Review the status of:
• beam dynamics understanding and simulations
• completeness of beam line description
• conceptual design of beam line components

Identify:
• What has been done
• What has to be done
• Which information or prerequisite is missing to continue the work
Topics

- Injector Introduction - Klaus Flöttmann
- Injector Simulations - Mikhail Krasilnikov
- Dark Current - Jang-Hui Han
- Optics - Winfried Decking
- Standard Diagnostics - Dirk Nölle
- PITZ Transverse Deflecting Structure - Sergey Korepanov
- Special Diagnostics - Holger Schlarb
- Beam Dump - Michael Schmitz
- Warm Magnets - Bernward Krause
- Vacuum Issues - Kirsten Zapfe
The injector starts at the gun and ends at the beginning of the first module in linac 1.
Introduction

- XFEL Injector is based on the FLASH / PITZ injector
- Will be housed in large hall on DESY site XSIN/XSE

- New design of section between gun and module
  - more space for more diagnostic and dark current removal kicker
- Special Gun RF components
  - high power T-combiner
  - high power RF window
  - high power, high precision directional coupler
Simulations

Beam transverse rms size and normalized emittance

- **Xemit (Ek=0.55eV), mm mrad**
- **Xrms (Ek=0.55eV), mm**

**proj.emittance 0.87 mm mrad**
Simulations

- Finalize Design of Gun-Module-Intersection

- Studies of tolerances for cathode laser parameters: FWHM, rise/fall time, flat-top modulation
- Influence of the vacuum components (like a vacuum mirror, diagnostic cross etc) on the beam quality
- Impact of photo injector imperfections (misalignment)
- Velocity bunching
- Explore gun parameter space (charge, bunch shaping, …)
Dark Current

- extrapolation of PITZ measured dark current to XFEL parameters
  - a reduction by 3 - 4 orders of magnitude is needed

\[ I_{ix} = C_1 E^{2.3} \exp(-C_2/E) \]

\[ \sim 0.2 \text{ mA} \]

\[ \sim 4 \text{ mA} \]

- include momentum and geometrical collimators between gun and module
  - momentum collimation especially efficient with longer half cell
  - position of geometrical collimator not optimized
  - these measures give reduction by factor of 30 in simulations
- improve cathode preparation (cleaning & polishing), conditioning, geometry (larger plug area) and mounting
- dark current kicker to collimate in time domain
  - this may require placement of absorbers into the module
- foresee additional momentum collimation in dogleg
Injector Beam Line Optics

Diagnostic Section

Dogleg ($R_{56} \approx -0.015$ m)

XFEL Injector - 24.06.05
Unix version 8.51/16
23/10/06 10.31.14

$\beta (m)$

$D (m)$

$s (m)$
Injector Beam Line Optics

• What’s missing
  – laser heater section (before diagnostic)
  – transverse deflecting structure
  – possibility of additional bunch compression

• Next Steps
  – refine diagnostic section, include laser heater, study bunch compression options
    Affects only XTIN, enough space, less time critical
  – improve chromatic/dispersive properties of dogleg
    May influence XSIN layout, asap
Standard Diagnostics

Injektor II

Gun Diagnostics
- 2+1 BPM (Button)
- 2+1 Screen & Faraday Cup
- 1 Toroid
- 1 Dark Current

Diag. Section
- 1 Cold BPM
- 5 BPM (Stripline?)
- 4 OTR/WS
- 2 Toroid
- 1 Dark Current

Spectrometer/Dump
- 2 BPM
- 1 Toroid
- 1 OTR/WS

Dogleg + U-Booster
- 6 BPM
- 1 OTR/WS
- 1 Toroid
- 1 Dark Current
- 1 SR Port

• Precision aligned BPMs needed
• Procure HOMCoupler-BPM electronics
• add SR ports

Beam Line Review Injector Summary 15/11/06 Winni Decking
Standing wave (classic and ‘Paramonov’) and traveling wave cavities (1.3 GHz) studied for diagnostic section at PITZ
Resolution limited due to longitudinal field component

<table>
<thead>
<tr>
<th></th>
<th>Classic cavity</th>
<th>“Paramonov” cavity</th>
<th>Travelling wave cavity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tomography</td>
<td>Dispersive</td>
<td>Tomography</td>
</tr>
<tr>
<td>Distance, m</td>
<td>2-4.2</td>
<td>6</td>
<td>2-4.2</td>
</tr>
<tr>
<td>$V_{\perp}$, MV</td>
<td>0.85-1.8</td>
<td>0.6</td>
<td>0.85-1.8</td>
</tr>
<tr>
<td>Q</td>
<td>21000</td>
<td>21000</td>
<td>15000</td>
</tr>
<tr>
<td>$P_{RF}$, MW</td>
<td>up to 1</td>
<td>0.12</td>
<td>up to 0.17</td>
</tr>
<tr>
<td>Field build up, $\mu$s</td>
<td>~20</td>
<td>~20</td>
<td>~20</td>
</tr>
<tr>
<td>Resolution</td>
<td>0.35 mm</td>
<td>25 keV</td>
<td>0.35 mm</td>
</tr>
</tbody>
</table>
Special Diagnostics - Wish List

• laser arrival time monitor (< 50 fs) (must)
  ➢ EOM technique
  ➢ balanced DFG generation (LbSyn versus UV)
• relative gun phase to laser phase monitor (can)
  ➢ launch of parasitic laser pulses (<50fs)
• high precision e-beam arrival time monitor (must)
  ➢ specs: < 30fs arrival time precision w.r.t LbSyn @ 5MHz readout
• transverse deflection structure for (must)
  ➢ longitudinal profile measurements: $\sigma_{res} < \sigma_t/20 = 300\text{fs}$
  ➢ slice emittance measurements: $\sigma_{res} < \sigma_t/10$, $d\varepsilon_{res}/\varepsilon < 10\%$
  ➢ slice energy spread: $\sigma_E < 1.3 \text{ keV}$
• online transverse profile control within macro-pulse (recommended)
  ➢ kicker and off-axis screens
• online longitudinal profile control (recommended)
  ➢ low frequency detector (50-400GHz), [fast, no bunch info]
  ➢ steak camera [only single shot, pure dynamic range]
  ➢ EO [multi-bunch possible, medium dynamic range]
• Several special diagnostic instruments still under development

• Special diagnostics concept has to be detailed
  – Reevaluate TDS specifications and resolution
  – Redesign lattice
  – Evaluate possible conflicts with dump requirements in the spectrometer/dump arm
Beam Dump

Required capability: \( E_0 \leq 300 \text{ MeV}, \ N_t \leq 2.5 \times 10^{13} \text{ e-} = 4 \mu \text{C}, \ I_{\text{ave}} \leq 40 \mu \text{A}, \ P_{\text{ave}} \leq 12 \text{ kW} \)

- Average heating no issue, slow sweep not required
- Cyclic effects determine the beam size
  - single bunch limit \( \geq 20 \mu \text{m} \) to \( 35 \mu \text{m} \), can not be decreased by fast sweeping
  - bunch train limit \( \geq 0.9 \text{mm} \) to \( 1.6 \text{mm} \) w/o fast sweep
- Fast sweeper requires 1m installation length and 2.5m resp. 5m drift space
- C-Cu dump can deal with smaller spot size than Al dump
Magnets

• Technical Specifications
  – magnet bore radius (half aperture): >20 mm
  – energy reach for magnet system: 100-150 MeV

• Quadrupols: 24
  Magnet length in beam direction: 250 mm
  Max. Gradient: 2.402 T/m
  Pole tip field: 0.048 T

• Corrector magnets: 24
  Magnet length in beam direction: 100 mm
  Field in the gap: 0.003 T

• Dipole magnets in the dogleg: 6
  Magnet length in beam direction: 500 mm
  Field in the gap: 0.314 T

• Magnet System specified
  – magnet field quality specifications missing
  – reduction of XFEL magnet types
  – responsibility for gun area magnets
Vacuum System

• FLASH injector perfect test bed for XFEL injector
  – test improvements for XFEL as soon as possible
• careful planning of complete system necessary
  – reserve sufficient space for installation of components
  – modular set-up for good accessibility of components
  – avoid patchwork installations as we do have at FLASH

Example: Flash gun section upgrade
Summary

• The present design of the injector is mainly based on FLASH
• Many system improvements under way but not fully incorporated into a coherent design
• Space contingency in the injector tunnel relieves time pressure somewhat
• Experimental program at FLASH and PITZ directed at XFEL needs has to be detailed (performance stability and reproducibility, diagnostic concepts, …)

Next Meeting
2nd Beam Line Review – Bunch Compression
December 11, 2006
14:00- 17:00