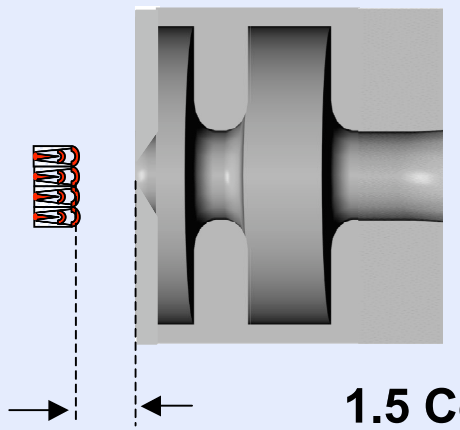
Low Emittance Gun Project

- Electron Source based on Field Emission
- Low Emittance Beam (5.10 $^{-8}$ m.rad ; 5 A; 30ps ; 3.5 MeV)
- Beam parameters must fit an X FEL gun requirement

http://leg.web.psi.ch/

Diode / RF Combination Gun Concept

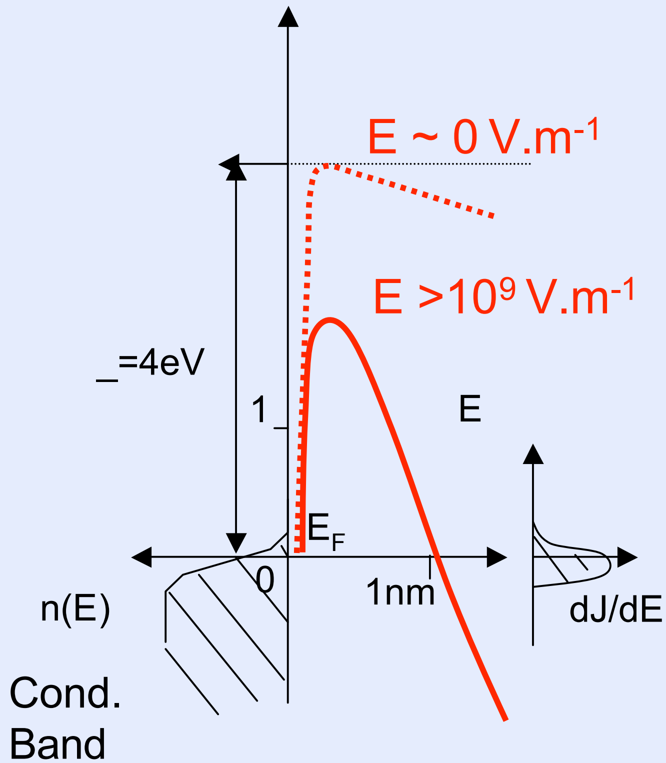
Electron Source
(Field Emitter Arrays or Single Needle Cathode)

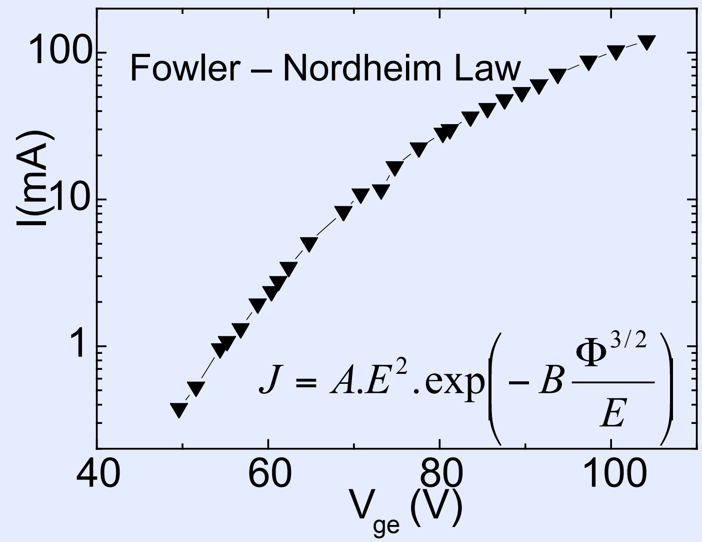


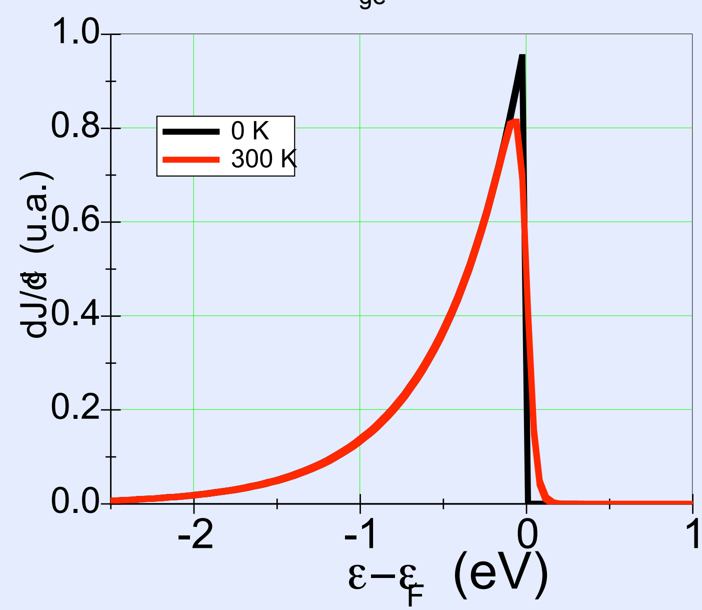
Pulsed Diode Acceleration
1 – 4 mm
250 – 1000 MV/m

1.5 Cell RF cavity
1.5 GHz + 3rd H.

Field Emission: Tunneling Process



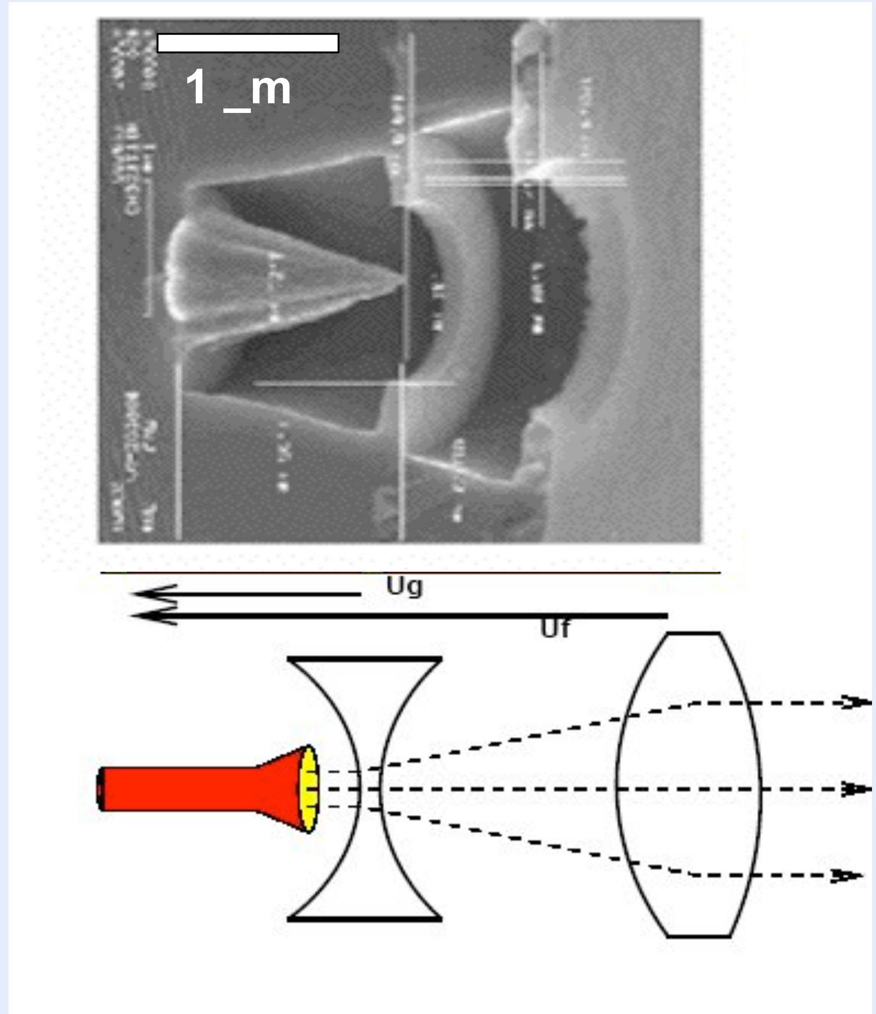




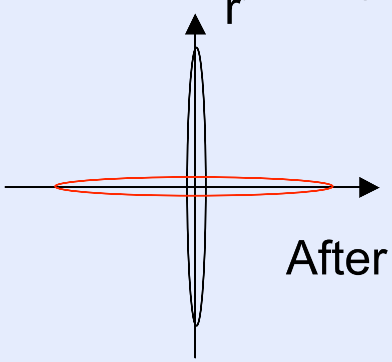
Energy Distribution=
Fermi Distribution * Tunneling Probability
(Δ_ ~ 4kT ~ 0.2 eV)

Field Emitter Arrays Concept

- > 5’000 Tips ; $Ø_{FEA} < 0.5mm$
- High Current density ($<10^{12}$ A/m^2)
- Self Aligned Focusing Gate



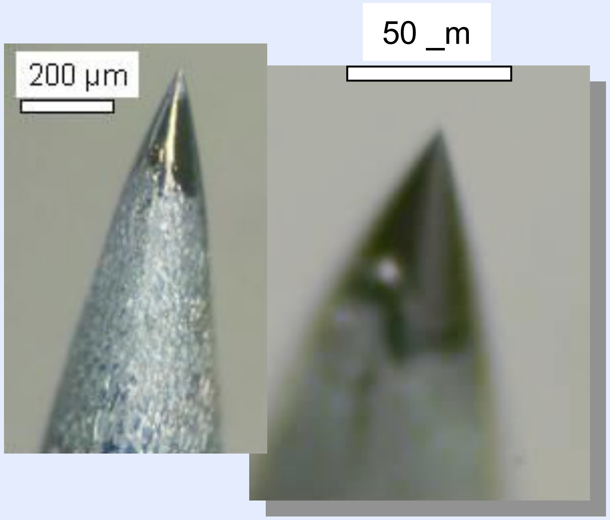
Initially



After Focusing

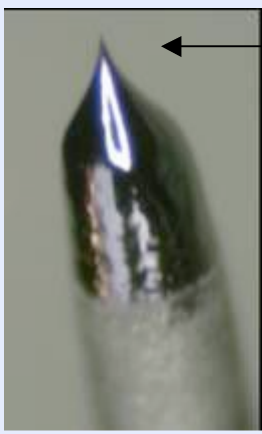
_n/Tip ~ 10^{-10} m.rad

Needle Cathode Electron Source



ZrC, HfC tips from Etched Wire

Goal:
I_{peak} > 5A if pulsed emission (Δt < 5ns)



r_{apex} ~ 1 to 5 _m

$$\beta = \frac{2}{r.\ln\left(\frac{4D}{r}\right)} \sim \frac{1}{5.r}$$

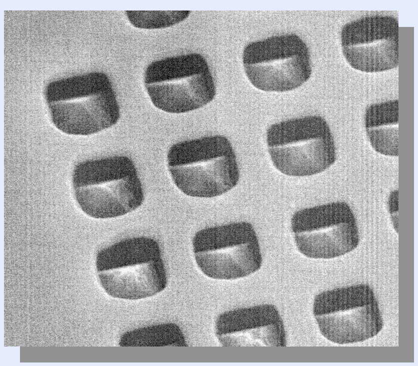
Time Modulation (ps) possible by Laser assisted Field Emission
(ref. C.H. Garcia and C. Brau, NIM A 483, 273-276 (2002))

V_{Tip} > 50 kV

1. **F**ield **E**mitter **A**rrays **E**lectron **S**ource

Experimental Tests

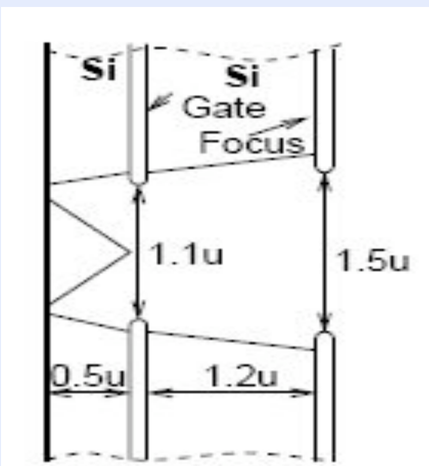
and Simulations at PSI

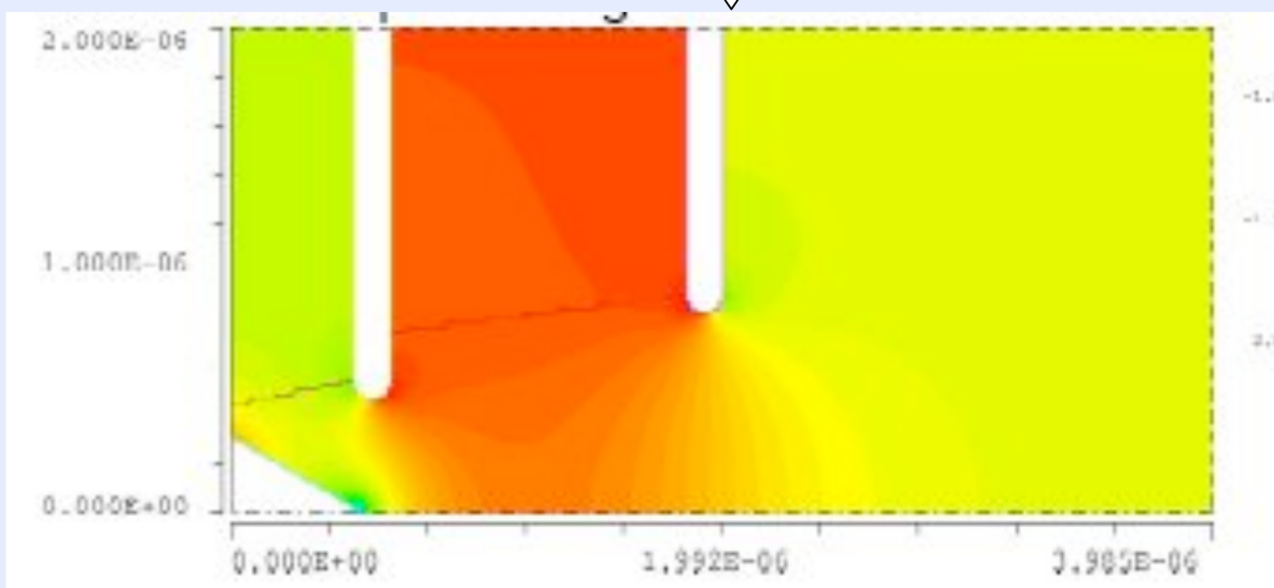


Cathode Simulations (M. Dehler, A. Candel)

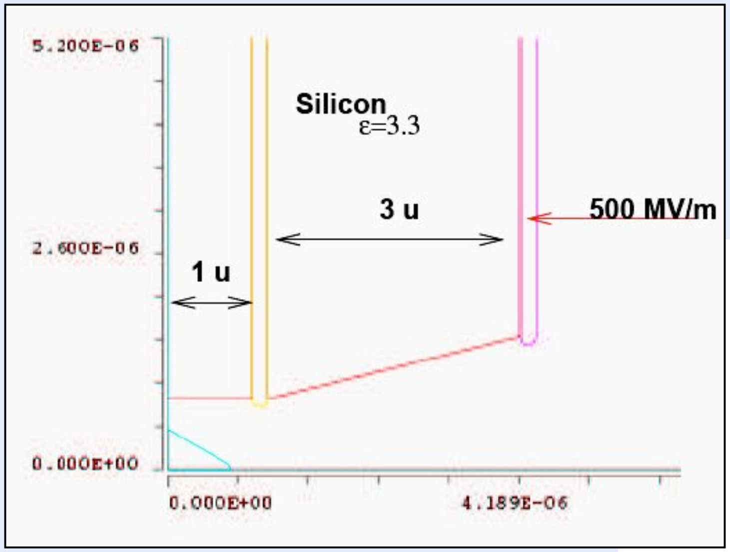
Mafia Simulation: One FEA emitting site

Double Gated FEA
3.10^{-10} m.rad (projected)
1 mA / tip

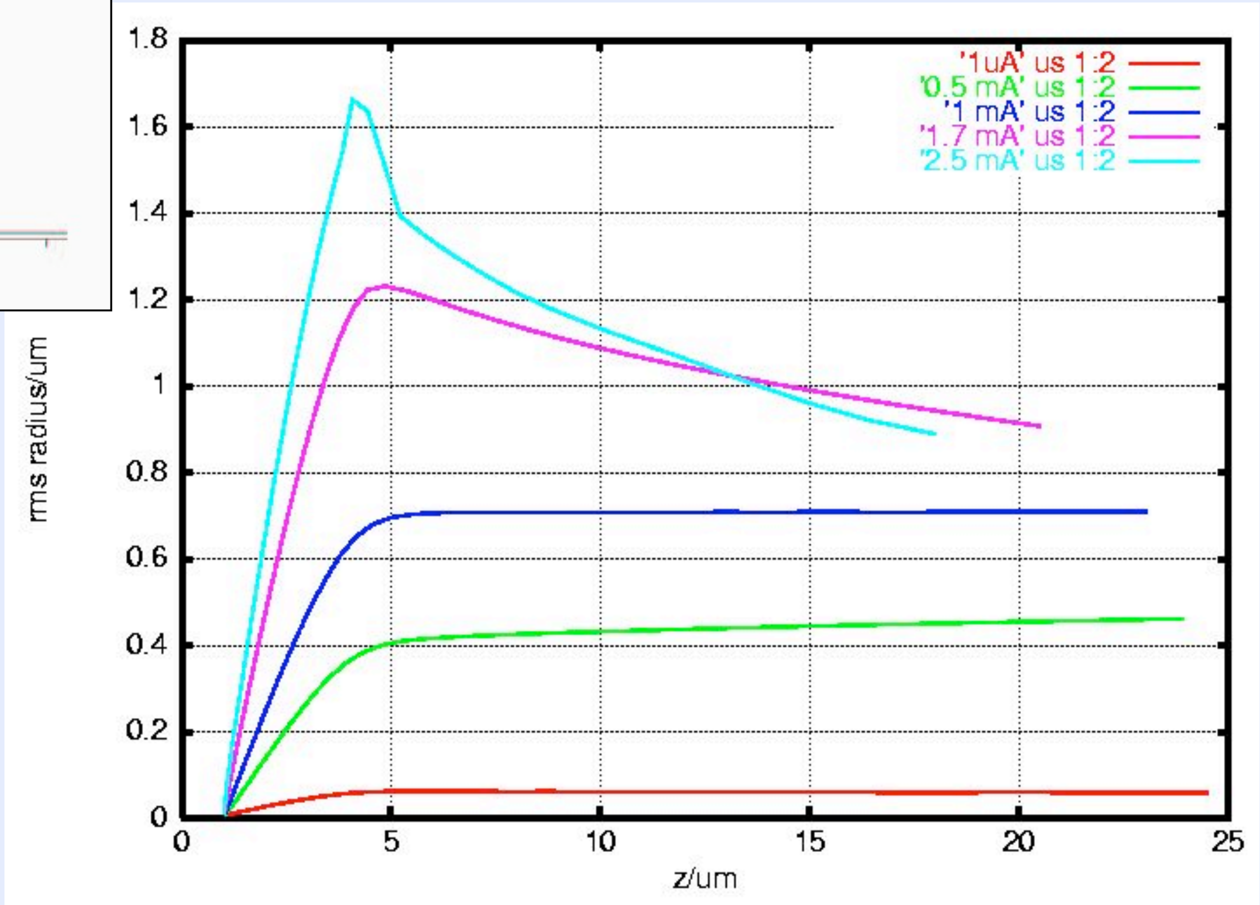




Cathode Simulations (M. Dehler, A. Candel)



Beam Enveloppe (< 1.5_m at 1mA)



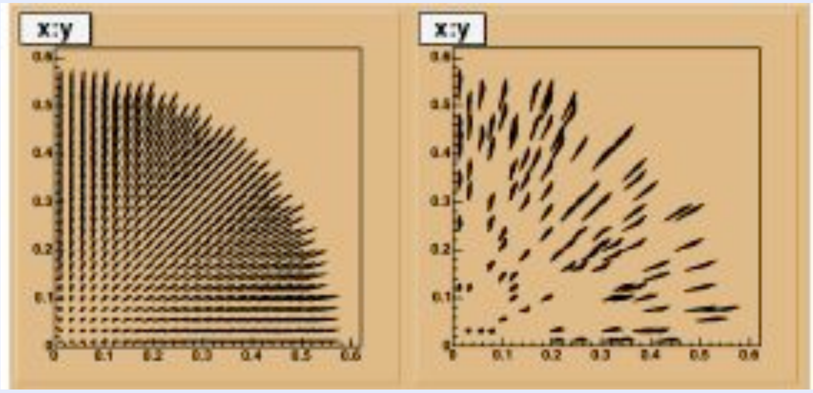
Cathode Simulations (M. Dehler, A. Candel)

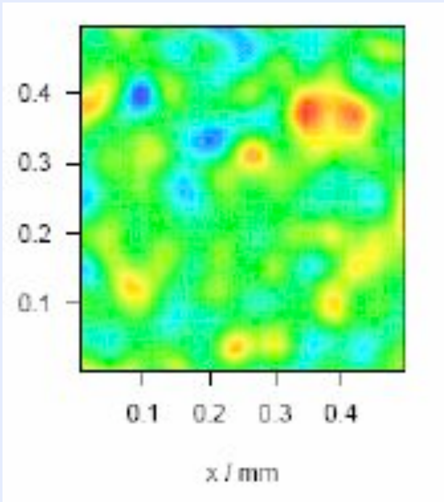
PSI Parallel Maxwell Solver: "Capone"

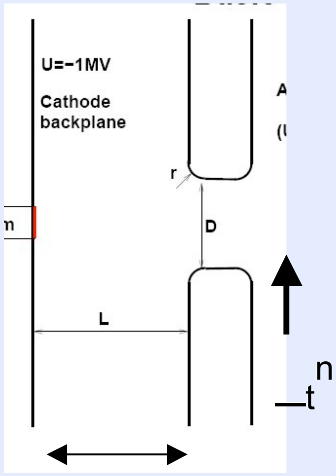
Full Tip array Simulation (Granularity)

Uniform emission _ **< 5.10^{-8} m.rad**

Non uniform emission _ 2.10^{-7} m.rad



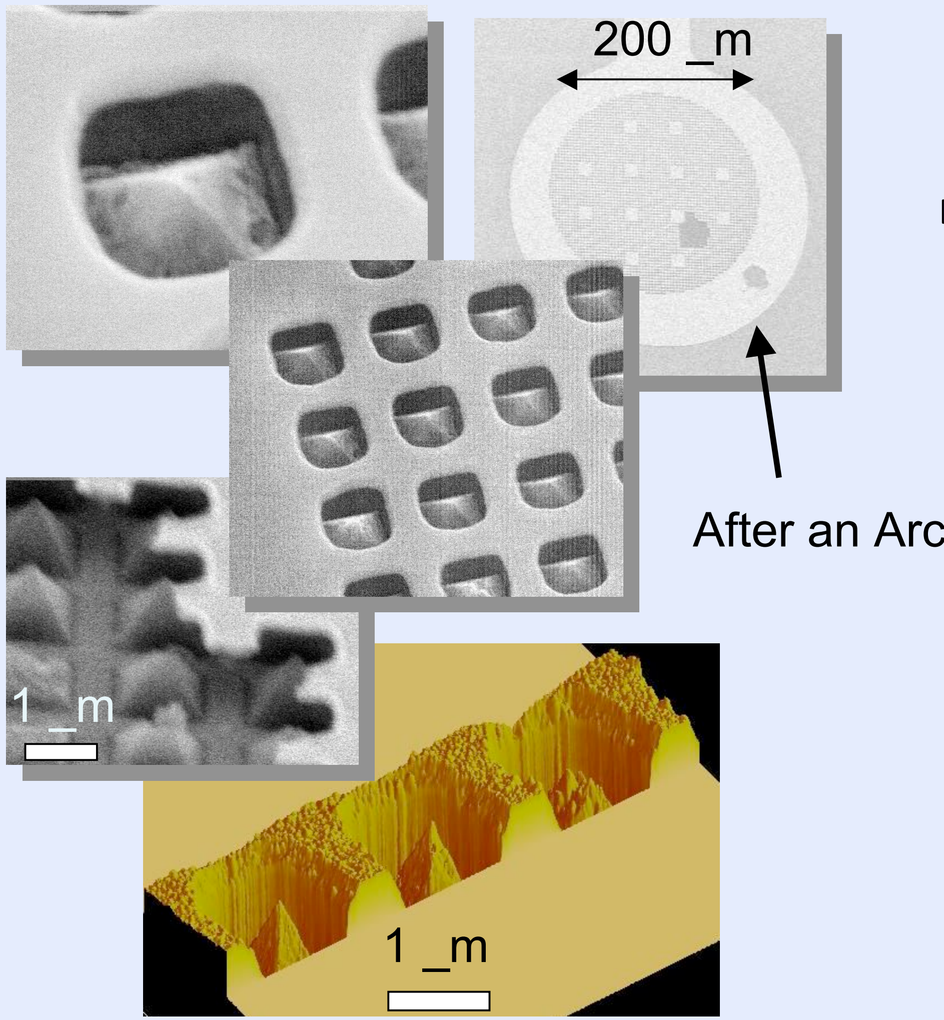




2 mm
1 MV

Emittance after Iris

Pulsed Tests on Commercial Samples

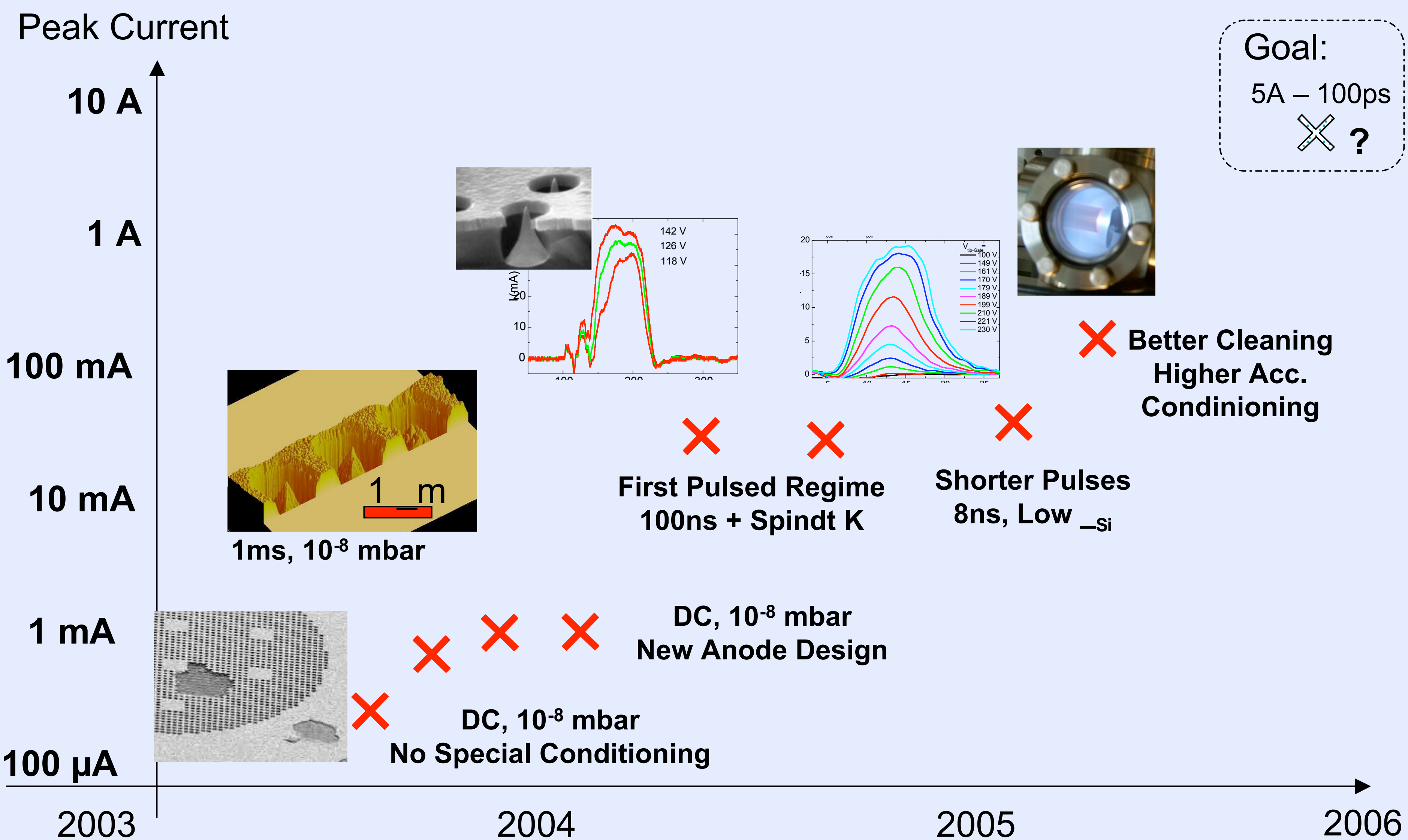


Goal:
Peak Current > 5 A

Limitations:
Breakdowns, Arcs (heat-up)
Non Uniformity (5% of tips)

Solutions:
Pulsed Emission (< ns)
Conditioning Techniques

FEA Peak Current Progress



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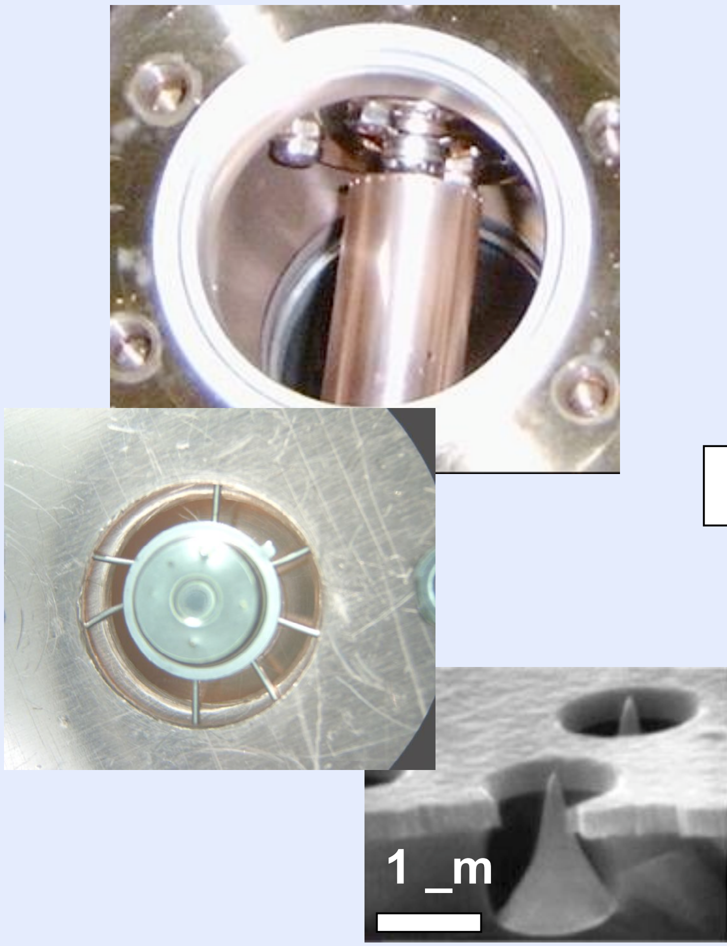
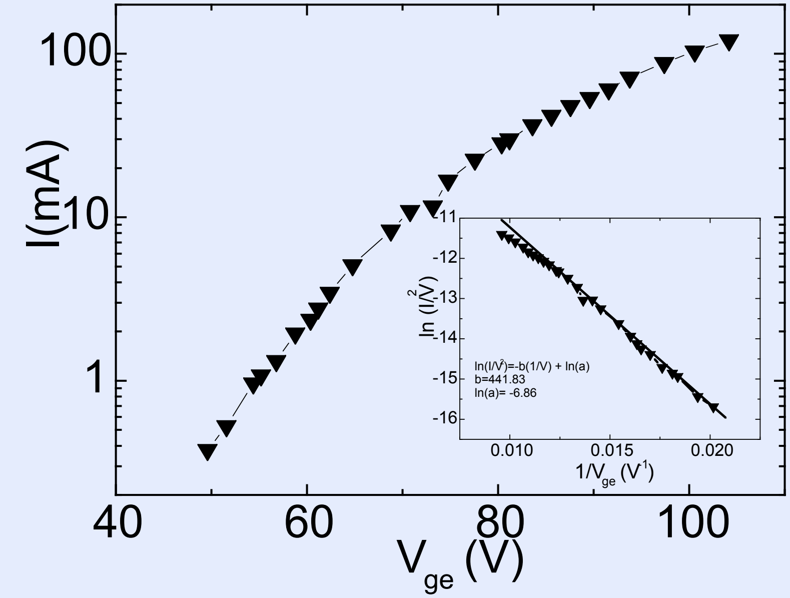
Field Emitters Array Cathode

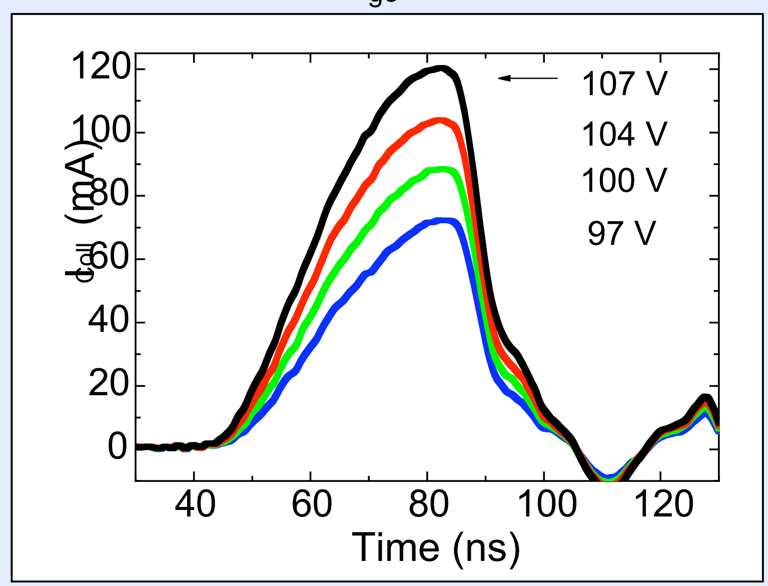
SRI Inc. FEA (Mo Tips)

Ø = 1 mm, 50’000 Tips





120 mA →

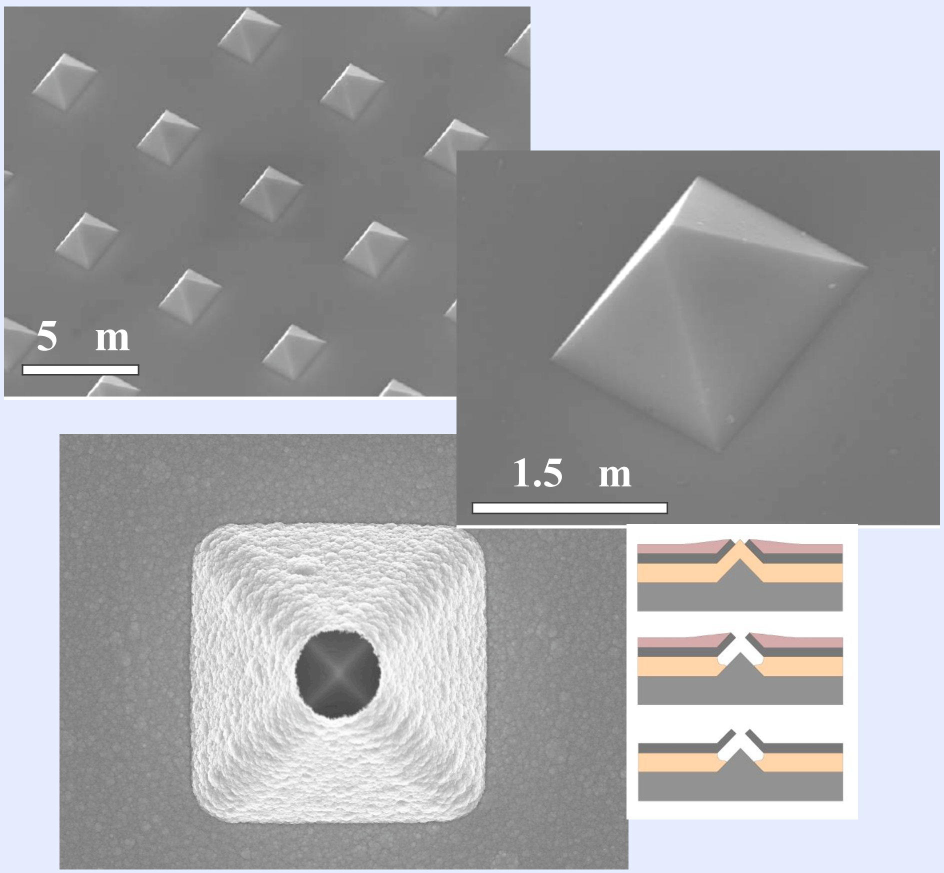


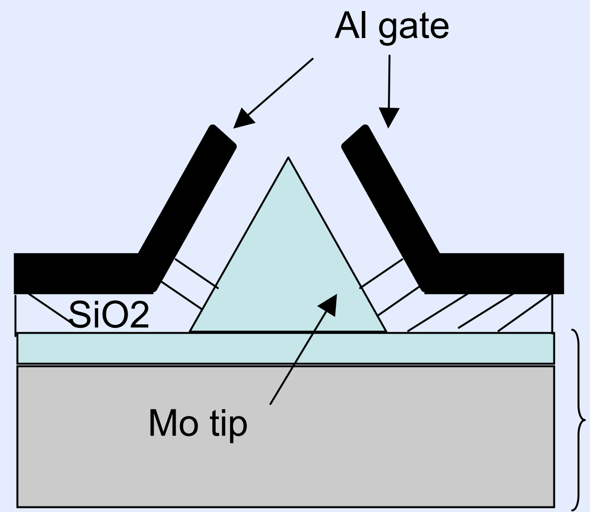
FEA fabrication at PSI

(E. Kirk, H. Sehr, J. Gobrecht)

Goal: Double gated Tip Array

Molding Process → Pyramidal Tips

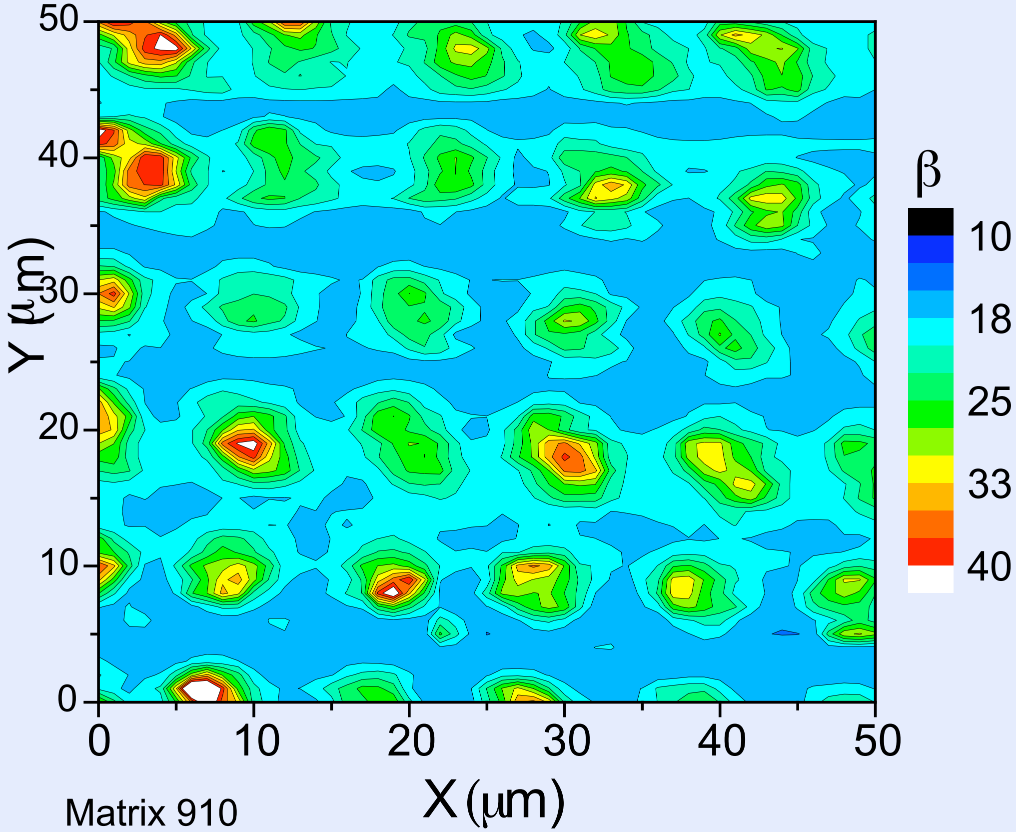




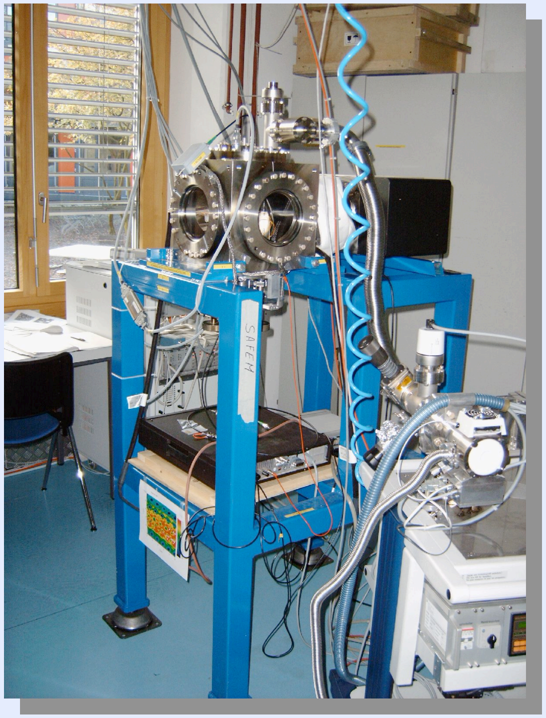
SAFEM Test Stand at PSI (E. Meier, F. Le Pimpec, R. Ganter)

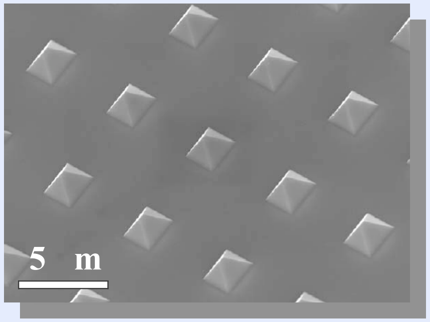
Scanning Anode Field Emission Microscope

Goal : Mapping of Field Emission
~ measure of uniformity



Matrix 910





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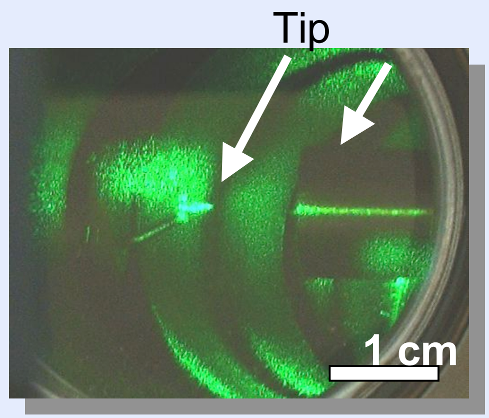
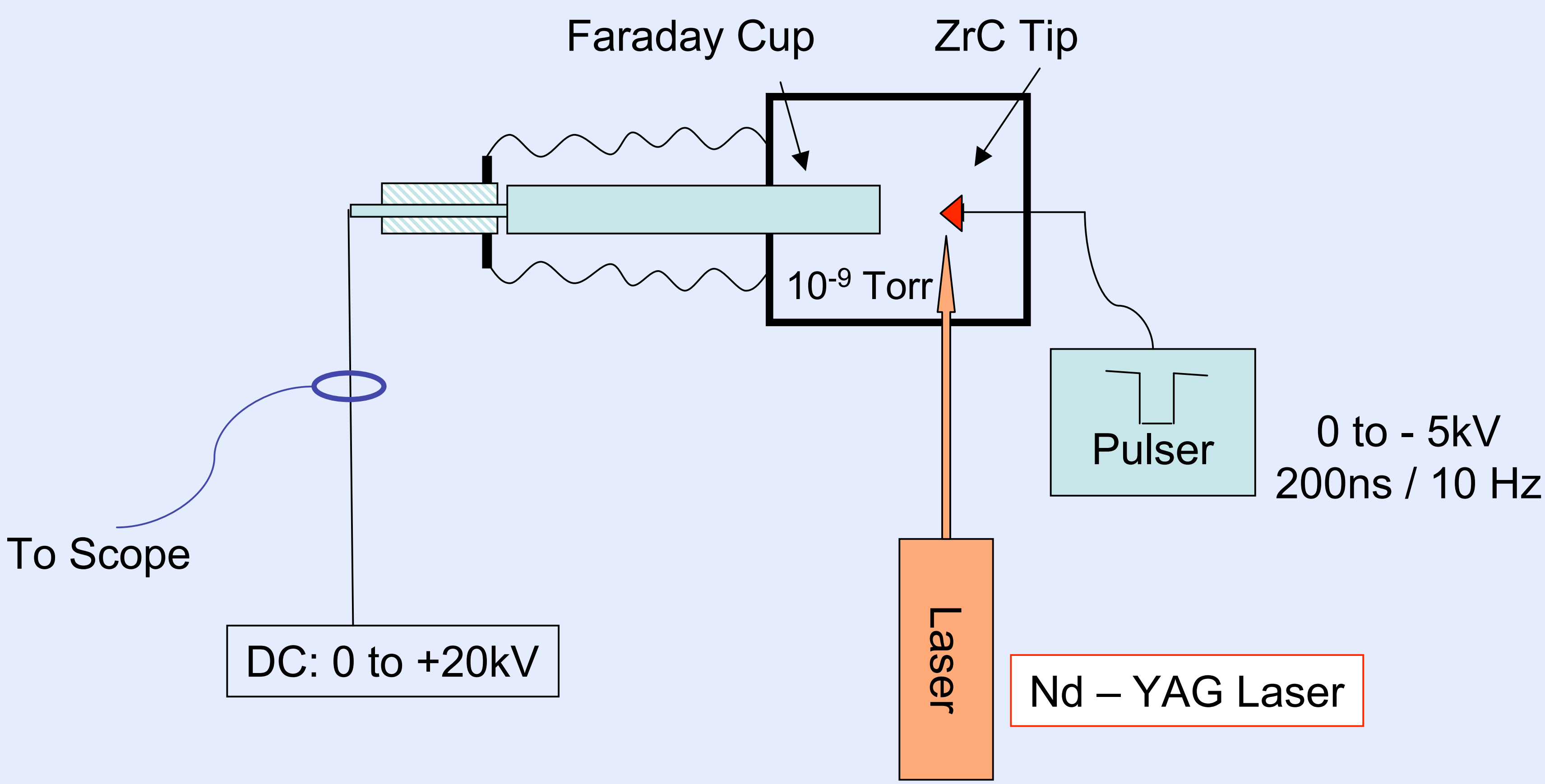
2. **L**aser **i**lluminated **N**eedle **C**athode

Electron **S**ource



Laser illuminated Needle Cathode



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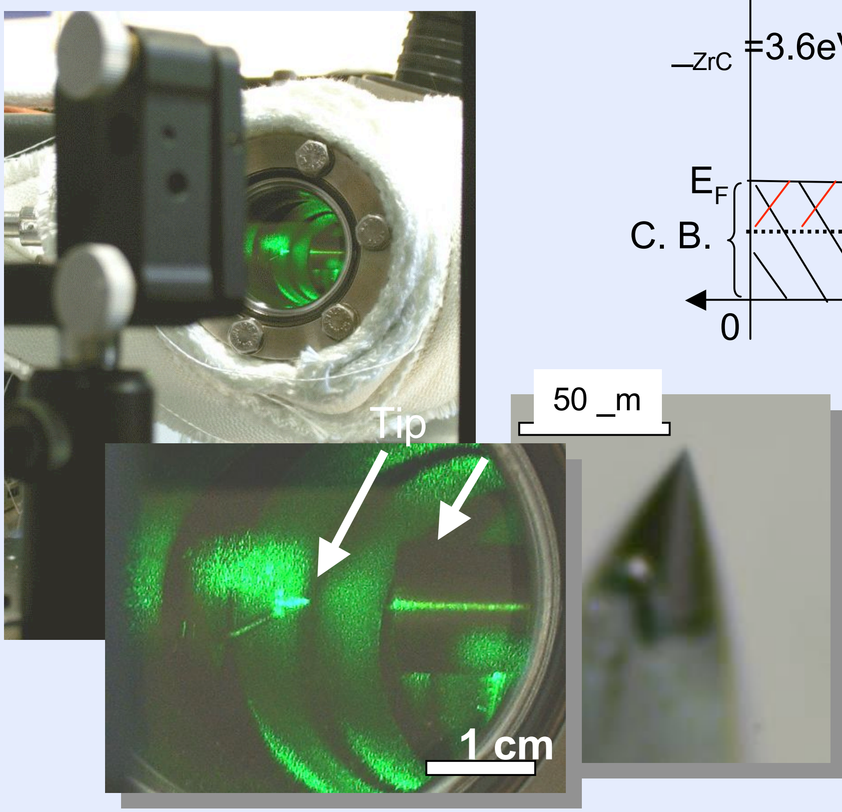
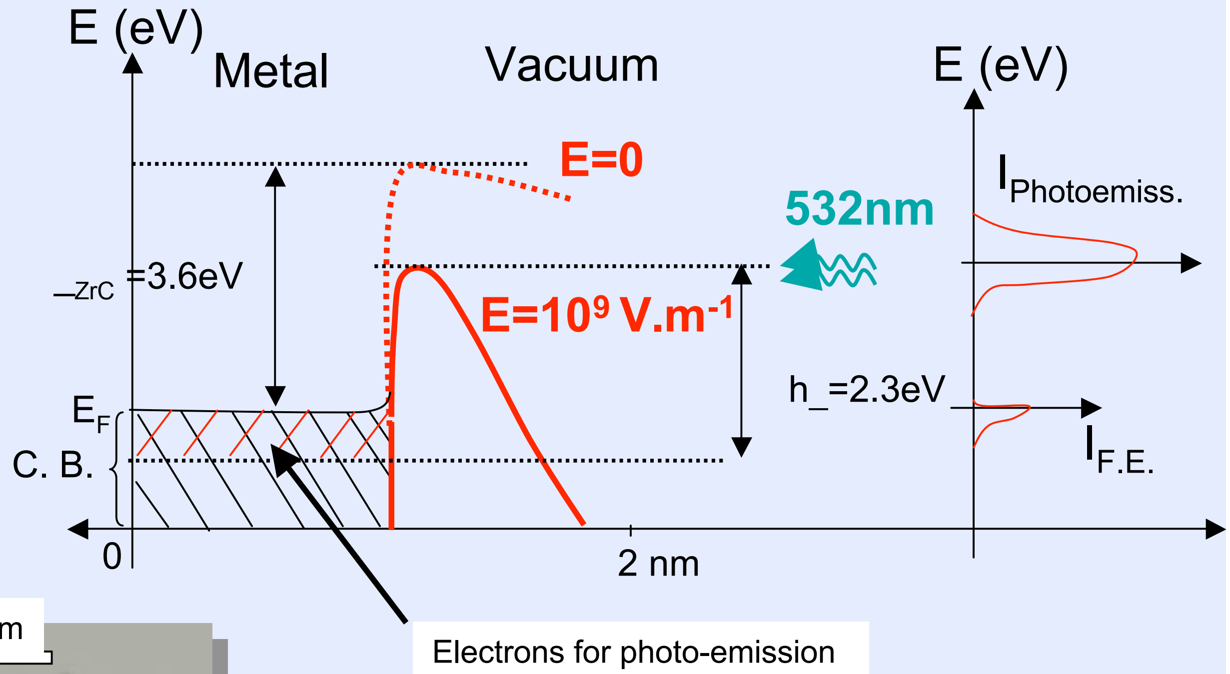
Laser Illuminated Needle Cathode

Needle Cathode (ZrC):

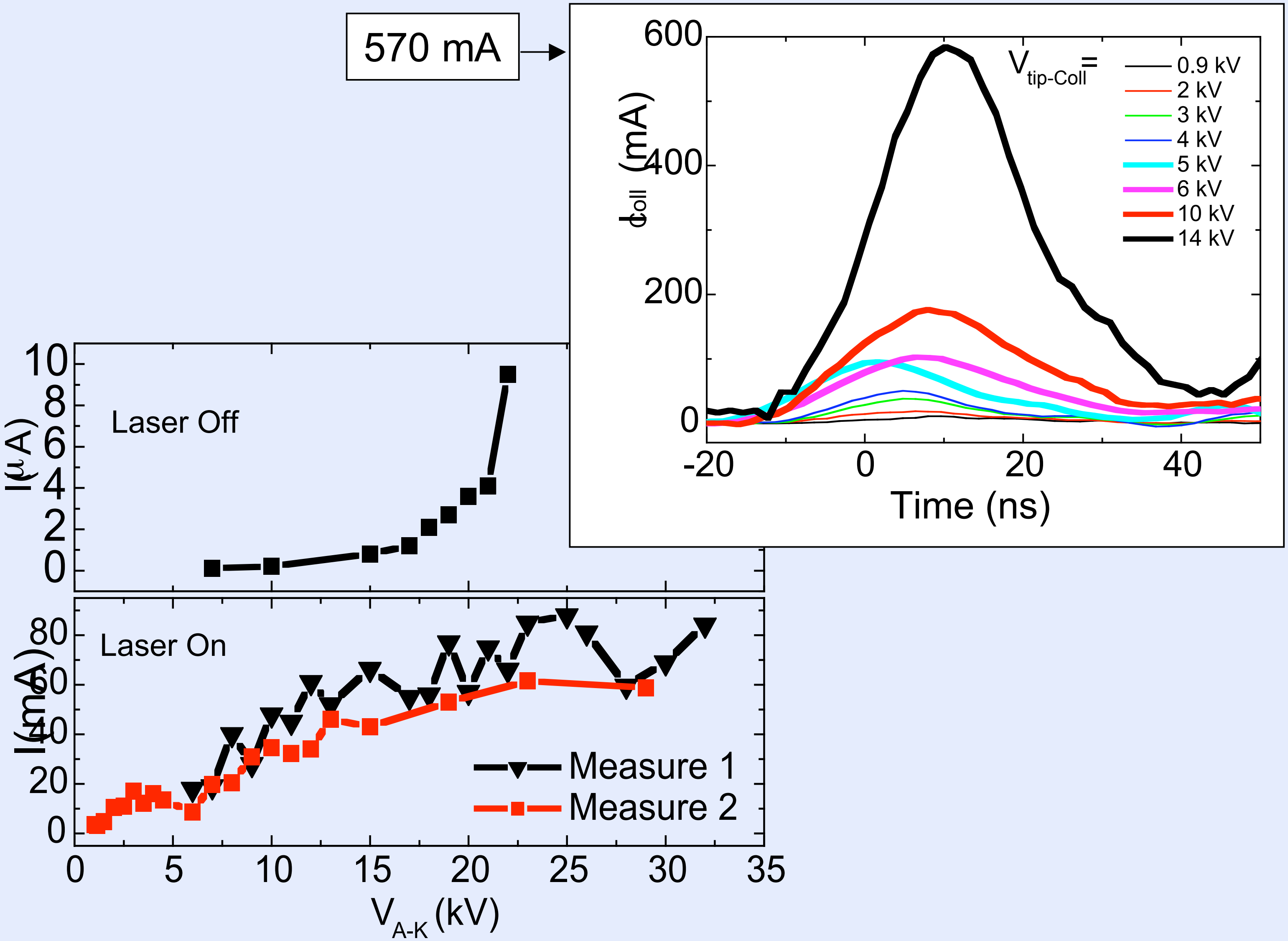
r_{apex} ~ 1 to 5 _m





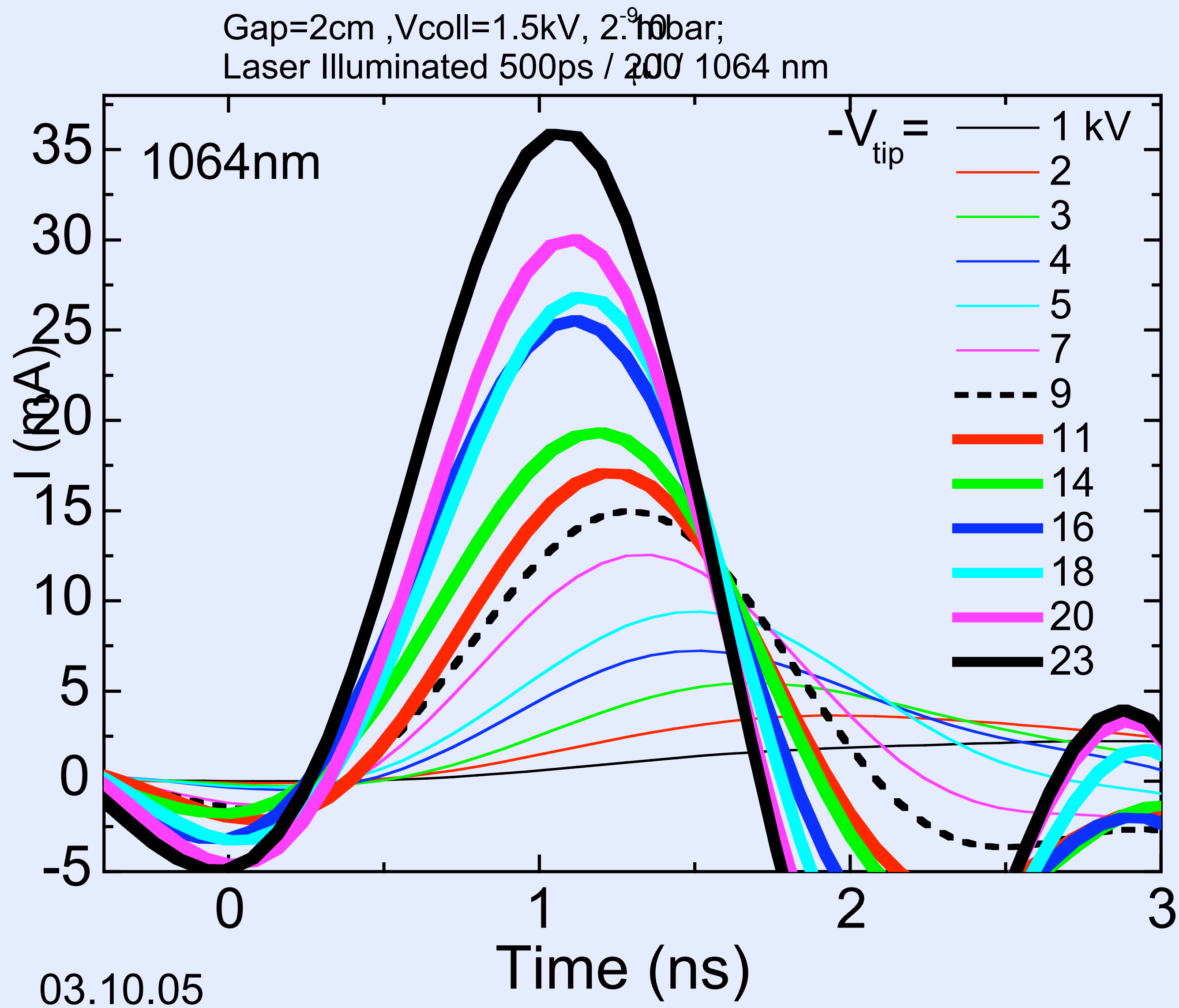
Electric Field ⇨ | - Higher Q. E.
- 532nm Photons

Laser Illuminated Needle Cathode

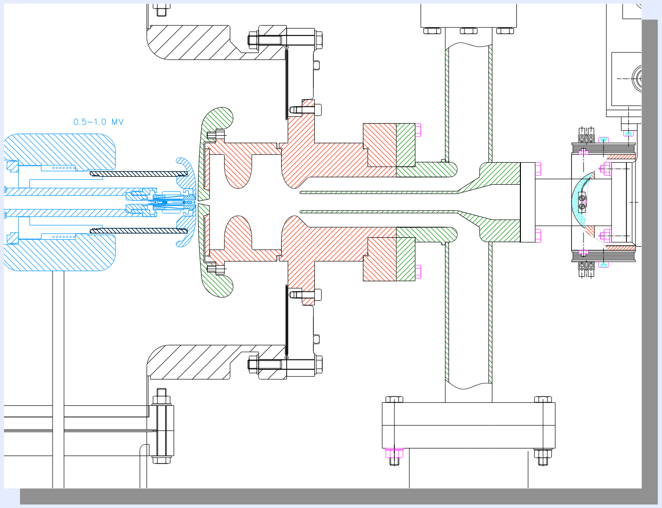


500 ps Laser Pulses (200_J) on a ZrC Tip

1064 nm
Laser Light !



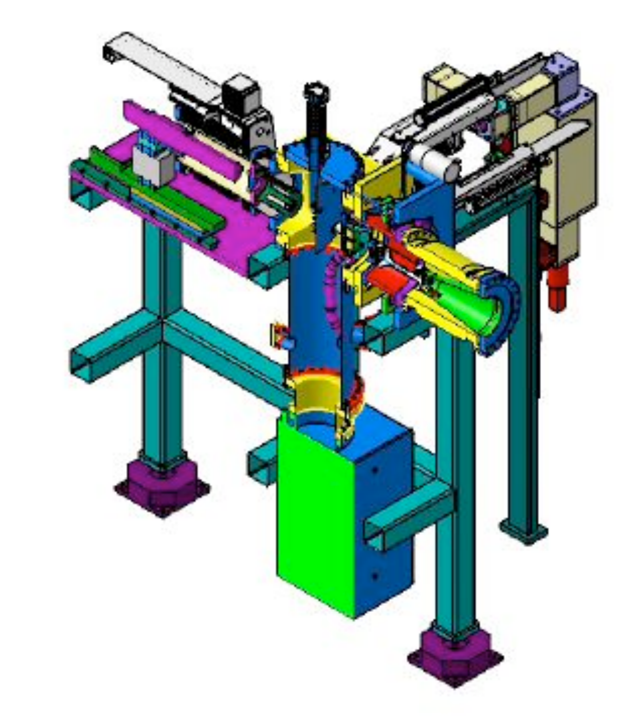
3. Test Stands in Preparation



DC Gun Test Stand (S. Leemann, V. Schlott, A. Streun)

Gun test stand (100 keV) :

Goal:
- First emittance measurements
- Solenoid Compensation Tests



- Pepperpot measurements, YAG screen, …
- Double slits systems
- Faraday Cup

Diode Acceleration (M. Paraliev, C. Gough)

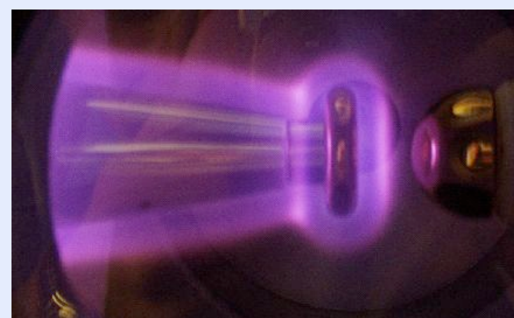
High Voltage Pulser Construction

500 kV - 250 ns - 10 Hz

Goal: $E_{acc.}$ > 250 MV/m
- Limit space charge effect
- Limit Anode Iris effect

High Voltage Pulser (under assembly !)
Air Core Transformer Technology

Glow discharge Conditioning
High field Strength



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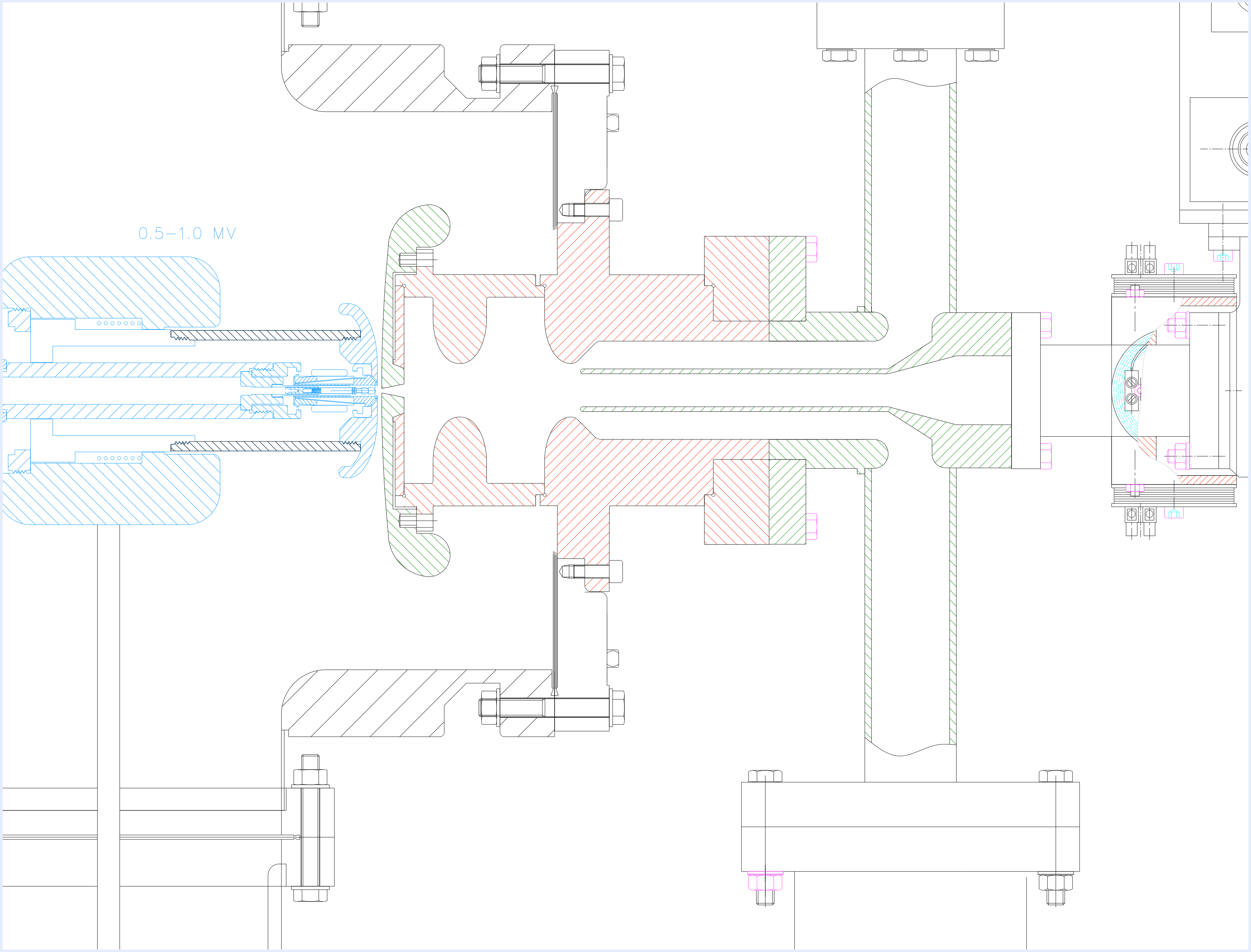
Perspectives

- Production of Double Gated FEA at PSI
- To demonstrate : 5 A peak current (12ps Laser / 100 kV Pulser)
- First Emittance Measurements
- 500 kV Pulser + RF Cavity in operation


0.5–1.0 MV

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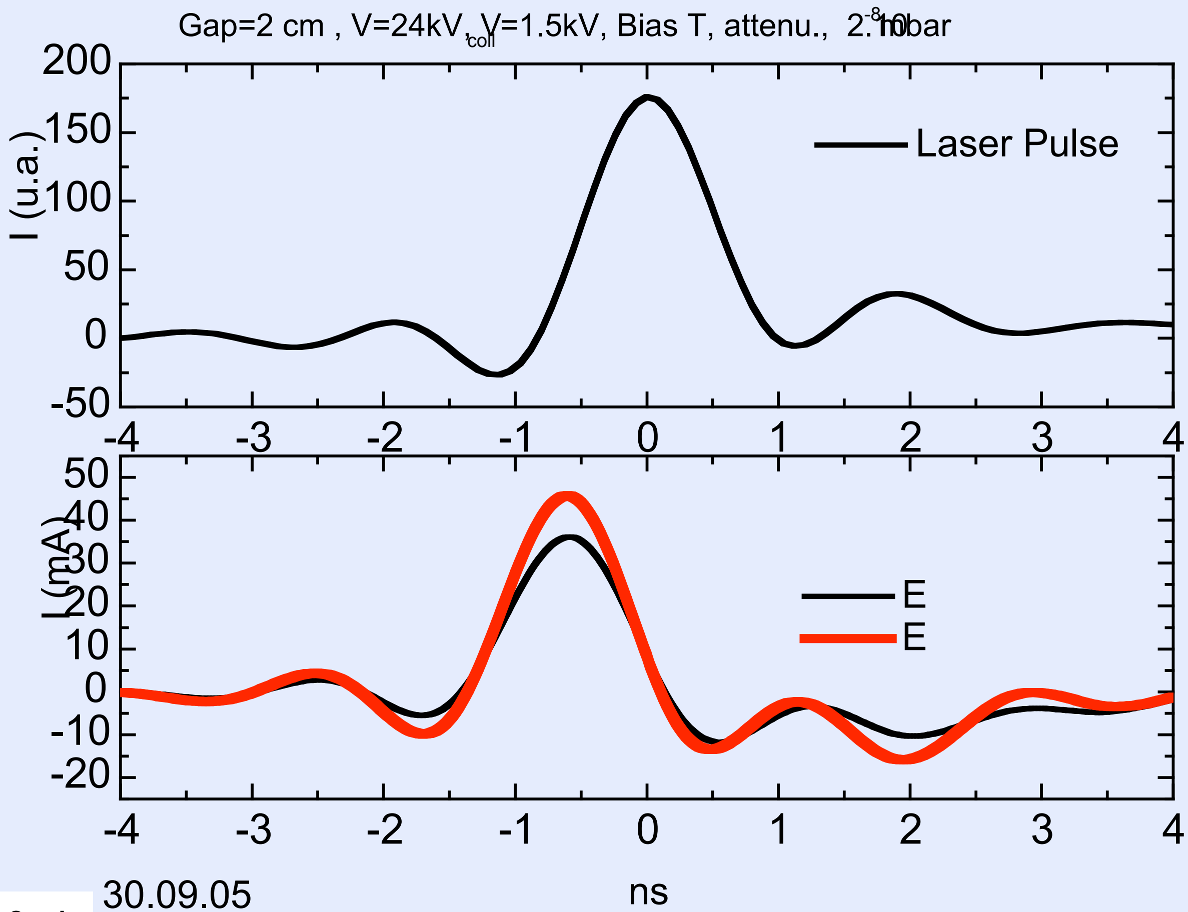
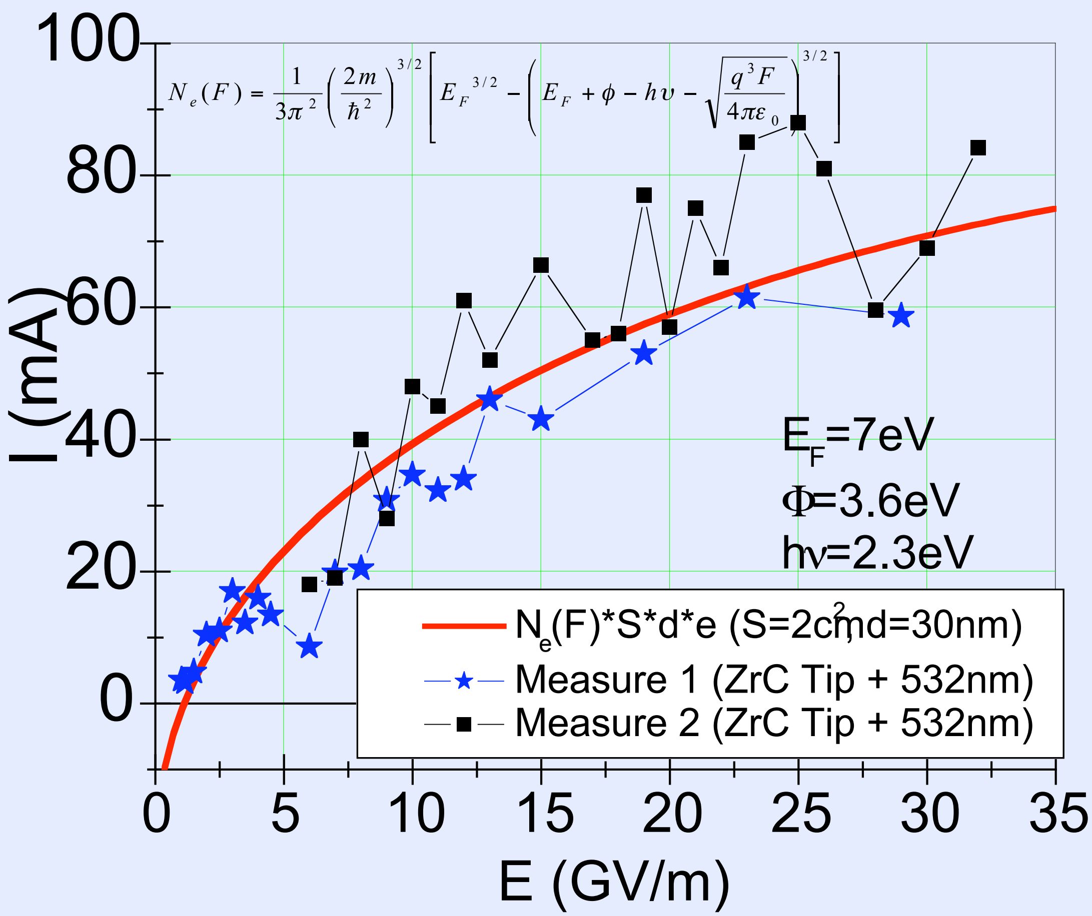
500 ps Laser Pulses (200_J) on a ZrC Tip



3Hz, 0.5ns, 200_J
1064 nm & 532 nm

Photo - Field Emission



Higher the Electric field

Lower Barrier Height

More electrons can be photoemitted (532nm)

$$N_e(F) = \frac{1}{3\pi^2}\left(\frac{2m}{\hbar^2}\right)^{3/2}\left[E_F^{3/2} - \left(E_F + \phi - h\upsilon - \sqrt{\frac{q^3 F}{4\pi\varepsilon_0}}\right)^{3/2}\right]$$

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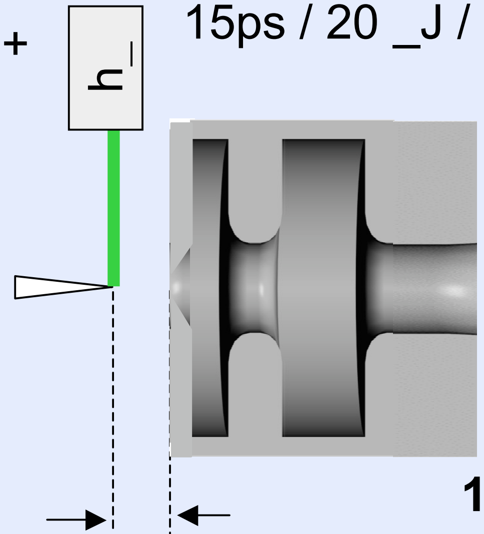
Needle Cathode Concept

FEA =
Small Beam Diameter
+ some Divergence

Laser 532nm
15ps / 20 _J / 10Hz

Single Tip +



1.5 RF cavities
1498.956 MHz + h

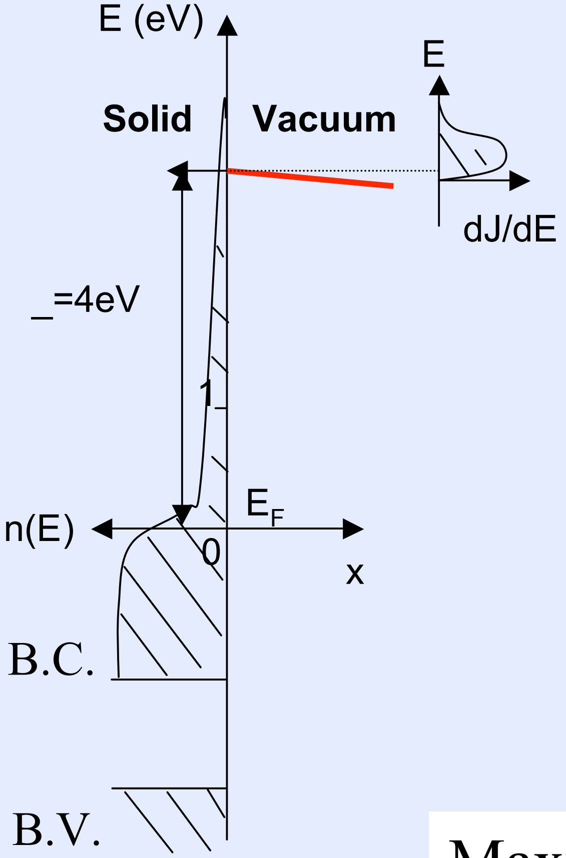
Pulsed Diode
Acceleration
1 - 4mm
250 - 1000MV/m

Diode / RF Combination Gun Concepts

Emitted Electron Energy Distribution 1D

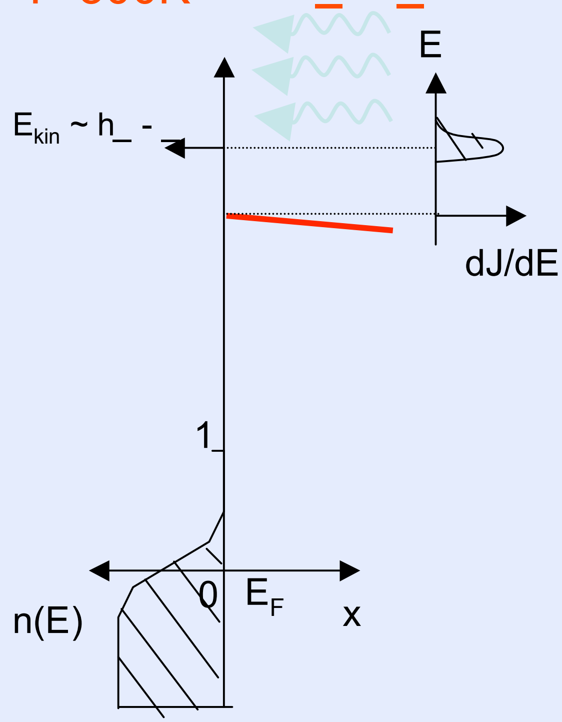
Themionic Emission

T=1500K



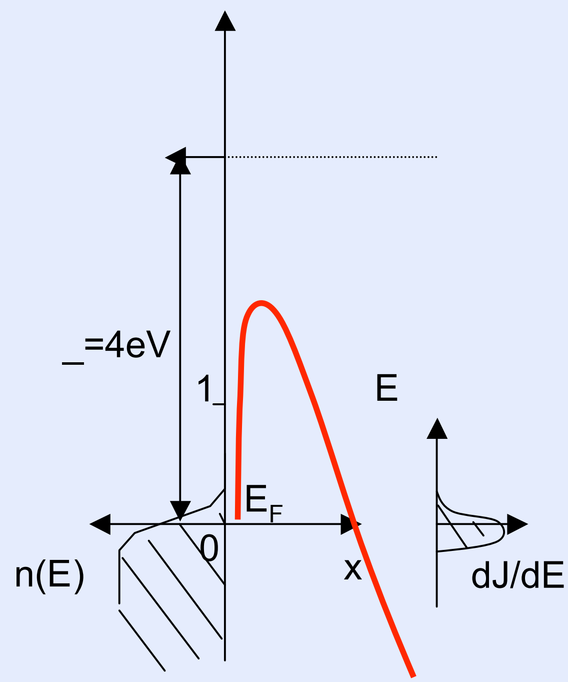
Photoemission

T=300K **h_ > _**



Field Emission

T=300K E=10^9 V.m^{-1}



Maxwell Distribution

Fermi Distr. x Tunneling Probability