Laser Heater Optical System

Operations Meeting 10 07 2008

Outline

- Laser Heater Optical System
- Alignment and Steering Stabilization
- Beam profile
- Attenuation required for OTR screens
- Adjustment of the timing overlap of the laser and e-beams
## Laser Heater Requirements

### Laser Heater Beam Parameters

*(ESD 1.2-122)*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Range</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wavelength</td>
<td>758</td>
<td>750 - 770</td>
<td>nm</td>
</tr>
<tr>
<td>Laser Beam Waist Radius (2σ)</td>
<td>0.36</td>
<td>0.32 – 0.60</td>
<td>mm</td>
</tr>
<tr>
<td>(in the center of the undulator)</td>
<td></td>
<td>(adjustable)</td>
<td></td>
</tr>
<tr>
<td>Laser Beam Rayleigh Range</td>
<td>50</td>
<td>42-1600</td>
<td>cm</td>
</tr>
<tr>
<td>Laser Pulse Energy (nominal/high setting)</td>
<td>44/200</td>
<td>0 - 200</td>
<td>μJ</td>
</tr>
<tr>
<td>Laser Pulse Duration (FWHM)</td>
<td>20</td>
<td>10 - 20</td>
<td>ps</td>
</tr>
<tr>
<td>Centroid Position Stability</td>
<td>&lt; 35</td>
<td></td>
<td>μm</td>
</tr>
<tr>
<td>Spatial Fluence Profile</td>
<td>Gaussian</td>
<td>20% (peak-to-peak)</td>
<td></td>
</tr>
</tbody>
</table>
Before

Laser heater here

Courtesy of Paul Emma
Optical LH system installed

Laser heater here
Laser Heater Table
Optical system

- 3 lens telescope with adjustable magnification. Changes waist size and position (beam collimation)
- 2 lenses focusing the beam into the LH
- Vertical and horizontal transport tubes under vacuum. Beam has a waist inside the vertical transport tube
- 3 mirrors on the LH table in the main beam path, beam is not parallel to the table surface
- Waveplate (placed downstairs) to adjust the polarization – manual.
- Steering stabilization system in the vault (2 cameras)
- Virtual Heater camera (VHC) – diagnostics and steering stabilization
Energy Control

Fast Energy Control – Pockels Cell and polarizer
- Inrad - PKC02-SG20 : KD*P Dual Crystal Pockels Cell, with AR coated windows, with sol-gel coated crystal - Aperture 20mm

Slow Energy Control – Waveplate and polarizer
Diagnostics

- **In the Laser Lab**
  - Two powermeters – beam energy out of the laser / after the attenuator
  - Streak camera – temporal diagnostics
  - Camera – beam shape - optional

- **In the injector Vault - Upstream of the undulator**
  - Camera VHC – virtual heater (spatial shape and position of the laser beam)
  - Powermeter

- **Downstream of the undulator**
  - Photodiode for timing adjustment
  - OTR screens
Layout of the Laser Heater Optical System in the Laser Lab

Adjustment of the telescope allows to change the beam size in the Laser heater.

Energy control

- Waveplate & polarizer
- PC & polarizer
- UV Conversion Unit
- IR Laser System
- Pulse Stretcher
- 3 lens Telescope
- PH1
- PH2
- UV beam
- To streak camera
- To vertical transport tube
- Path Length Adjuster
- To vertical transport tube
- To streak camera
Transport tubes in the vault

- All transport tubes are connected
- Turbo pump upstairs
- Ion pump downstairs
Optics inside the ceiling box

- Motorized mirror MH4 (open loop)
- Focusing Lens
- Flipper with a filter to protect OTR (not in yet)

LH horizontal tube
UV beam tube
Layout of the Laser Heater Optical System in the Injector Vault

We had to put in additional lens to get the required beam size

MH4, MH3, MH2 - Motorized mirrors
Waveplate and polarizer in front of both cameras
Laser Heater Table in the Vault
Laser Heater Table in the Vault

From MH2

Waveplate

To VHC

50% beamsplitter

MH1
Alignment

- Before the magnets had been installed we put a camera in the center of the undulator.
- This camera was placed on the rail, which was aligned along the undulator axis.
- We aligned the laser beam, so that it was centered on the camera at any Z-position.
- Beam was centered on the cameras VHC and CH1.
- We adjusted the Z-position of the VHC, so that the beam size on the camera is the same as in the center of the undulator.
Alignment of the telescope for the required beam size and waist position in the LH

- Adjustment of LH2 position for the beam size
- Coarse adjustment of LH3 position to collimate the beam
- Precise adjustment of LH3 position for the minimum beam size in the center of the undulator
Precise alignment of the telescope lens LH3 for waist position

Alignment is manual

Beam R in the LH center, mm

L3 alignment, mm

-5 -4 -3 -2 -1 0 1 2 3 4 5

0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6

Beam R in the LH - w=0.32mm
Beam R in the LH - w=0.6mm

October 08 2008 Laser Heater Optics
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Beam in the Undulator Center and VHC

Undulutor Center

VHC

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Beam on the OTR’s position

OTRH 1

- $x_{\text{mean}} = 367.40 \, \mu\text{m}$
- $y_{\text{mean}} = -116.04 \, \mu\text{m}$
- $x_{\text{rms}} = 206.61 \, \mu\text{m}$
- $y_{\text{rms}} = 289.71 \, \mu\text{m}$
- corr = -0.91
- sum = 9.18 MeV

OTRH 2

- $x_{\text{mean}} = 349.43 \, \mu\text{m}$
- $y_{\text{mean}} = 378.40 \, \mu\text{m}$
- $x_{\text{rms}} = 214.27 \, \mu\text{m}$
- $y_{\text{rms}} = 356.37 \, \mu\text{m}$
- corr = 0.49
- sum = 10.61 MeV
Beam on the CH1 camera

CH1 camera

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OTR Damage Threshold

- Piece of OTR foil was placed on the OTRH1 location and illuminated by the laser beam for about 3-5 min (beam rms was about 320um).
- There was small damage at the energy 7uJ.
- At the beam energy 2.3uJ we did not see any damage.
- We will put flipper filter to attenuate the laser beam below 2uJ (at min setting of the energy control units)
- When the filter goes out, a blank plate will go in
Laser Beam Timing

- Photodiode ET-2030 in the output beam
- Oscilloscope to watch a PD signal – in the Laser lab
- Additional attenuation of the laser beam might be required

### Photodiode ET-2030 spec

<table>
<thead>
<tr>
<th>Detector Type</th>
<th>PIN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risetime</td>
<td>&lt;300ps</td>
</tr>
<tr>
<td>Falltime</td>
<td>&lt;300ps</td>
</tr>
<tr>
<td>Responsivity @830nm</td>
<td>0.4A/W</td>
</tr>
<tr>
<td>Bias Voltage</td>
<td>9V</td>
</tr>
<tr>
<td>Cut Off Frequency (into 50?)</td>
<td>&gt;1.2GHz</td>
</tr>
<tr>
<td>Active Area</td>
<td>0.4mm dia.</td>
</tr>
<tr>
<td>Dark Current</td>
<td>&lt;0.1nA</td>
</tr>
</tbody>
</table>
Things to Do before November 1

- Flipper filters
- Shutters
- Steering Feedback loop
- Photodiode – install and check required attenuation
- LH Stretcher alignment
- Pockels cell controls
Issues

- No steering feedback loop upstairs
  - Feedback loop downstairs should take care of the small beam motions
  - Large beam shift can cause clipping on the flipper filter, lens or tube windows
  - After the laser is turn on or changes in the system had been made we should check for clipping

- Multiple reflections on the cameras
  - Should replace tube windows by coated ones
Back up Slides
# Laser Heater Requirements

Physics Requirements for the Laser Beam (PRD 1.2-004)

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<tr>
<th>Parameter</th>
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<th>value</th>
<th>range</th>
<th>unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wavelength</td>
<td>$\lambda L$</td>
<td>765</td>
<td>-</td>
<td>nm</td>
</tr>
<tr>
<td>Rayleigh range</td>
<td>$LR$</td>
<td>60</td>
<td>-</td>
<td>cm</td>
</tr>
<tr>
<td>Waist size</td>
<td>$\sigma L-x,y$</td>
<td>0.2</td>
<td>-</td>
<td>mm</td>
</tr>
<tr>
<td>Energy per pulse</td>
<td>$uL$</td>
<td>24/400</td>
<td>0 - 400</td>
<td>$\mu$J</td>
</tr>
<tr>
<td>Pulse duration (FWHM)</td>
<td>$\Delta \tau L$</td>
<td>20</td>
<td>10 - 20</td>
<td>ps</td>
</tr>
</tbody>
</table>
Laser-Heater Layout

755 nm laser (25 µJ)

Paul Emma

Jan. 17, 2008; PE, AM