European XFEL photcathode laser installation and commissioning.

Laser installation, UV beamline, diagnostics and beyond

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European XFEL photcathode laser installation and commissioning
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Outline

> MBI photocathode laser installation
  - Short overview of the laser system
  - jddd software control
  - Commercial spare laser evaluation

> UV beam transport system
  - Design of the beam aperture imaging system
  - Mechanical construction and integration into XFEL structures
  - Diagnostics

> Open issues and tasks

> Conclusion
MBI PHOTOCATHODE LASER
MBI laser installation – DESY jddd software controls
Long term power stability

- Power drop of 27% over 2 days – **not solved so far**
- Local Damage of the BBO crystal in the frequency conversion stage
- Contaminations on UV optics – **investigations ongoing**
Timeline Injector Laser

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Timeline:
- **2014**: First e-beam out of RF gun installed at XFEL
- **2015**: Injector cooldown
- **2016**: Linac tunnel closed
- **2017**: SA1, SA3, SA2
  - 1st lasing possible
  - Start user operation
- **2018**: Full TDR performance

**Injector laser installation**
- Commissioning
- MBI laser
- Various developments*
- *Simple pulse shaper
- Initial diagnostics
- Laser heater amplifier

**Single photocathode laser with no downtime coverage possible**
Spare injector laser

Proposal for DESY RnD of spare injector laser presented at September Laser Advisory Committee Meeting 2014:

- 3 prototyping phases (laboratory, engineering and final prototype)
- Each prototype suitable to cover operation of MBI laser
- Focus on highest reliability and implementation of advanced features (shaping and diagnostics) from the beginning
- But, for sophisticated development of spare laser system, fulfilling all relevant specifications, **2.5 – 3 years are needed**
- RnD spare laser can not cover for LINAC commissioning due to time constrains

Laser Advisory Committee statement in report#4 from Sep. 2015:

„LAC recommends to purchase a cheap very simple backup laser with minimum specs for commissioning the XFEL LINAC. This gives operation reliability and freedom for the proposed development of a better (spare) gun laser. LAC stresses that commissioning depends on highly reliable photo-injector laser operation, and the commissioning process is highly visible to the worldwide community.”
Spare injector laser

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> Following the LAC statement:

- Find commercial available solution for a spare laser system
- Evaluate laser system regarding specifications, costs and delivery time
- Hand in commercial spare laser proposal
- Update injector laser proposal to include newest developments
  - shorter pulses
  - higher degree of freedom for temporal pulse shaping
  - alternatives to generate a spatial flat-top beam profile
- Apply for XFEL research budget
Commercial spare laser evaluation

**AMPHOS 400 (450+)**

- **Output power:** > 400W
- **Max. pulse energy:** > 300 µJ
- **Wavelength:** 1030 nm
- **Pulse duration:** < 1ps ... > 5ps
- **Repetition rate:** 1.4 MHz ... 20 MHz
- **Beam quality:** $M^2 < 1.5$

**Amplitude Systemes**

- **Output power:** 50 W
- **Max. pulse energy:** < 10 µJ @ 1MHz
- **Wavelength:** 1064nm
- **Pulse duration:** 10 ps +/- 2ps
- **Repetition rate:** 200 kHz ... 8 MHz
- **Beam quality:** $M^2 < 1.5$

**neoLASE**

- **Output power:** 5W, 50W, >50W
- **Max. pulse energy:** > 2 x 50 µJ
- **Wavelength:** 1064nm
- **Pulse duration:** 8 ps +/- 2ps
- **Repetition rate:** single shot to 20MHz
- **Beam quality:** $M^2 < 1.2$

UV BEAM TRANSPORT SYSTEM
UV beamline optical design

FLASH beamline
-200mm +350mm -600mm BWA 1.5m -0.75m -0.75m 1.5m GUN

XFEL UV laser beamline concept
-200mm +500mm -600mm aperture

22 m distance to gun
UV beamline optical design

- Beam expander telescope without intermediate foci
- CaF2 lenses to withstand high flux in burst
- Magnification 1:7.5 / 1:15 with lens change
UV beamline optical design

XFEL UV laser beamline concept

-200mm  +500mm  -600mm aperture

SHG  FHG

object

22 m distance to gun

f=5.5m

in media shaft

photocathode of electron gun

image

f=5.5m

delay line
All diagnostics are non-invasive and can monitor parameters at the gun when using the laser.

The beam for the virtual cathode is taken from the back reflection of the uncoated surface of the input window to the gun, which is tilted by an angle of 3°.
Auto-alignment drift compensation

Preliminary results during injector commissioning

- Current auto-alignment system reduces drifts by a factor of two → improvements on control algorithm is ongoing
- Current data was taken during gun commissioning → movement of laser spot on cathode
- Positional change of spot on cathode is possible but rather slow → working on code
Pulse energy diagnostic

Online diagnostic of each pulse in:
- Energy (with resolution better than 0.5% rms)
- Full integration in DOOCS
- **Non-invasive diagnostic** (not reducing the No. of UV photons to much)

Developed photo diode:
- High quantum efficiency at 257 nm > 20%
- High linearity over three orders of magnitude
- High amplification for low pulse energies of less then 10 pJ
- Gaussian filter to allow sampling and readout by DOOCS DAC (limited to 108MHz sampling)
Open tasks and issues

> Find cause for power drop over time
  - Rework of frequency conversion stage for more stability
  - Laboratory air analysis

> Install first version of temporal pulse diagnostics
  - Solve problem with missing short pulse as a reference
  - Find scheme working at lowest possible UV energies per pulse

> Test first temporal pulse stacker:
  - Evaluation of simple two pulse UV stacker
  - Full blown IR Lyot type stacker for 20 ps flat-top

> Purchase, install and commission spare laser until end of the year 2015
Conclusion

> Progress since 2013:
  - Completed laser lab infrastructure
  - Installed and commissioned photocathode laser
  - Designed and commissioned 22 m UV beamline, online laser diagnostics and laser control panels
  - Two successful gun commissioning runs, no major laser issues

> Ongoing:
  - Developing advanced diagnostics and pulse stacking
  - Developing booster amplifier for laser heater

> Issues:
  - Frequent failures of sub-components
  - Continuous degradation of UV conversion
  - Lack of spare laser → high risk of laser failure caused delays