Progress Report on the SwissFEL Injector Test Facility

SwissFEL

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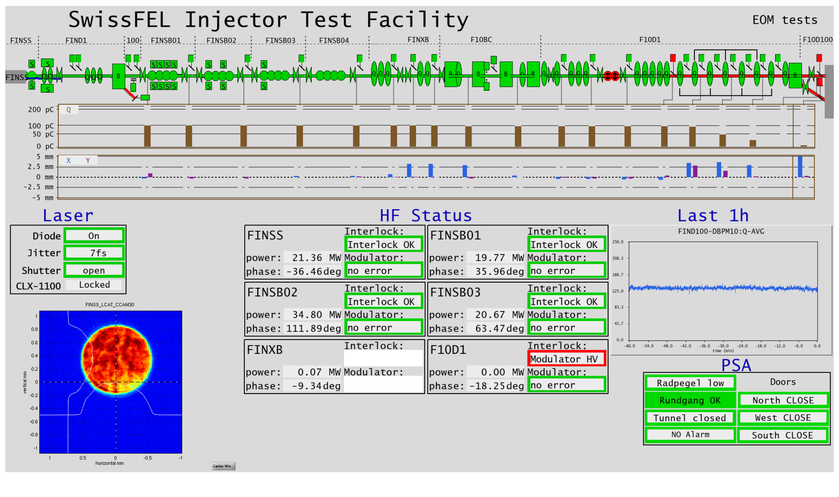
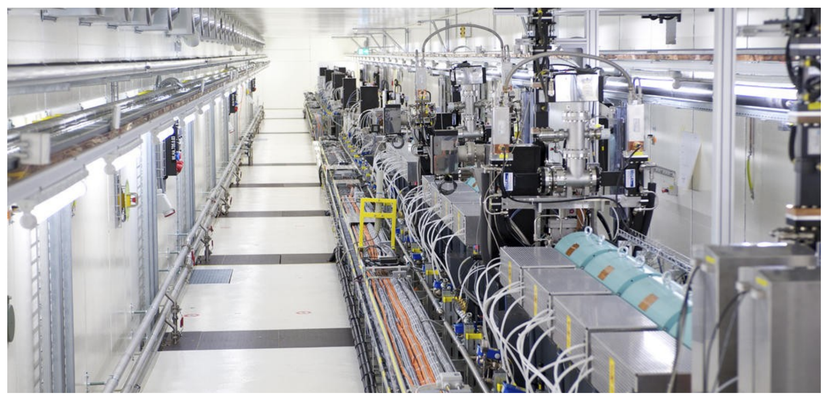
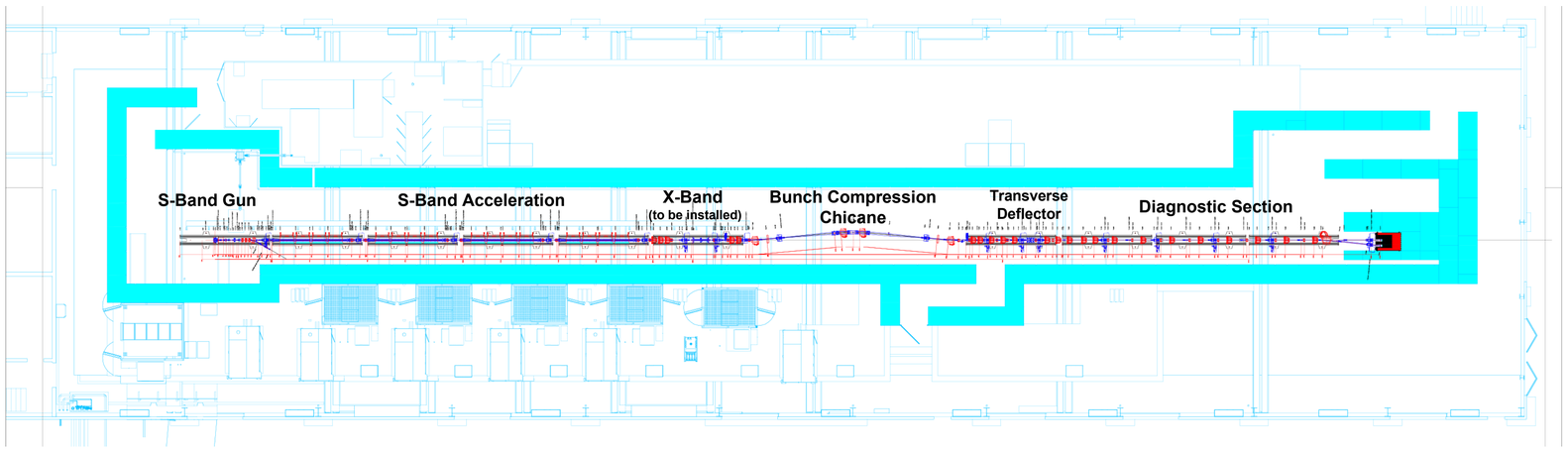
Abstract

The SwissFEL injector test facility at the Paul Scherrer Institute is the principal test bed and demonstration plant for the SwissFEL project, which aims at realizing a hard-X-ray Free Electron Laser by 2017. The RF photoinjector facility has been in operation since 2010 and has recently reached its design energy of 250 MeV. A newly installed movable magnetic chicane allows longitudinal bunch compression studies. We report on the first experience with the bunch compressor and present the latest results of projected and slice emittance measurements.





Machine layout



Commissioning phases

Phase 1: Electron source and diagnostics

March 2010 to June 2010
Characterization of the electron source (Nd:YLF laser)
Installation of remaining machine behind shielding wall

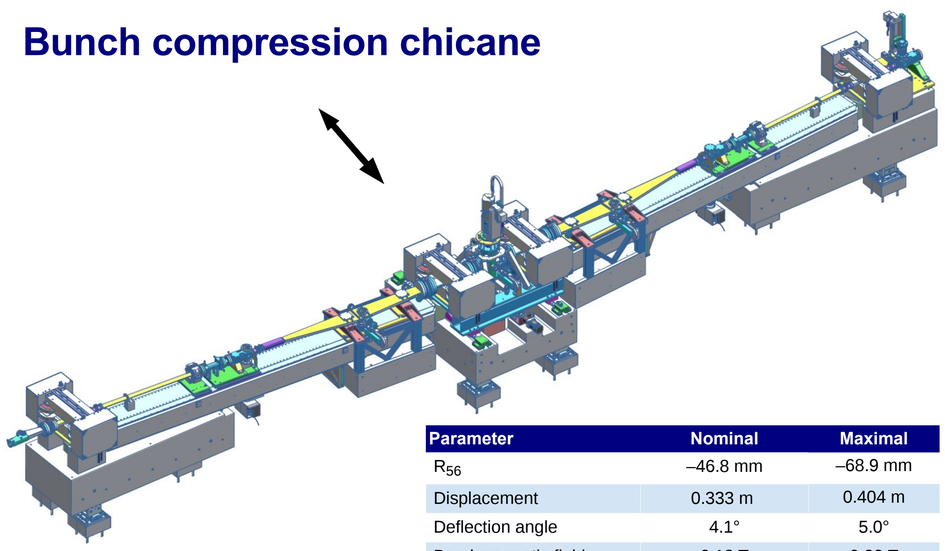
Phase 2: Phase 1 + S-band acceleration

August 2010 to May 2011 (official injector inauguration 24 August)
Optics matching and emittance measurements
Nd:YLF and Ti:Sapph laser

Phase 3: The full machine

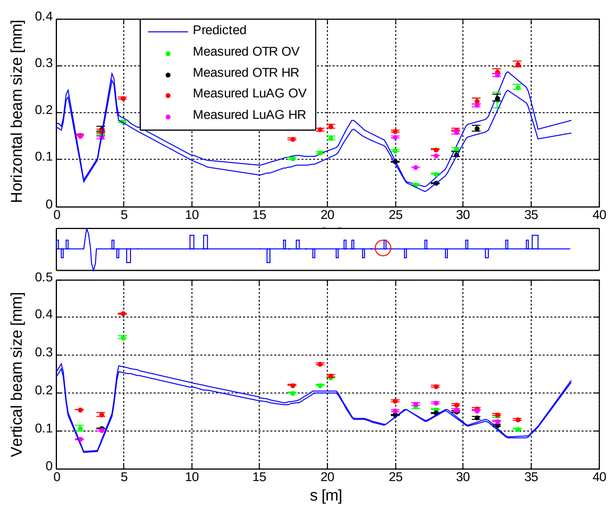
Started April 2012, Ti:Sapph laser
With bunch compression chicane
X-band cavity to be installed in summer 2012

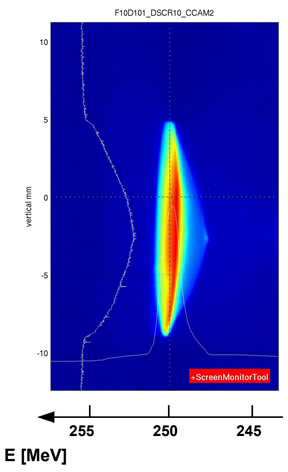
Bunch compression chicane



Parameter	Nominal	Maximal
R_{56}	–46.8 mm	–68.9 mm
Displacement	0.333 m	0.404 m
Deflection angle	4.1°	5.0°
Bend magnetic field	0.18 T	0.22 T
Total length	11.16 m	
Inner drift length	0.75 m	
Outer drift length	7.0 m	
Dipole length (effective)	0.25 (0.303 m)	

Beam optics matched and understood





Beam energy ≥ 250 MeV
(first reached on April 11)

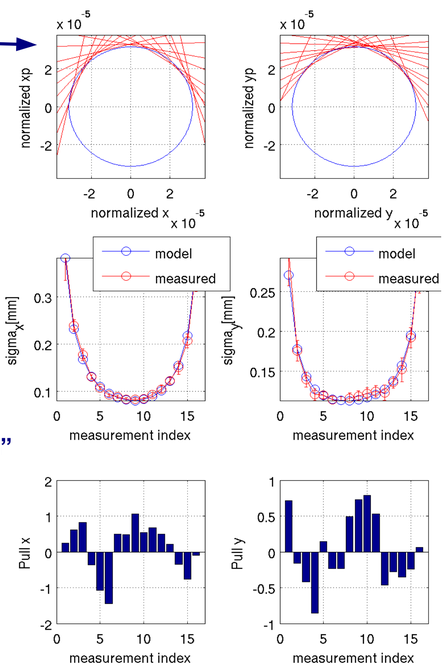
(for bunch compression studies energy limited to ~230 MeV)

Projected emittance

ε_{proj}(x) = 0.45 mm mrad
ε_{proj}(y) = 0.44 mm mrad

Main method: "single-quad scan"

- *Phase-advance scan with single quad:* use last matching quad upstream of FODO section to generate phase advance simultaneously in x and y. Possible if optics at quad fulfils some conditions (matching is crucial):
  - $\beta_x = \beta_y = \beta_0$, $\alpha_x = \alpha_y = \alpha_0$ (same optics x and y)
  - $\alpha_0 \times L = \beta_0$ (L is distance to observation screen)
- Beam size measurement with screen downstream of FODO section.



Alternative method: "multi-quad scan"

- *Phase-advance scan with three quads:* use three quads upstream of FODO section to generate phase advance, first in x then in y, while keeping the beam size under control.
- Beam size measurement with screen downstream of FODO section.

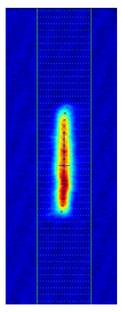
(No longer used: "FODO scan")

Optimization (parameter study) ongoing...

Slice emittance

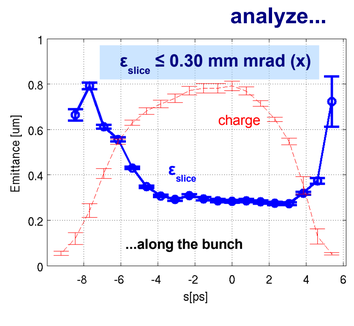
Method:

- *Transverse deflection ("streaking"):* the bunch is streaked in the transverse deflecting cavity, then recorded on a screen downstream of the FODO section.
- *Phase-advance scan:* change optics using five matching quads between transverse deflecting cavity and FODO section:
  - Generate regular phase advance in x
  - Keep beam size under control
  - Keep longitudinal resolution constant
- *Slice analysis:* split beam into slices (use centroid from Gauss fit as reference). Beam size from Gauss fit to slice profile.
- *Transverse deflector calibration:* change deflector phase at each optics setting to obtain individual mm ↔ ps calibration for each optics setting (add the data for increased statistics).
- *Mismatch parameter:* determined for each slice, checked against central slice and design optics.



streak & slice

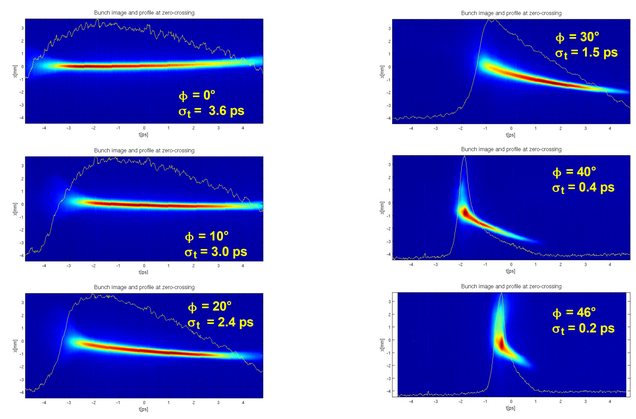
analyze...



Bunch compression

- First demonstration of bunch compression (April 18)
- Bunch length (rms from Gauss fit) reduced from 3.6 ps to 200 fs.
- BC angle 4.07° (R_{56} = –46.19 mm)

ϕ: phase in FINSB03/04
σ_t: bunch length



3.6 ps → 200 fs (rms)

Conclusion and outlook

- After consolidation of S-band RF systems, reached design energy of 250 MeV (200 pC bunch charge).
- Projected emittance measured, below 0.5 mm mrad in both planes.
- Slice emittance measured in the horizontal plane, below 0.3 mm mrad for core slices.
- Successful demonstration of bunch compression (3.6 ps to 0.2 ps rms).
- X-band harmonic cavity in front of bunch compressor will be installed in summer 2012.

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