Status Report

100 keV DC Gun Test Stand

May 17, 2006
What Happened Since the MAC Meeting

- The short (and miserable) life of SRI-1257C
  - Maximum emission no higher than $\sim 300 \, \mu A$ and $\sim 5 \, pC$
  - Bad pulse shape
  - Lots of discharges from tips to gate $\rightarrow$ can cause HV breakdown
  - Gradual decrease of ohmic resistance between tips and gate
    (from $> 2 \, M\Omega$ down to $\sim 55 \, k\Omega$)
  - Bridged $\rightarrow$ no emission $\rightarrow$ R.I.P.

- Inserted new FEA (SRI-1257B)
  - Stable operation possible up to $\sim 2 \, mA$ and $\sim 80 \, pC$
  - Decent pulse shape
  - More emission possible by further increasing gate voltage $\rightarrow$ however, this causes sporadic discharges from tips to gate $\rightarrow$ avoid such operation due to risk of HV breakdown
What Can Be Measured at Low Intensity

- No transverse single-shot measurements possible (SNR of P43!)
- No obstructive transverse measurements possible (slits, pepper-pot)
  → Integrate over several shots in order to increase signal level
  → Minimize noise level (no ambient light sources, narrow shutter time)

![Graph showing Sigma_x vs z for different intensity levels](image-url)

- 40kV, $U_g=190V \rightarrow 1mA/59pC$, 10 shot average
- $I_{sol} = 49.3mT$
- $I_{sol} = 43.3mT$
- $I_{sol} = 37.3mT$
- $I_{sol} = 31.3mT$
Emittance Measurement

- Can emittance still be derived without obstructive measurements?
- Yes! Theoretical understanding of solenoid focussing $\rightarrow$ “Solenoid Scan”

$$\sigma_{x,y}^{(i)} = f(l_{\text{sol}}^{(i)}, \epsilon, \alpha_s, \beta_s)$$
Solenoid Scan Measurement Method (1)

- Solenoid is a focusing element and a rotator \( \rightarrow \) if measurement is rotationally symmetric, treat solenoid as pure focusing element in both transverse planes.

\[
\mathbf{M} = \mathbf{M}_S \mathbf{M}_L = \begin{pmatrix} 1 - L \cdot kl & L \\ -kl & 1 \end{pmatrix}
\]

where \( k = \left( \frac{\int B ds}{2 p/e} \right)^2 \)

- Use thin lens approximation and calculate transformation of Twiss parameters from transfer matrix.

\[
\begin{pmatrix} \beta \\ \alpha \\ \gamma \end{pmatrix} = \begin{pmatrix} C^2 & -2CS & S^2 \\ -CC' & CS' + C'S & -SS' \\ C'^2 & -2C'S' & S'^2 \end{pmatrix} \begin{pmatrix} \beta_s \\ \alpha_s \\ \gamma_s \end{pmatrix}
\]

\[
\sigma^2 = \varepsilon \beta = C^2 \varepsilon \beta_s - 2SC \varepsilon \alpha_s + S^2 \varepsilon \gamma_s
\]
Solenoid Scan Measurement Method (2)

- Beam size can be expressed as a function of $k$

$$
\sigma^2 = \varepsilon \beta = C^2 \varepsilon \beta_s - 2SC \varepsilon \alpha_s + S^2 \varepsilon \gamma_s
$$

$$
= k^2 \left( L^2 l^2 \varepsilon \beta_s \right) + k \left( 2L^2 \varepsilon \alpha_s - 2Ll \varepsilon \beta_s \right) + \left( \varepsilon \beta_s - 2L \varepsilon \alpha_s + L^2 \varepsilon \gamma_s \right)
$$

- Parabolic fit for $\sigma^2(k) \rightarrow c_i \rightarrow$ Twiss parameters

$$
\varepsilon^2 = \frac{c_0c_2 - c_1^2/4}{L^4l}
$$

$$
\beta_s = \frac{1}{\varepsilon} \frac{c_2}{L^2l^2}
$$

$$
\alpha_s = \frac{1}{\varepsilon} \left( \frac{c_1}{2L^2l} + \frac{c_2}{L^3l^2} \right)
$$

$$
\gamma_s = \frac{1}{\varepsilon} \left( \frac{c_0}{L^2} + \frac{c_1}{L^3l} + \frac{c_2}{L^4l^2} \right)
$$
Solenoid Scan Measurement Method (3)

- Derive source properties by backtracking from solenoid through drift space

\[
\beta = \frac{1}{\gamma} = \frac{1}{\gamma_s}
\]

\[
\sigma = \sqrt{\varepsilon \beta} = \sqrt{\frac{\varepsilon}{\gamma_s}}
\]

\[
\Delta s = \frac{-\alpha_s}{\gamma_s}
\]

- Implemented application **SOLSCAN** that takes raw measurement data, transforms \( l_{\text{sol}} \) to \( k \) values, plots measurement data, fits the parabola, calculates the optical parameters and outputs them together with the phase space ellipse
Example Solenoid Scan Measurement (1)
Example Solenoid Scan Measurement (2)

40kV, z=293mm, U_g=184V -> 661µA, 39.6pC, 10 shot average
Example Solenoid Scan Measurement (3)

40kV, z=293mm, U_g=184V -> 661uA, 39.6pC, 10 shot average

\[ (\sigma_x)^2 \ [m^2] \]

\[ k \ [1/m^2] \]

Fit \( f(x) = c_2 x^2 + c_1 x + c_0 \)
Example Solenoid Scan Measurement (5)

\[ \epsilon_n = (4.01 \pm 0.12) \cdot 10^{-7} \, \text{m} \cdot \text{rad} \]
\[ \beta = (0.216 \pm 0.013) \, \text{m} \]
\[ \alpha = (-5.669 \pm 0.277) \, \text{rad} \]

source: \[ \sigma = (8.05 \pm 0.22) \cdot 10^{-5} \, \text{m} \]
Application: Emittance vs. Bunch Charge

40kV, z=344mm, 10 shot average

Normalized Transverse Emittance [m*rad]

Bunch Charge [pC]
Outlook

• Non-linear fit, thick lens evaluation of measurement data
  → Improve emittance measurement
  → Verify if current results are correct (thin lens approximation!)

• Obstructive measurements (slits, pepper-pot) with max. beam intensity
  (or with a different FEA type which emits a decent amount of charge!)
  → Improve emittance measurement
  → Reconstruction of phase space density, not just Twiss parameters
  → Single-shot measurement
  → Measure emittance at any solenoid setting

• Compare/benchmark these different measurement techniques

• Try to calibrate MAFIA model to experimental data