Laser systems for science instruments

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Outline

- Introduction
- Lasers for experiments at the EXFEL
- Pump-Probe laser
  - Concept, R&D results and some specs
  - Production systems and installation
- Beam delivery and day-1 conditions
- Summary and outlook
Introduction

- 3 underground experimental areas with 3 X-ray beams
- 6 experiment stations
- Up to 60% of experiments require optical lasers.
Laser systems for science instruments

**Experiment Hall**

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<th>MID</th>
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**Types of experimental lasers:**

- **PP-type**
  - high rep-rate, sync

- **HE/HI-type**
  - 10Hz

- **PP**: pump-probe:
  - sub-15…300fs, mJ-class, 0…4.5MHz, 800nm
  - UV…mid-IR, THz

- **MAL**: molecular alignment:
  - sub-20fs, 1…10mJ, 800nm ("kick")
  - 1J-class, 10Hz ns ("adiabatic")

- **100TW**: high intensity (HI):
  - <30fs, 10Hz, 100 TW-class laser, Tisa

- **100J**: high energy (HE):
  - 100J…kJ-class ns-laser, 10Hz, green, exp. ramp

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Pump-Probe laser goals

The European XFEL mode of operation: 10Hz Burst

- up to 2700 "e- bunches" a 0.1...1 nC => eff. rep-rate: 27000 Hz

- Match XFEL: 10Hz burst, 0 – 4.5MHz
- 800nm: 15 - 300fs, mJ
- Arbitrary pulse pattern selection
- Frequency conversion

Δt = 220 ns
4.5 MHz

<100 fs x-ray pulse
FEL process

600 μs
100 ms
Pump-Probe laser concept: fs-pumped NOPA


**Pulse energies:**
- 80 µJ @ 4.5MHz
- 330 µJ @ 1.1MHz

**Burst power:** 360W (600 µs)

**Pulsewidth:** 15fs

**Spectrum:** 13.8 fs Fourier-limited pulse

**Burst-noise:** 2.5 % rms (scope, high air flow conditions)

**Burst shape:** clean, arbitrary sequences possible
Gaussian fit >94% for 15 Rayleigh ranges

Close to diffraction limited Gaussian beam: $M^2 < 1.1$
**NOPA I + II + III**

- **Pulse energy:** 1.7mJ @ 188kHz
  
  2.5mJ @ 100kHz

- **Burst power:** >250W (600 µs)

- **Pulsewidth:** <15fs

- **Beam quality:** similar to NOPA I + II
Dispersion management

**Short pulse dispersion management:** 15fs pulse duration

1. From SCG
2. CMs
3. - Φ"
4. Multi-stage parametric amplifier
5. Pump pulse

**Long pulse dispersion management:** 25-300fs pulse duration

1. From SCG
2. CMs
3. + Φ”
4. Multi-stage parametric amplifier
5. Pump pulse
6. + Φ”
7. Bulk Fused silica compressor
8. - Φ”
9. Transmission grating compressor
Long pulses from the NOPA

60 fs pulse (Treacy compressor)

\[ \tau_{\text{Gauss}} \approx 50 \text{fs} \]

280 fs pulse (No compressor)

\[ \tau_{\text{Gauss}} \approx 240 \text{fs} \]
1030nm pump beam and mixed-mode

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Mixed-mode: e.g. 100kHz, 1mJ / 15fs / 800nm and 10mJ / 400ps / 1030nm
Production system SASE 1

- SASE 1 Layout
- 1 laser for 2 experiments
- Installation schedule:
  - Laser tables: May 2016
  - Components + comm.: July 2016
  - Beam at experiment: May 2017
Pump-probe laser hutch SASE 1

Clean room, 
+/- 0.1° C

Prep-area 
+/- 1° C
XHEXP 1 with laser installations

HI/HE SASE 2

PP SASE 3

PP SASE 1

PP SASE 2
Beam delivery concept and responsibilities

**WP78**
- Laser configuration
- 800nm / 1030nm / f / \( \tau \)
- Burst and pulse selection
- Overlap delay
- Limited tuning

**Instruments, WP78**
- Beam routing
- Dispersion management
- Various controls
  - Attenuation
  - Pulse selection
  - Overlap delay
  - Shutter
  - Limited tuning
- Harmonics?
- TOPAS?
- ...

**Instruments, WP78**
- Pump-probe delay
- Various controls
  - Attenuation
  - Pulse selection
  - Overlap delay
  - Shutter
  - Limited tuning
- Coupling to experiment
- Timing tool
- Harmonics?
- TOPAS?
- ...

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Example SPB-SFX:

1) From PP-Laser hutch:
   - **800 nm**, ~ 300fsec (chirped, compressible to 15fs when passing correct length of UV-grade fused silica)
   - Pulse energy: ~ 50 μJ
   - Polarisation: Linear, vertical
   - Rep-rate: **100 kHz**
   - Alignment laser: 787 nm and 1055 nm (collimated laser diodes)
   - Remote operation of alignment laser and shutter.

2) Laser Specs at SPB experiment:
   - **400 nm** – *SHG provided by WP78*
   - Beam diameter: **50 μm on target**
   - Pulse duration: ~ **15 fsec**
   - Pulse energy: **1 μJ**
   - Polarisation: Linear
   - Repetition Rate: 100 kHz
   - Delay time: -2, -1, 0, 1, 2, 3….100 ps. -100, -90, …. 100, 110, 120…. 1000 fs 100 – 200 time point
Schedules

General PP-laser installation schedule:

- **Task 1**: Laser tables and infrastructure in PP and ILH-hutches  
  - month 1-3
- **Task 2**: Components + commissioning in PP and ILH-hutches  
  - month 4-11
- **Task 3**: Beam at experiment for day-1  
  - month 12

SASE-specific milestones:

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<th>Milestone</th>
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Summary PP-laser for science instruments

- **800nm burst-mode NOPA:**
  - burst average power of >300W
  - up to >2mJ single pulse energy
  - <15fs … 300fs, close to transform limited
  - nearly diffraction limited beam quality
  - 4.5MHz, 1.1MHz, 200kHz, 100kHz, arbitrary pulse sequences

- **1030nm burst-mode:**
  - Burst average power of >4kW
  - up to 40mJ single pulse energy
  - 800fs or 400ps
  - M² < 1.5
  - 4.5MHz, 1.1MHz, 200kHz, 100kHz, arbitrary pulse sequences

- **Installation of production systems starts in May 2015 at SASE 1**
Thank you!

WP78:

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