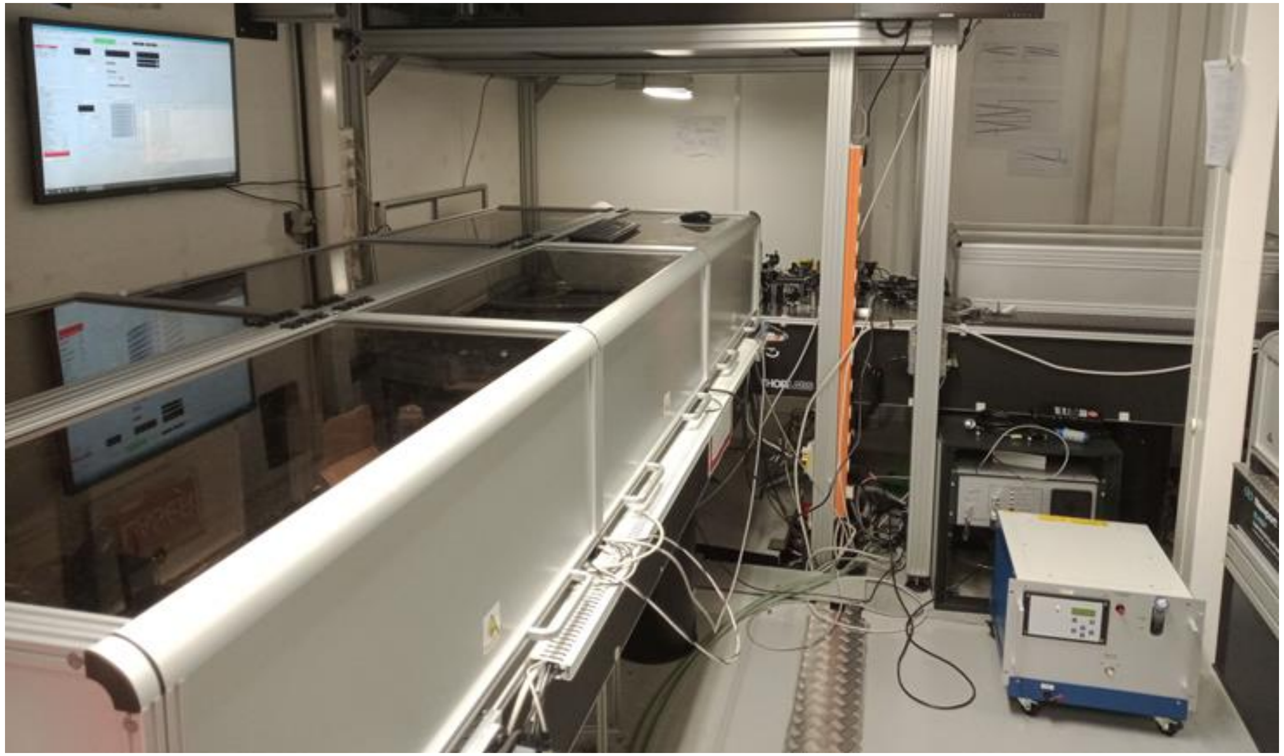
PITZ Laser Upgrade 2021

Green pulse shaper, UV stretcher, double pulses and TG FROG

James Good, Andreas Hoffmann
Zeuthen, 28^{th} September 2021

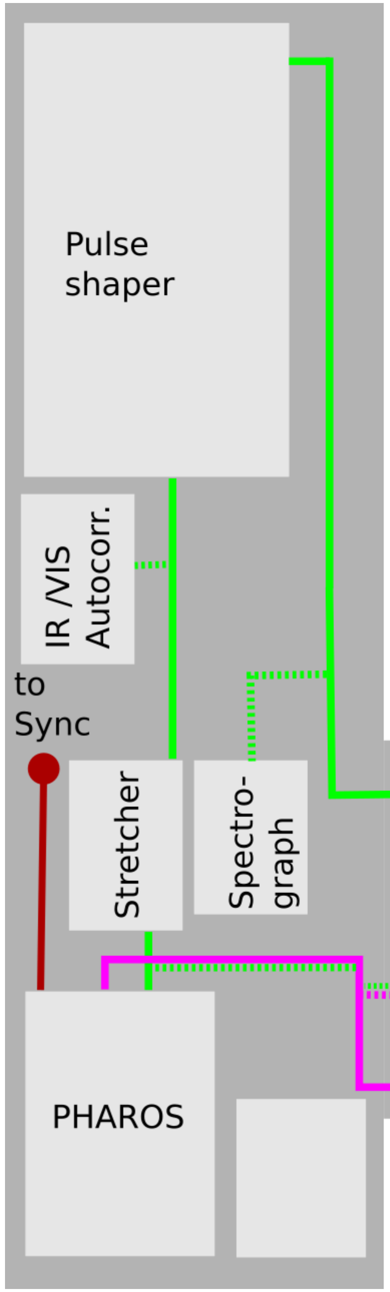


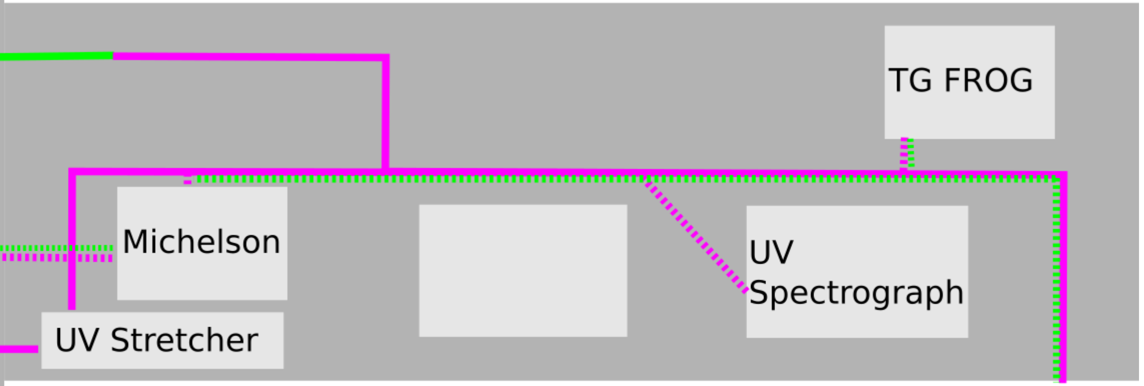
Overview

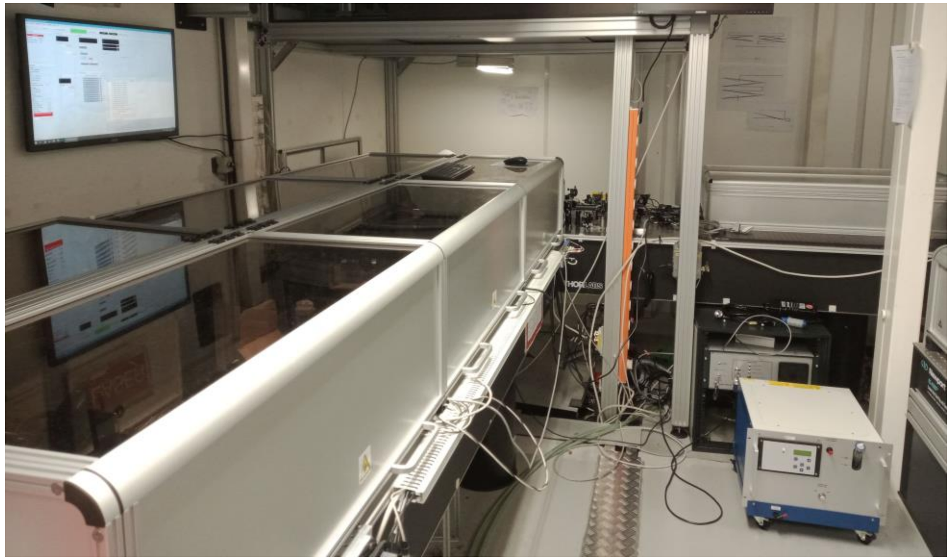
PHAROS table

News

- PHAROS is back from the manufacturer
- Pulse shaping now with green laser output and only one frequency conversion step
- TG FROG for characterization of the pulse shaping
- Dual band upgrades of beamline diagnostics
  - → IR:VIS autocorrelator
  - → VIS:UV Michelson
  - → VIS:UV Near field /Far field

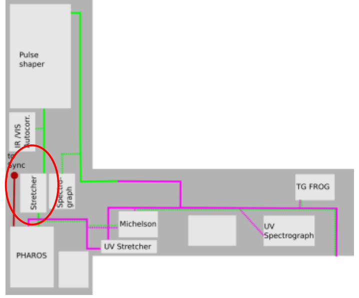






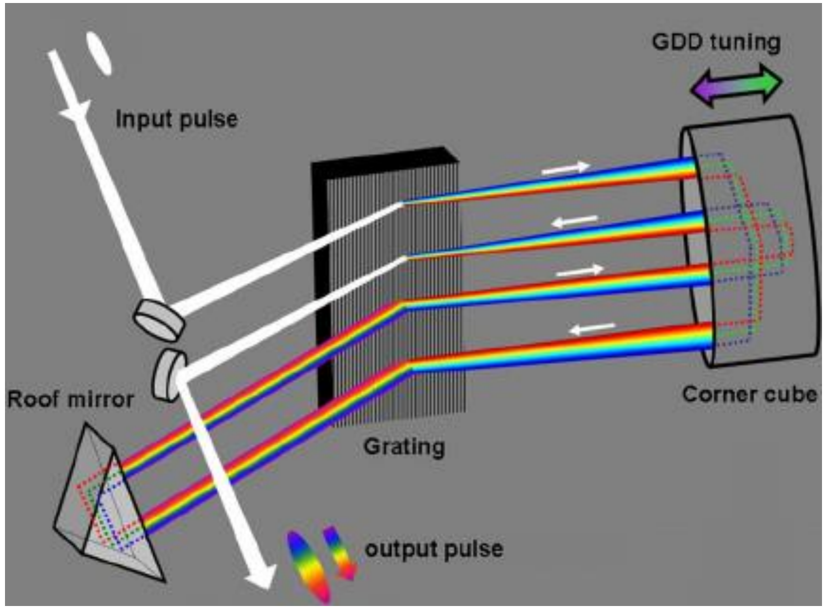
Green ELLA

Pulse stretching



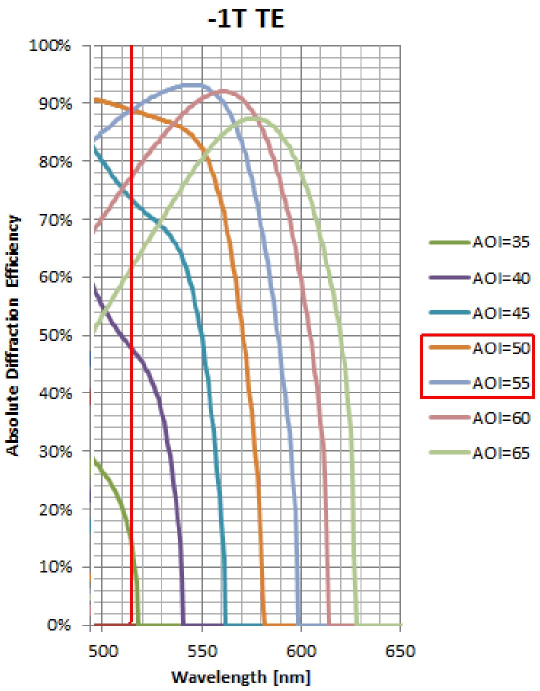
Dual-pass grating stretcher

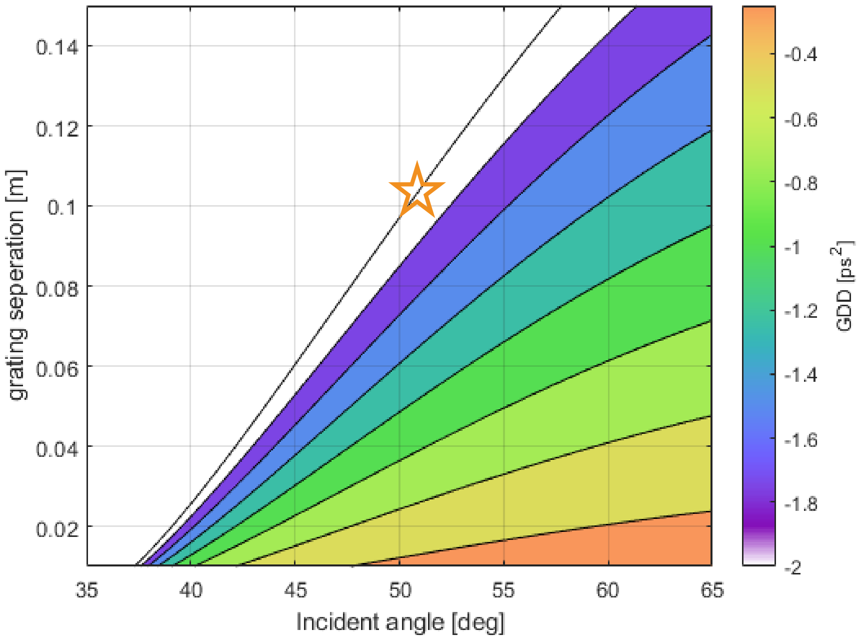
- Chirp: $GDD = \frac{\Delta t_{in}}{4(ln2)}\sqrt{{\Delta t_{out}}^2 - {\Delta t_{in}}^2}$



- $GDD = -\frac{2\lambda^3 D}{2\pi c^2 d^2 \cos^3(\theta_d)}$

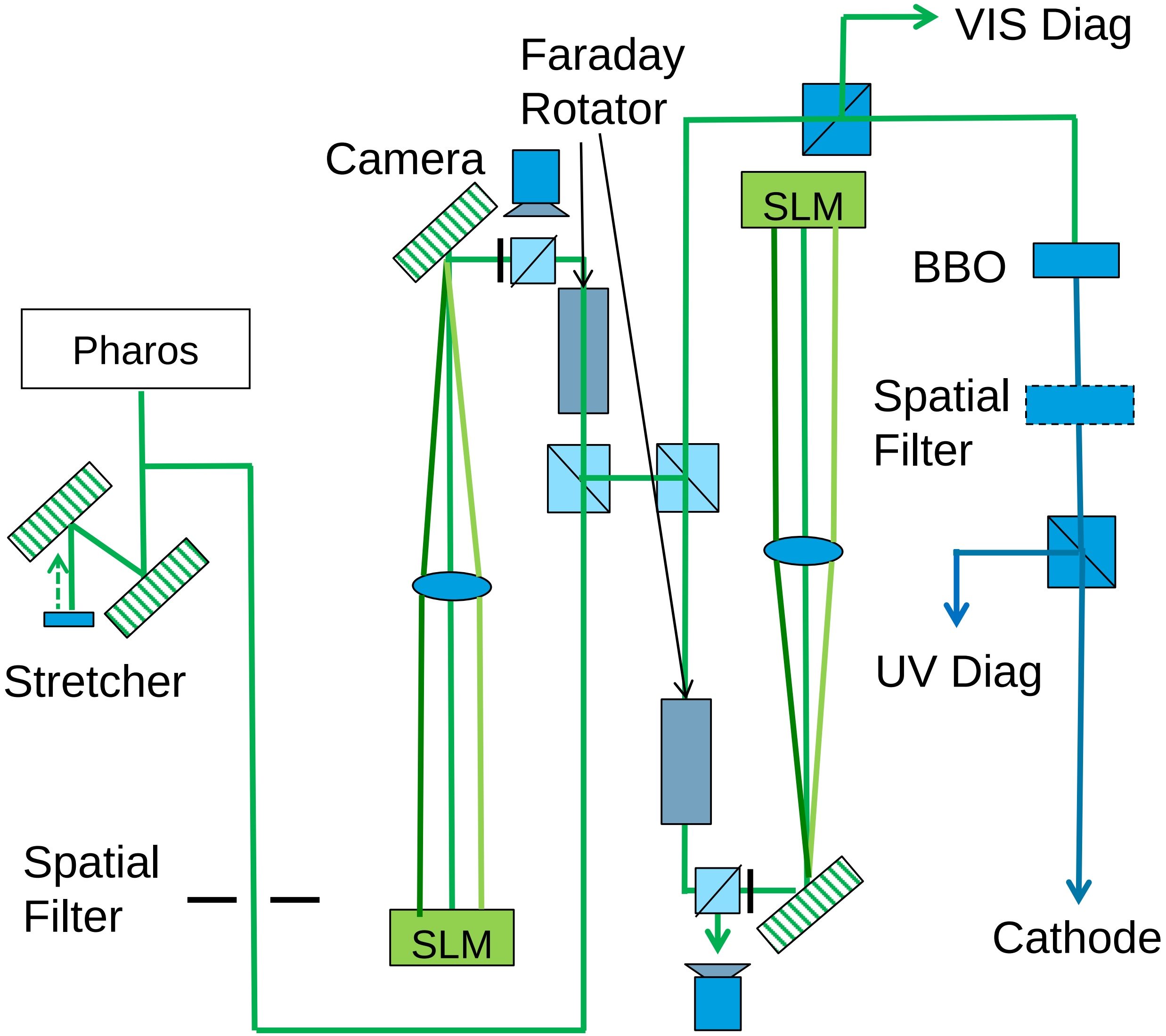
- Ibsen 3040 l.mm^{-1} transmission grating

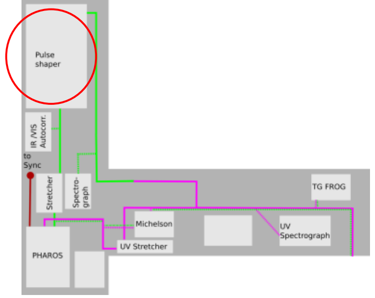




- $\theta_{Littrow}$ = 51.5deg
- Efficiency: $(0.9)^4$ = ~0.65!
  - UV grating stretcher: $(0.6)^4$ = ~0.13

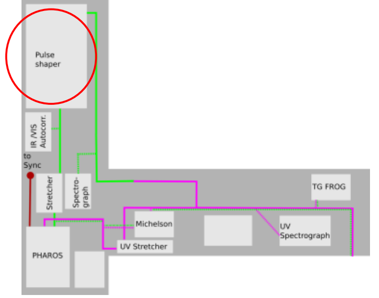
Conceptual Design





Green pulse shaper

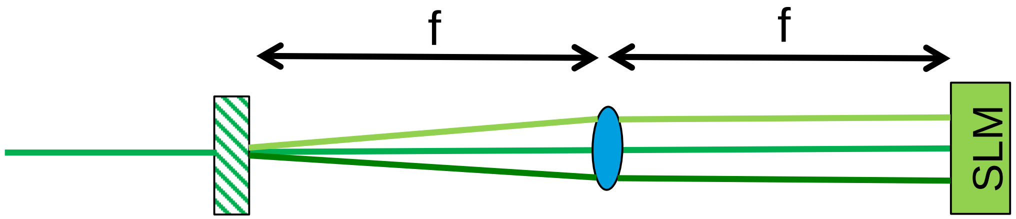
Balance between spatio-spectral resolutions



Spectral factors

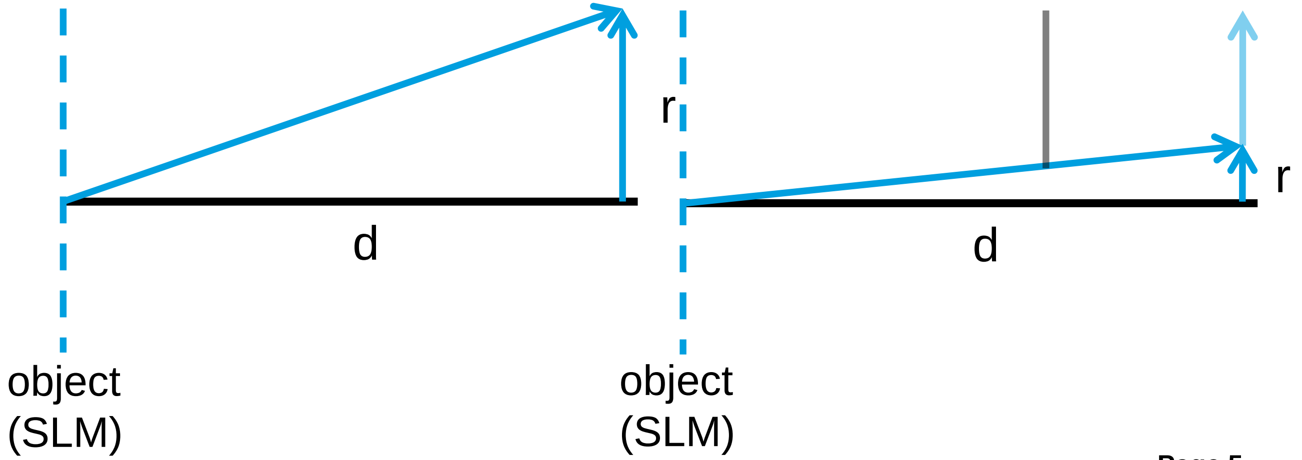
- TBP: $\Delta\tau \frac{\Delta\lambda}{{\lambda_0}^2} c = \frac{2 \ln 2}{\pi} \Rightarrow \Delta\lambda \propto {\lambda_0}^2$

  $\Delta\lambda(1030\text{ nm}) = 5.2\text{ nm}$
  $\Delta\lambda(515\text{ nm}) = 1.3\text{ nm}$

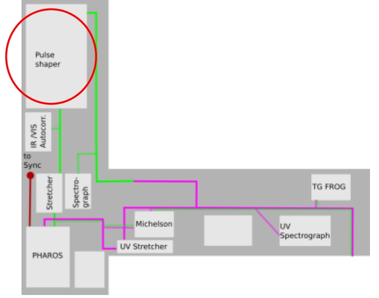


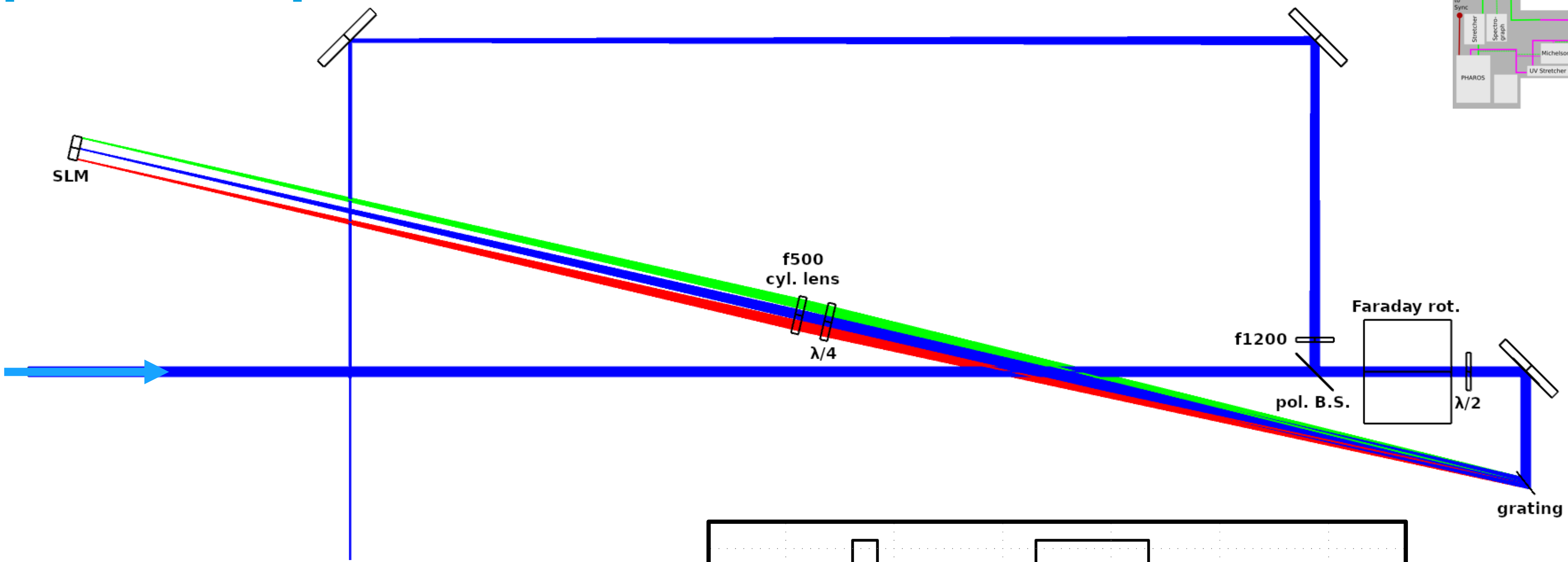
Spatial factors:

- MTF limit: $MTF_{max} = \frac{2 \sin \tan^{-1}(r/d)}{\lambda}$
- SLM resolution: 20 um/px → 25 l.mm^{-1}



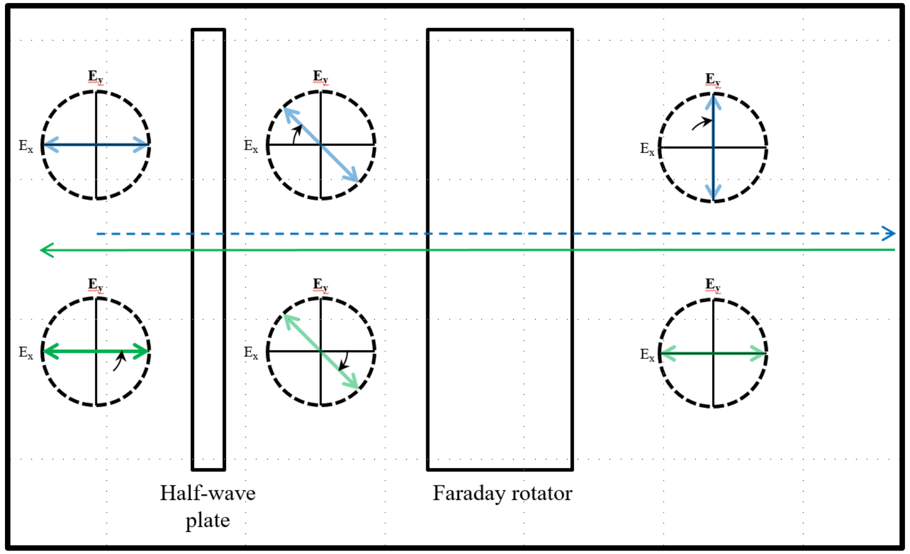
Green pulse shaper





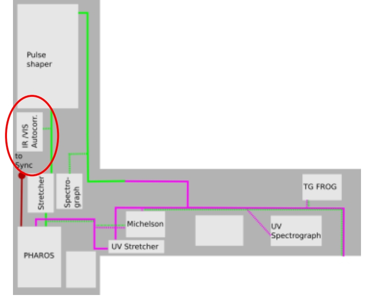
Spatial factors:

- Ø12 mm Faraday rot. at 1.1 m → 21 $l.mm^{-1}$
- $d\lambda/dx = 0.725$ nm/mm



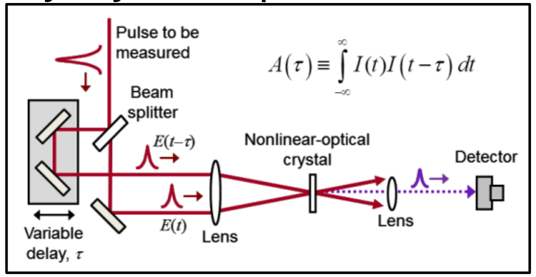
Dual-band Autocorrelator

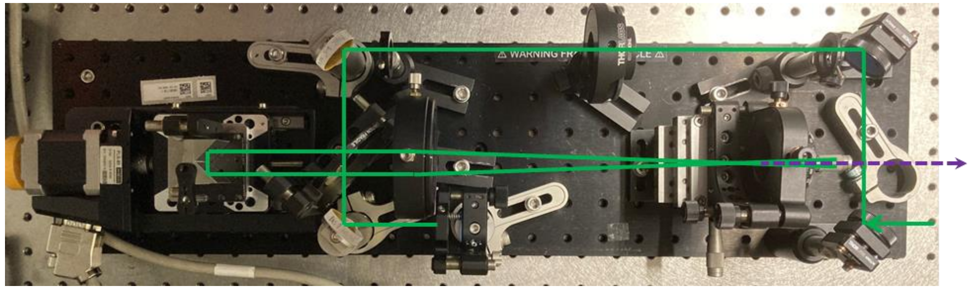
IR / Green intensiometric autocorrelation



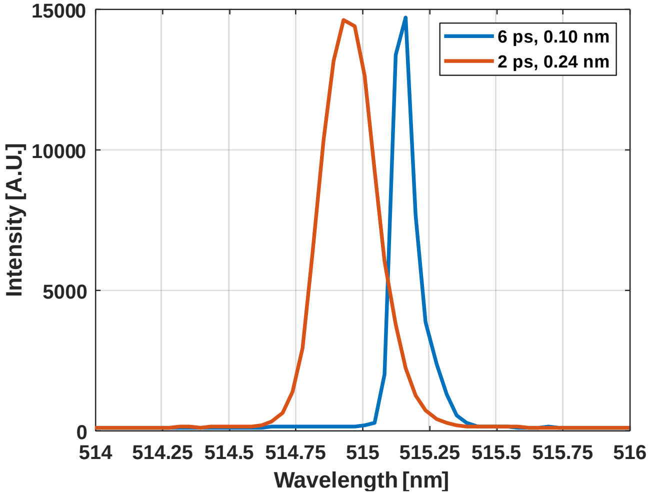
New!

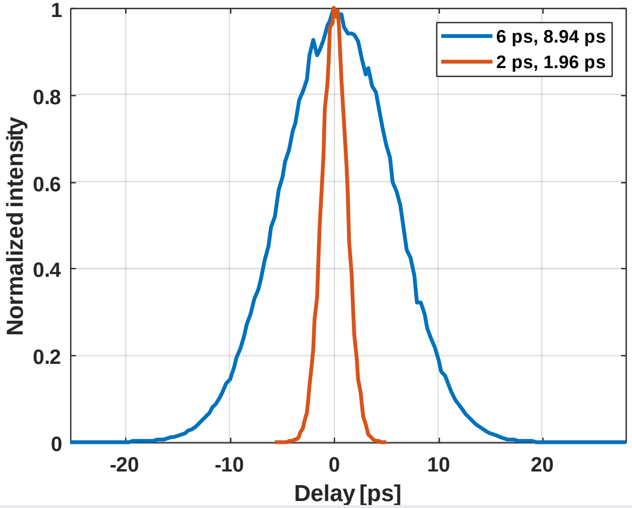
- Dual-band optics & achromat
  → only crystal dependent





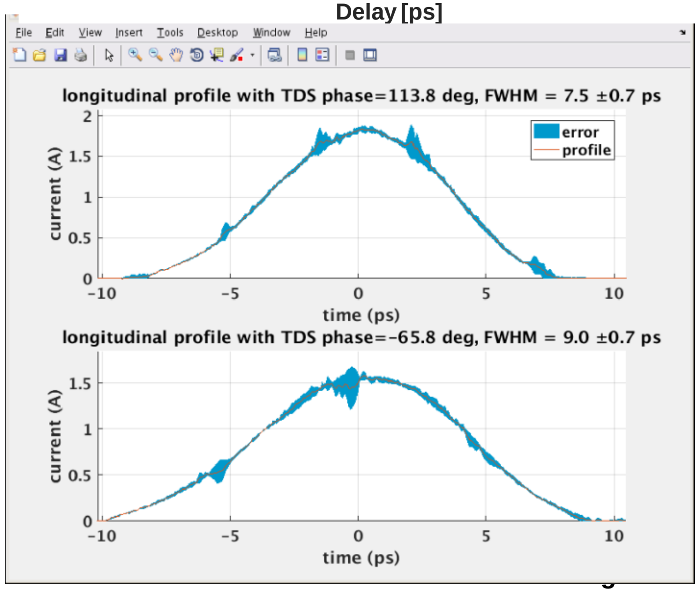
$$TBP:\ \Delta t \cdot \frac{\Delta\lambda}{\lambda^2} = 0.44$$





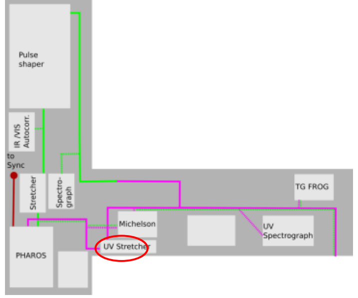
MBI Measurements

- "6 ps UV": ~9 ps AC trace & photoelectrons → 0.04 nm BW
- "2 ps UV": ~2 ps AC trace 0.2 nm BW
- To-do: measure Pharos outputs & calibrate green stretcher



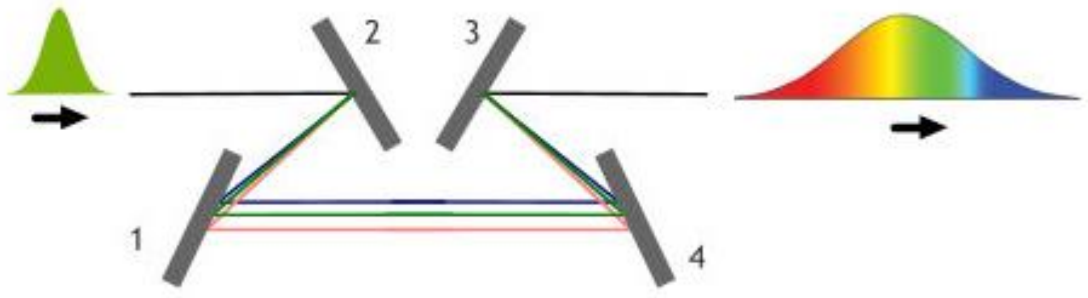
UV stretcher (with negative dispersion)

Classic compressor design



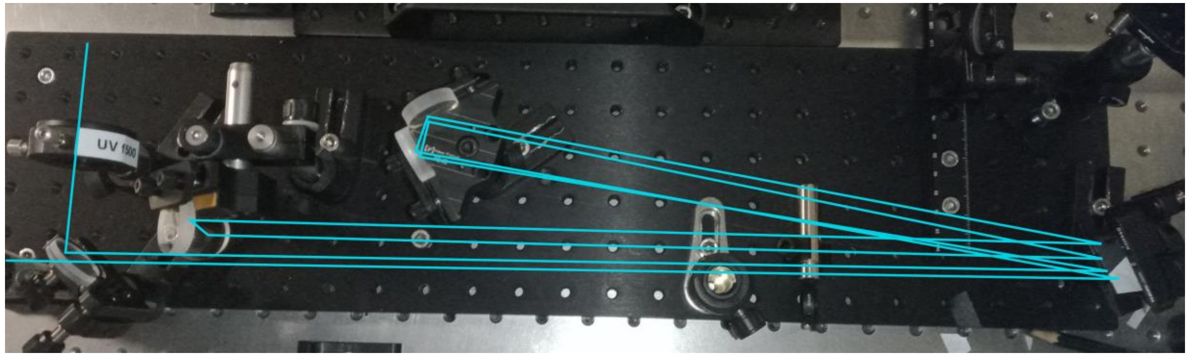
Design idea

- Horizontally and vertically folded design with 4 passes over a single grating
- Adjustable pulse duration
- Easy alignment



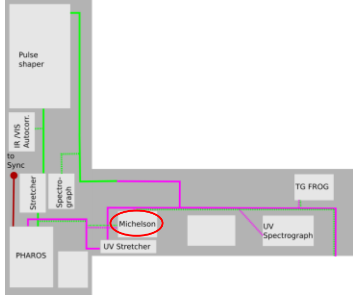
Key features

- Low energy backup for MBI laser (15% of PHAROS output energy)
- Adjustable between 2ps and 18ps FWHM Gaussian pulses



Double pulses for response time measurements

Dual-band green / UV Michelson interferometer



Upgrade

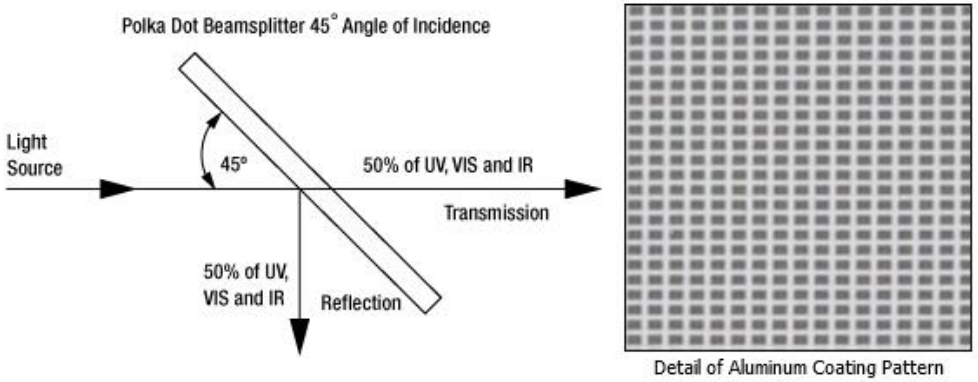
- Broadband Polka dot beamsplitter (0.25 µm – 2 µm)
- Dual-band beamline and diagnostic

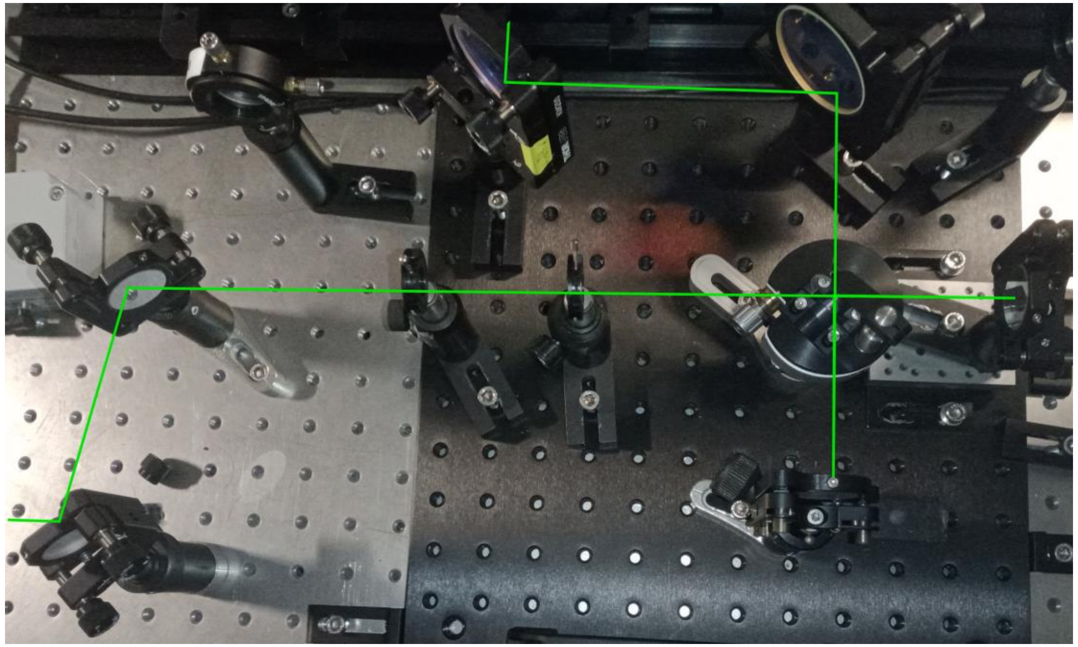
Achievements

- Successful test with green cathodes
- Response time of ~50 fs for CsK_2Sb #147.1 (see RC 20210727)

Next steps

- Motorization (measurements without laser experts) & compacting

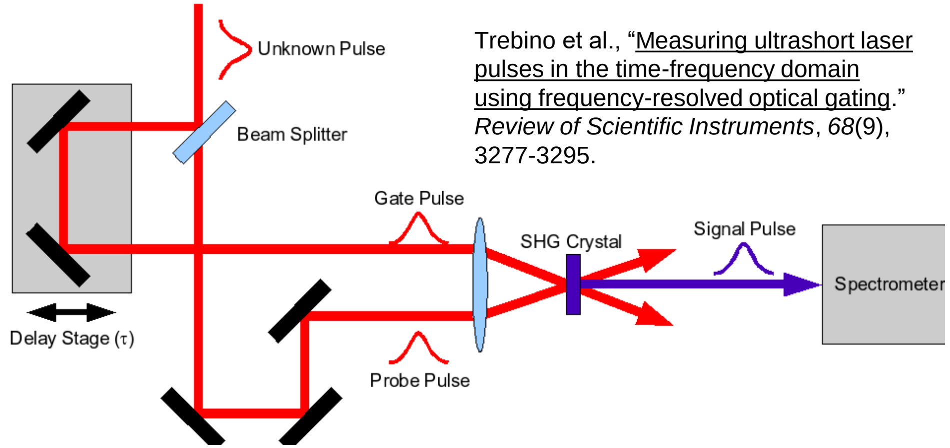




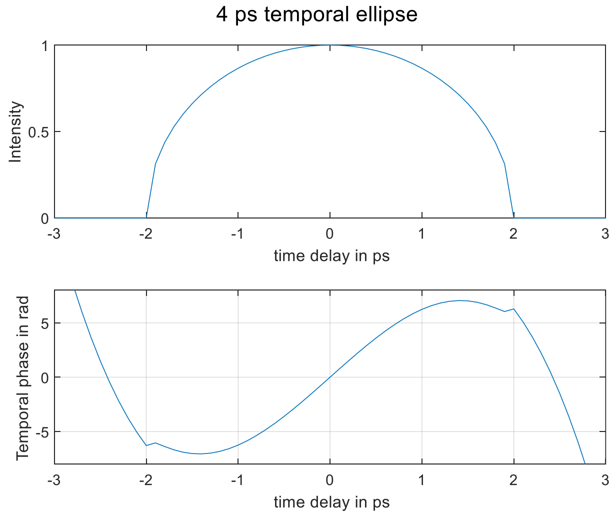
Characterization of shaped pulses

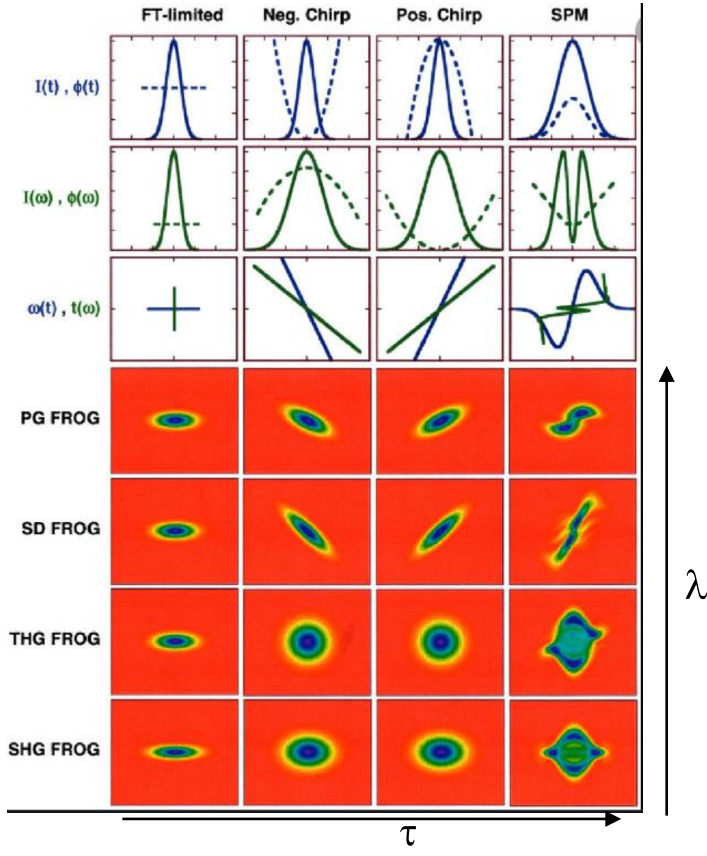
Frequency resolved optical gating (FROG)

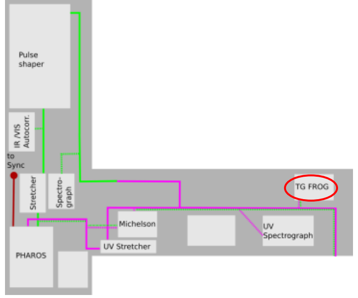
- FROG measures the spectrum vs. temporal delay
- Phase retrieval algorithm for the temporal / spectral pulse shape
- FROG error allows to judge the quality of the reconstruction
- Various FROG techniques exist (SHG,THG, SD, PG) [DOI: 10.1063/1.1148286]
- PG and SD do not covert the frequency and their traces are very intuitive for chirp
- TG FROG is a 3-beam alternative for UV pulse demands



Trebino et al., "Measuring ultrashort laser pulses in the time-frequency domain using frequency-resolved optical gating." *Review of Scientific Instruments*, *68*(9), 3277-3295.



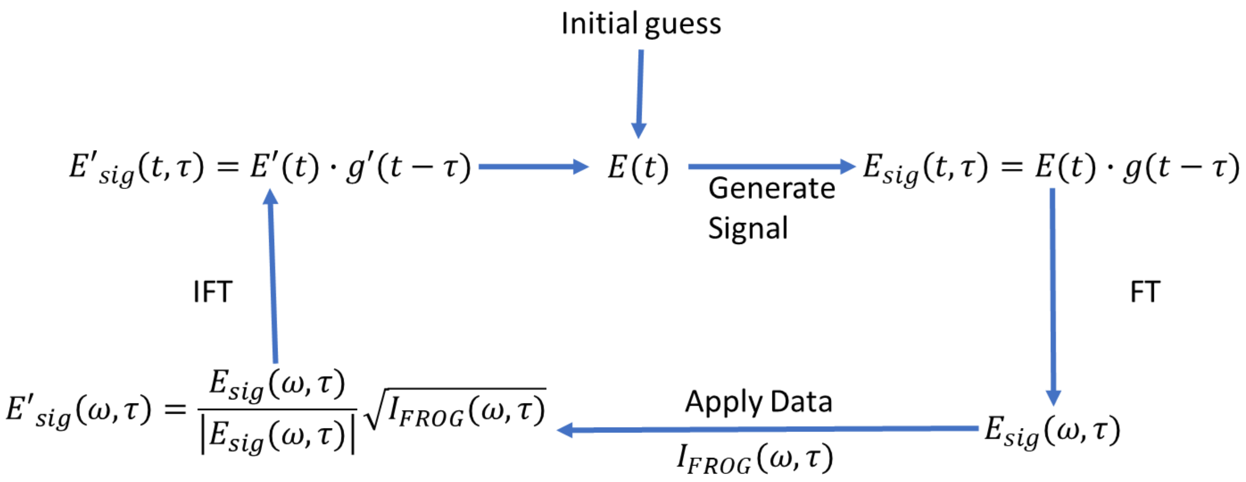


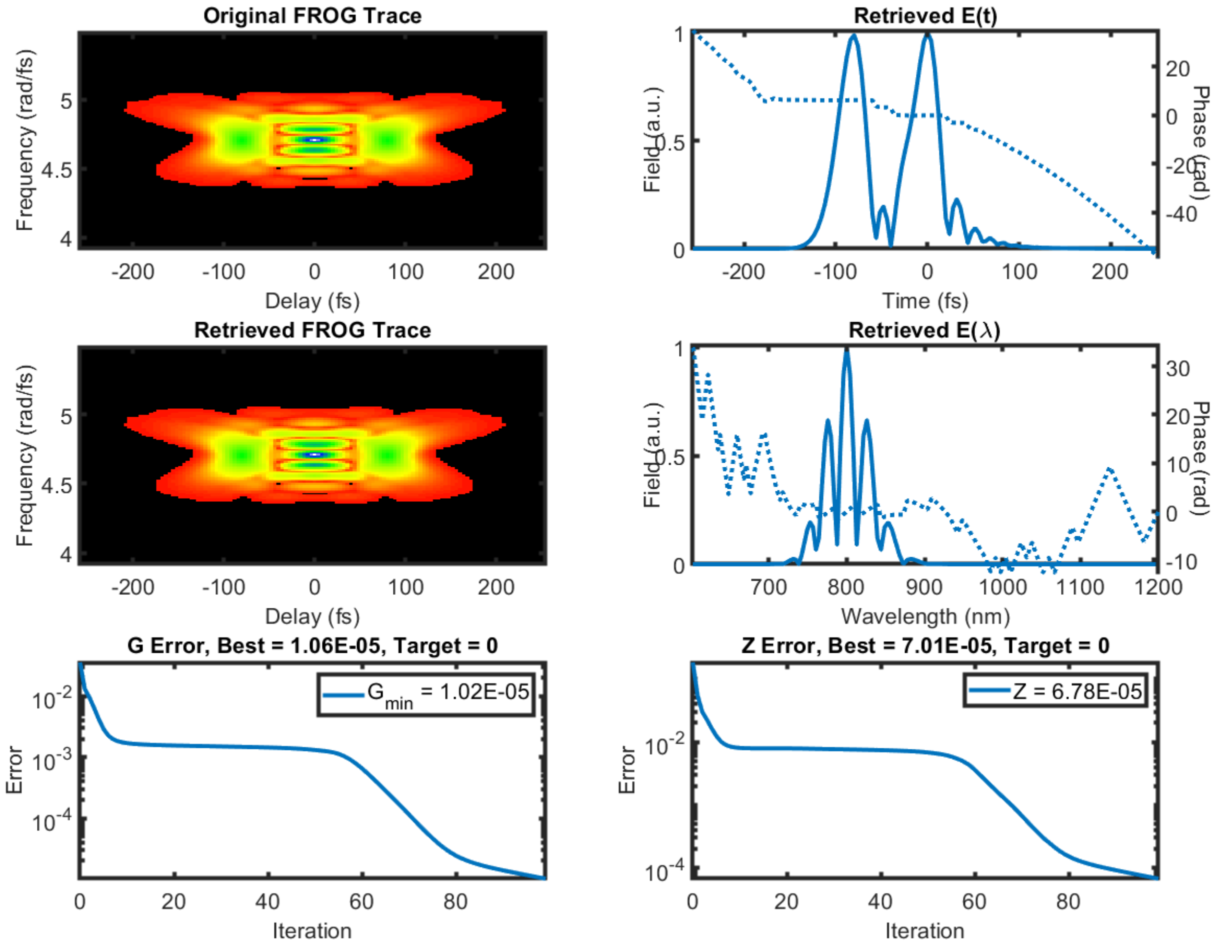


FROG algorithm

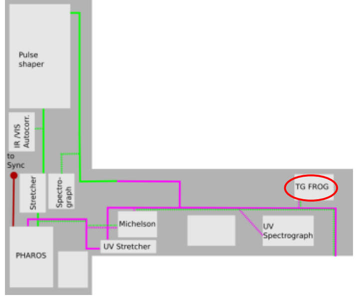
Determination of amplitude and phase of an electric field E(t)

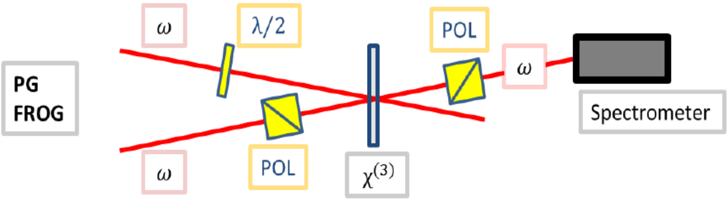
- Measure I(ω) vs delay τ
- Generate FROG trace I(ω,τ)
- Run Phase retrieval algorithm

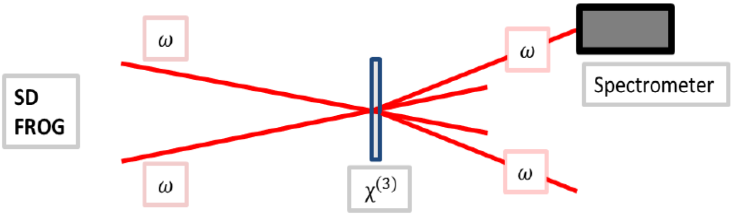


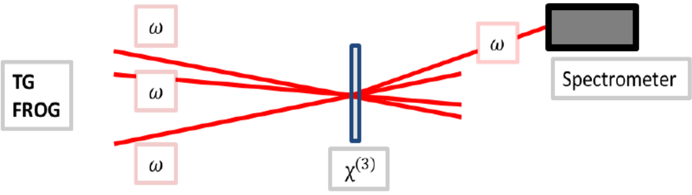


FROG methods





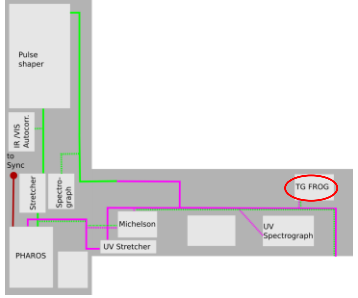




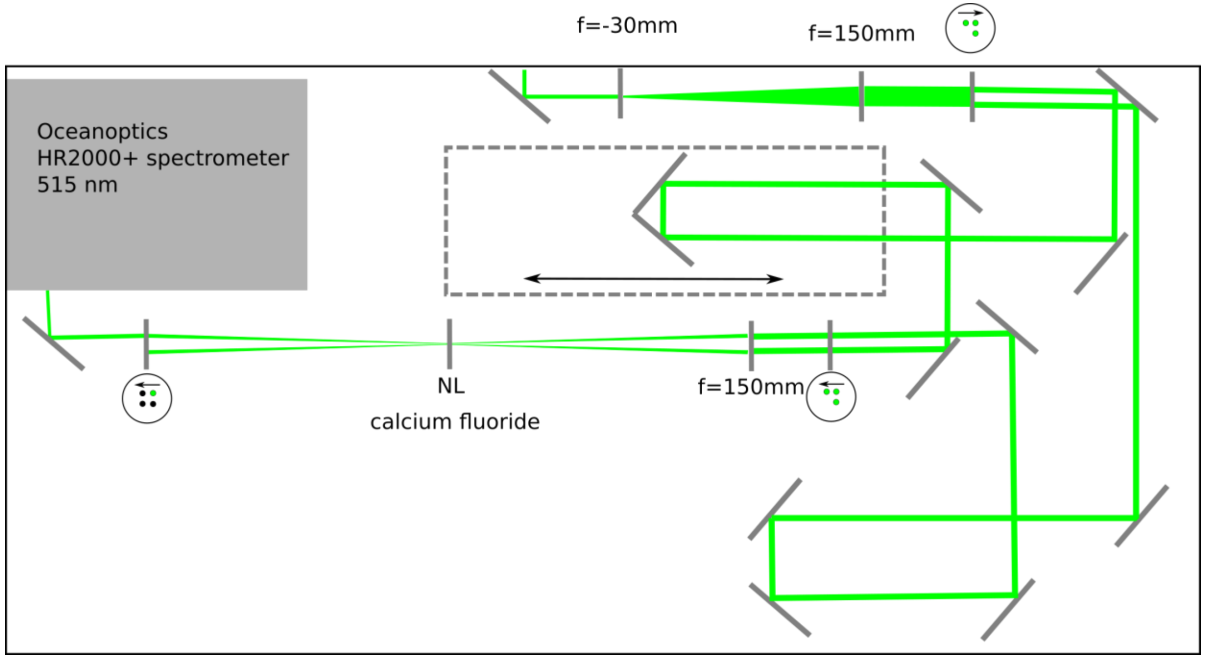
Polarization Gated	Self-Diffraction	Transient-Grating
~100 nJ in scanning mode	~1 µJ in scanning mode	~10 nJ in scanning mode
~ 1 µJ for single-shot mode	~ 10 µJ for single-shot mode	~ 100 nJ for single-shot mode
+ intuitive trace	+ intuitive trace	+ background-free
+ automatic phase-matching	- Not phase-matched	+ phase-matched
- Requires high quality polarizers	- Requires a thin medium	+ intuitive trace
		- 3 beams

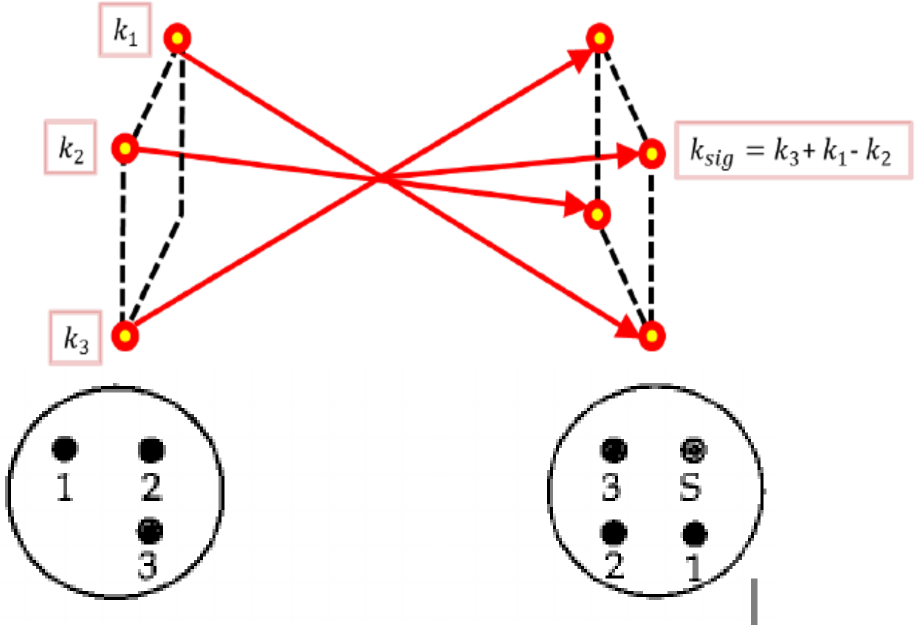
TG FROG

Setup



- TG FROG geometry is usually achieved by beam diameter expansion and an input mask
- TG FROG trace is equivalent to SD FROG when arm 2 is delayed and equivalent to PG FROG when arm 1 or 3 are delayed





Outlook

	Characterization of TG FROG	Pulse shaping experiments with PHAROS (pure optical)	Pulse shaping experiments with MBI laser (pure optical)	Pulse shaping experiments with the electron beam
Q3/Q4 2021	• Measurement with stretched pulses and double pulses from PHAROS	• Begin construction • Test the green pulse shaper and benchmark its shaping capabilities		
Q1 2022		• Optimize the pulse shape with TG FROG measurements • Characterize UV conversion geometries: SHG vs. SFG	• Reinvestigate the shaping capabilities of the birefringent shaper • Optimize the pulse shape with TG FROG measurements	
Q2/Q3 2022				• Improve and benchmark ellipsoidal shaping • Green vs. IR shaping • MBI vs. PHAROS shaping • TG FROG vs. TDS

Summary

PHAROS table

Under construction

- Green stretcher & pulse shaper
- TG FROG

Ready to use

- Adjustable UV stretcher
- Dual-band Michelson interferometer
- Dual-band Autocorrelator
- Dual-band Near field / Far field diagnostic