The Superconducting CW Driver Linac for the BESSY FEL User Facility

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The BESSY-FEL User Facility

- Three independent FELs using HGHG
  - FEL 1: 24-120 eV, FEL 2: 100-600 eV, FEL 3: 500-1000 eV
- CW Operation
Linac Layout

- RF Photoinjector (65 A)
- BC2 (2 kA)
- Arc (240 A) 753 MeV
- L2
- BC1 (200 A)
- L1 + Booster (L0)
- L3
- EXT1
- L4
- EXT2
- 219 MeV
- 3rd harmonic cavity
- 1020 MeV
- 2300 MeV
- Collimators
- FEL3
- FEL2
- FEL1
- EXT2
The Injector

- Initially use NC Injector based on PITZ
- 1 kHz operation, 2.5% duty factor → 75 kW
- Improved cooling required
- For 2.5 nC bunches slice emittance < 1.5 π mm mrad

- Upgrade: CW superconducting gun
- Preliminary simulations: required slice emittance can be attained with a split system

![Diagram of the Injector system]
The Accelerating Modules

- Use TTF-type modules with 8 TESLA cavities each
- 15.7 MV at $Q > 1.3 \times 10^{10}$ (conservative)
- 1.8 K operation, $Q > 2 \times 10^{10}$ → design for 1.8 K
- Dynamic power < 20 W/cavity, 3 kW/linac
- Modified layout to handle larger CW power

One supply valve per module

- Enlarged chimney to 90 mm ID
- Reservoir with heater and level meter
- Enlarged 2-phase supply line to 100 mm ID
- One supply valve per module

Section 1
Section 2
Section 3
Section 4

Modules 1-8
9-18

EXT1
Arc+BC2
BC1

Helium plant

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Cryogenics

- Simulations of 2-phase flow
- No boiling in LHe expected
- Pressure drop in linac is < 0.1 mbar
- 2-phase flow is stratified and stable

A = 1.800 K
B = 1.802 K
C = 1.803 K
D = 1.805 K

Pressure drop

- Pressure in 2-phase line
- Pressure in the gas-return pipe
- Pressure in warm by-pass sections

1.8-K operation

Non Stratified

Stratified

Liquid helium level/tube diameter

Position (m)

Pressure (mbar)
RF System

• RF Power
  – Require 15 kW peak, 5 kW ave due to microphonics
  – Each cavity powered by a 20 kW transmitter for flexibility
  – IOTs are more efficient than klystrons → investigate in HoBiCaT

• RF Feedback
  – Low-level RF using digital FPGA-based system
  – Simulate performance
  – Timing jitter < 50 fs can be achieved
Bunch compression

- Bunch compression optimized to limit emittance dilution due to CSR effects
  - use more, but shorter magnets with weaker fields
  - S chicane preferred over U chicane

BC1
- 6 magnet chicane
- Lowest possible energy to limit required voltage of 3rd harmonic cavity
- Space-charge effects $\rightarrow > 219$ MeV

Arc+BC2
- Arc must precede BC2 to limit CSR
- Arc is isochronous
- BC2: 8 magnet chicane
- Two additional quads for flexibility in adjusting $\beta$-function
- CSR $\rightarrow$ Energy limited to 753 MeV
Beam quality

- Start-to-end simulations to determine quality of beam
  - ASTRA from the gun to the injector where space charge effects end
  - ELEGENT from Injector to the collimator

- $\varepsilon < 1.5 \pi \text{ mm mrad (slice)}$
- $\sigma_E/E < 5 \times 10^{-5} \text{ (slice)}$