Specifications on the RF-gun stability for the European XFEL photo injector (shot-to-shot as well as within the 650us pulse train):

- Phase $\rightarrow$ 0.01 deg (rms)
- Amplitude $\rightarrow$ 0.01% (rms)

Tools to achieve the specs:

- LLRF $\rightarrow$ uTCA
- Gun water cooling system (WCS)

Stability monitoring tools:

- uTCA (RF) measurements
- Beam-based procedures
Improved beam-based method for RF photo gun stability measurements

Beam based gun stability measurements - summary

Basic measurement → gun phase scan for a bunch charge (common fit of measured bunch charge and charge jitter as a function of the gun launch RF phase):

- Photocathode laser → Gaussian temporal profile
- Assuming independence of jitter sources and their normal distribution → error function (integral of Gaussian distribution) is used for fit
- Minimize the space charge effect:
  - Lower the bunch charge (laser pulse energy)
  - Lower the space charge density (increase the spot size)
- Simultaneous fit of several curves (e.g. same laser parameters)

Results (e.g. WCS=stab, FB=ON):

\[\sigma_\varphi = (0.114 \pm 0.036) \text{deg}\]
\[\sigma_{\text{laser}} = (0.951 \pm 0.127)\%\]
\[\sigma_{\text{el.noise}} = (1.976 \pm 0.205) \text{pC}\]

Laser pulse duration:
4.5 ps (rms) / 10.6 ps (FWHM)

Charge fit: \(Q_{\text{fit}}(\text{SPPhase}) = Q_{\text{bkg}} + A \cdot F_{\text{schottky}}(\varphi) \cdot (1 - \text{Erf}[C \cdot \varphi])\)

Charge error fit \(\delta Q_{\text{fit}}(\text{SPPhase})\):

- \(\delta Q_{\text{el.noise}}\) - electronic noise (scope, dark current,…)
- \(\delta Q_{\text{laser}}\) - charge fluctuations due to laser pulse energy jitter
- \(\delta Q_\varphi\) - charge fluctuations due to rf phase jitter
Simultaneous Fits of Pgun=4.5MW Measurements

<table>
<thead>
<tr>
<th>run</th>
<th>RF pulse length</th>
<th>Pgun</th>
<th>WCS</th>
<th>FB</th>
<th>shift</th>
<th>linear phase jitter (deg)</th>
<th>phase jitter (deg)</th>
<th>Laser pulse energy jitter(%)</th>
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<th>Qbig</th>
<th>Phi0</th>
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**FB=OFF**

- **S5:** phase jitter = (0.642 +/- 0.130) deg
- **S6:** phase jitter = (0.180 +/- 0.042) deg
- **S7:** phase jitter = (0.464 +/- 0.036) deg
- **S8:** phase jitter = (0.114 +/- 0.036) deg

**FB=ON**

- RMS phase jitter = 0.180 deg
- Laser rms (fwhm) = 4.50(10.60) ps
- RMS laser pulse E-jitter = 0.951 %
- RMS el. noise = 1.98 pC

**WCS → Operation**

- S5: phase jitter = (0.642 +/- 0.130) deg
- RMS phase jitter = 0.642 deg
- Laser rms (fwhm) = 4.50(10.60) ps
- RMS laser pulse E-jitter = 0.951 %
- RMS el. noise = 1.39 pC

**WCS → Stabilization**

- S7: phase jitter = (0.464 +/- 0.036) deg
- RMS phase jitter = 0.464 deg
- Laser rms (fwhm) = 4.50(10.60) ps
- RMS laser pulse E-jitter = 0.951 %
- RMS el. noise = 2.04 pC

**WCS → Operation**

- S6: phase jitter = (0.180 +/- 0.042) deg
- RMS phase jitter = 0.180 deg
- Laser rms (fwhm) = 4.50(10.60) ps
- RMS laser pulse E-jitter = 0.951 %
- RMS el. noise = 1.98 pC

**WCS → Stabilization**

- S8: phase jitter = (0.114 +/- 0.036) deg
- RMS phase jitter = 0.114 deg
- Laser rms (fwhm) = 4.50(10.60) ps
- RMS laser pulse E-jitter = 0.951 %
- RMS el. noise = 1.98 pC