Preliminary Results from the Laser System generating Quasi 3-D Ellipsoidal Photocathode Laser Pulses at PITZ


1. Introduction
2. Concept
3. First results
4. Conclusion

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1.1 Photoinjector Test Facility

Focus:

> Conditioning, characterization, testing, development, and optimization of high brightness electron sources for superconducting linear accelerator driven Free Electron Lasers (FELs), e.g. FLASH and the European XFEL
1.2 Introduction

**Motivation:** Improve the electron beam quality by improving photocathode laser profile

Advantages:

- Minimizes space charge influence on emittance
- Improved longitudinal compress
- Reduced beam halo
- Reduced machine sensitivity
1.3 New laser optical layout

harmonic generation

| 515 nm | 25 - 30 μJ |
| 257.5 nm out | 4 - 5 μJ |

1030 nm in
1 μJ, 0.2 - 100ps

90° rotation

10-pass amplifier

SLM shapers

70 μJ
2.1 Current pulse shaper: Super-Gaussian

> „Generation of flat-top picosecond pulses by coherent pulse stacking in a multicrystal birefringent filter“, Ingo Will & Guido Klemz

*Optics Express, Vol. 16, Issue 19, pp. 14922-14937 (2008)*

![Diagram of pulse shaping process](image)

**principal of operation**

**optically sampled 20 ps super-gaussian**
2.2 Spectral mask-based pulse shaping

- Concept: Spectrally separated chirped pulse transversally modulated by amplitude-phase mask prior to recombination
2.3 Masks: Spatial Light Modulator (SLM)

> Masks
- Binary array
- Lithographic plates
- Spatial Light Modulators

> Holoeye Pluto
- High-resolution LCOS phase-only SLM
- 1920x1080 8 µm matrix of 8-bit phase retarders
2.4 1D Spatial Light Modulator (SLM) shaping

\[ E_{\text{out}}(x, y, \omega) = E_{\text{in}}(x, y, \omega) \cdot M(y, \omega)e^{i\varphi(y, \omega)} \cdot M(x, \omega)e^{i\varphi(x, \omega)} \]
3.1 SLM mask simulations

Amplitude mask:

Phase mask:

Simulated temporal slices
3.2 Temporal and spatial correlation

Temporal binary mask

Spatial binary mask

cross-correlation functions

Temporal and spatial correlation functions.
3.3 Cross-correlated camera images

**Spatial shaping experiments:**

Cross-correlation slices of laser pulses without shaping
3.4 Measured temporal laser pulse profiles
4. Conclusions and projections

> In conclusion:

- Homogenous pulse with quasi-ellipsoidal envelope shown by simulations
- Laser system capable of producing quasi 3-D ellipsoidal laser pulses installed and undergoing commissioning
- Diagnostics implemented and utilized
- Temporal slicing and intensity modification demonstrated

> Outlook

- Beam transport to cathode and generation of photoelectrons ongoing
- 1st electron beam characterization using shaped laser pulses
- Iterative/adaptive pulse shaping
- (Demonstrate improvement in electron beam quality)
Thank you for your attention
Backup slides
## Laser parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Unit</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>wavelength</td>
<td>255-270</td>
<td>nm</td>
<td>4&lt;sup&gt;th&lt;/sup&gt; harmonic of Nd</td>
</tr>
<tr>
<td>micropulse energy</td>
<td>10-12</td>
<td>µJ</td>
<td>for 1 nC bunch production from Cs&lt;sub&gt;2&lt;/sub&gt;Te photo cathodes</td>
</tr>
<tr>
<td>pulse train frequency</td>
<td>1</td>
<td>MHz</td>
<td>In the future 4.5 MHz will be a goal</td>
</tr>
<tr>
<td>pulse train length</td>
<td>0.3</td>
<td>ms</td>
<td>In the future 0.6 ms will be a goal</td>
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<tr>
<td>pulse train rep.rate</td>
<td>10</td>
<td>Hz</td>
<td>1,2,5 Hz as an option</td>
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<tr>
<td>micropulse rms duration</td>
<td>6±2</td>
<td>ps</td>
<td>3D quasi ellipsoidal distribution</td>
</tr>
<tr>
<td>diagnostic pulse duration</td>
<td>150</td>
<td>fs</td>
<td></td>
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<tr>
<td>transverse rms size</td>
<td>0.5±0.25</td>
<td>mm</td>
<td></td>
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General Scheme of PITZ Ellipsoidal Laser (ELLA)

Fiber part

Working channel

\[ E=1 \, \mu J, \, T=0.2-100\, \text{ps} \]

Diagnostic channel

\[ E=1 \, \mu J, \, t=200\, \text{fs} \]

Temporal and spatial control of intensity distribution in cross-correlator

Photocathode

Fast CCD Camera

Photodiode

Shaper

\[ 90^\circ \text{Beam rotator} \]

Thin disk Amplifier

Yb:KGW

SH Generator

UV Generator

\[ E=25-30 \, \mu J, \, \lambda=515\, \text{nm} \]

\[ E=4-5 \, \mu J, \, \lambda=257.5\, \text{nm} \]

10 shots/300usec

10 shots/300usec
Perpendicular quantization

Cylindrical lens

\[ M(x, \omega) \]

\[ \frac{\lambda}{2} \]

\[ \sim 10^\circ \]

1px