Integrating the ANGUS 200 TW laser into the accelerator infrastructure at DESY

Andreas R. Maier
CFEL, UHH, LAOLA.
andreas.maier@desy.de
lux.cfel.de

LAOLA. is a collaboration of
LUX Research Group

Research group at CFEL and Hamburg University

commission & operate 200 TW ANGUS laser system

build and operate the LUX beamline for laser-plasma driven undulator radiation

close collaboration of University and DESY (called LAOLA)

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what you will see is mostly Matthias’, Spencer’s, Vincent’s and Philipp’s work
Laser-Driven Plasma Acceleration

ANGUS
new 200 TW laser

LUX
undulator radiation

60 m tunnel

see also lux.cfel.de
More related talks

Continuous Flow Operation of LWFA Targets

Niels Delbos, 2/8/2016 - 16:10, WG 5

Integrating the ANGUS 200TW Laser Into the Accelerator Infrastructure at DESY

Andreas R. Maier, 1/8/2016 - 16:20, WG 8

Plasma-driven ultrashort bunch diagnostics

Irene Dornmair, 3/8/2016 - 11:10, WG 5

Commissioning of the LUX Beam Line for Laser-Plasma Driven Undulator Radiation

Andreas R. Maier, 3/8/2016 - 11:30, WG 5
ANGUS

ANGUS parameters
(the BELLA frontend)
• 200 TW
• 5 J, 25 fs, 5 Hz rep. rate

performance
• < 3 µrad rms pointing
• < 1 % rms energy stability
• strehl better 0.9

this was measured at SAT by THALES

but can we keep that performance in daily operation?
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initially: NO … (now we do)

our goal: daily operation with ramp-up < 2 hrs, 6 hrs operation
Philosophy

> we come from a laser lab (MPQ, Munich)
> now at a national accelerator lab

> CLASH of cultures
> offers a lot of concepts, ideas and technology to learn from

(my personal) lesson learned
> lab culture is key
> function follows form
> avoid the „voodoo healing hands“ guys

… this talk is about how we implemented this.
Monitoring Tools

- Quality and stability monitoring software for a 200TW laser

Power/energy measurement:
- After every amplification stage
- Photodiodes for MHz and kHz range (power)
- Thermoelectric sensors for 5Hz Pulses (energy)

Temperature measurement:
- Temperature measurement of the different laser crystals
- Measurement of air/table temperature of each laser box

Spectrometers
- to get the laser spectrum to the corresponding energy/power values

Camera server:
- to monitor the beam pointing in crucial parts of the laser chain
- Future plan: humidity sensors

Big number of monitored important laser parameters

Integration into the DESY Tine Control System to be able to access it from any DESY pc and to store the data permanently

TINE: Three-fold Integrated Networking Environment
- Multi-Platform (Win, UNIX, MACOS,…)
- Multi-Protocol (UDP, TCP, IPX, and PIPEs)
- Multi-Architecture Client-server Publisher-Subscriber Producer-Consumer
- Plug and Play

Local Storage (for 90 days)
- Short-term: 10min with 1/s, long-term (>10min) with 1/15min when changes<10%

Central Archive (for years)
- Adjustable for all kinds of needs

Professional and approved solution for data archiving

Long-term Analysis / Benefits
- We are now able to see how the system reacts on:
  - Perturbations like vibration (people working in the lab)
  - Temperature changes
  - Influence/quality of the cooling circuit
  - Degradation over time
  - Warm up time to get stable
  - Energy correlations between the amplification stages
  - Correlations between energy, temperature, beam pointing and spectrum

Therefore we can locate and solve problems faster

Important for a reliable and stable laser

Power/Energy stability measurements of the oscillator and the whole laser chain:
A. Measurement of the ML power loss of the oscillator during normal working conditions
B. Full chain stability measurement, right after starting the laser
C. Observation of the oscillator behavior while keeping it in ML

Control Panels and Analysis Software
- Control panels showing all important laser parameters for all amplification stages
- Data access for analysis:
  - MatLab
  - Different in-house java applications

Monitored values:
- Picture of the beam spot
- Beam centroid
- Energy trend and latest value
- Temperature
- Current spectrum and reference spectrum

Angus Laser in Concept

Oscillator Regen Booster PreAMP AMP1 AMP2

1.8 J, 5 Hz
1.8 J, 5 Hz
1.8 J, 5 Hz
14 J, 5 Hz

Stretcher
Compressor XPW Stretcher

1.8 J, 5 Hz
1.8 J, 5 Hz

1.8 J, 5 Hz

• based on a THALES ALPHA 5
• we replaced all diagnostics
• added many more diagnostics
• added active stabilization
• integrated the system into the accelerator controls system @ DESY
**Monitoring Tools**

**LAOLA**

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**Professional and approved solution for data archiving**
for each box...

- spectrum w/ reference
- temperature at relevant points (crystals)
- online energy (power) measurement w/ trend chart
- near- and farfield at the output
- get centroids of NF/FF and display trend chart on laser position and direction
... the whole system ...
... and in real life. (copied now all over campus)
One more thing … beam stabilization

![Beam stabilization diagram]

- Camera-based slow stabilization (drift)
- PSD-based kHz stabilization

**Diagram:**
- Oscillator
- Regen
- Booster
- PreAMP
- AMP1
- AMP2
Everything goes in the Controls System

- temperature
- beam position, centroids, size, …
- spectrum
- energy

> based on FEL data acquisition system
> can handle well above 10 Hz
> comes with lots of tools
We generate a lot of data…

energy/power  pointing  temperature

spectrum centroid  spectrum width
Availability - 7 Week Performance Test

> think about lessons learned
> ... get some data & analyze

> think about lessons learned
> ... get more data & analyze

> ... repeat ...
A few numbers...
Availability - 7 Week Performance Test

- 7 weeks, 35 days
- turn on the system every day at 09.00 am
- let it run for two hours
- with all diagnostics channels getting data
- then use the laser…

- test does not include last pump laser
- identified timing system as a major problem

- **91 %** successfully completed daily startup & test
- **9 %** timing system failed during the test
Availability - 7 Week Performance Test

- 7 weeks, 35 days
- turn on the system every day at 09.00 am
- let it run for two hours
- with all diagnostics channels getting data
- then use the laser…

Daily startup time including warm-up

- only pushing buttons not opening covers or touching mirrors
- touch only one of the 5Hz multipass mirrors
- more significant work

Statistics: The Daily Startup

<table>
<thead>
<tr>
<th>Percentage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>11%</td>
<td>only pushing buttons</td>
</tr>
<tr>
<td>40%</td>
<td>not opening covers or touching mirrors</td>
</tr>
<tr>
<td>49%</td>
<td>more significant work</td>
</tr>
</tbody>
</table>
Examples

... lots of data to look at ...
Beam Stabilization works… (here: REGEN)
Stabilizes XPW energy

- Stabilization OFF
- Stabilization ON
Found Oscillations in the REGEN Energy…

> even with stabilization there seem to be some oscillations in the energy.
Found Oscillations in the REGEN Energy…

> even with stabilization there seem to be some oscillations in the energy.

> yeap, there are real.
Found Oscillations in the REGEN Energy…

> even with stabilization there seem to be some oscillations in the energy.

> yeah, there are real.

> obviously caused by pump laser

> is it the chiller? - add temperature sensors…
More examples...

> corelated laser performance to lab temperature

> found a damaged crystal coating due to drop in energy (even before we saw it on the xtal itself)

> massive spectral fluctuations cause by heat from one specific camera

> investigate pump laser long-term performance
whats next?

> more diagnostics
> absolute calibrations
> automated analysis
> machine protection system
> ...


Triggered DAQ

- REGEN
- Oscillator
- Photodiode Filter Amplifier
- x2timer card
- External timebasis for THALES ISEO
- 5 Hz trigger
- Unique shot ID

- 90%
- 10%
- ~83 MHz
- ~1 MHz
- Energy
- Spectrum
- Cameras
conclusions / lessons learned

**good news**

> „boxes“ help to quickly isolate problems with the laser  
> long-term trends & archive help to evaluate the severity of a problem and solve them  
> we learn A LOT about the system

**bad news**

> high up-time creates new problems:  
> slow, long-scale damage builds up (for example: back-reflections)  
> damage threshold

**(my personal) conclusions**

> technology is only a tool; what counts is the mind set (lab culture)  
> make the laser operation independent of the operator (avoid the „voodoo“ guys)
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