CONSTRUCTION OF THE EU-XFEL LASER HEATER*

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Abstract

Installation of the laser heater for the EU-XFEL is completed and first commissioning runs are imminent. We discuss the installation of the key elements and provide an outlook of the commissioning phase.

INTRODUCTION

The low momentum spread of the cold electron bunches emitted from the photo-cathode of the EU-XFEL makes the accelerator sensitive to micro bunching instabilities. A laser heater is implemented to overcome this. In this proven concept a laser beam is overlapping the electron bunches as they are travelling through an undulator in a chicane. The net result after leaving the chicane is a decreased phase-space density i.e. warmer electron bunches [1-2].

The EU-XFEL laser heater is a Swedish in-kind contribution. Setup and tests were described earlier [3-4]. This paper focus on the installation of the key elements such as laser laboratory setup, laser transport vacuum system, laser routing and stabilisation system, optical stations and ultra-high vacuum (UHV) chambers before ending with an outlook.

IR LASER SOURCE SETUP

Directly after the IR laser source located on level 5 in the injection building all optical parts such as: Mirror mounts, beam-expansion telescope, retro-reflector stage (for time delay adjustment), safety shutter, active mirror mount and flip mirror for realignment are now installed. The system is also prepared for easily implementing motorized filter wheel and λ/2 rotation stage if the commissioning shows that this is a favorable position.

Furthermore a PLC system box is constructed, programmed, tested and ready to work in this location. The last mirror in this location is actively adjusted with the routing and stabilization system described below.

LASER TRANSPORT VACUUM SYSTEM

Leaving the optical table on level 5 the laser directly enters a 40 m long DN63 vacuum pipe system used to preserve the laser beam from atmospheric disturbances. The system was assembled during November to May. The strategy of the system is to use ion pumps to reduce disturbances from vibrations.

Initially the system was closed and turbo stations left to work one week before the ion pumps were switched on and the turbo stations removed. After two weeks monitoring at the three ion pumps in the system the pressure was below 10^{-6} mbar and the trend a steady decrease.

In early June, test of the motorised routing system inside of the vacuum was undertaken. We investigated the behaviour of the pressure when the stepper motors work inside of the vacuum. It was clear that the pressure up to that time had decreased to about $2x10^{-7}$ mbar. When the motors started and therefore also start outgassing in the process, the pressure rised to below $4x10^{-6}$ mbar (well in the safe region). After turning off the motors, the pressure quickly dropped down to $6x10^{-7}$ mbar. A view of part of the system is shown in Figure 1 whereas the pressure rise is illustrated in Figure 2.

In the last passage of the IR laser transport vacuum system at level 7 the laser enters goes from the wall out over the optical station 0 and towards the remaining laser heater setup (see overview in Figure 3).

Figure 1: Vacuum chamber located close to the electron gun in the injector hall (red mount). The laser is redirected from the vertical shaft downstream the tunnel wall.

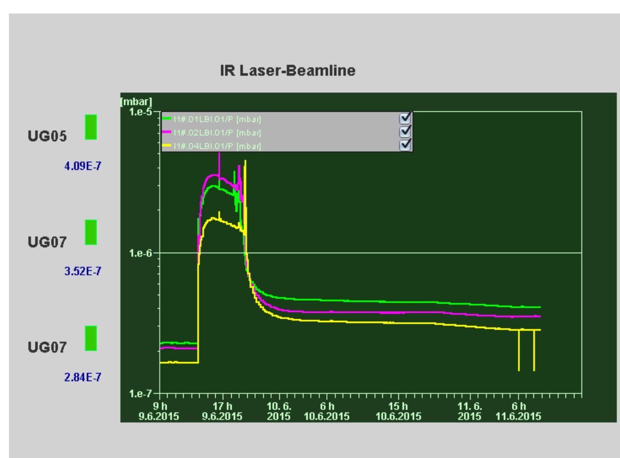

Figure 2: Pressure rise in laser transport vacuum system due to motors outgassing.

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Figure 3: Overview over the laser heater on LVL7 (injector). The large optical table (OS0) is to the right side, undulator in the middle and the small table (OS1) on the left side. On top of OS0 the horizontal beam contains part of the laser vacuum system which continues along the wall to the right.

LASER ROUTING AND STABILISATION SYSTEM

This system consists of two parts build together. 1) The routing system which reads out the signal from a photo-diode behind each mirror while scanning an upstream mirror. 2) The stabilization system which quickly adjust the beam position and angle (4D stabilization) utilizing piezo actuators, microstepper motors and readout from PSD detectors. An example of signal from scanning the laser on top of the mirror is shown in Figure 4. The signal shows a clear peak when the laser is impinging on the centre of the mirror. Ring structures appear outside the centre position due to reflections in the pipe when scanning far outside. The routing system was first tested in March with good results running the full distance in air. The system was re-tested in June with better collimated beam and with the major parts of the mirrors inside vacuum. The full routing process passing each mirror from laser lab down to optical station 0 and passing 7 active mirrors lasted six hours when thoroughly tested.

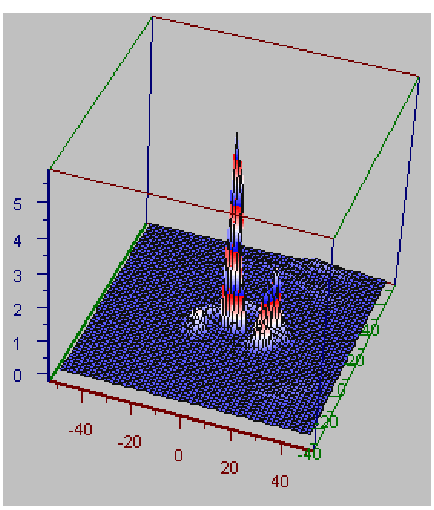

Figure 4: The 3D image shows that the signal is strongest when the laser is hitting the center of the mirror. The bottom plane is the scan area whereas the height represents signal intensity, units are arbitrary.

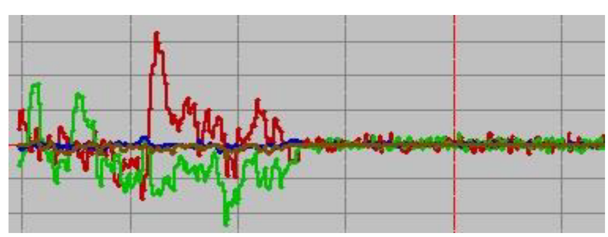

Figure 5: Signal from PSD located at the same distance as the undulator center (arbitrary units). Horizontal-axis is time (~10 s), vertical-axis is position (red is x-position, green y-position). The stabilisation system is turned on after half the time and the position is stabilised significantly.

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Figure 6: The OS0 when looking downstreams. The telescope lenses are clearly visible in the center of the optical table. More optical components toward the end of the table are at the time covered with plastic bags for dust protection.

The 4D stabilization system was subsequently tested and found to be working well. After a calibration made by TEM-Messtechnik they concluded that the typical jitter at the undulator position ~50 m downstream from laser source was in the order of 4 µm (below 30 µm is wanted for good laser heater functionality). See Figure 5.

OPTICAL STATION 0

The optical station 0 (OS0 see Figure 6) is the 3.6x0.9 m optical table in the in the injector building used for reading out laser properties and focusing it into the centre of the undulator. All essential hardware is there and the system is working.

OPTICAL STATION 1

The optical station 0 consists of a 0.75x0.75 m optical table downstream the undulator in the injector building. The OS1 has periscope, PSD and camera.

UHV VACUUM CHAMBERS

The Ultra High Vacuum (UHV) chambers are located in the electron beamline behind the optical tables in the injector building. This include inlet/outlet chambers for coupling in the laser into the vacuum; crosses for OTR screen positioning readout; L-pipes going from below the OTR crosses down to pumps; undulator pipe with implemented bellows. All vacuum chambers are mounted and leak tight.

UNDULATOR

The undulator is tested, in position and awaits alignment and subsequent commissioning in location.

OUTLOOK: REMAINING PARTS AND TASKS

The installation of the laser heater is finished. Commissioning will follow. The system needs further adjustment and fine tuning during the coming year. This includes:

- Handling the laser power dynamic range of 5 orders of magnitude without disturbing the laser positioning or destroying detectors
- Precise alignment throughout the laser pathway including the movable focusing telescope located at OS0
- Lead shielding of the optical stations
- Full implementation of the PLC system including control and update of the interfacing system
- Photo-diode implementation at OS1 and readout for timing
- Pipes will be implemented around the laser beam on the laser table on LVL5. This will further reduce disturbances caused acoustic wave fluctuations in air faster than the laser repetition rate of 10 Hz which are impossible to stop with the stabilization system.

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REFERENCES

[1] Z. Huang et al., Phys. Rev. ST Accel. Beams 13 (2013) 020703

[2] S. Spampanati et al., Phys. Rev. ST Accel. Beams 17 (2014) 120705.

[3] M. Hamberg and V. Ziemann, TUPSO25, Proceedings of FEL2013, New York, NY, USA.

[4] M. Hamberg and V. Ziemann, THPRO024, Proceedings of IPAC2014, Dresden, Germany.

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