Experimental results with the SPARC emittance-meter

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**GUN PARAMETERS**

- **Frequency:** 2856 MHz
- **Peak Field:** 120 MV/m
- **Beam Energy:** 5.6 MeV
- **Charge:** 1 nC
- **Emittance:** < 2 mm-mrad
- **Laser:** 10 ps (Flat Top with <2 ps rise time)

**LINAC PARAMETERS**

- **Frequency:** 2856 MHz
- **Accelerating Field:** 25 MV/m
- **Wavelength:** 530 nm

**FEL PARAMETERS**

- **Frequency:** 2856 MHz
- **Wavelength:** 530 nm
- **Energy Spread:** $10^{-3}$
- **Peak Current:** 100 A
Recently Approved Project
SPARX
1-2 GeV ==> 10 - 1 nm FEL

C. Vaccarezza et al., Status of the SPARC - SPARX project  TUPMN039
Modified UV stretcher to obtain shorter rise time

C. Vicario et al., Drive Laser System For Sparc Photoinjector TUPMN040
Cu Cathode QE ~ 10^{-4} improved by laser cleaning

1 nc with 50 µJ laser pulse energy at 120 MV/m peak field on the cathode with a time jitter standard deviation of 350 fs

A. Gallo et al., Laser and RF Synchronization Measurements at SPARC TUPMN036
Emittance evolution for different pulse shapes
The SPARC Emittance Meter

- 7X 50 µm, 500 µm spaced
- 1X 100 µm
- 1X 50 µm

~1250 mm
Phase space reconstruction
Energy spread evolution along the drift
Beam Envelope automatic measurement
Beam Emittance automatic measurement
Result highlights
\( T = 5.6 \text{ MeV}, \ I = 92 \text{ A}, \ \varepsilon_n = 1.6 \mu\text{m} \implies B = 7 \times 10^{13} \text{ A/m}^2 \)

- Charge: 0.83 nC
- Pulse length (FWHM): 8.9 ps
- Rise time: 2.6 ps
- RMS spot size: 0.36 mm
- RF phase \((\varphi - \varphi_{\text{max}})\): -8°
phase space - simulation and measurements
Flat top vs gaussian pulse shape

- RF phase ($\varphi - \varphi_{max}$): $-8^\circ$
- RMS spot size: 0.31 mm
- Rise time: 2.6 ps
- Pulse length (FWHM): 8.7 ps
- Charge: 0.74 nC
Looking for the double minimum

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>charge</td>
<td>0.5 nC</td>
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<tr>
<td>pulse length (FWHM)</td>
<td>5 ps</td>
</tr>
<tr>
<td>rise time</td>
<td>1.5 ps</td>
</tr>
<tr>
<td>rms spot size</td>
<td>0.45 mm</td>
</tr>
<tr>
<td>RF phase ($\phi - \phi_{\text{max}}$)</td>
<td>+12°</td>
</tr>
</tbody>
</table>

C. Wang et al., Criteria for Emittance Compensation in HB Photoinjectors TUPMN103
Solenoid scan at a fixed position z = 150 cm
Emittance measurements with the selected solenoid current $I=198\ A$
Z-Scan

\[ Z \sim 1500 \text{ mm}, I_{\text{sol}} = 198 \text{ A} \]

B-Scan

\[ Z \sim 1500 \text{ mm}, I_{\text{sol}} = 198 \text{ A} \]
- HB at 150 MeV, Slice emittance
- SASE & Seeding
- Velocity Bunching
- Blow Out
- Laser Comb
- Thomson backscattering
- Plasma acceleration
- QFEL
Thank you
B-scan: Comparison between gaussian pulse - flat pulse

Flat pulse: FWHM=6 psec
Q=650 pC r.t.=1.2 psec σ=0.45 mm
φ - φ_max=8*, E=120 MV/m

Gaussian pulse: FWHM=6 psec
Q=650 pC, σ=0.45 mm
φ - φ_max=8*, E=120 MV/m

Emittance double minimum=flat pulse signature
## Tolerances

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase jitter</td>
<td>$\pm 3^\circ$</td>
</tr>
<tr>
<td>Charge fluctuation</td>
<td>$+10%$</td>
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<tr>
<td>Gun magnetic field</td>
<td>$\pm 0.4%$</td>
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<tr>
<td>Gun electric field</td>
<td>$\pm 0.5%$</td>
</tr>
<tr>
<td>Spot radius dimension</td>
<td>$\pm 10%$</td>
</tr>
<tr>
<td>Spot ellipticity</td>
<td>$3.5%$ ($x_{\text{max}}/y_{\text{max}}=1-1.035$)</td>
</tr>
</tbody>
</table>

*Minimum variation of the single parameters value for an emittance increase=10%*