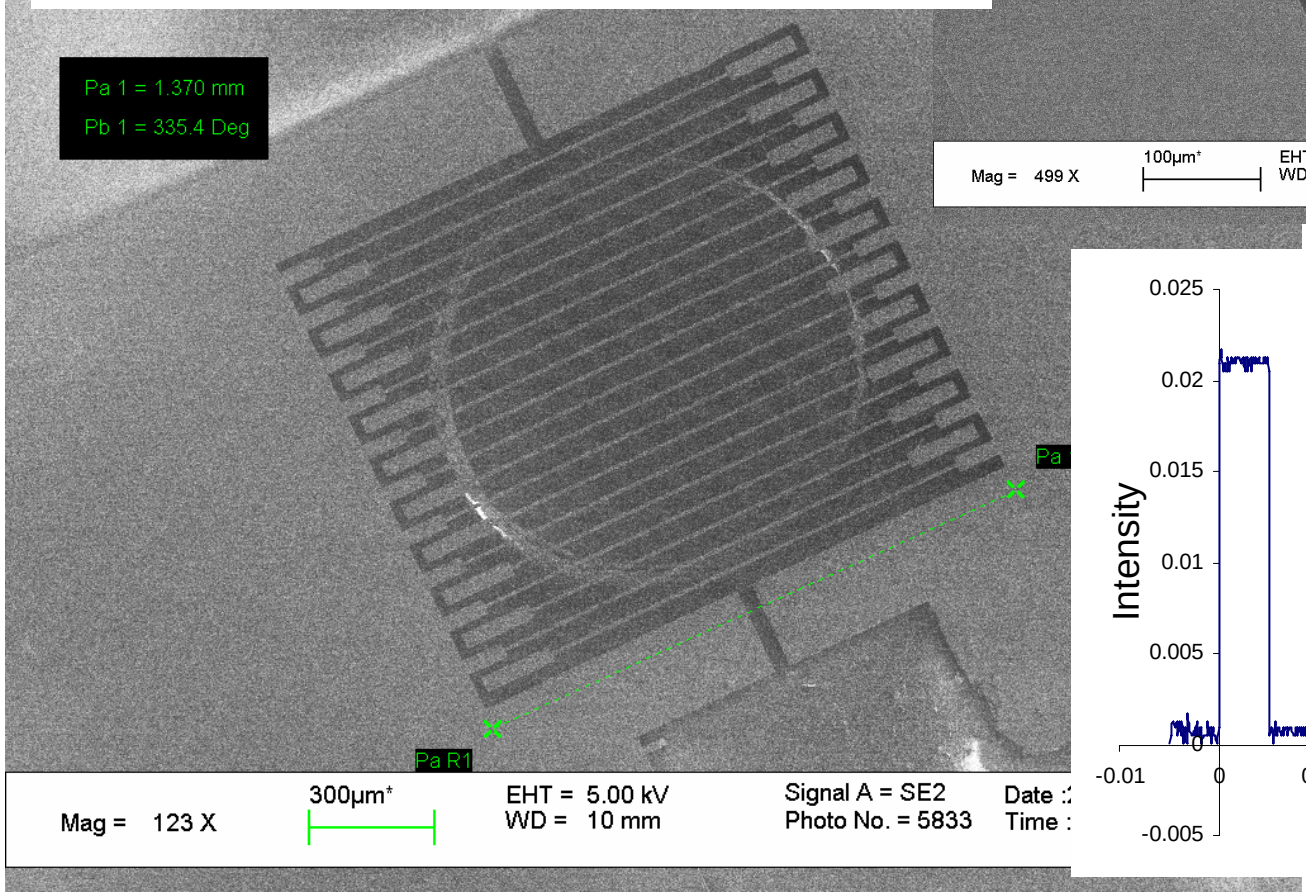


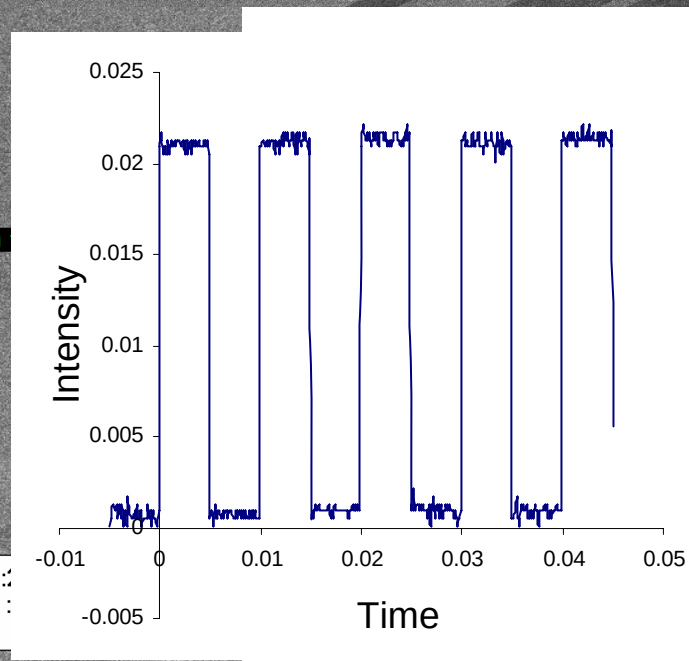
SimIon 7.0 Simulation: 10um thick, 50um space

Benefits: 1. No assembly
2. Low Voltage Requirements

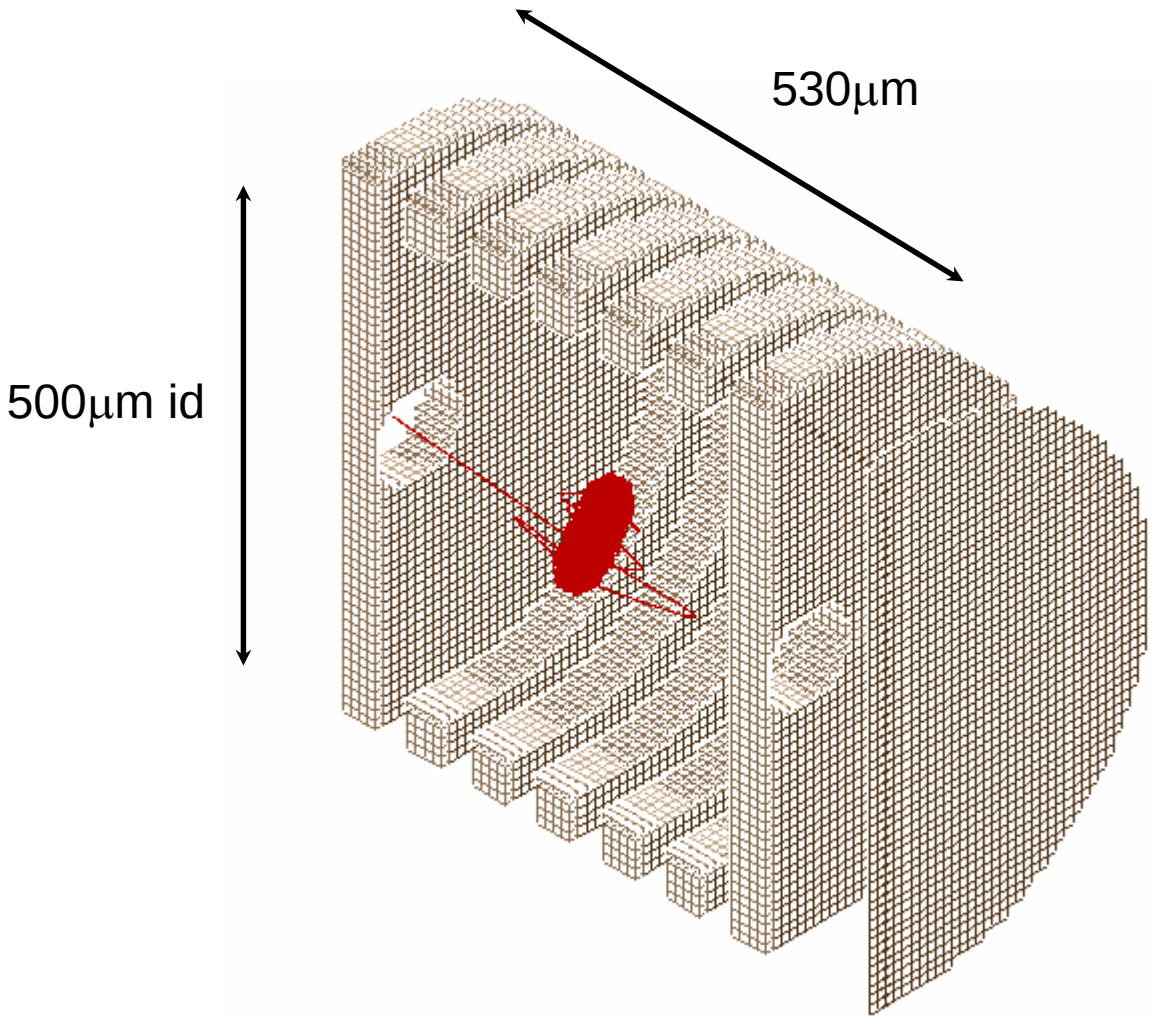

Intensity
0.025
0.02
0.015
0.01
0.005
0
-1.00E-07
0.00E+00
1.00E-07
2.00E-07
Time


Mag = 499 X
100µm*
EHT = 5.00 kV
WD = 10 mm
Signal A = SE2
Photo No. = 5832
Date :22 May 2006
Time :9:23


Pa 1 = 1.370 mm
Pb 1 = 335.4 Deg
Pa
Pa R1
Mag = 123 X
300µm*
EHT = 5.00 kV
WD = 10 mm
Signal A = SE2
Photo No. = 5833

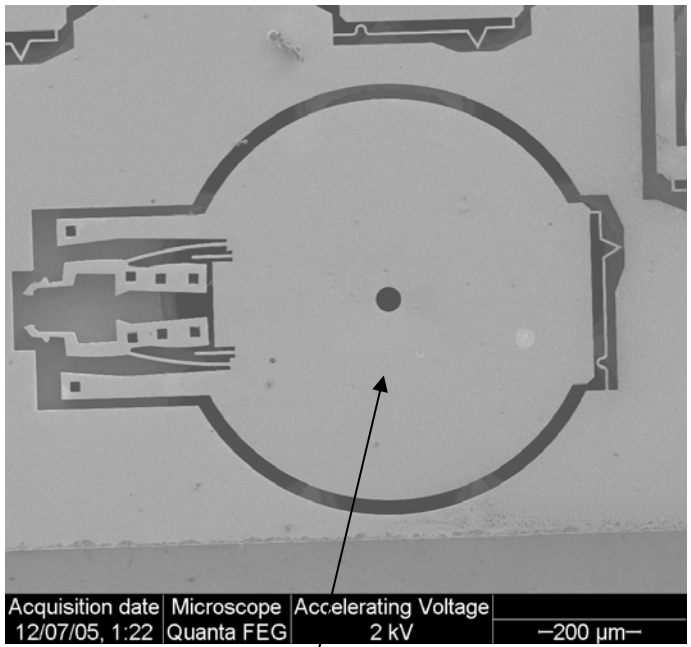

Intensity
0.025
0.02
0.015
0.01
0.005
0
-0.005
-0.01
0
0.01
0.02
0.03
0.04
0.05
Time

# Coaxial Ring Ion Trap (CRITter)

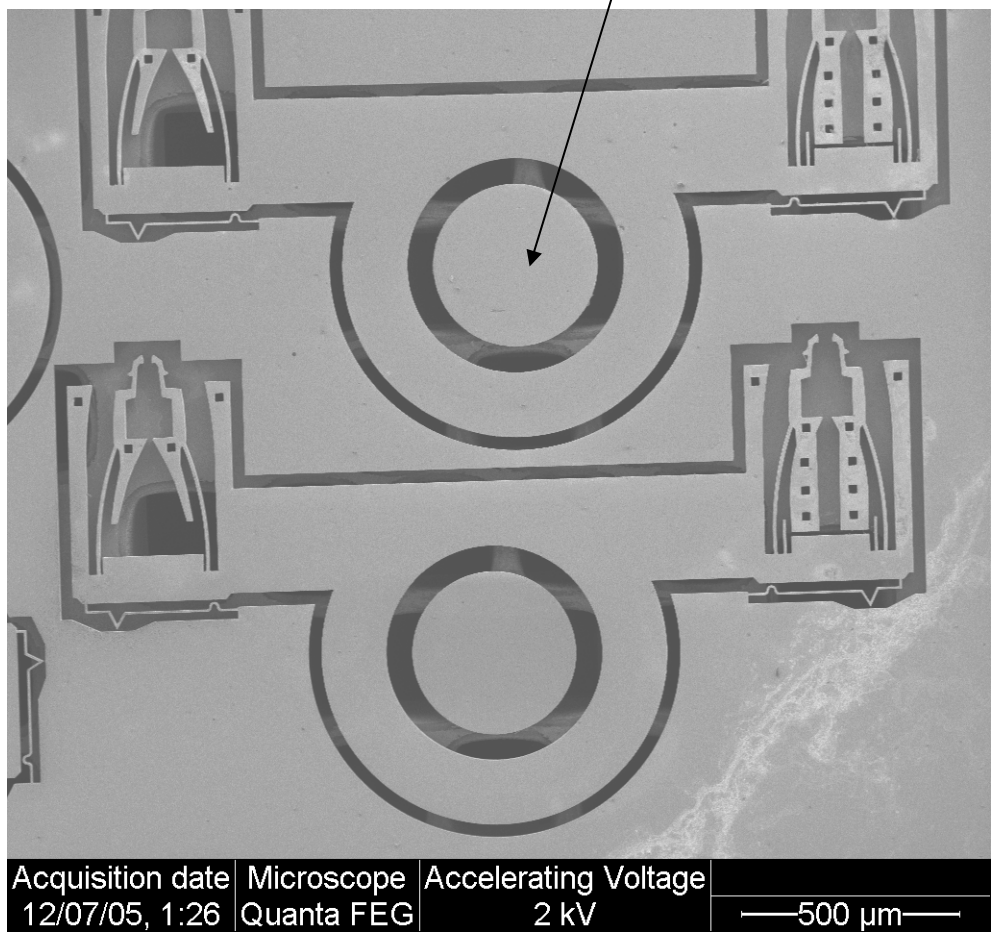


# Coaxial Ring Ion Trap (CRITter)

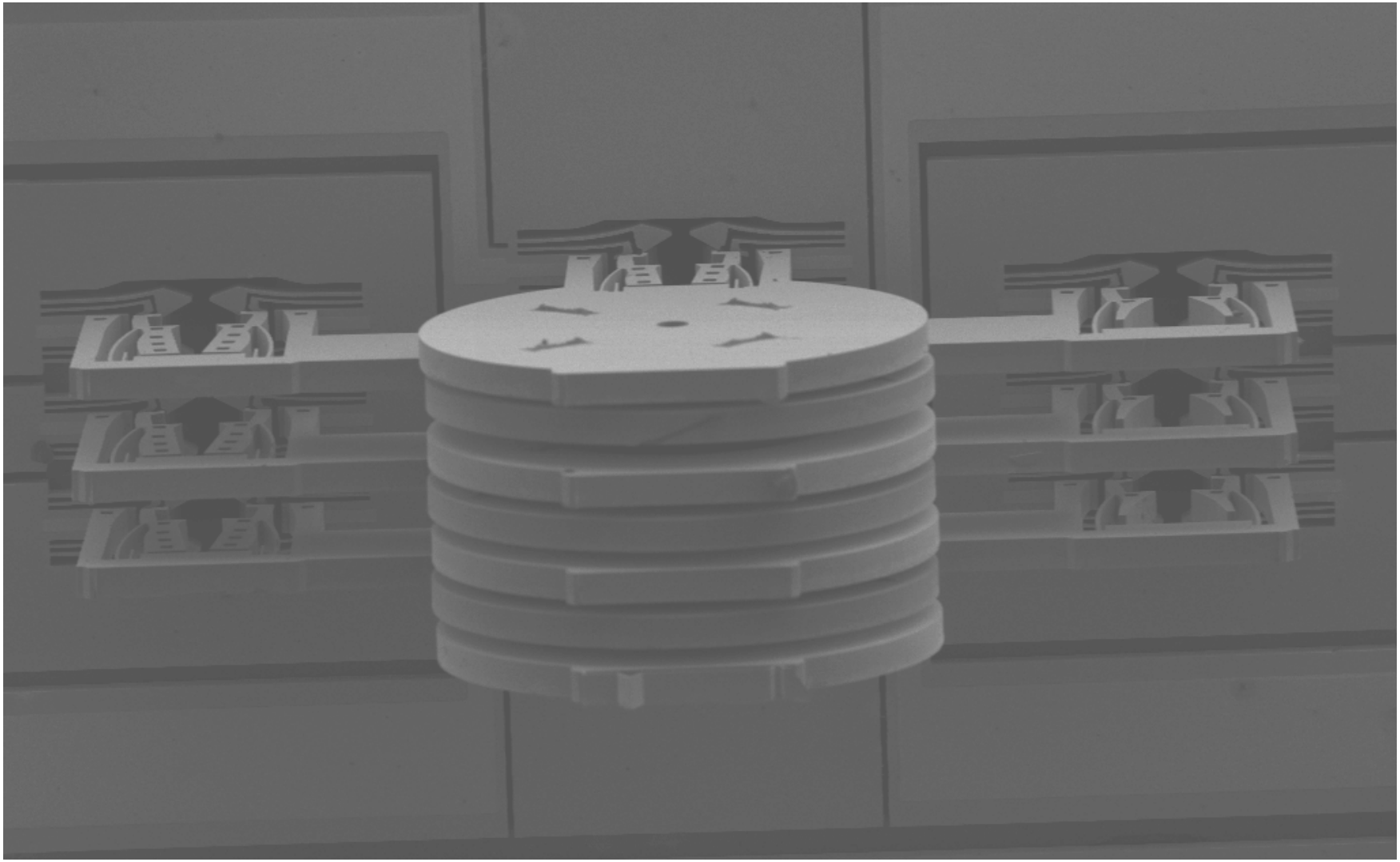
500um Trap Lens



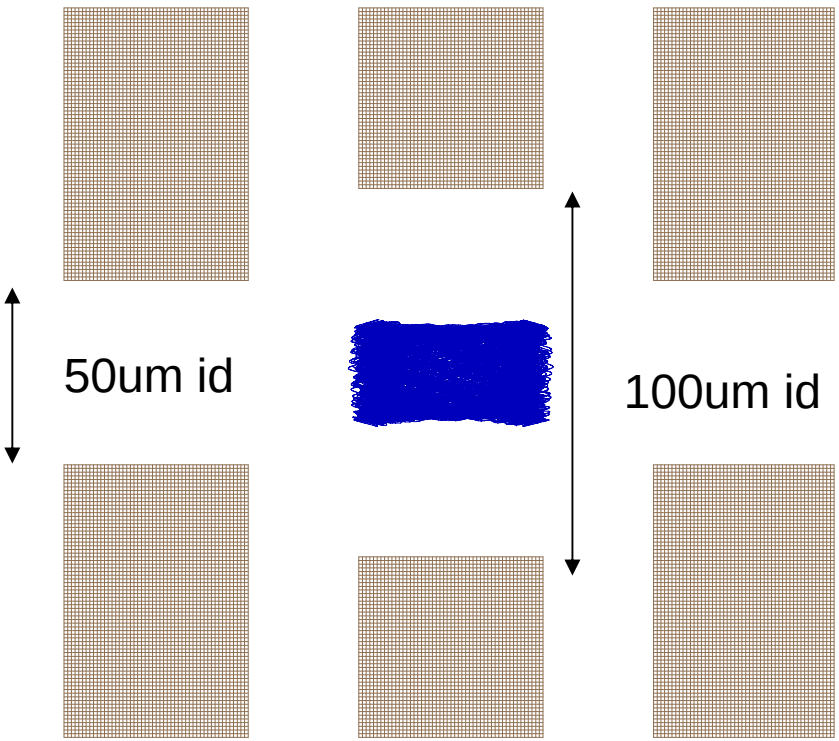

Endcap 75um

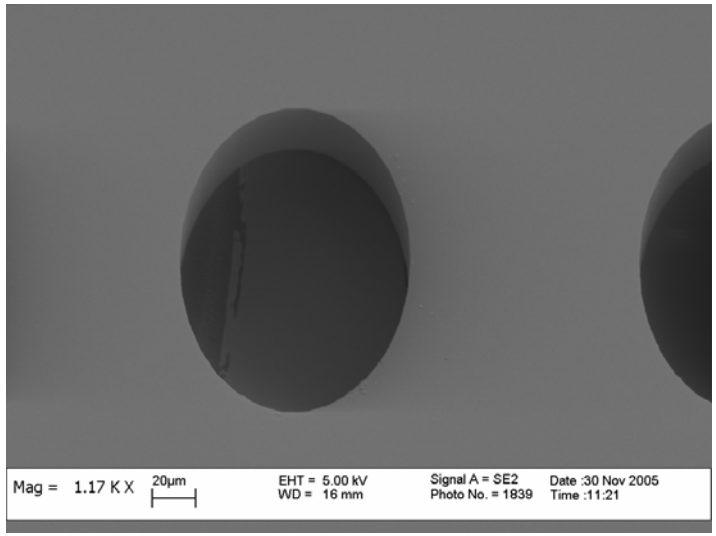


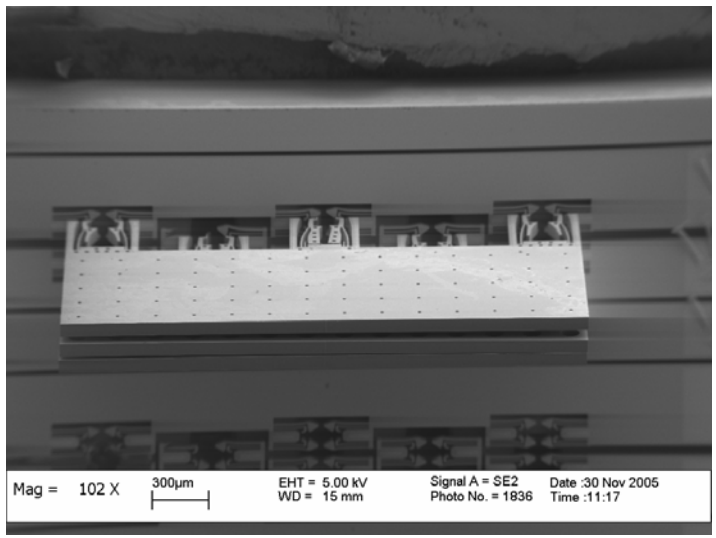
# Coaxial Ring Ion Trap (CRITter)



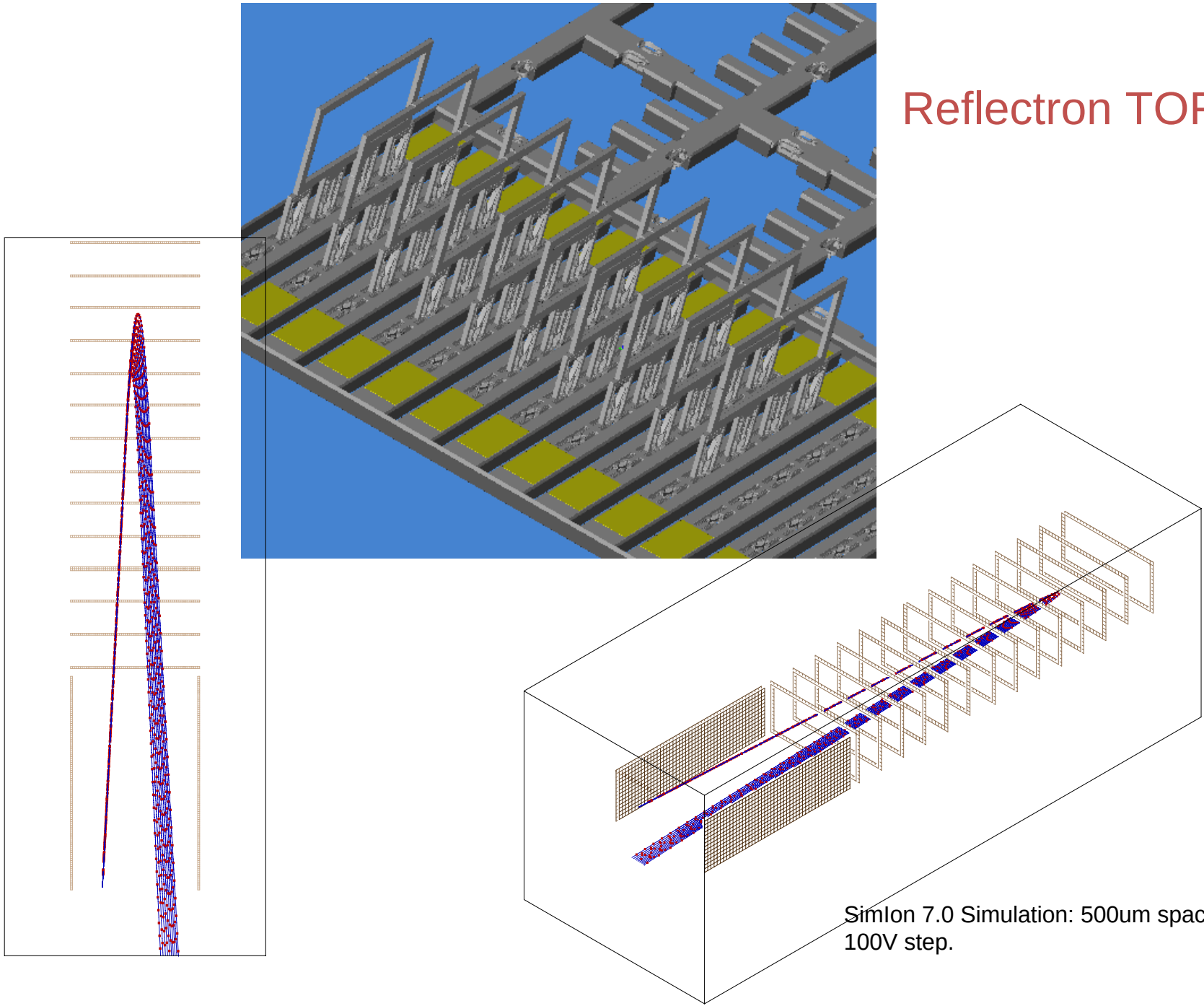
# 100um CIT Array



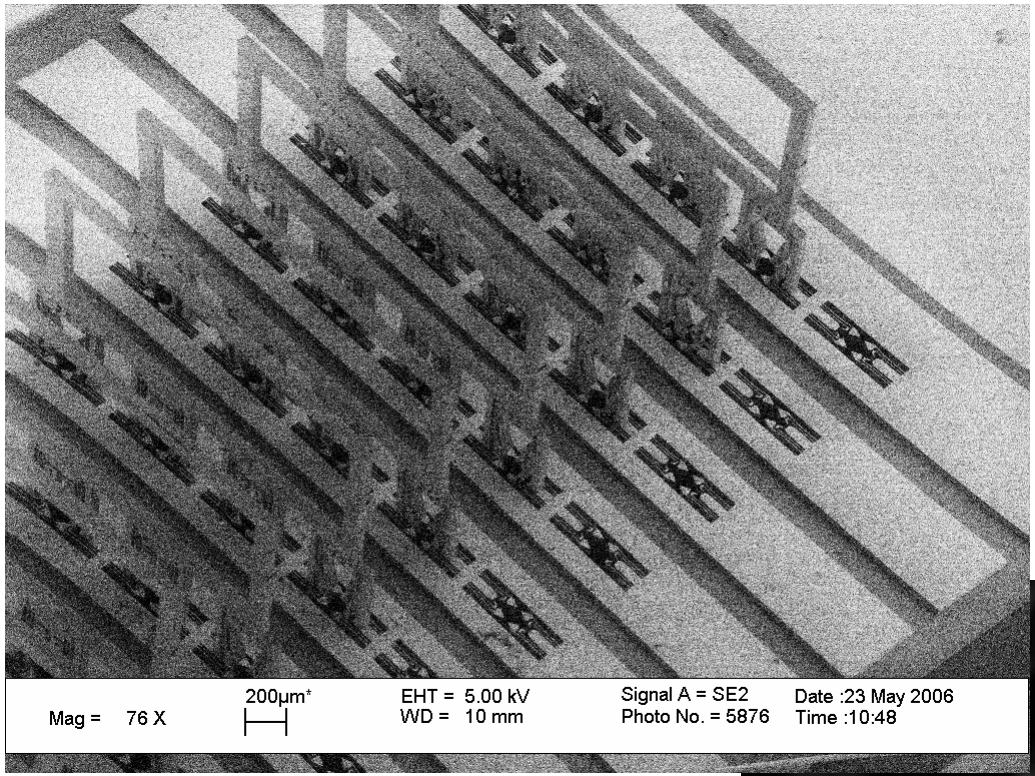



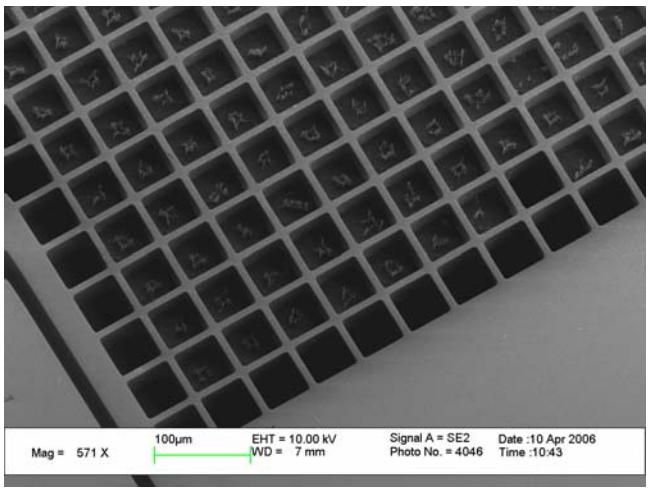
# Reflectron TOF

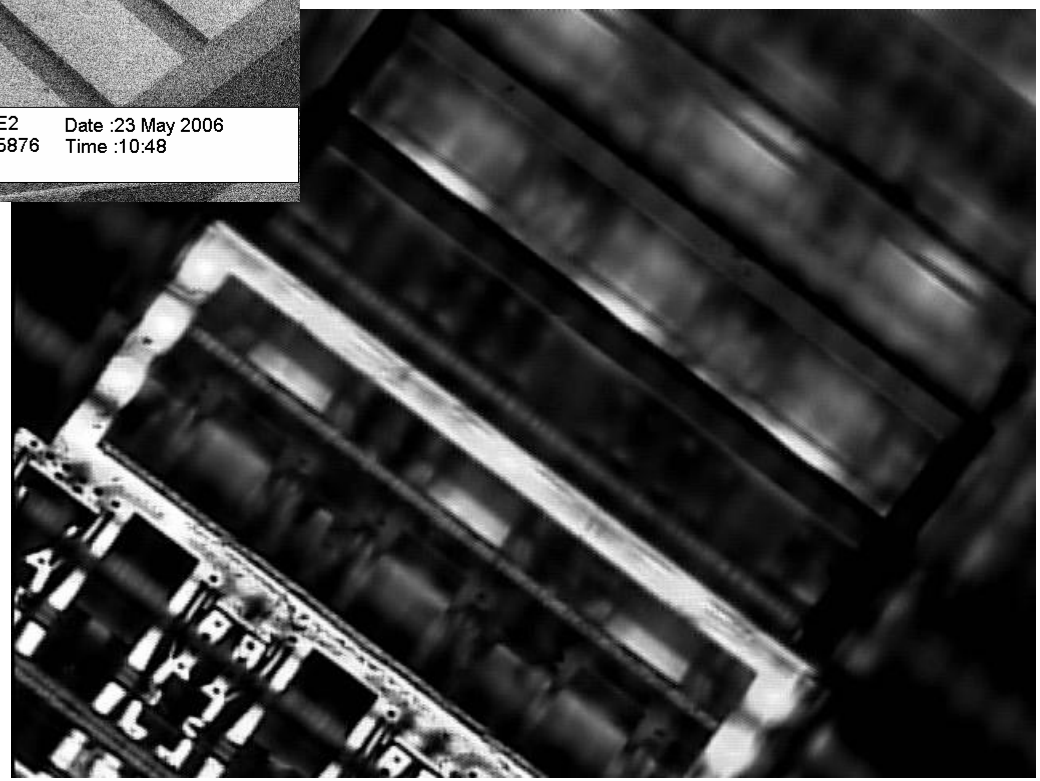


SimIon 7.0 Simulation: 500um spacing, 100V step.

# Reflectron TOF

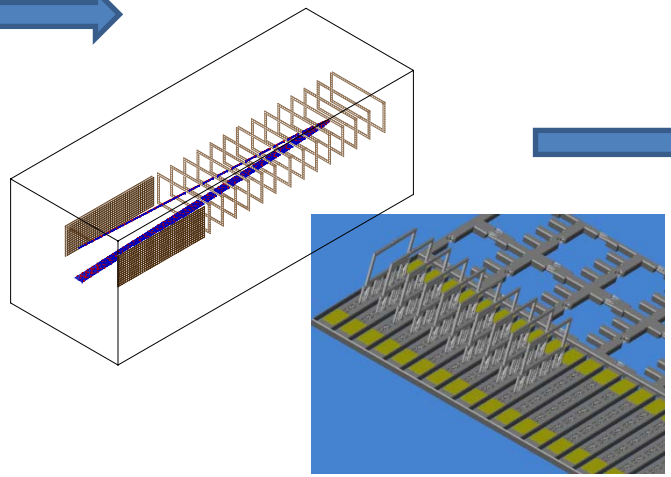


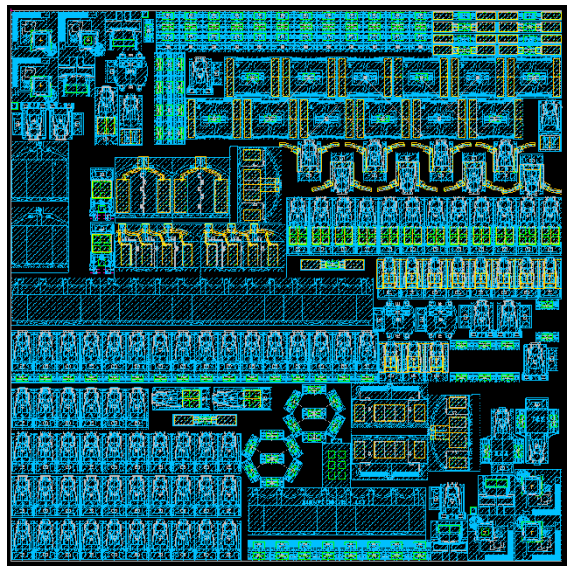



Idea

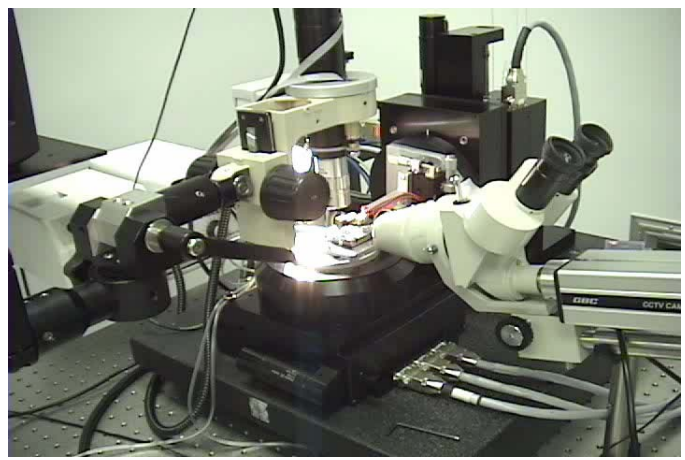
Design



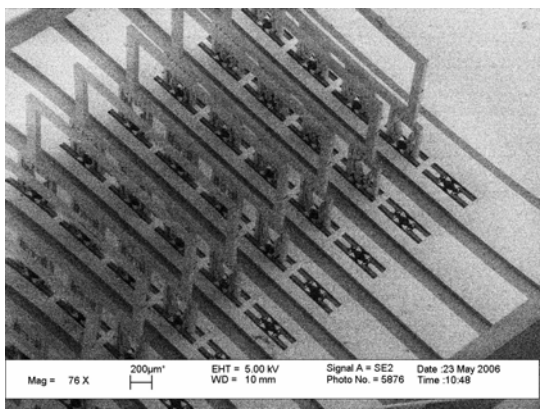
Layout Process



Assembly

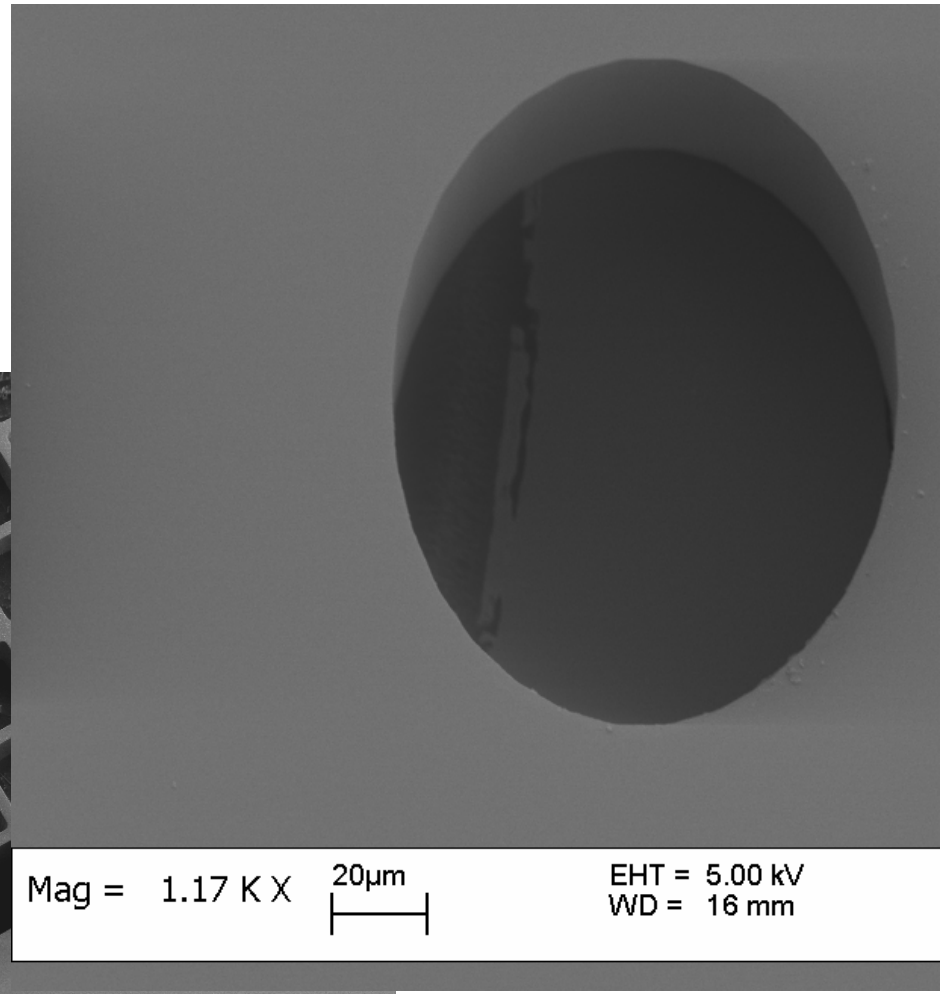


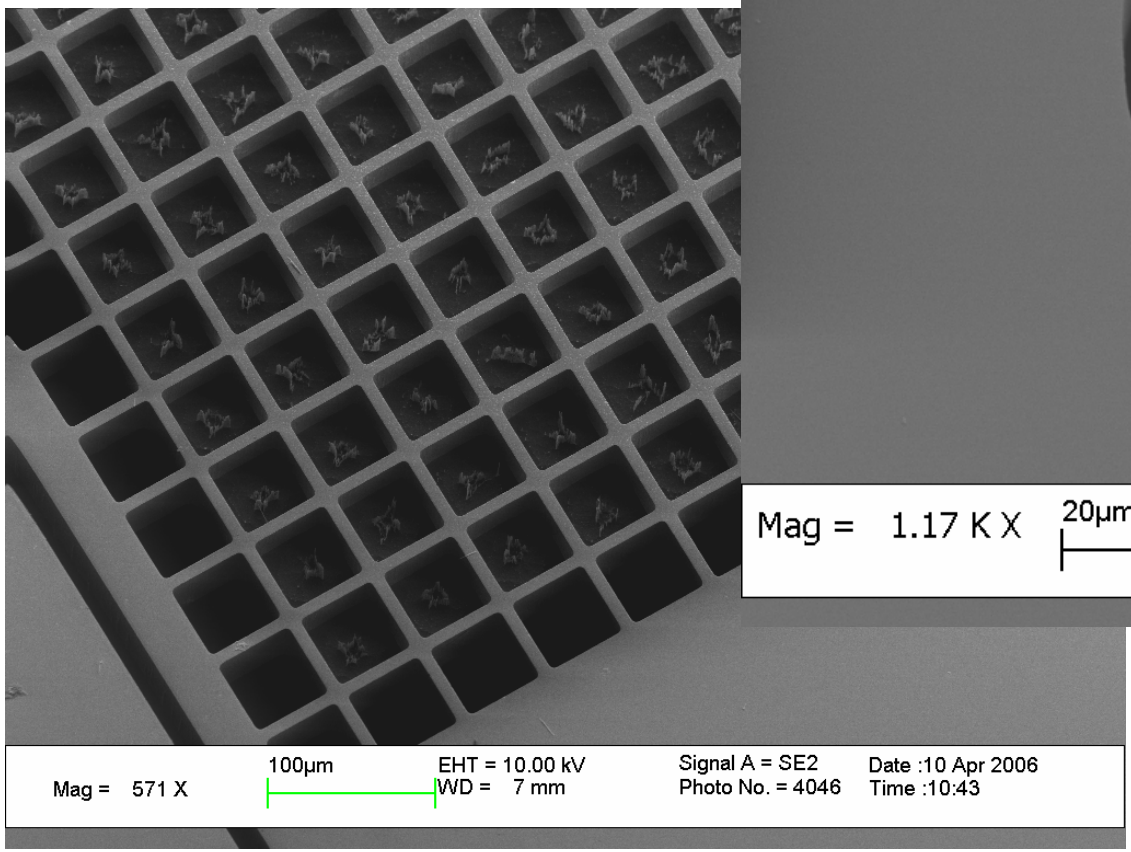
Test



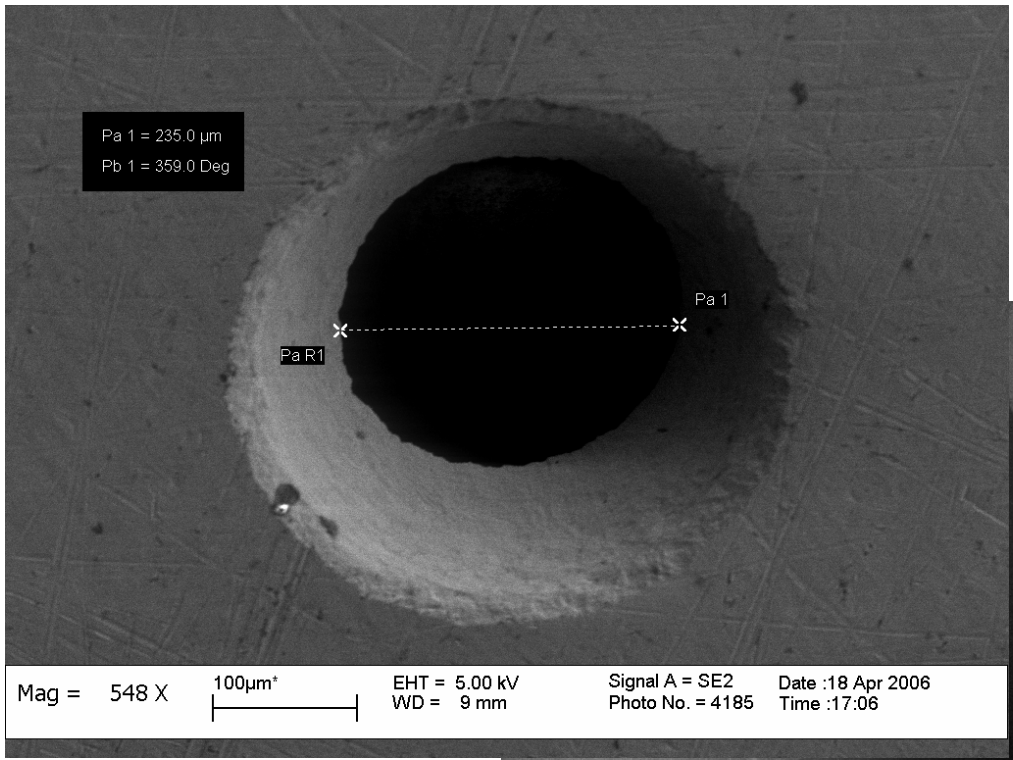
SOI Process

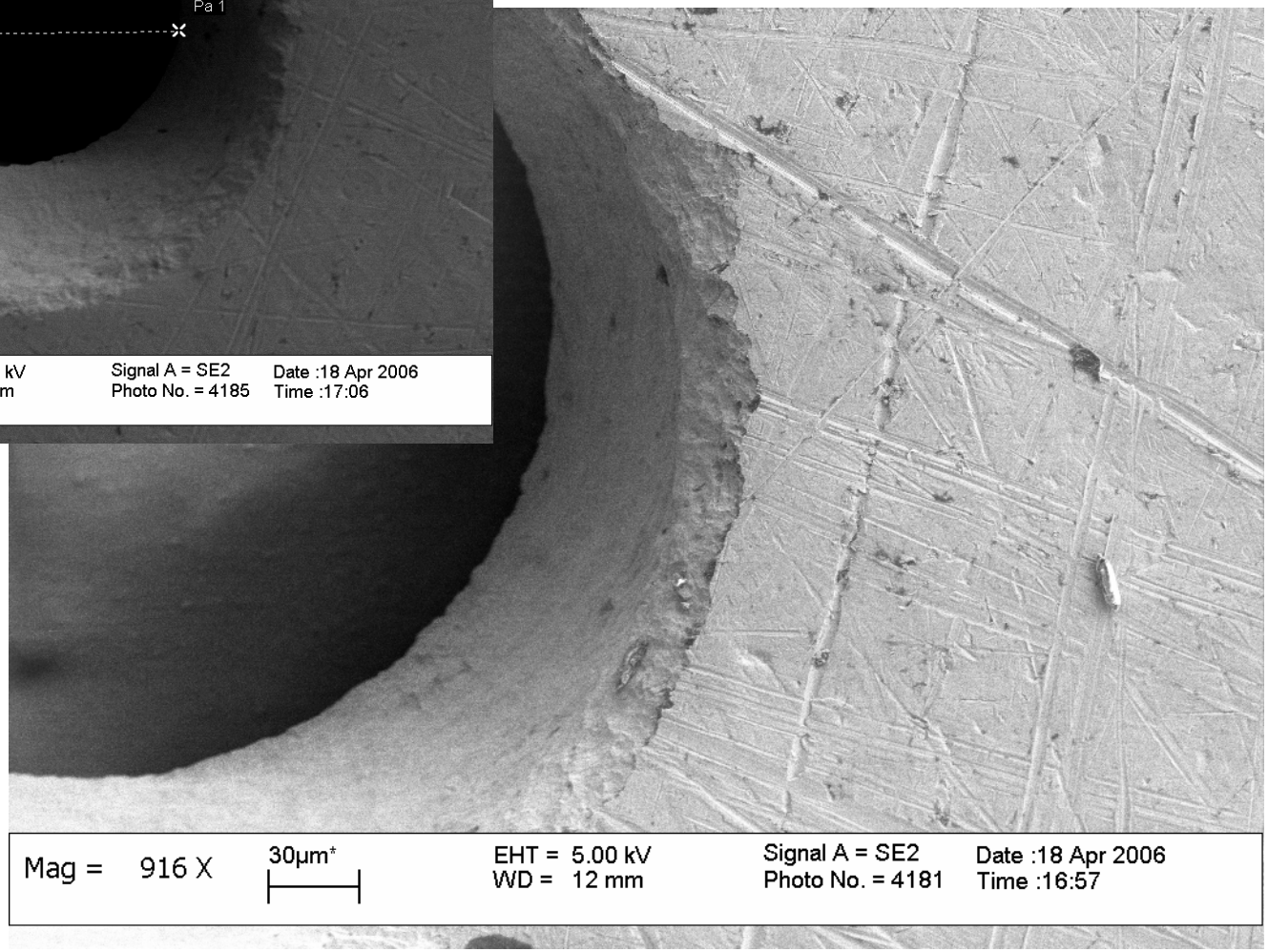
Why MEMS?



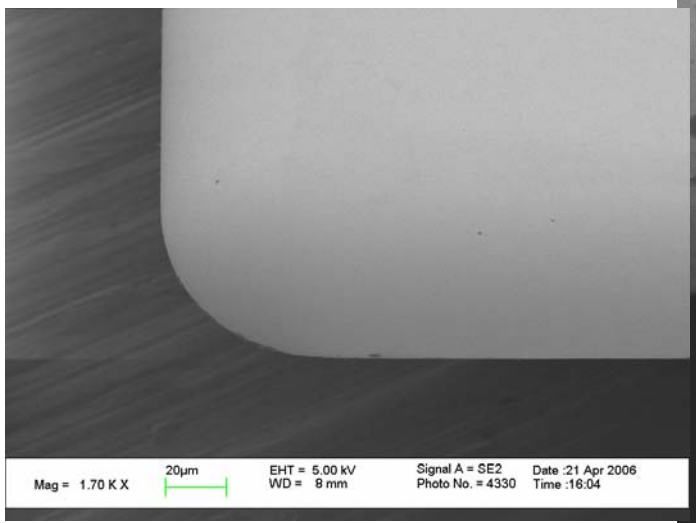



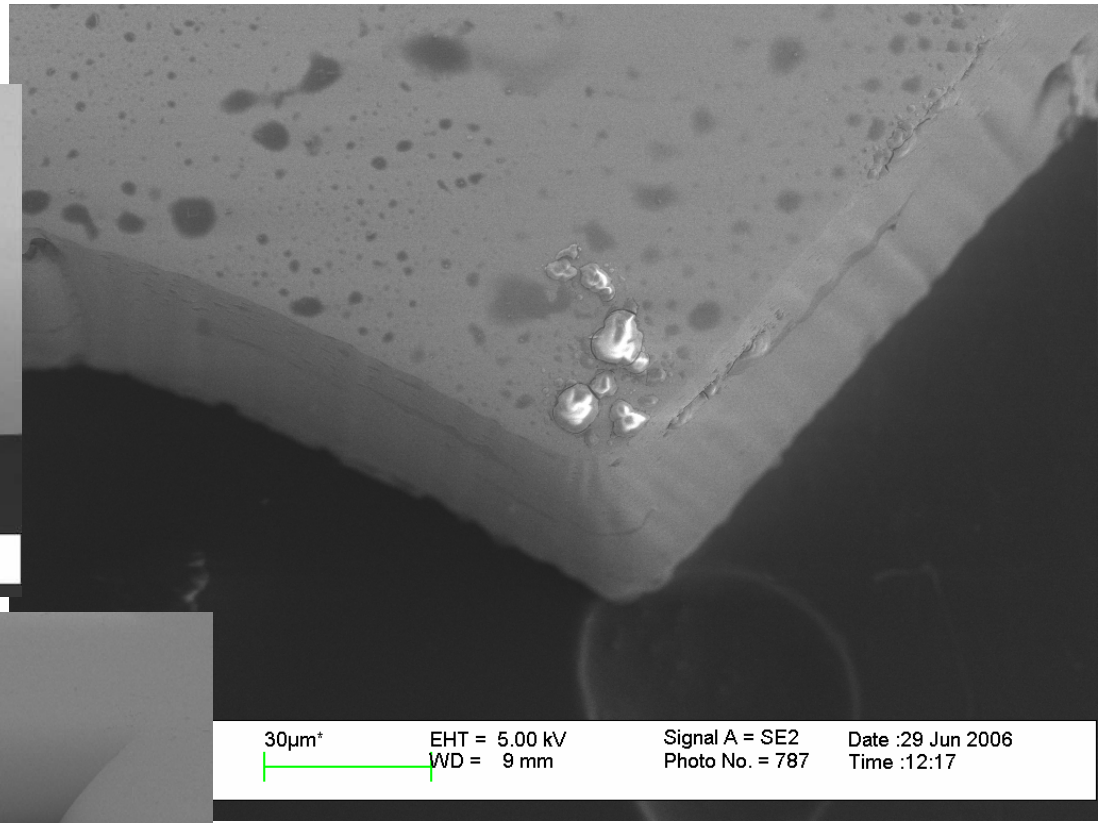
# Chemical Etch

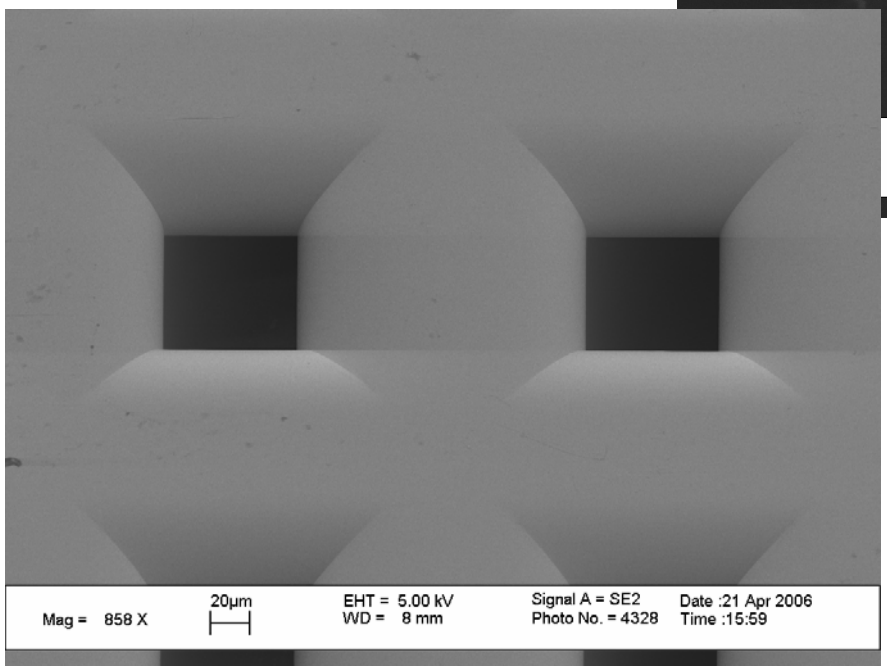


# Electroforming



Space-charge effects

$$N_{\max} = \frac{3\varepsilon_o v_o^2}{4m\Omega^2 z_o^4}$$

$$z = \frac{1.07}{k} r$$

$$k^2 = \frac{P}{8\pi\varepsilon_o \left(\frac{2q}{m}\right)^{\frac{1}{2}}}$$

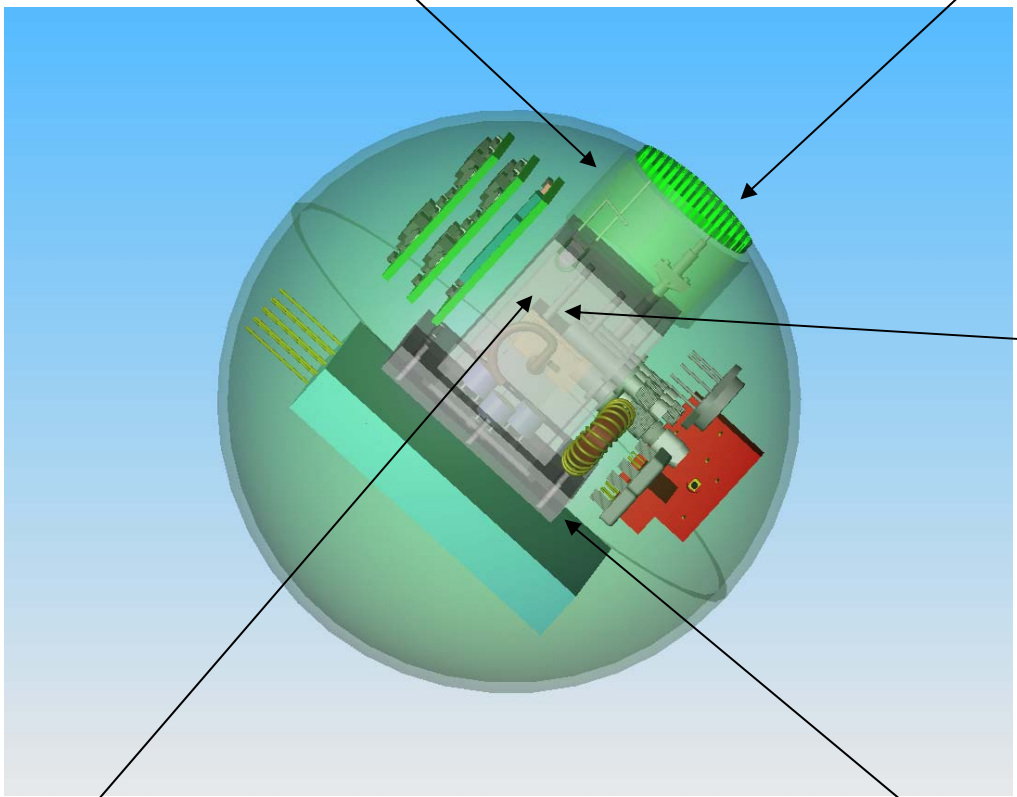
Surface-charge effects

$$q = \int \sigma(r) d^3 r$$

$$\sigma = \frac{q}{A}$$

MEMS – Microvalve
Thermal Inlet

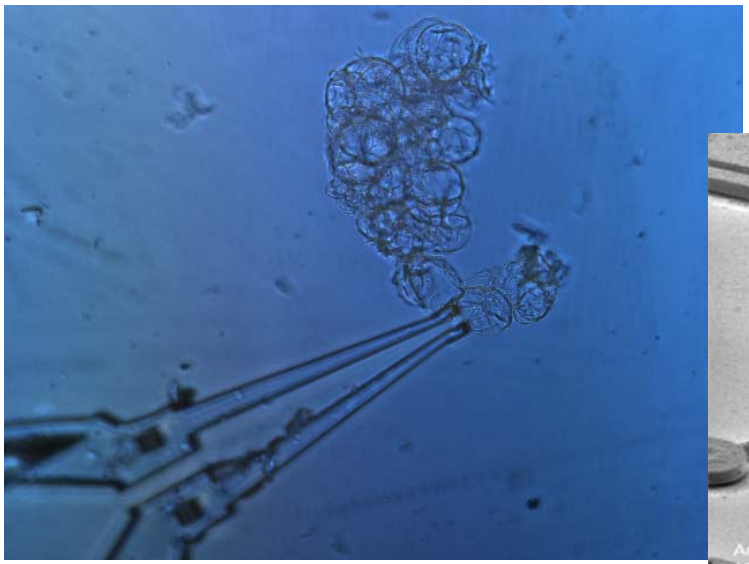
MEMS – Actuator (Pressure Regulator)

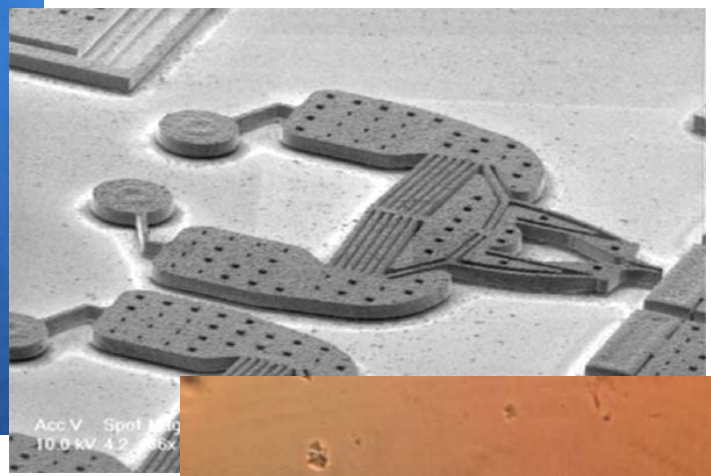


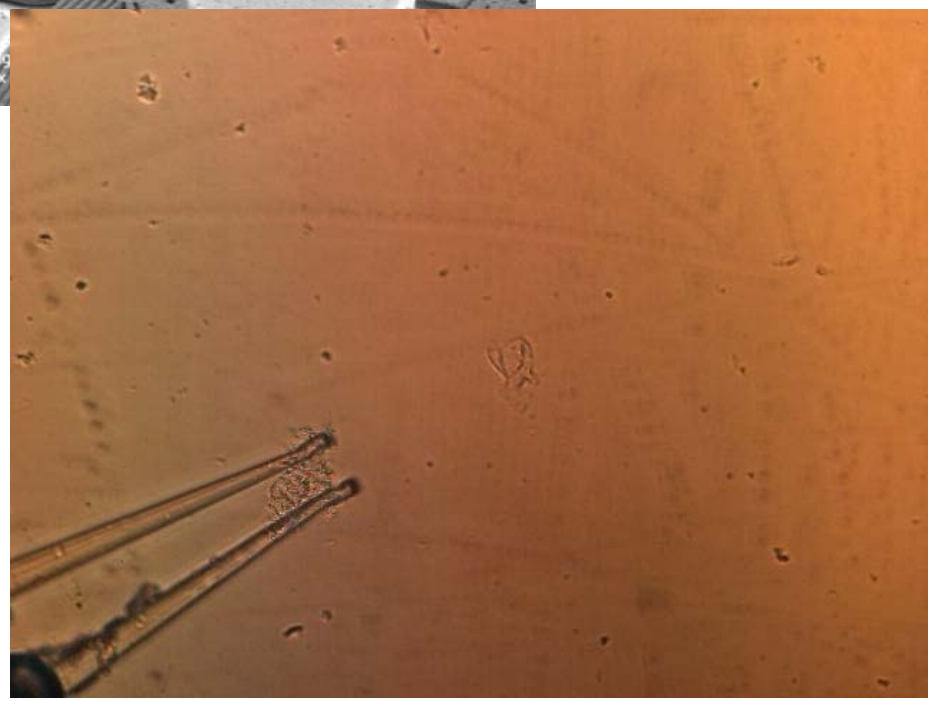
MEMS - MS

MEMS - Micropirani

MEMS – Source (Field Ionization)





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## Conclusions

Thank you


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