XFEL Photocathode Laser Operator Training

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HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

DESY.

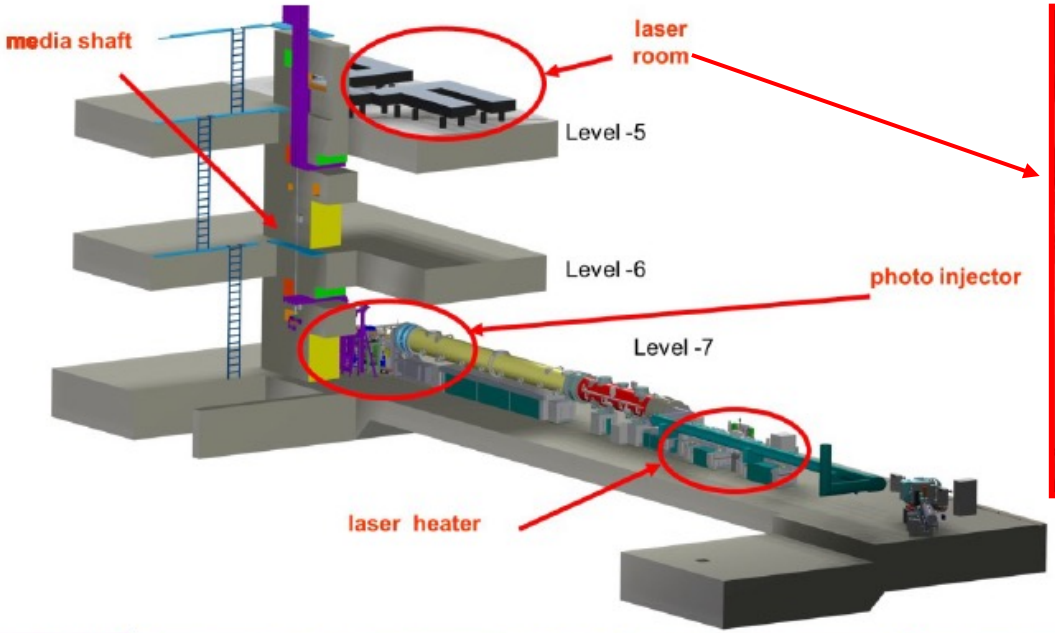
Overview

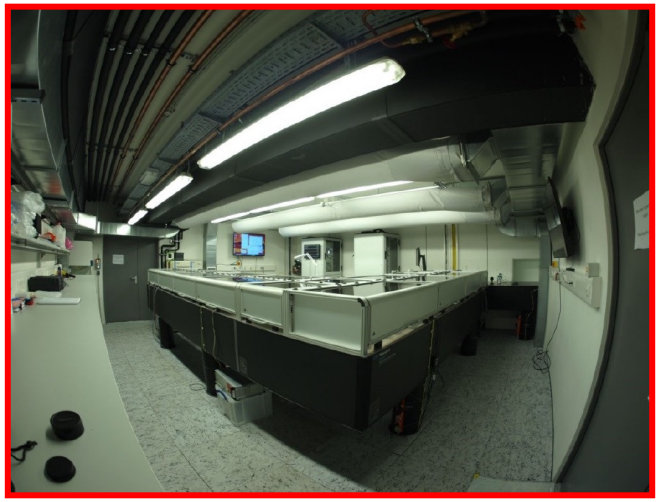
XFEL Photocathode Laser Operator Training

1. The Laser System
2. Control via DOOCS
3. Allowed & Not Allowed
4. Contacts

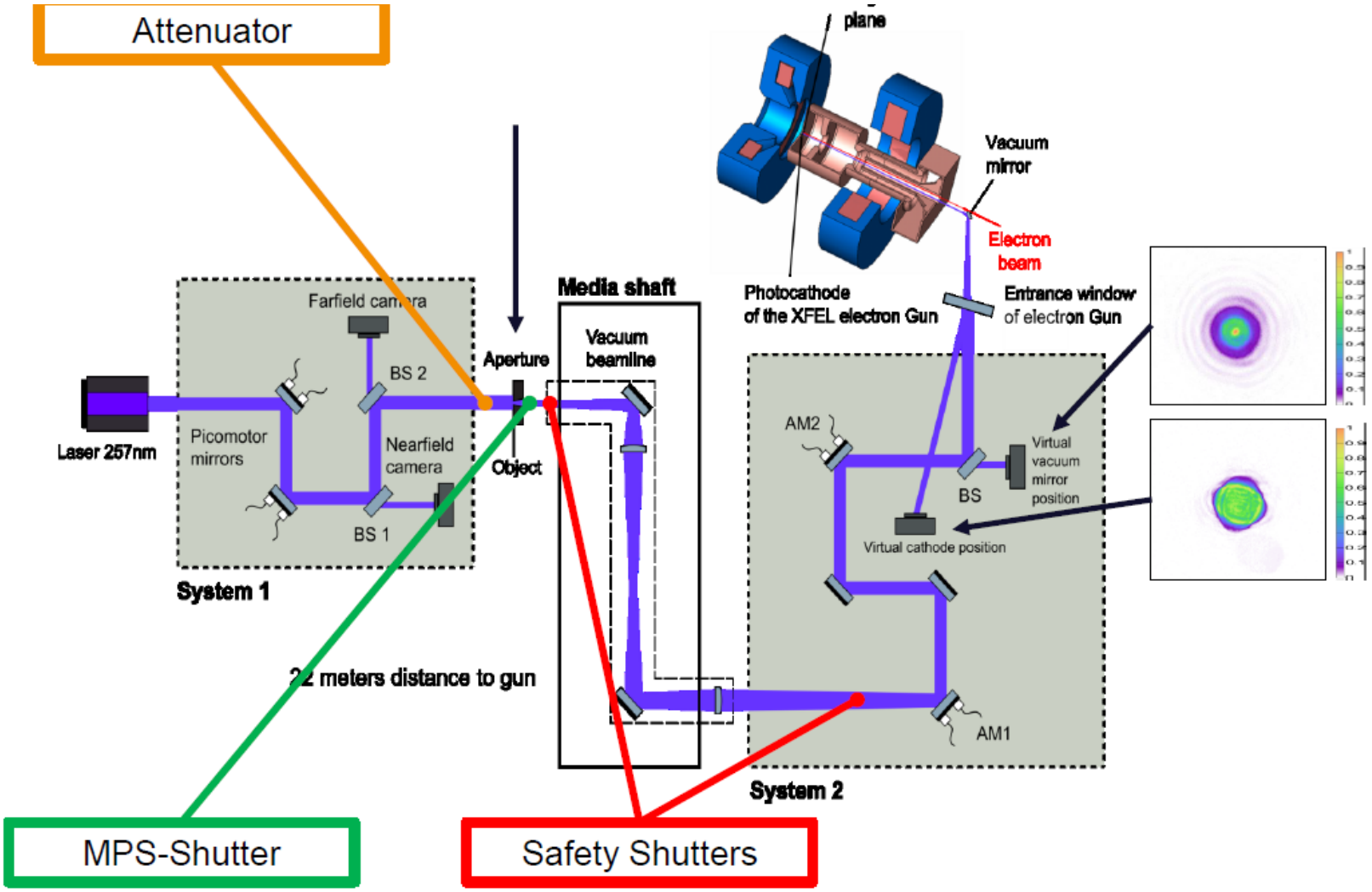
The Laser System

Photocathode Laser Building





Beamline


Attenuator
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Vacuum mirror
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Photocathode of the XFEL electron Gun
Entrance window of electron Gun
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Picomotor mirrors
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Object
BS 1
System 1
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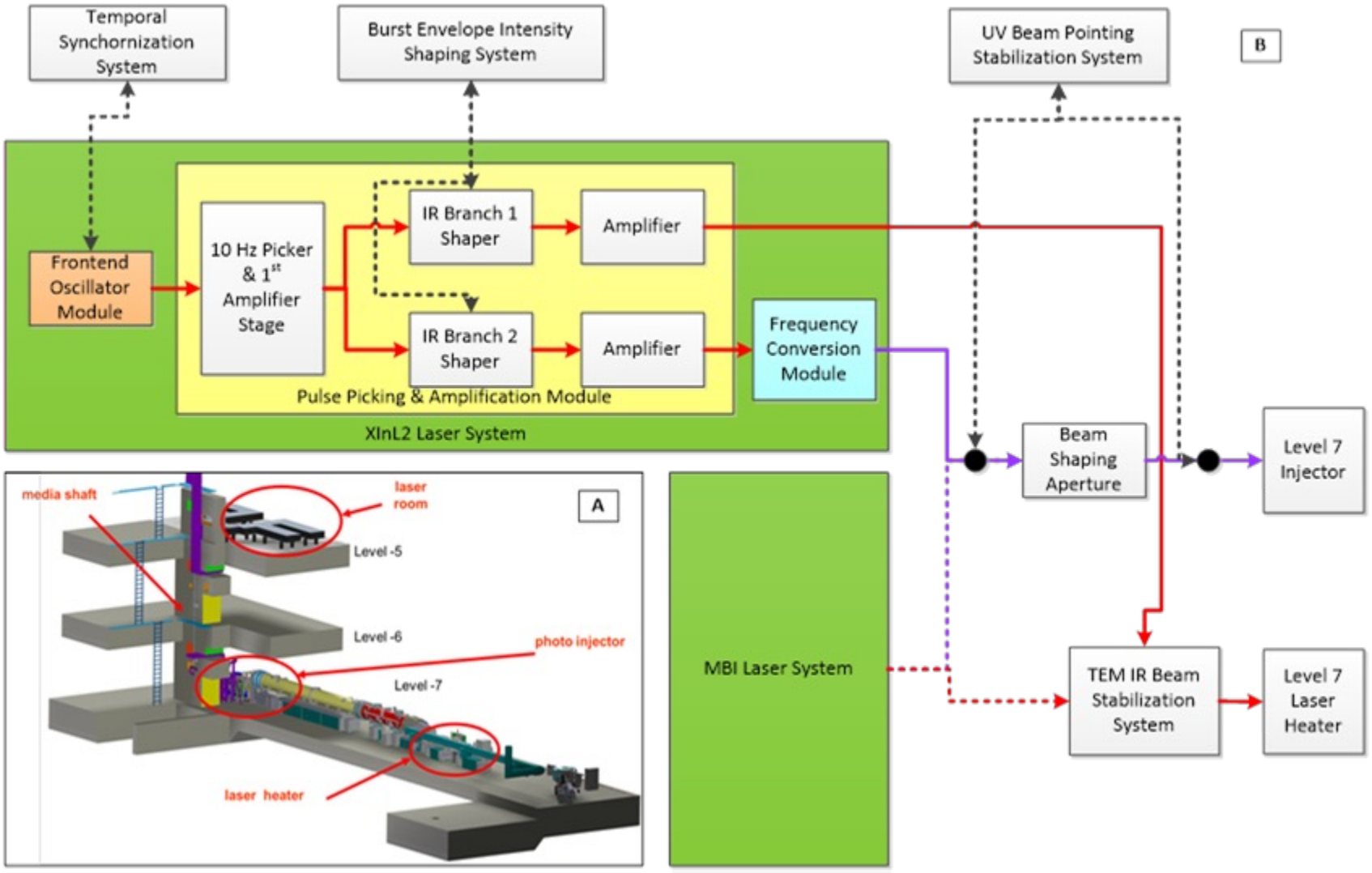
Virtual vacuum mirror position
BS
Virtual cathode position
2 meters distance to gun
AM1
System 2
MPS-Shutter
Safety Shutters

Laser 2: Prime UV Laser

266nm, 8ps, 500kHz – 4.5MHz



Laser 1 and Laser 2

- Two operational laser systems to provide backup and multiplexed simultaneous operation.
- Currently **XlnLas1** provides the light for the laser heater, **XlnLas2** provides the UV light for the photocathode.

	$Nd:YVO_4$ Laser	Yb:YAG Laser
Oscillator Type	Yb:fiber	Yb:YAG
Amplifier Type	$Nd:YVO_4$	Yb:YAG
IR Wavelength	1064 nm	1032 nm
UV Wavelength	266 nm	257 nm
Pulse Width (UV)	8 ps	Short pulse: 3 ps Long pulse: 12 ps
Intra burst repetition rate	500 kHz, 1.13 MHz, 2.25 MHz, 4.5 MHz	
Energy (UV)	>5 µJ / pulse	>3 µJ / pulse
Energy (IR)	50 µJ / pulse	

Laser 2: Hybrid Yb:fiber-NdYVO4 System

Hybrid Yb:fiber-Nd:YVO_4 Laser System

Front-End

- Saturable absorber-modelocked polarization maintaining **(pm) Yb:fiber linear cavity** design
- High speed fiber-coubled Acousto-Optic Modulator (AOM) picks pulses 4.5MHz
- pulses amplified to ~1.2µJ/pulse in **cascaded pm-Yb:fiber and Nd:YVO4 preamplifier**

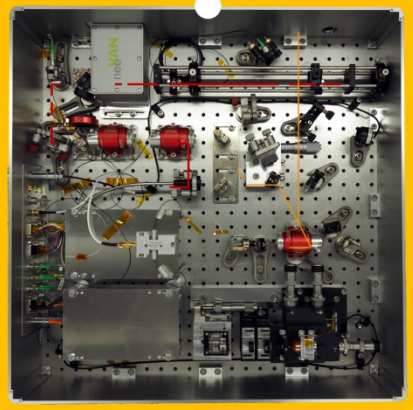


Figure 2: Hybrid Yb:Fiber Frontend Module

Pulse Picking & Amplification

- AOM B cuts out 10 Hz bursts, AMP B amplifies pulses to ~8.5µJ.
- **Parallel arms:** AOM C & AOM D shape intensity envelope, AMP C and AMP D amplify pulses to ~50 µJ / pulse in each arm.

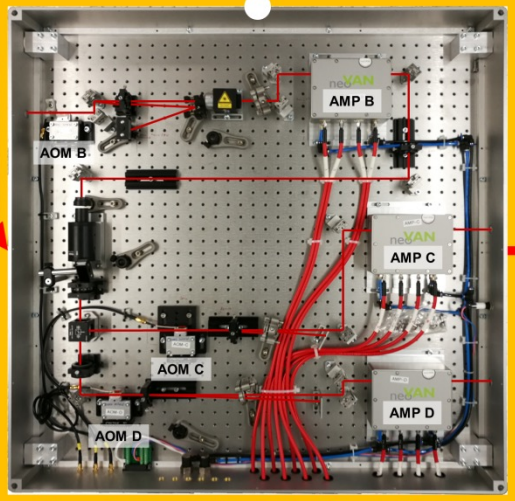


Figure 3: Pulse Picking & Amplification Module

Control Technologies

Laser Synchronization and Timing

- Phase Locked Loop (PLL) type scheme locks the oscillator repetition rate's 25th harmonic (1354 MHz) to the main RF master oscillator running at a RF cavity resonance frequency of 1.3 GHz.
- Measured drifts are compensated by acting on the set-point within the oscillator RF synchronization loop.
- Electron bunch arrival time drift of 45 fs over 8 hours demonstrated.
- Oscillator timing jitter rms is 25fs

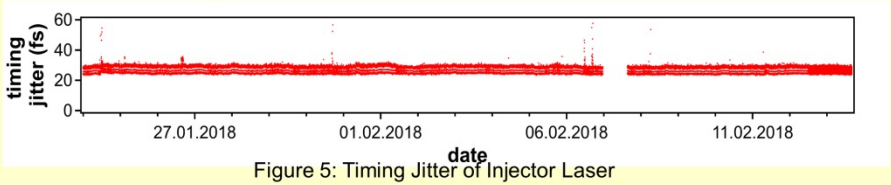


Figure 5: Timing Jitter of Injector Laser

Charge Envelope Shaping Over the Burst and Charge Stability

- FPGA-controlled fast digital to analog convertor (DAC) amplitude-modulates the RF driver of the AOMs
- <0.1% control accuracy at diffraction efficiency of 70% achieved, charge stability of 0.7rms of XFEL electron gun.

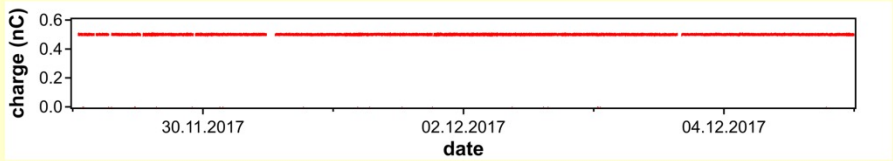


Figure 6: Charge Stability at of XFEL Electron Gun

Laser 2: Hybrid Yb:fiber-NdYVO4 System

Frequency Conversion, Beam Shaping & Transport

- **25% overall conversion efficiency**: 1064 → 532nm in 6mm critically phase-matched Lithium Borate (LBO) followed by 532nm → 266nm in 2mm beta Barium Borate (BBO).
- **Beam Shaping Aperture (BSA)** shapes gaussian beam profile into flat-top.

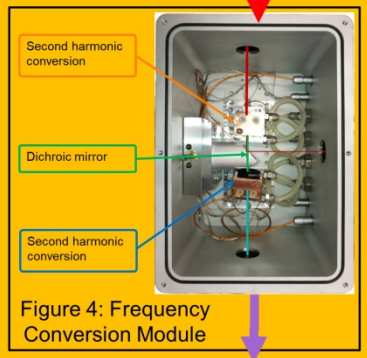


Figure 4: Frequency Conversion Module

Beam Shaping & Transport

IR Beam Stabilization

- 2 floors + 46m beamline, requires <10µm jitter in spot position at the laser heater. Demonstrated reduction of 30µm input jitter (in laser room) to 7µm rms at laser heater.
- System: 7 actuated mirrors and feedback photodiode relay.

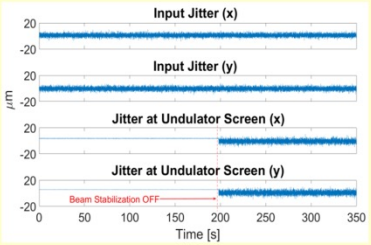


Figure 7: Effect of Active Beam Stabilization on IR Laser heater Jitter

UV Beam Stabilization

- 22m vacuum beamline without climate control, requires jitter of max 5% of beam spot at photocathode (spot size from 0.1mm to 3mm diameter). Demonstrated 1% jitter of max beam spot.
- System: actuated mirrors and UV cameras in lead-shielded housing

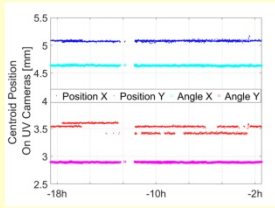
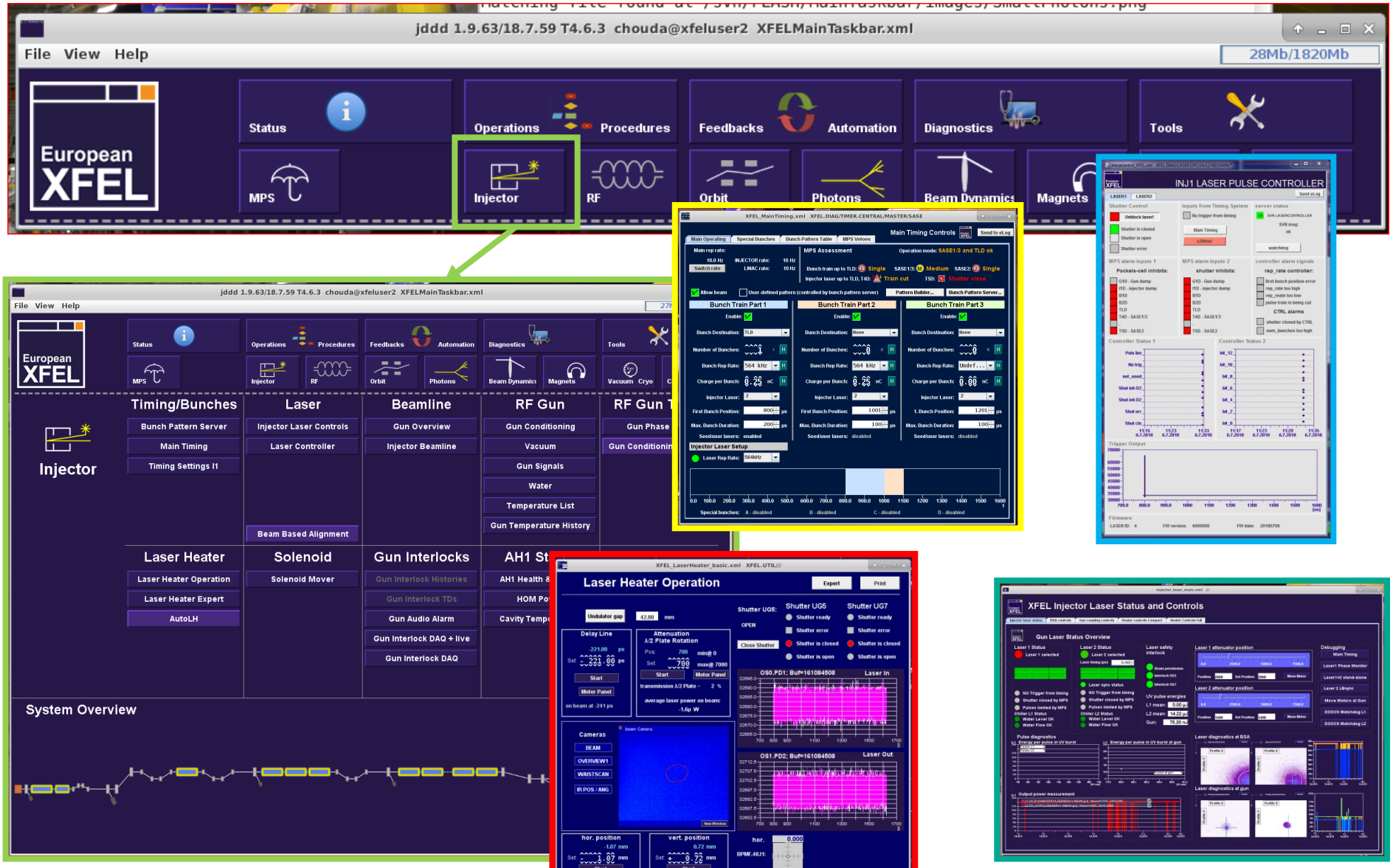


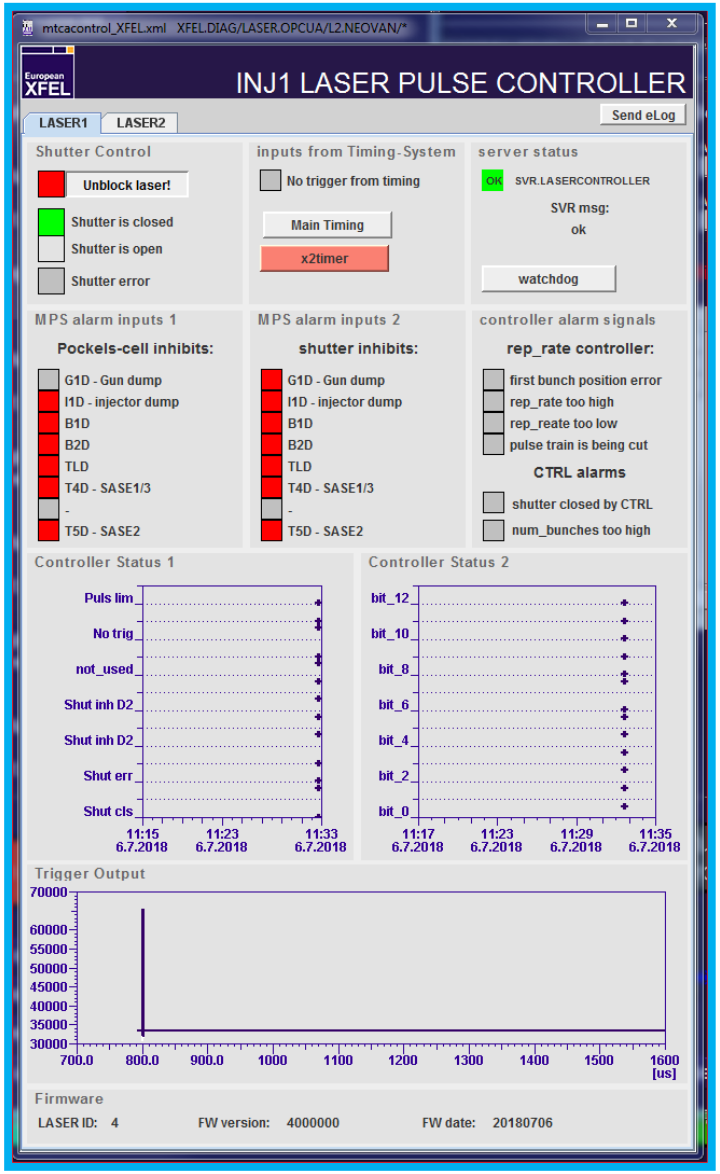
Figure 8: UV Beam Centroid at Photocathode

Info & Control via DOOCS

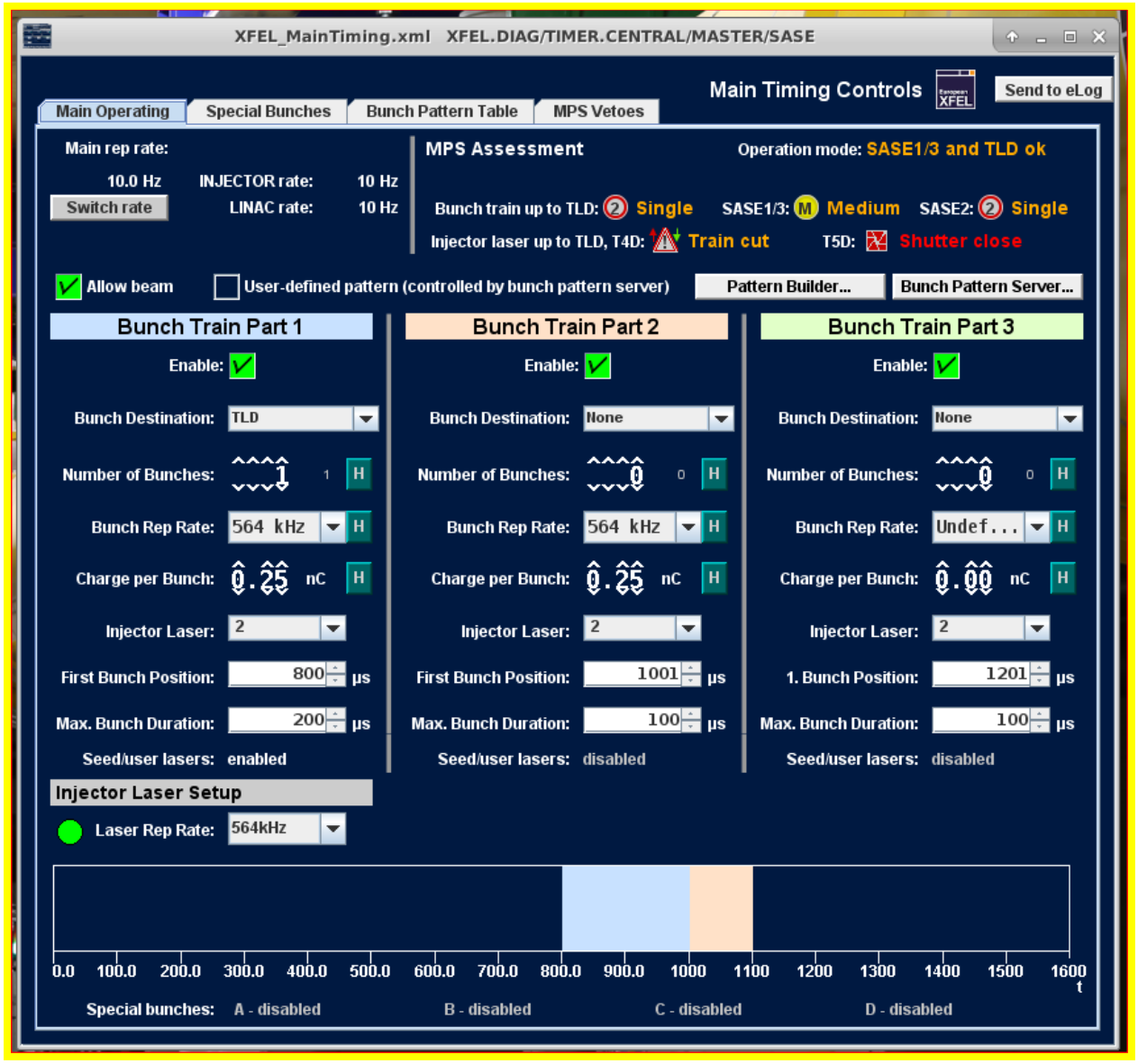
How To Get To The Laser Controls



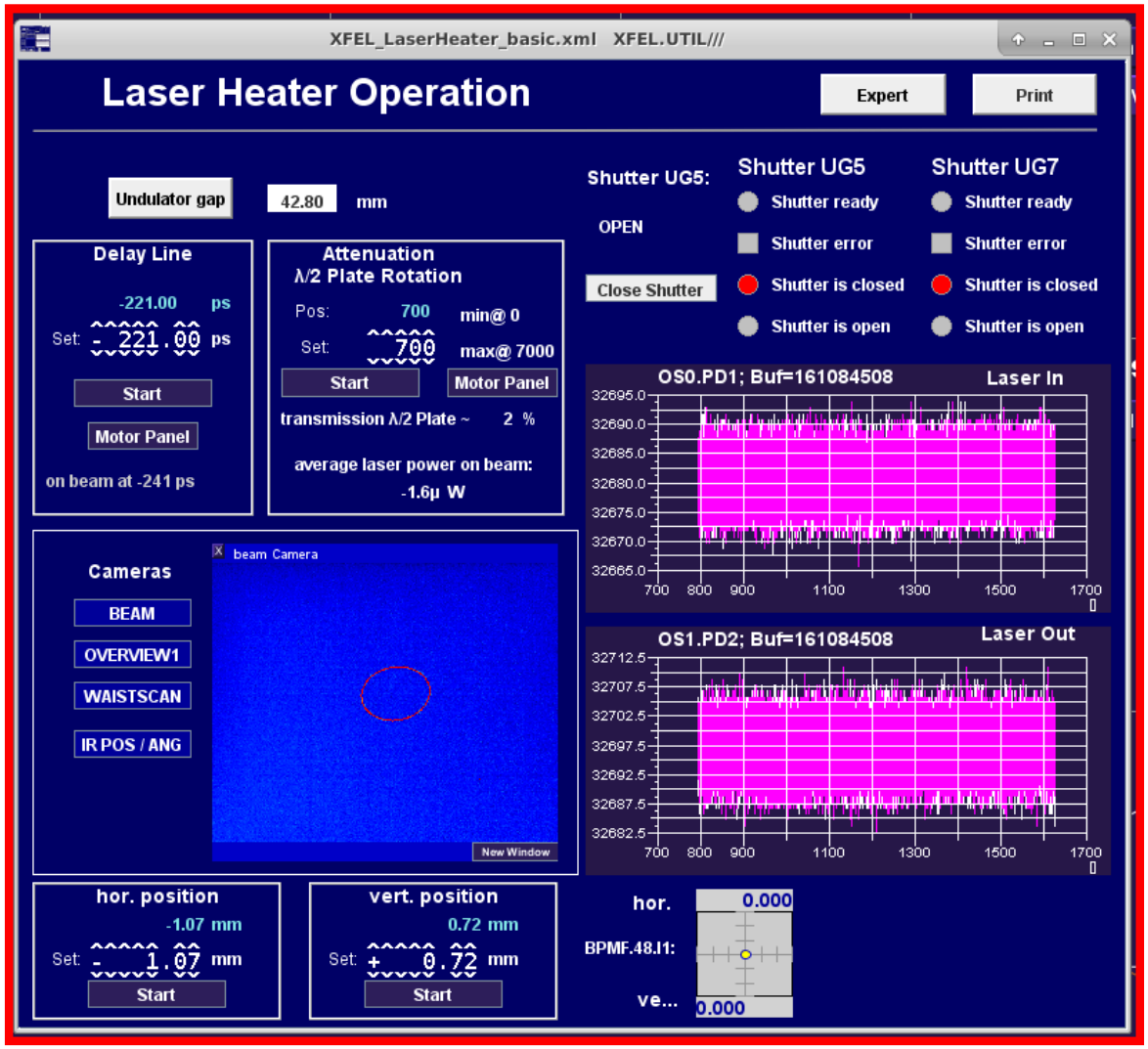
The Laser Controller



Main Timing


XFEL_MainTiming.xml XFEL.DIAG/TIMER.CENTRAL/MASTER/SASE
Main Timing Controls
Send to eLog
Main Operating
Special Bunches
Bunch Pattern Table
MPS Vetoes
Main rep rate:
10.0 Hz
INJECTOR rate: 10 Hz
Switch rate
LINAC rate: 10 Hz
MPS Assessment
Operation mode: SASE1/3 and TLD ok
Bunch train up to TLD: Single
SASE1/3: Medium
SASE2: Single
Injector laser up to TLD, T4D: Train cut
T5D: Shutter close
Allow beam
User-defined pattern (controlled by bunch pattern server)
Pattern Builder...
Bunch Pattern Server...
Bunch Train Part 1
Bunch Train Part 2
Bunch Train Part 3
Enable:
Bunch Destination: TLD
Bunch Destination: None
Bunch Destination: None
Number of Bunches: 1
Number of Bunches: 0
Number of Bunches: 0
Bunch Rep Rate: 564 kHz
Bunch Rep Rate: 564 kHz
Bunch Rep Rate: Undef...
Charge per Bunch: 0.25 nC
Charge per Bunch: 0.25 nC
Charge per Bunch: 0.00 nC
Injector Laser: 2
Injector Laser: 2
Injector Laser: 2
First Bunch Position: 800 µs
First Bunch Position: 1001 µs
1. Bunch Position: 1201 µs
Max. Bunch Duration: 200 µs
Max. Bunch Duration: 100 µs
Max. Bunch Duration: 100 µs
Seed/user lasers: enabled
Seed/user lasers: disabled
Seed/user lasers: disabled
Injector Laser Setup
Laser Rep Rate: 564kHz
0.0 100.0 200.0 300.0 400.0 500.0 600.0 700.0 800.0 900.0 1000 1100 1200 1300 1400 1500 1600
t
Special bunches: A - disabled
B - disabled
C - disabled
D - disabled

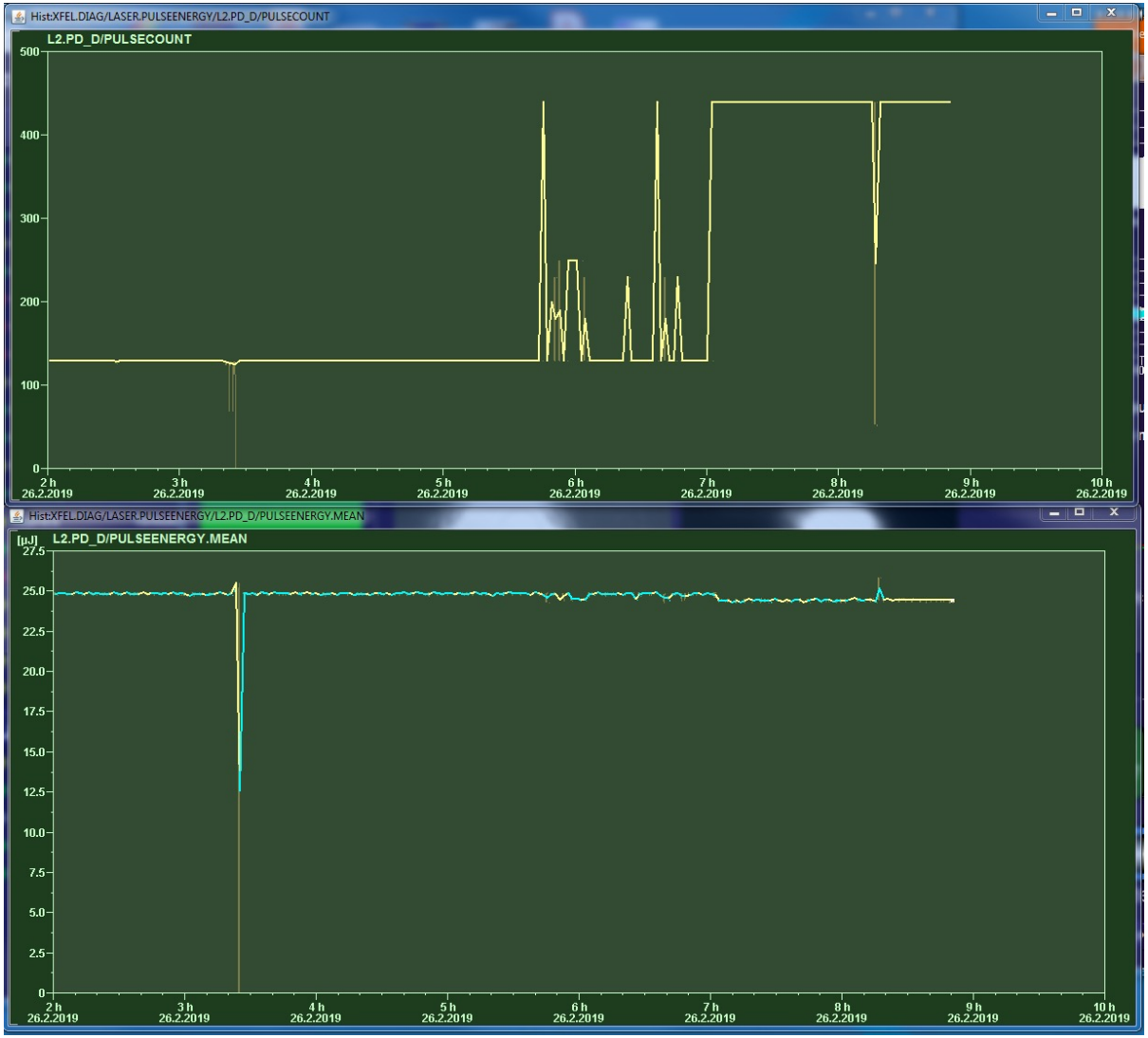
Laser Heater Panel



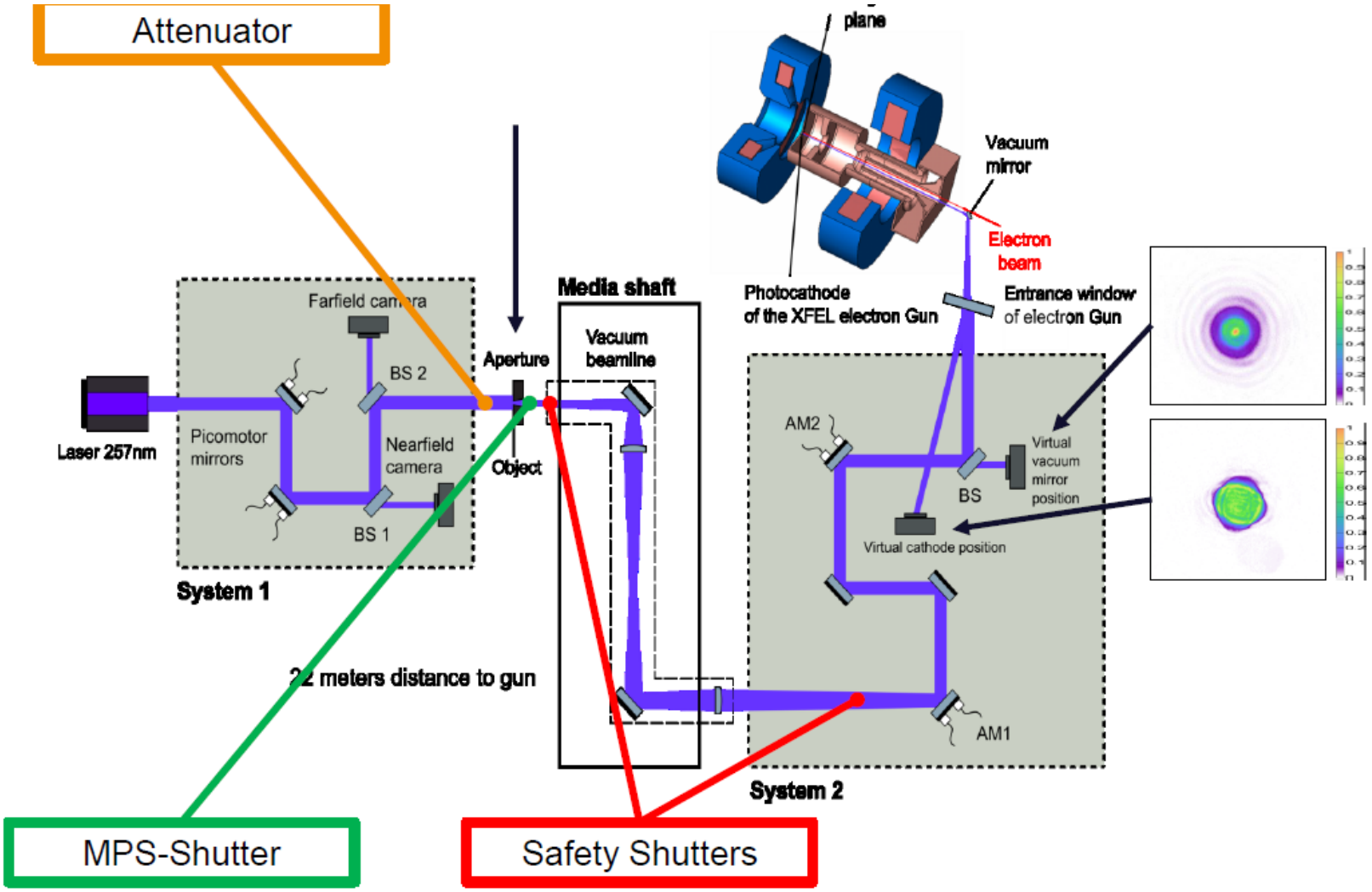
Injector Laser Status & Controls: Status

XFEL Injector Laser Pulse Count & Energy

Last 8-Hour Shift 26/02/2019 AM



Beamline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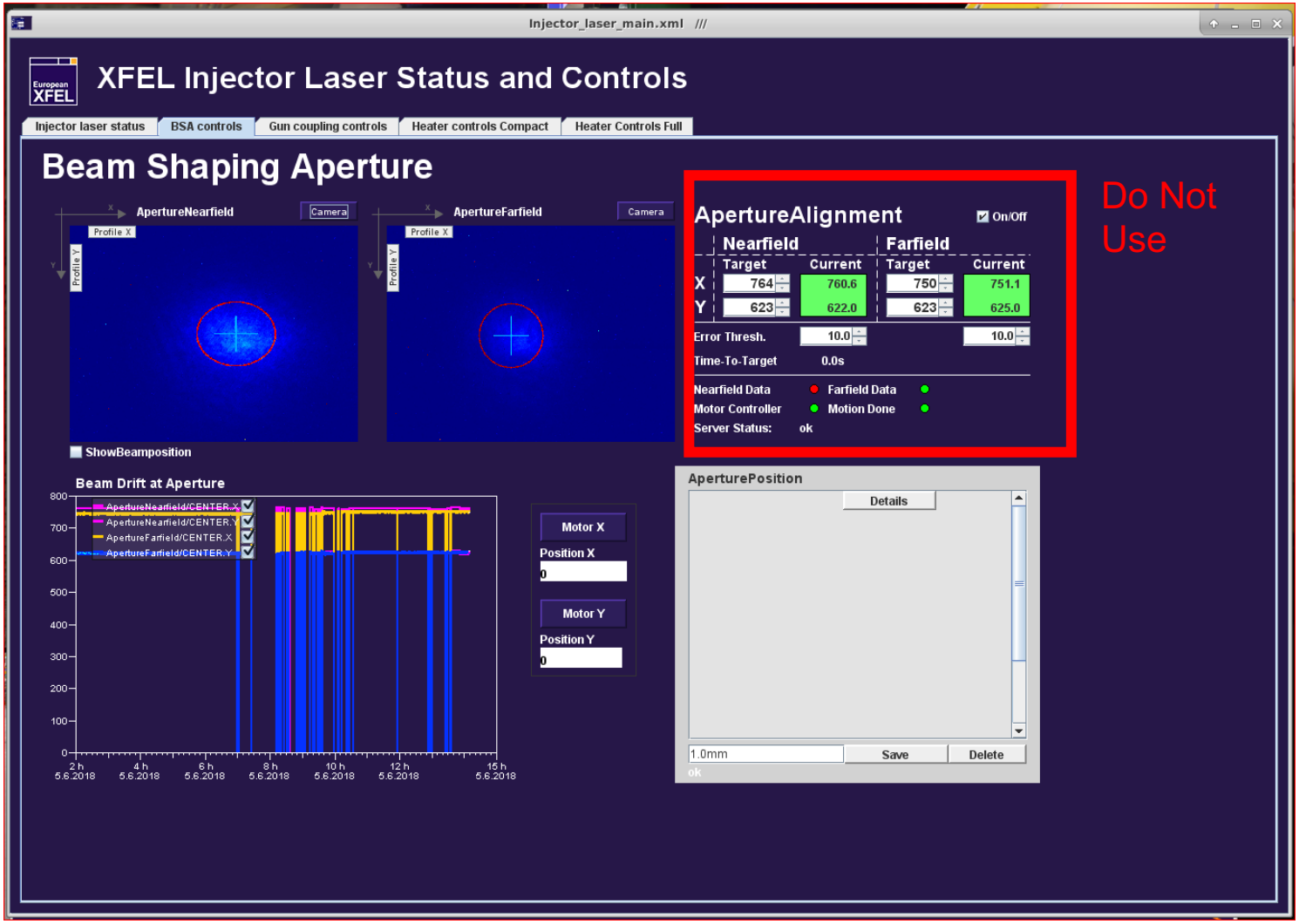
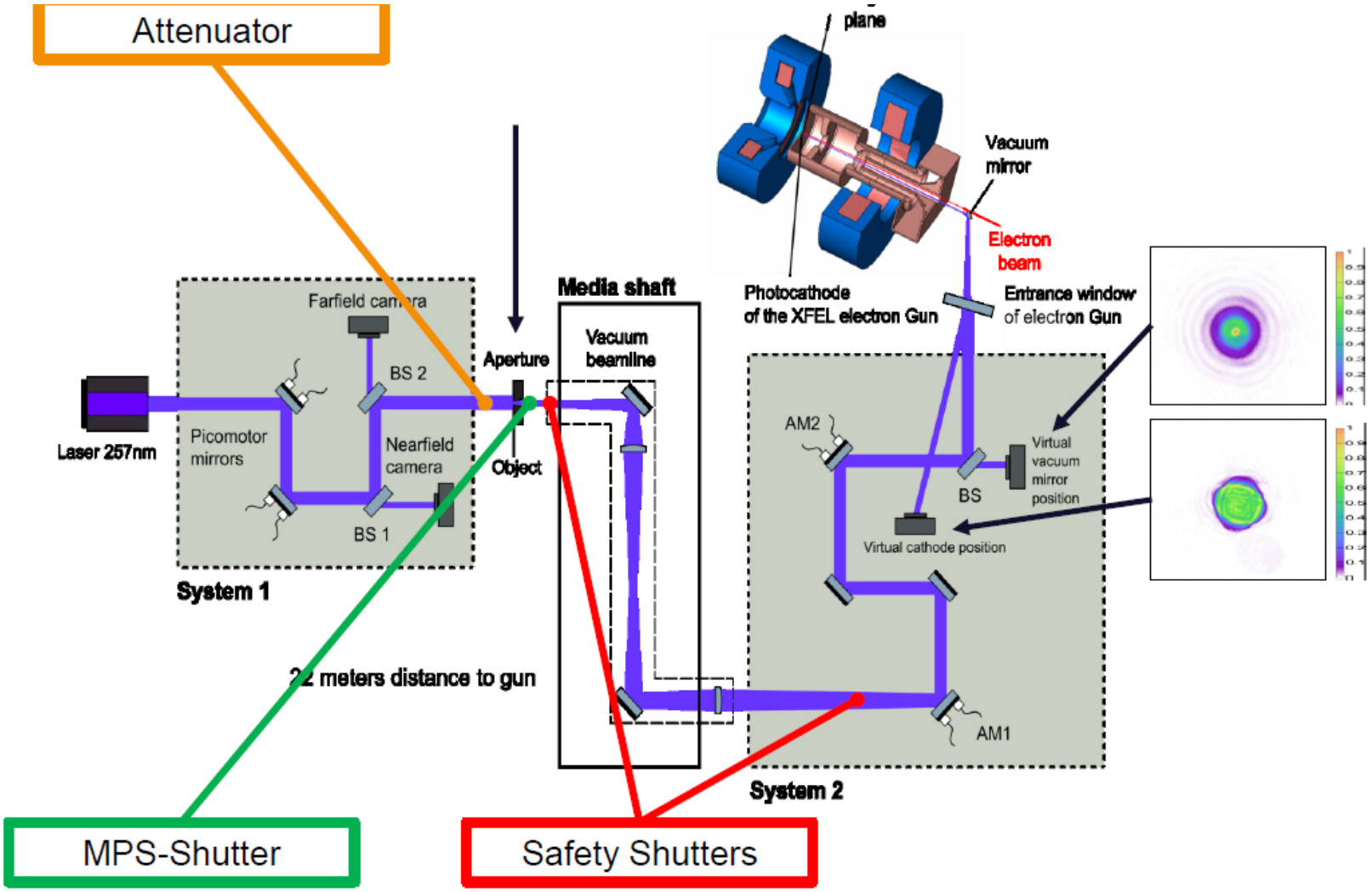
Vacuum mirror
Electron beam
Photocathode of the XFEL electron Gun
Entrance window of electron Gun
Media shaft
Vacuum beamline
Farfield camera
BS 2
Aperture
Picomotor mirrors
Nearfield camera
Laser 257nm
Object
BS 1
System 1
AM2
Virtual vacuum mirror position
BS
Virtual cathode position
2 meters distance to gun
AM1
System 2
MPS-Shutter
Safety Shutters

Injector Laser Status & Controls: BSA Controls



Beamline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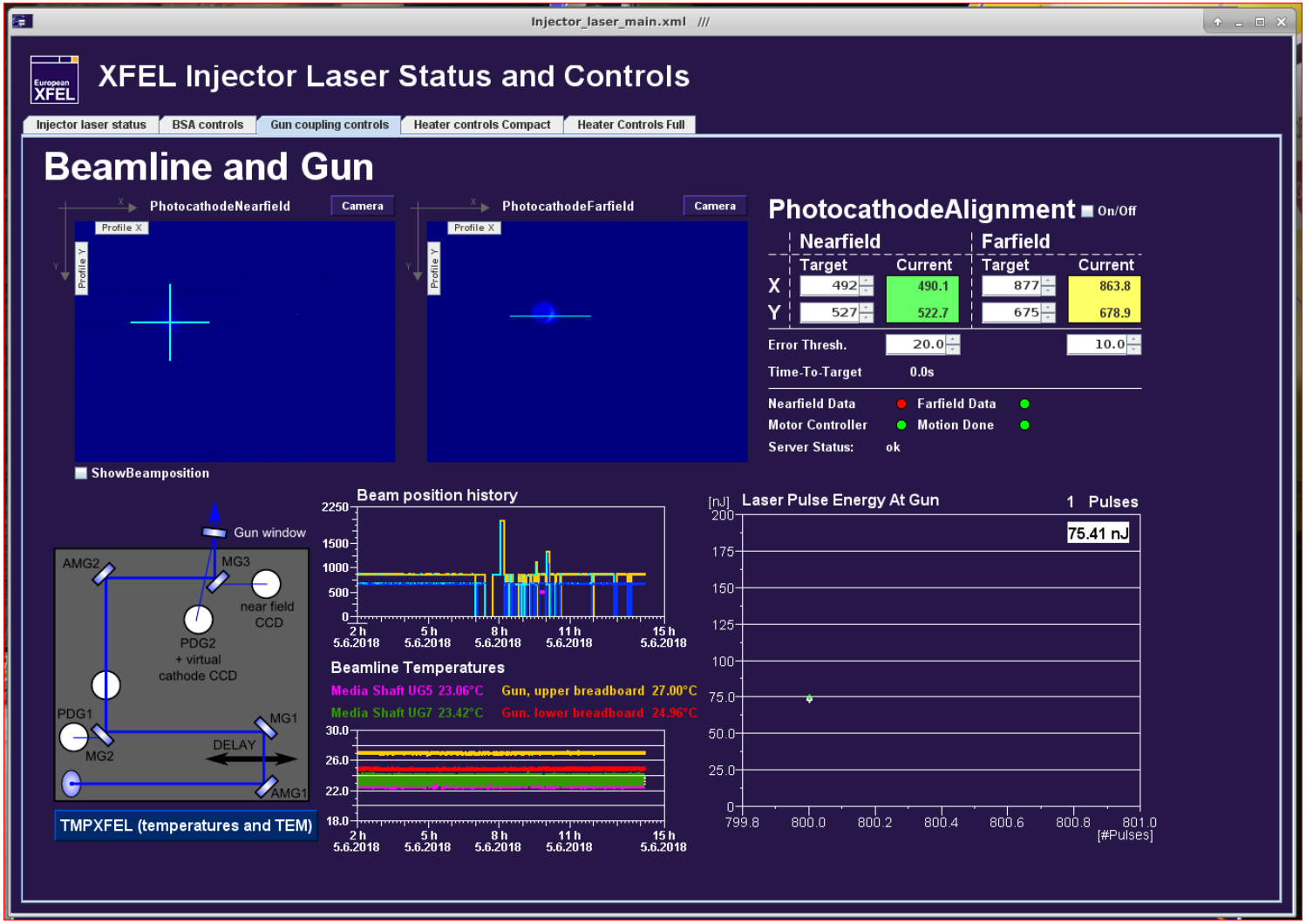
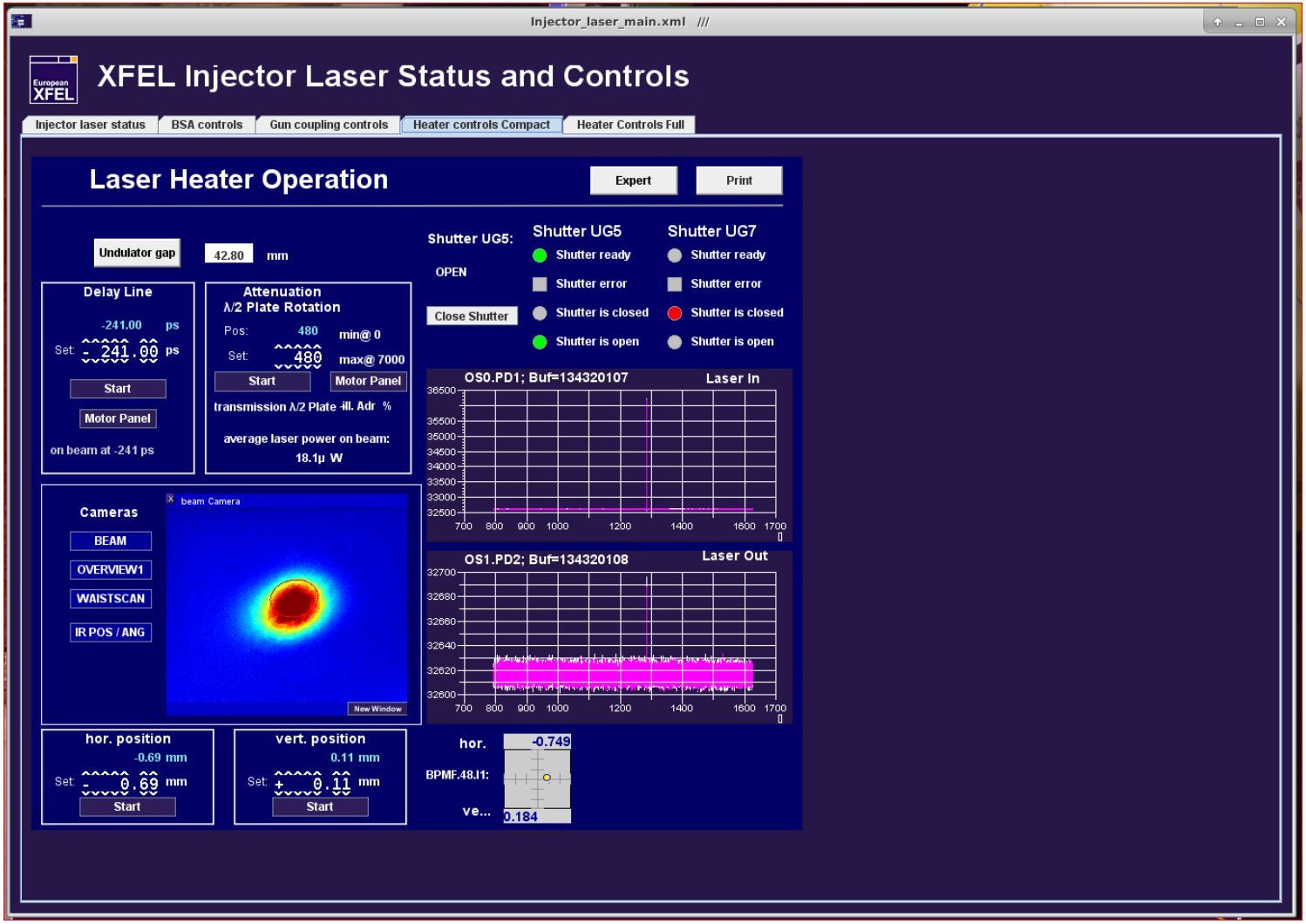
Virtual vacuum mirror position
BS
Virtual cathode position
2 meters distance to gun
AM1
System 2
MPS-Shutter
Safety Shutters

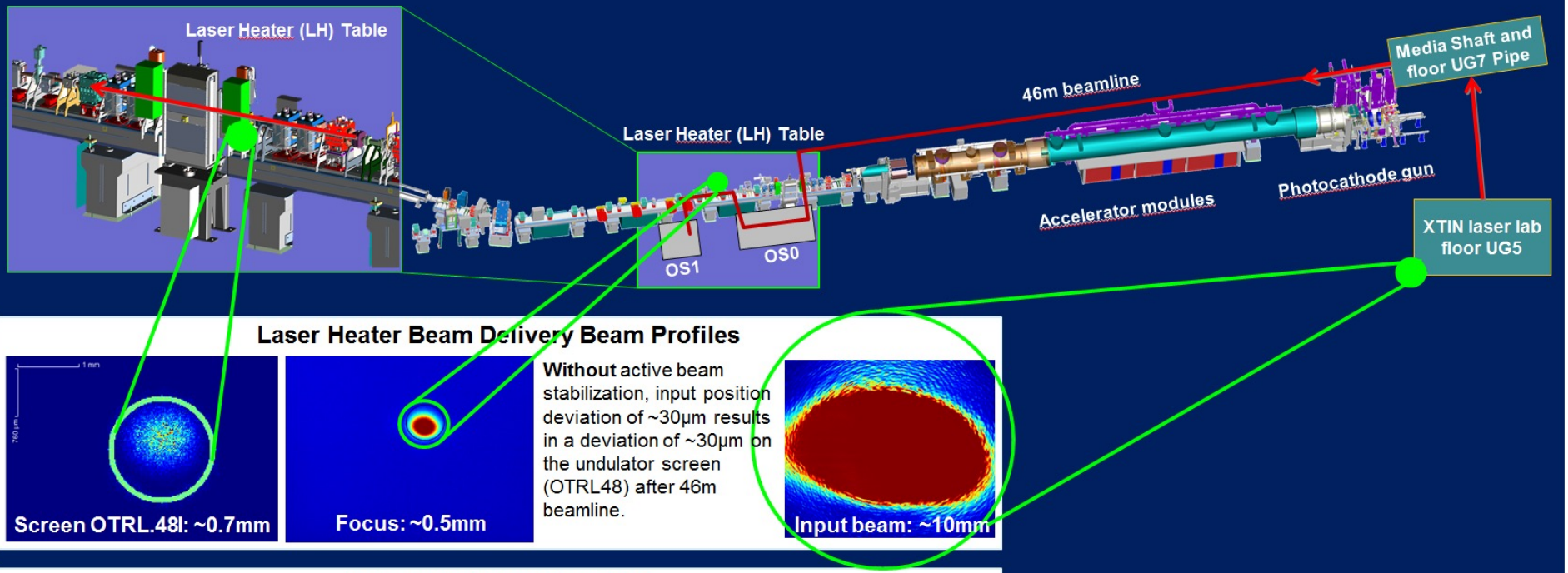
Injector Laser Status & Controls: Gun Coupling



Injector Laser Status & Controls: Laser Heater



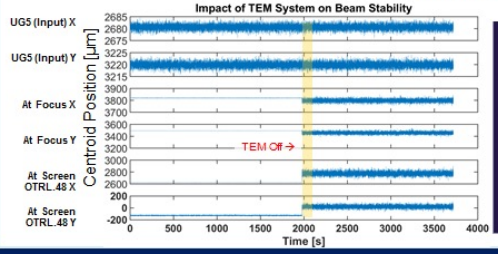
Laser Heater Beam Stabilizer Evaluation

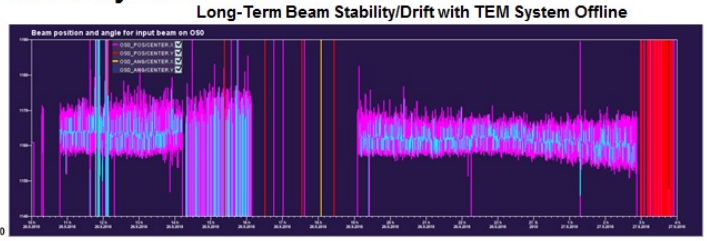


Laser Heater Beam Delivery Beam Profiles

Without active beam stabilization, input position deviation of ~30µm results in a deviation of ~30µm on the undulator screen (OTRL48) after 46m beamline.

Beam Stability: TEM On/Off





Demo: Common Tasks

How-To

- Block and Unblock Laser
- Change UV pulse energy
- Change Repetition Rate, Number of Bunches
- Change beam position on cathode

Common Issues

How-To

- No Pulses
  - Check Main Controller Panel (Trigger from timing? Shutters? Attenuator? Camera?)
  - Is the Beam Allowed? Is the number of bunches set to greater than 0?
- Pulses, but no energy at gun
  - Stand-Alone Mode→ was the beam allowed without turning the physical key in UG5?
  - Attenuator settings
- Beam Drift → saturation on camera? Beam autoalignment system?
- Laser is not synchronized/locked → call expert
- Shutter is stuck → call expert
- Burst is not flat → call expert

Not Allowed!

- Bursts with gaps
- Repetition rates

Contact

DESY. Deutsches
Elektronen-Synchrotron

www.desy.de

First Contact: Ara Choudhuri, xt. 6347

Expert: Lutz Winkelmann, xt. 6385

Deputy: Sarper Haydar Salman, xt. 6083

Laser On-Call: 5581