Progress in photo cathode laser pulse shaping towards ultimate low-emittance beams

Experimental progress in infrared shaping & Progress of conversion section design by Christian Koschitzki
Photo Injector Test facility at DESY in Zeuthen (PITZ)

**Homogeneous ellipsoidal electron bunch results in linear phase space → ultimate low emittance**

Pulse should only experience linear distortions

** Beam emittance vs. Bunch Charge **

- **meas. (53MV/m, Gaussian laser)**
- **simul. (53MV/m, Gaussian laser)**
- **meas. (60.6MV/m, flattop laser)**
- **simul. (60.6MV/m, flattop laser)**
- **simul. (60MV/m, 3D-ellipsoidal laser)**
Laser Shaping at PITZ

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


Proof of principle demonstrated with IAP system (single SLM -> dual path) at PITZ in 2016

Comparison with simulated e\(^{-}\) beam shapes (500pC): similarity in shape

Gaussian laser

Flattop laser

Ellipsoidal laser

J. Good et al., Proc. 38\(^{th}\) FEL Conf., WEP006 (2017)

Problems: pointing stability, spectral width and conversion

Measurement
Example for the key principles: The spectrograph

- Polarizing beamsplitter
- Waveplate
- Reflect and reverse optical path

Only rectangular shapes because of projection
Schematic setup of infrared shaping

SLM $\lambda$-X Shaper

SLM $\lambda$-Y Shaper

Volume Bragg Grating Shaper

Pharos laser

Output Power: 20W
Rep. Rate: 0.1-1 MHz
Pulse duration: 0.25 – 15 ps
Wavelength: 1030 nm

Provides rotational symmetry

Standard VBG

Modified VBG

Cylindrical Lens

Spherical Lens

Grating

SLM

Waveplate

Dove Prism

Image Start

Image Out
Shaping with spectrograph feedback

- Pharos laser
- Spectrograph
- Inverted MZ Interferometer
- SLM
- SLM

Gaussian (unshaped) profile
3D Measurement with Spectrograph Slit Scan

Spectrograph Data →
Slices in λ-X along Y

Transverse Slices
Nonlinear Conversion

Input beam
- Wavelength: 1030 nm
- Fourier Limit: 0.211 ps
- Diameter: 0.25 mm
- Pulse duration: 30 ps
- Pulse Energy: 20 µJ
- Material: BBO
- Propagation: 2.5 mm
- BBO Walk Off: 57 mrad

Without angular chirp
Efficiency 20%

With angular chirp
Efficiency 36%

Matched angular chirp:
AC = 0.275 mrad per nm
Slant angle = 25 deg

Animation over 2.5 mm propagation
Nonlinear Conversion

Pump Pulse (IR)

Harmonic Pulse (VIS)

Input beam
Wavelength: 1030 nm
Fourier Limit: 0.211 ps
Diameter: 0.25 mm
Pulse duration: 30 ps
Pulse Energy: 20 µJ
Material: BBO
Propagation: 2.5 mm
BBO Walk Off: 57 mrad

Without angular chirp
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Animation over 2.5 mm propagation
Conversion to Fourth Harmonic

Nonlinearity: \( E_{\text{out}} \sim E_{\text{in}}^4 \)
- 20 \( \mu \)J in \( \rightarrow \) 2.75 \( \mu \)J out (14%)
- 10 \( \mu \)J in \( \rightarrow \) 0.38 \( \mu \)J out (4%)

Broadband Phasematching:
- Suppression of spectral components due to wavelength dependent phase matching
  \( \rightarrow \) Compensate with matched angular chirp

Spatial Walk Off:
- Edge Softening due to propagation difference between pump and harmonic beam.

Softening in 0.8 mm BBO
First Conversion Tests and Outlook

Variable Magnification Telescope

Image in IR from old IAP system

Image in IR (1030 nm)

Image after first Conversion in VIS (515 nm)

Collaboration with Chiang Mai University Thailand by Narupon Chattrapiban
Summary & Outlook

- 3D shaping capabilities in IR demonstrated
- Image preservation in Second Harmonic shown
- Preparing for Fourth Harmonic (UV) experiments (UV Spectrograph)
- Investigation of time coordinate using cross correlation
- Improved 3D shaping with Volume Bragg Gratings

Thank you for your attention