PAUL SCHERRER INSTITUT

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

FIRST MEASUREMENT RESULTS AT THE LEG PROJECT'S 100 keV DC GUN TEST STAND

S. C. Leemann, Å. Andersson, R. Ganter, V. Schlott, A. Streun, A. F. Wrulich
PSI, Villigen, Switzerland

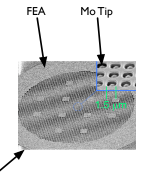
Introduction

The Low Emittance Gun Project (LEG) at PSI aims at developing a high-brightness, high-current electron source: a 20-fold improved brightness compared to present state-of-the-art electron guns. The source is intended to form the basis for a cost-efficient implementation of a high-power X-ray FEL light-source for scientific research at PSI.

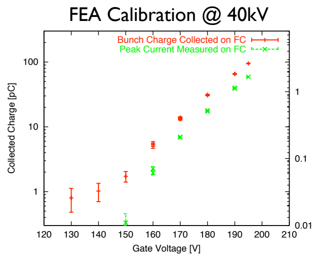
A field emitter array (FEA) cathode is being considered a source candidate. In order to study pulsed field emission from such a cathode and to investigate space charge compensation techniques as well as to develop diagnostic procedures to characterize the beam resulting from an FEA cathode, a 100 keV DC gun test stand has been built. The test stand gun and diagnostics have been modeled with the codes MAFIA and GPT. From extensive parameter studies an optimized design has been derived and construction of the gun and diagnostics have recently been completed. We report on the commissioning of the test stand and present first measurement results.

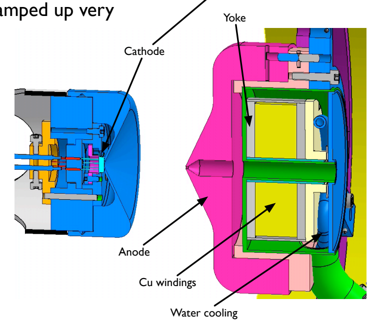
Test Stand Setup

- FEA consists of thousands of gated molybdenum nano-tips; put on negative DC potential of 100kV
- Each FEA tip emits a beamlet when the gate layer is pulsed (>5ns, <320V)
- Bunch accelerated in 11mm gap (E < 20MV/m)
- In-vacuum DC solenoid capable of delivering 200 mT on axis; field confined by iron yoke; heat dissipated by water-coolong circuit
- FEA is destroyed by HV breakdown → DC HV has to be ramped up very carefully (60kV stable operation has been reached)

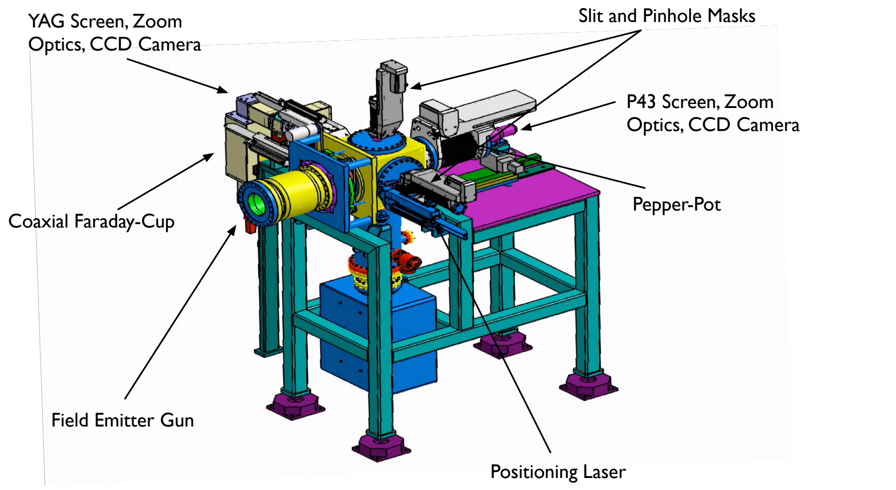


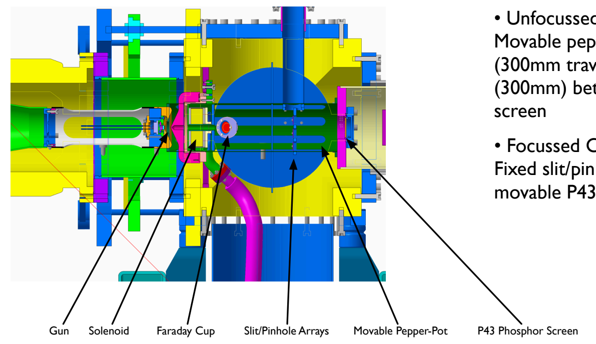
FEA Calibration @ 40kV



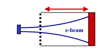


Diagnostics Overview

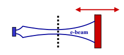




- Unfocussed Case
Movable pepper-pot arrangement (300mm travel) with fixed distance (300mm) between pepper-pot and P43 screen



- Focussed Case
Fixed slit/pinhole array insert with movable P43 screen (300mm travel)



Emittance Measurements

Solenoid Scan

- Rotationally symmetric beam → solenoid is purely focussing in both planes with

$$k = \left(\frac{B}{2(p/e)}\right)^2, \qquad \text{where } B = \frac{\int B\,\mathrm{d}s}{l_{\mathrm{eff}}}$$

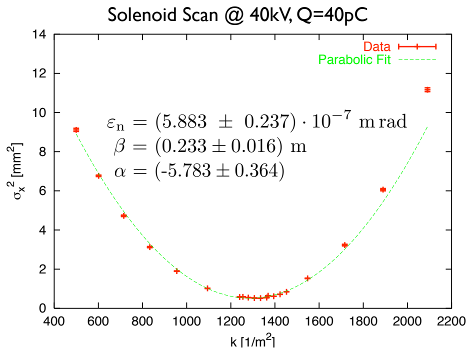
- In thin lens approximation

$$\sigma_{x,y}^2 = c_2 k^2 + c_1 k + c_0$$

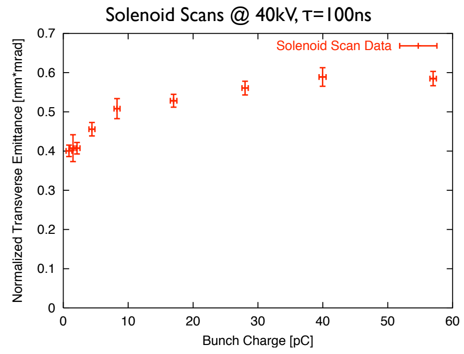
- Measure downstream beam size as a function of solenoid current
- From quadratic fit derive emittance and twiss parameters at solenoid location

$$\sigma^2 = \varepsilon\beta = \mathcal{M}_{1,1}^2 \varepsilon\beta_0 - 2\mathcal{M}_{1,1}\mathcal{M}_{1,2}\varepsilon\alpha_0 + \mathcal{M}_{1,2}^2\varepsilon\gamma_0$$

Solenoid Scan @ 40kV, Q=40pC



Solenoid Scans @ 40kV, τ=100ns



Slit / Pinhole Array Measurements

- Single slit (20μm): If beam size at slit is known, measuring the downstream beamlet width gives emittance in one shot (per plane)

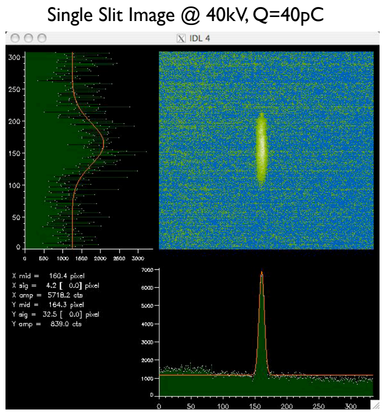
$$\varepsilon_x = \sqrt{\langle x^2\rangle \cdot \langle x'^2\rangle}\ , \quad \text{where} \langle x'^2\rangle = \sigma_x^2/L^2$$

- Slit Array (20μm, 170μm pitch): Measure beamlet distributions and relative intensities; beamlet widths give momentum spread within each slit; correlated momentum spread of the entire bunch given by envelope over all beamlets → emittance, twiss parameters and phase space density measured in one shot (per plane)

$$\overline{x}_i{'} = \langle x_i - \overline{x}_i\rangle / L$$
$$\sigma_i{'} = \sqrt{\langle (x_i - \overline{x}_i)^2\rangle / L^2 - (\overline{x}_i{'})^2}$$

- Pinhole Array (50μm, 320μm pitch): Similar to slit array, but delivers emittance, twiss parameters and phase space density in one shot for both planes!

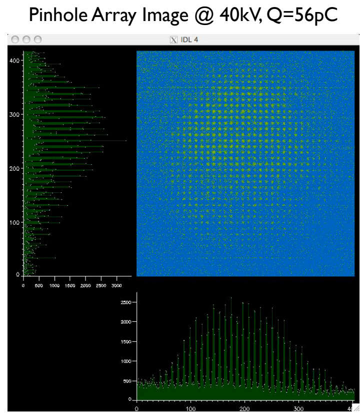
Single Slit Image @ 40kV, Q=40pC



ΔL=39mm, I_{sol}=+0.81A → B_z=47.3mT
Beam size at slit: σ_x=715μm

$$\varepsilon_x = (2.54 \pm 0.29) \cdot 10^{-6} \text{ m rad}$$

Pinhole Array Image @ 40kV, Q=56pC



ΔL=39mm, I_{sol}=+0.44A → B_z=25.7mT

$$\varepsilon_x = (1.47 \pm 0.29) \cdot 10^{-6} \text{ m rad}$$
$$\varepsilon_y = (2.14 \pm 0.43) \cdot 10^{-6} \text{ m rad}$$

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