Green pulse shaper update

3D Ellipsoidal laser pulses for EuXFEL

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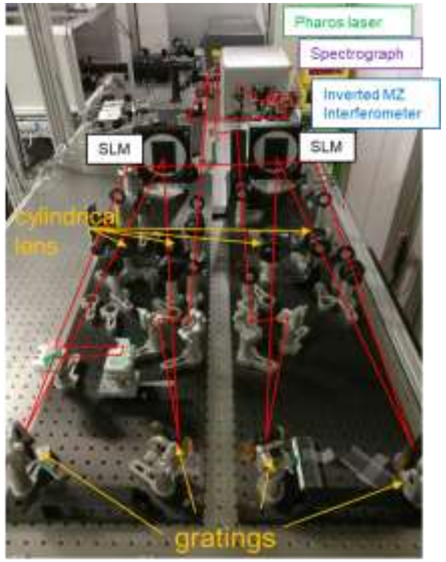
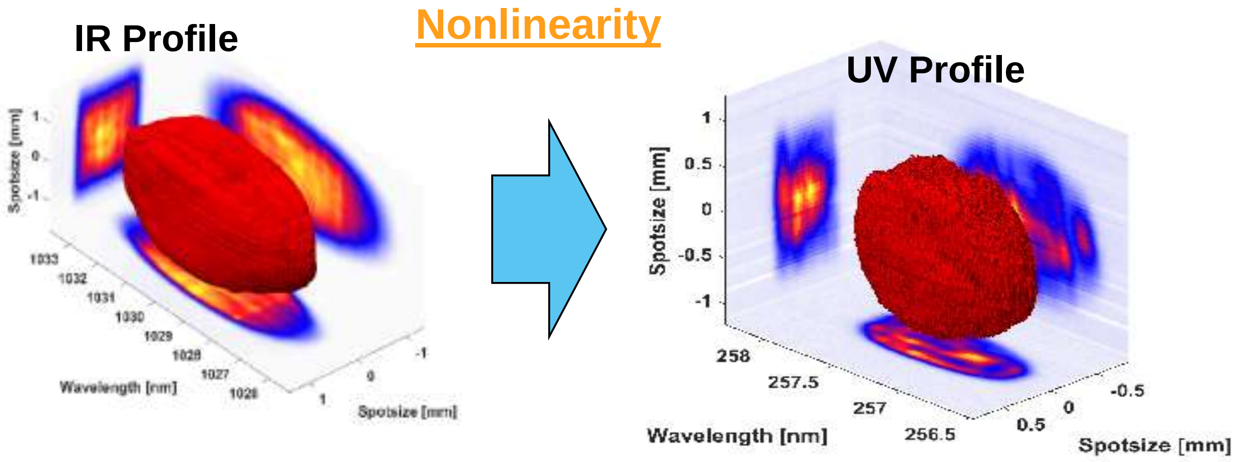
Outline

- IR pulse shaper recap
- Green pulse shaper
  - Idea and layout
  - Stretcher
  - First test measurements
  - UV conversion tests
  - Measurement of temporal pulse shape
- Next steps

IR pulse shaper





Nonlinear conversion processes amplify intensity fluctuations, severely reducing UV pulse quality

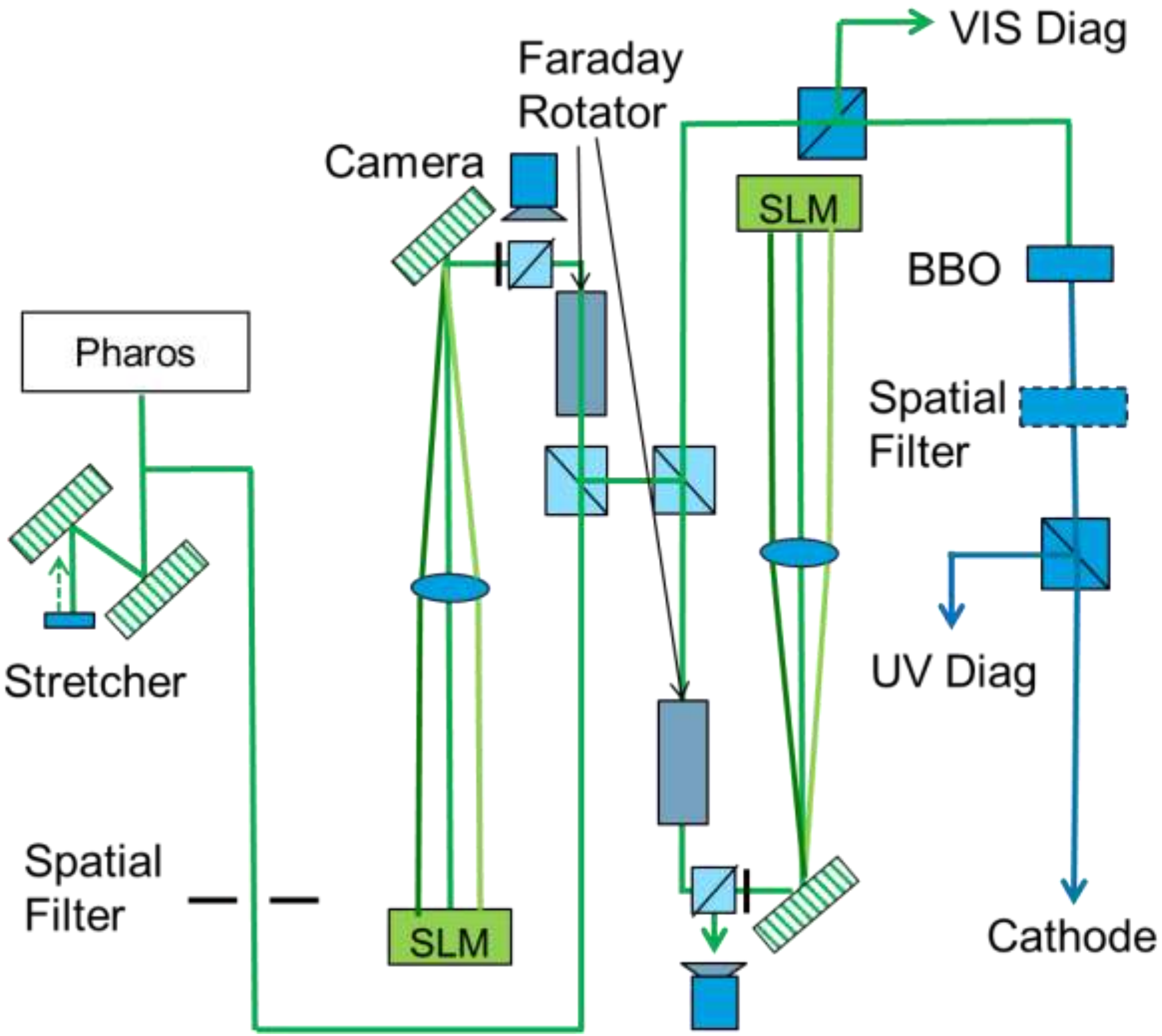
	IR ELLA	MBI
IR output energy	160 µJ @ 125 KHz	310 µJ (10 Hz / 1 MHz)
Shaper transmission	several µJ	
UV output energy	tens of nJ	1.8 µJ
Conversion efficieny	~ 1%	> 1%
QE 5% (0.01 nC/nJ + space charge)	500 pC	5 nC

Goals of green shaping

- Simplified frequency conversion: One conversion from VIS to UV
- Achieve high conversion efficiency of ellipsoidal pulses
- Simplified shaper setup
- Direct use on green cathodes
- Works with 1 MHz trains

	GrELLA	MBI
Output energy	10 µJ (10Hz / 1 MHz)	310 µJ (10 Hz / 1 MHz)
Shaper transmission	1 µJ	
UV output energy	100 nJ	1.8 µJ
Conversion efficieny	~ 10%	> 1%
QE 5% (0.01 nC/nJ + space charge)	1 nC	5 nC

Pulse shaper design



Green stretcher:
- 250 fs from Pharos to 10 ps

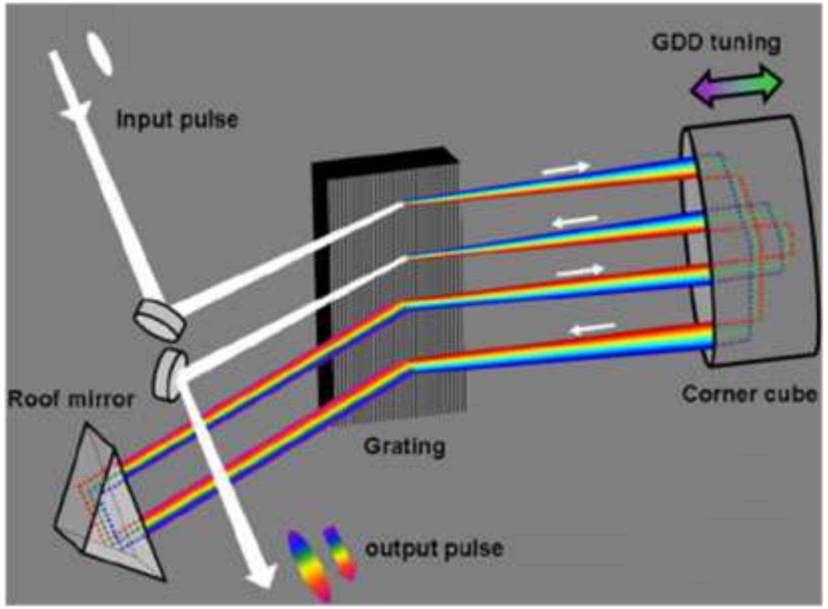
Simplified shaper design:
- x-λ amplitude shaping
- y-λ amplitude shaping

Green stretcher

Conceptional design

Dual-pass grating stretcher

- Chirp: $GDD = \frac{\Delta t_{in}}{4(ln2)}\sqrt{\Delta t_{out}{}^2 - \Delta t_{in}{}^2}$



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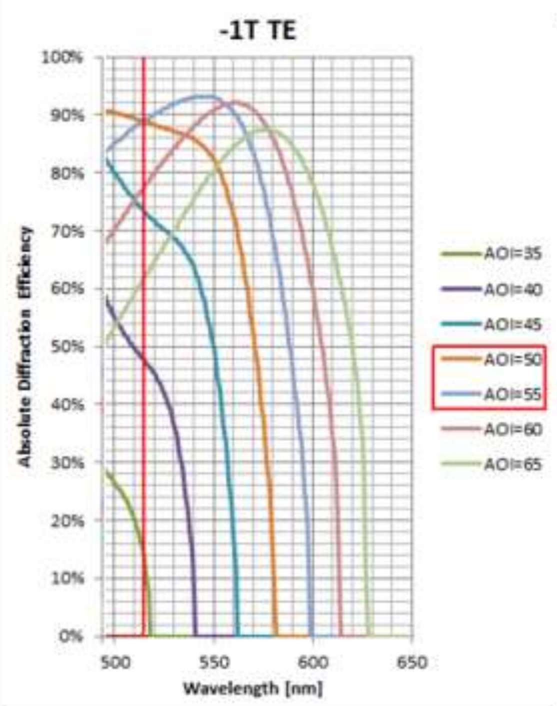
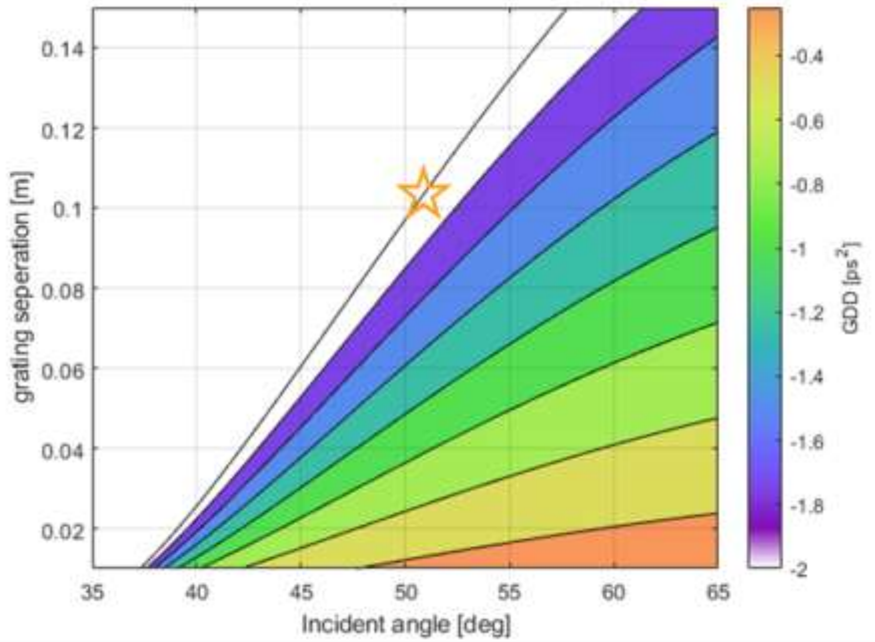
- Ibsen 3040 l.mm^{-1} transmission grating

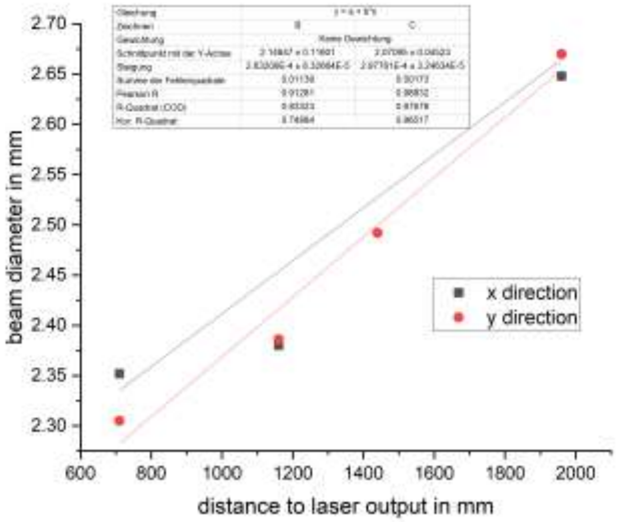




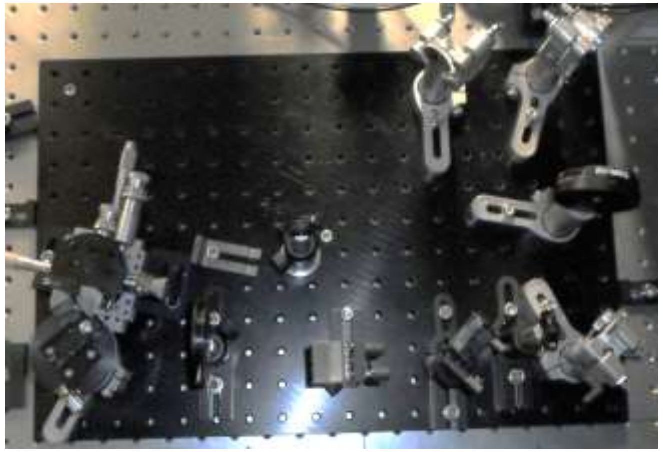
- $\theta_{Littrow}$ = 51.5deg
- Efficiency: $(0.9)^4$ = ~0.65!

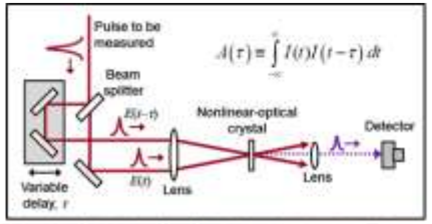
Pulse shaper reality

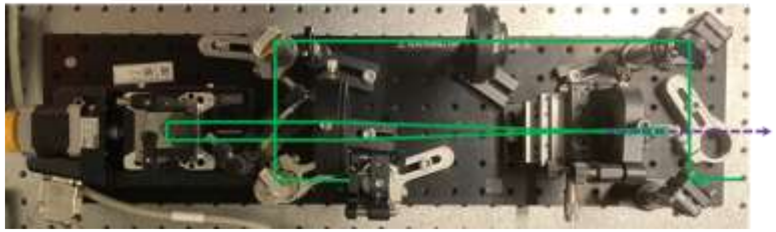
Divergence of Pharos laser



Setup



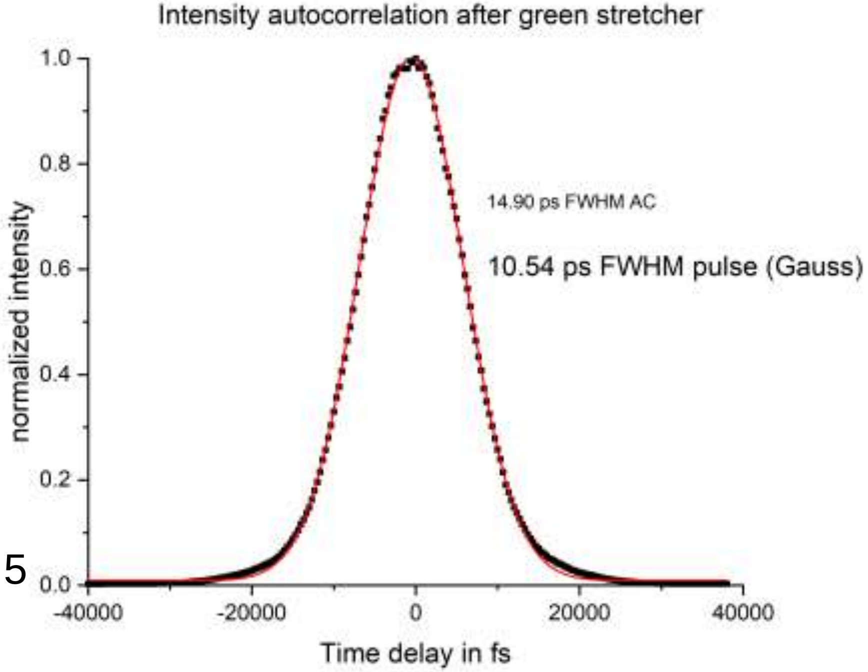




Transmission

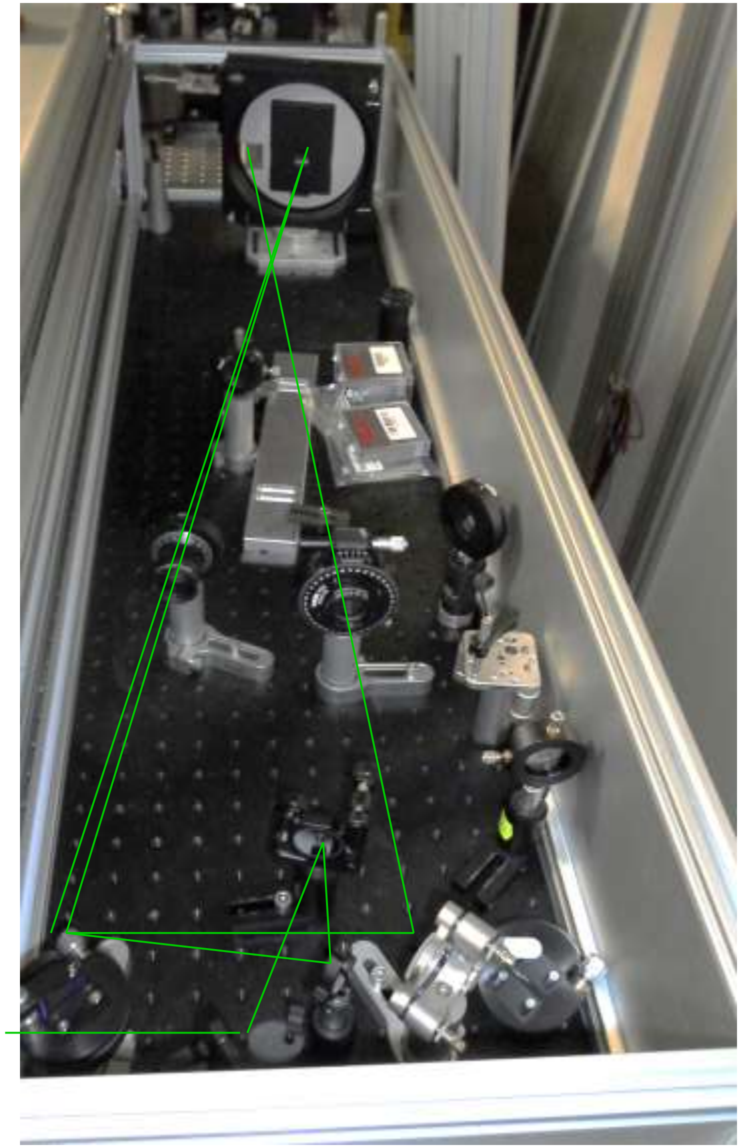
Total transmission: 0.4
6 reflections on protected Ag: 0.96^6 = 0.78
4 grating passes: (0.4/0.78)^(1/4)= 0.85 per pass

Transmision can be increased by HR mirrors to 0.5
Same gratings in pulse shaper



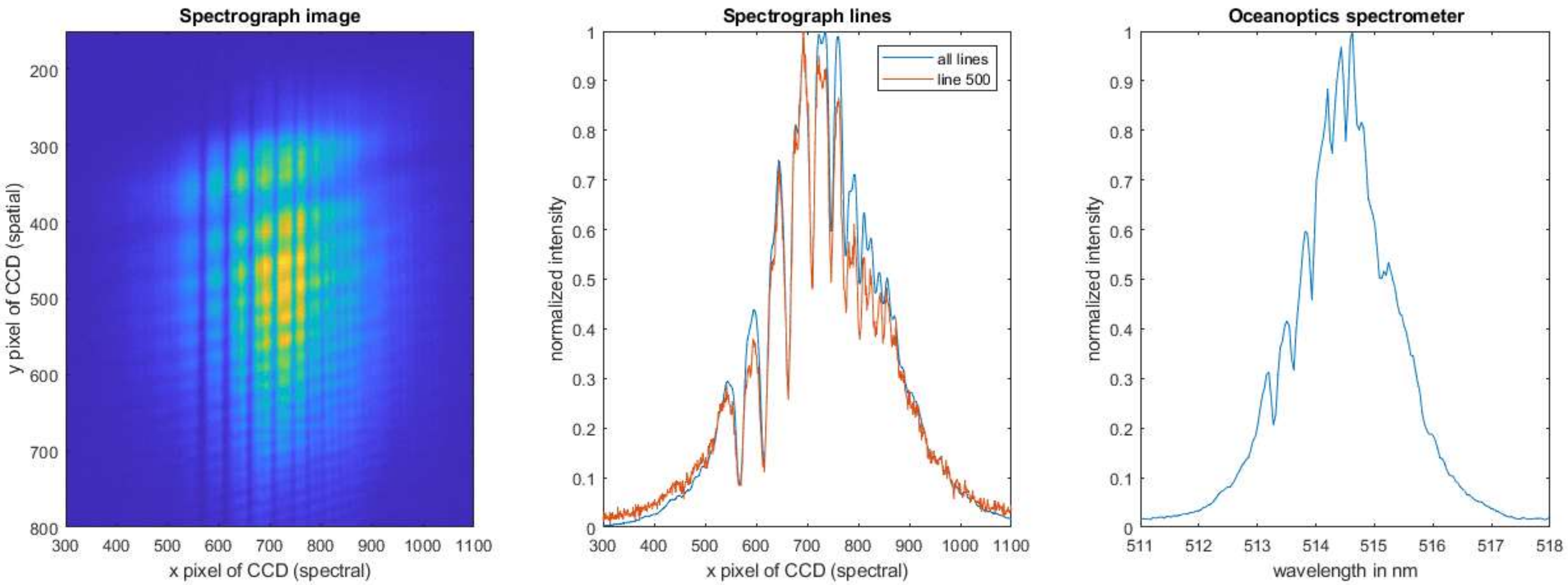
First experiments: Spectral resolution

Spectral resolution of amplitude shaping capabilities



First test of amplitude shaping:

- Calibration of pulse shaper voltage range
- Test of spectral resolution of the shaper and green spectrograph
- Spectral width of the modulated peaks is influenced by the pixel resolution of the shaper and the imaging quality to the spectrograph



First experiments: Spectral resolution & spatial resolution

Double pass grating in 4f geometry

E. Frumker and Y. Silberberg Vol. 24, No. 12/December 2007/J. Opt. Soc. Am. B 2941

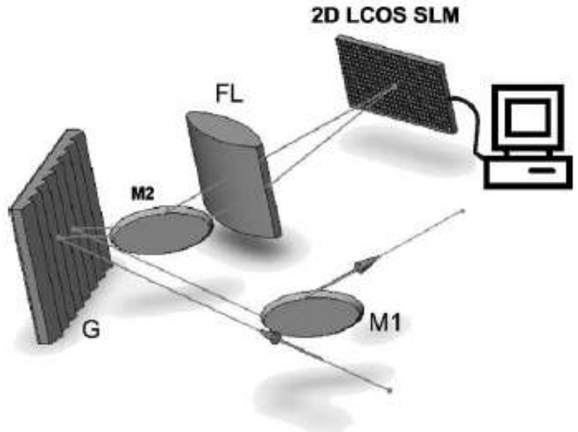
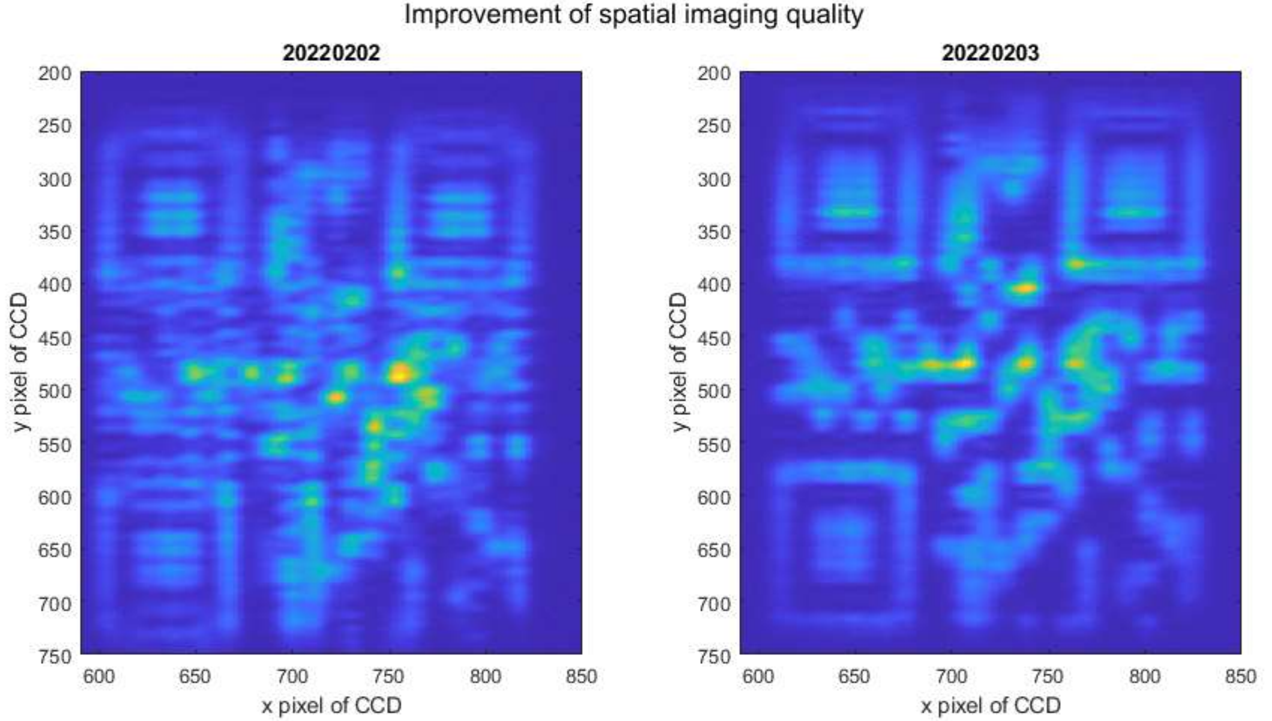


Fig. 1. Schematic of the 2D phase and amplitude SLM pulse shaper.

- Faraday rotators of the shaper design were massively delayed
- Beam separation in horizontal plane is standard approach
- Careful alignment improves the imaging to the spectrograph

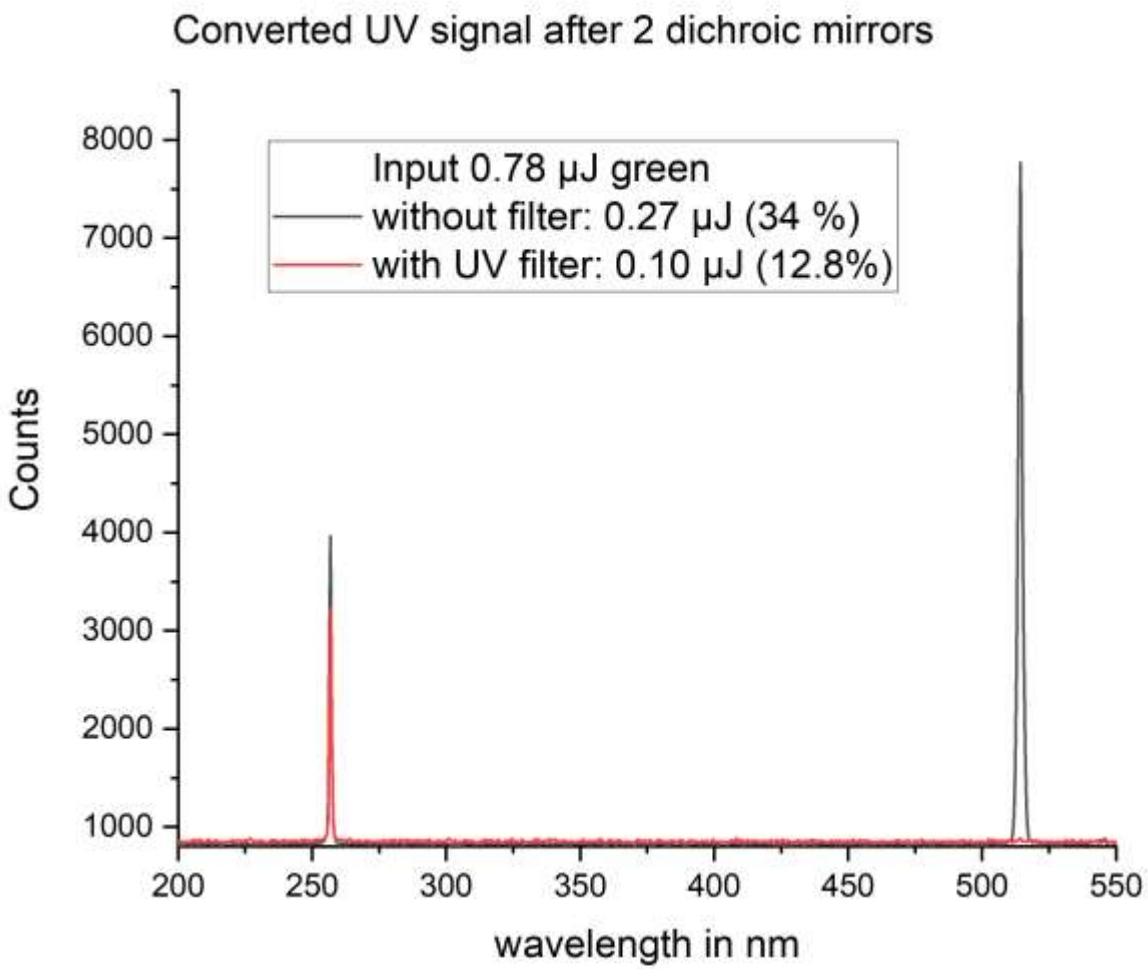
QR code encoded to laser pulse and send to spectrograph

Spatial axis



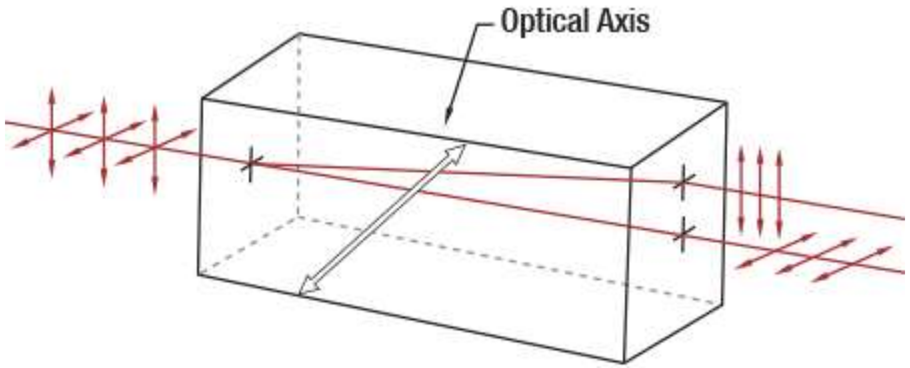
Spectral axis

UV conversion tests



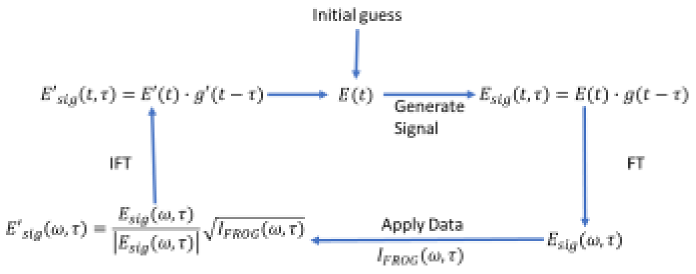
Next steps:

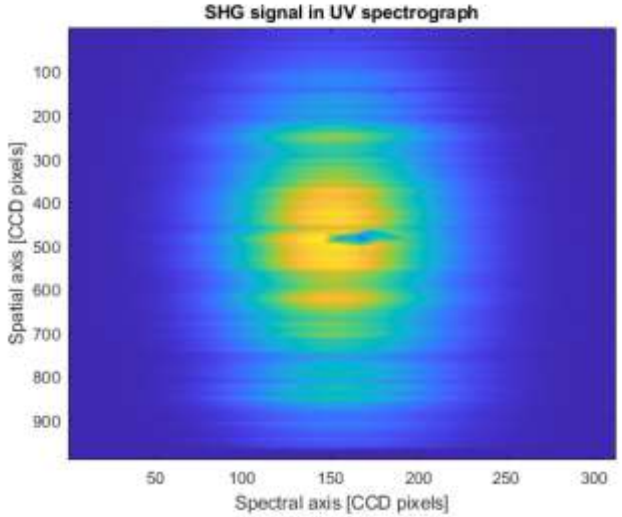
- Geometrical wavelength seperation with a Calcite wedge
- Check image quality through focus and frequency conversion by test images

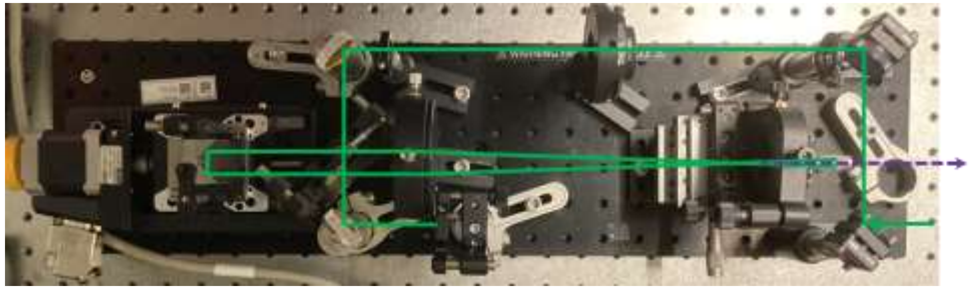


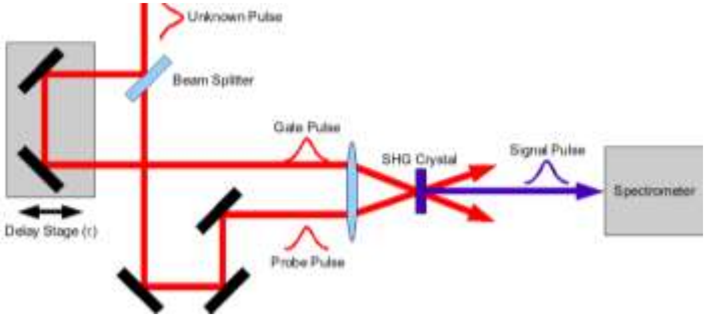
SHG FROG with UV spectrograph

Reconstruction of the pulse shape





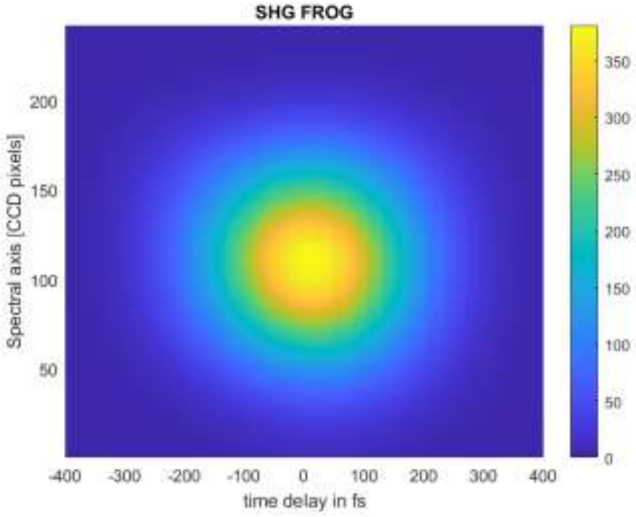


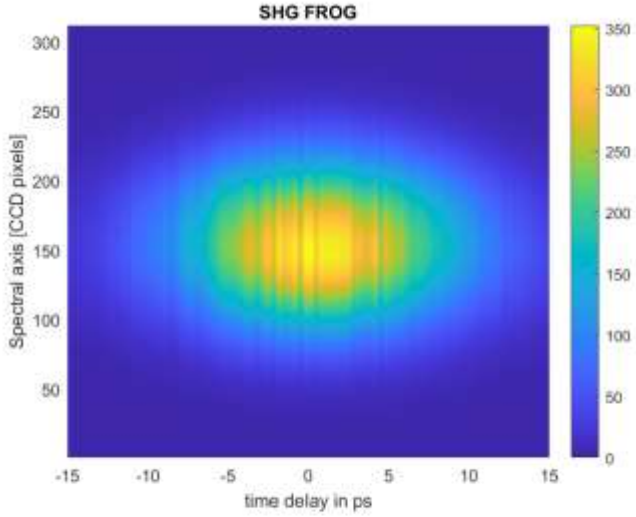


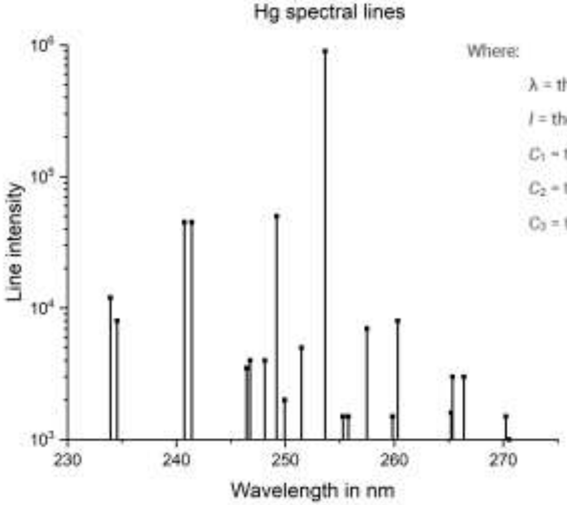
$\lambda_p = I + C_1 p + C_2 p^2 + C_3 p^3$

Where:

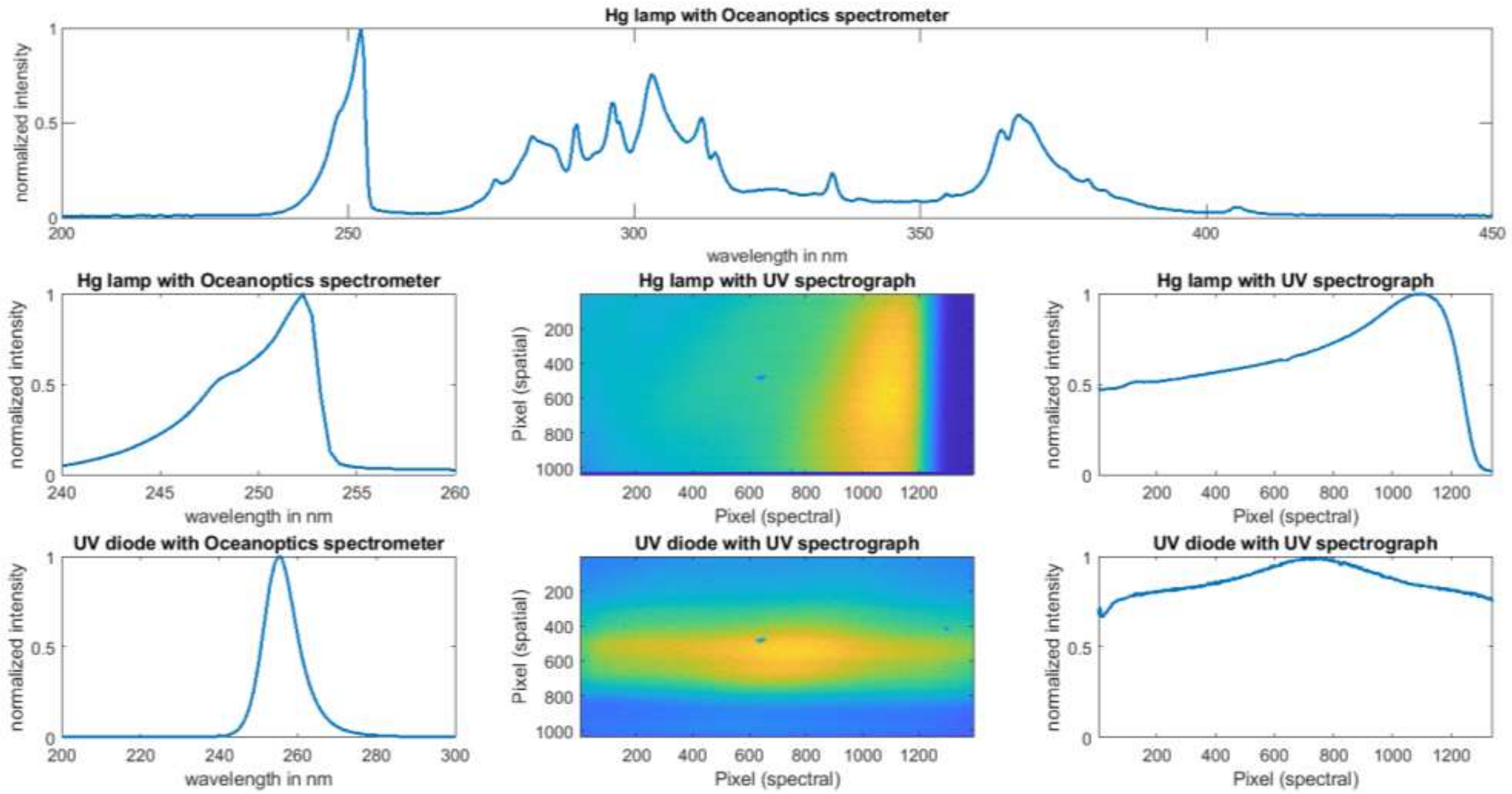
- λ = the wavelength of pixel p
- I = the wavelength of pixel 0
- C_1 = the first coefficient (nm/pixel)
- C_2 = the second coefficient (nm/pixel²)
- C_3 = the third coefficient (nm/pixel³)







Technical detail: Wavelength calibration of UV Spectrograph



TG measurements

Direct measurement of photocathode time response in a high-brightness photoinjector

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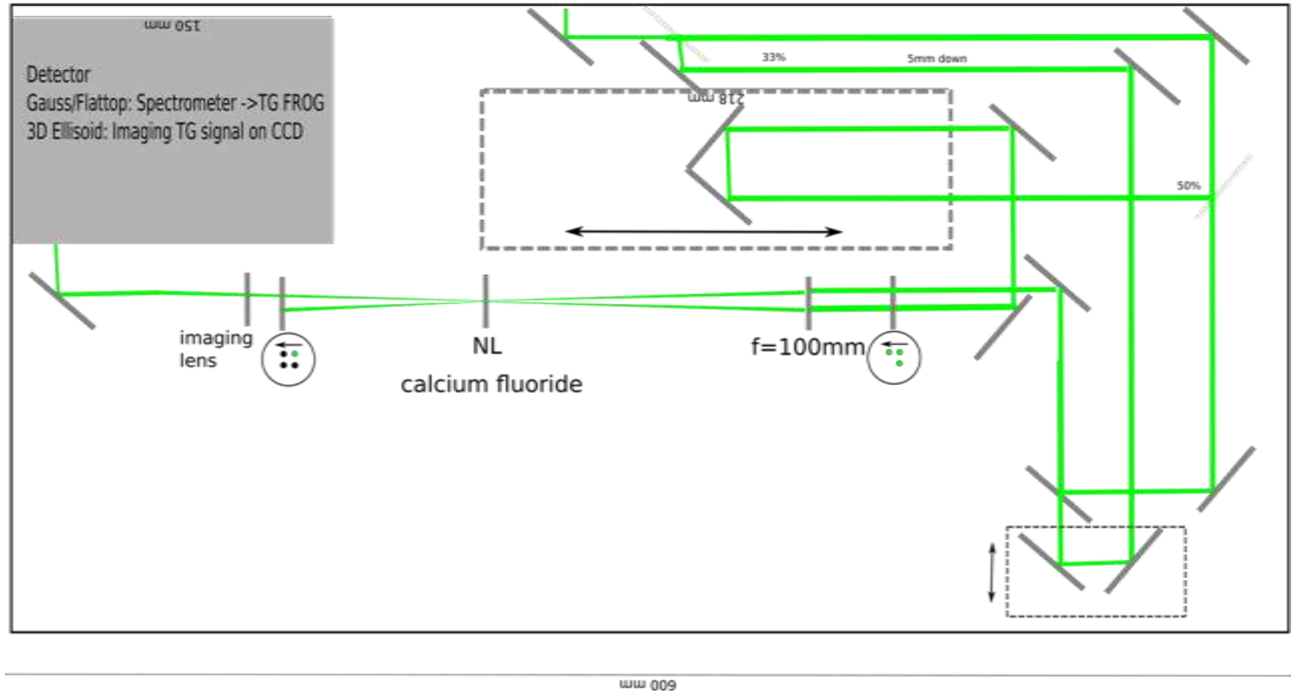
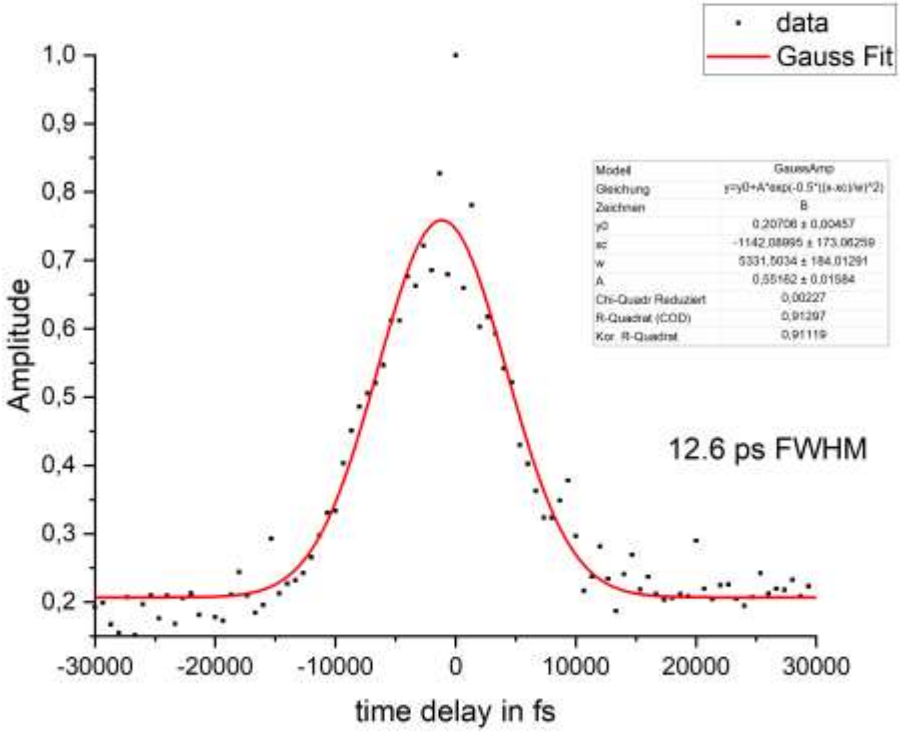
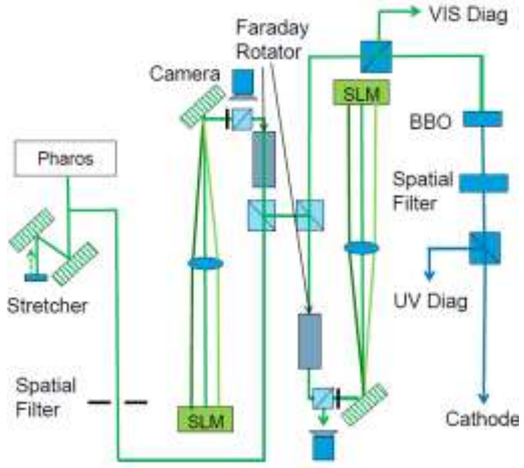
- Accurate measurement of fs to ps pulses
- For 10 ps the intensity in the focus is at the lower limit for a transient grating
- For 10 ps pulses shorter focal length and higher n_2 is needed





Summary



Green pulse shaping

Simplified design for

- x-λ shaping
- y-λ shaping

Frequency conversion

- One conversion stage: VIS → UV
- Goal: Achieve high conversion efficiency with ellipsoidal laser pulses

Diagnostics for shaping experiments

- Full characterization of spectral / temporal amplitude and phase by frequency resolved optical gating
- Measurement of the spectral amplitude by spectrographs in VIS and UV

Current status:

Shaper

- Setup phase for stretcher and shaper finished
- First calibration and shaping tests
- Further design optimizations

Frequency conversion

- Conversion efficiency VIS → UV above 10%
- Image quality tests ongoing

Diagnostics for shaping experiments

- TG FROG and SHG FROG for characterization of shaped pulses

Next goals:

- Improve emittance with pulse shaping
- Direct shaping on green cathodes
- Optimized pulses for bunch compressor and THz undulator

Next steps

Pulse shaping experiments with PHAROS (pure optical)

Pulse shaping experiments with the electron beam

~~Q4 2021~~
Q1 2022

- Begin construction
- Test the green pulse shaper and benchmark its shaping capabilities

Q2/3 2022

- Optimize the pulse shape and its characterization
- UV pulse characterization
- 3D Ellipsoidal pulses on the laser table

Q4 2022

- Improve and benchmark ellipsoidal shaping
- Green vs. IR shaping
- MBI vs. PHAROS shaping
- TG FROG vs. TDS