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

![Photoinjector Test Facility images]
1.2 Introduction

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

- 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

- 90° rotation

- SLM shapers

- 10-pass amplifier

- 1030 nm in, 1 μJ, 0.2 - 100ps

- 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)*

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

![Phase Modulation Transmissive Mode](image)
2.4 1D Spatial Light Modulator (SLM) shaping

\[ E_{\text{out}} (x, y, \omega) = E_{\text{in}} (x, y, \omega) \cdot M (y, \omega) e^{i\phi(y, \omega)} \cdot M (x, \omega) e^{i\phi(x, \omega)} \]

Cylindrical lens

Spherical lenses

Faraday Isolator, polarizer and 90° beam rotation
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
3.3 Cross-correlated camera images

Spatial shaping experiments:

Cross-correlation slices of laser pulses without shaping
3.4 Measured temporal laser pulse profiles

![Intensity distribution plots](image)

Int. dtr. x-mean, Intensity slices (uframe 5), Intensity dtr. y-mean.
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
### Laser parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Unit</th>
<th>Remark</th>
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<tbody>
<tr>
<td>wavelength</td>
<td>255-270</td>
<td>nm</td>
<td>4\textsuperscript{th} harmonic of Nd</td>
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<tr>
<td>micropulse energy</td>
<td>10-12</td>
<td>μJ</td>
<td>for 1 nC bunch production from Cs\textsubscript{2}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>
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<tr>
<td>diagnostic pulse duration</td>
<td>150</td>
<td>fs</td>
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<tr>
<td>transverse rms size</td>
<td>0.5±0.25</td>
<td>mm</td>
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General Scheme of PITZ Ellipsoidal Laser (ELLA)

Fiber part

Working channel

Diagnostic channel

Thin disk Amplifier
Yb:KGW

Shaper

90° Beam rotator

E=1 μJ, T=0.2-100 ps

Temporal and spatial control of intensity distribution in cross-correlator

E=1 μJ, t=200 fs

UV Generator

SH Generator

Fast CCD Camera
10 shots/300 usec

Photodiode

Photocathode

E=25-30 μJ, λ=515 nm

E=70 μJ

E=4-5 μJ, λ=257.5 nm

ν=1 MHz

James Good | “Preliminary Ellipsoidal laser results at PITZ” | 12.02.2015 | Page 17
Perpendicular quantization