NLTL National Laser-Initiated Transmutation Laboratory University of Szeged

HUNGARIAN NATIONAL LABORATORY

A 100 Hz Laser System With Few-cycle and TW Pulses

P. Gaal, B. Nagyilles, M. Karnok, A. P. Kovacs,
T. Gilinger, M. Fule, R. Nagymihaly, I. Seres, S. Toth,
K. Osvay

EAAC'23, Isola d'Elba
19th September, 2023

History

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A table-top high contrast TW laser system

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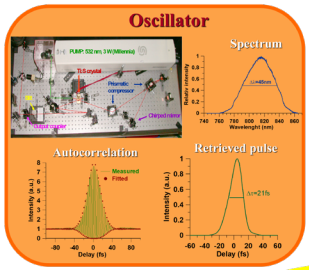
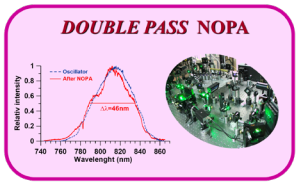
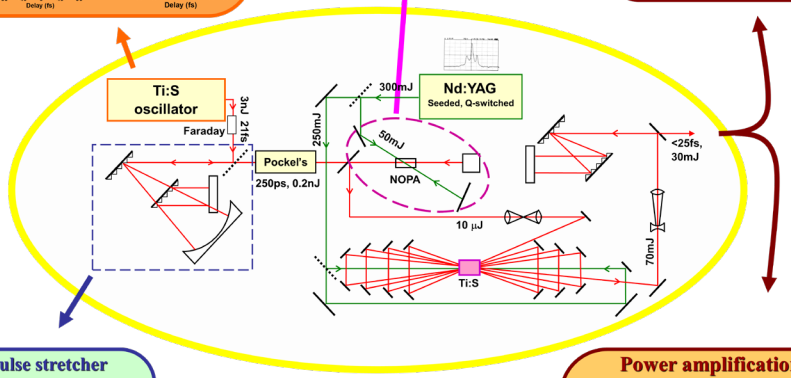
[2]HAS Research Group On Laser Physics, University of Szeged, P.O. Box 406. H-6701 Szeged, Hungary
[3]Dept. of Mathematics and Physics, Kecskemét College, P.O. Box 91. H-6000 Kecskemét, Hungary
[4]Focus Medical Ltd., Margaret Island, H-1138 Budapest, Hungary

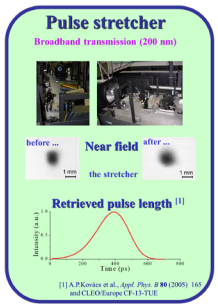


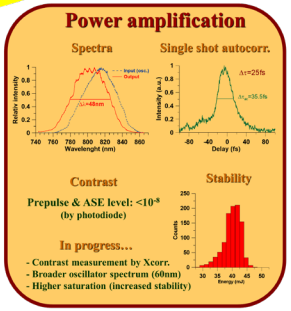


Available pulses

800 nm: 3 nJ, 21 fs, 72 MHz
30 mJ, 25 fs, 10 Hz
532 nm: 380 mJ, 10 ns, 10 Hz
350 mJ, 3 ns, 10 Hz
400 nm: 1 mJ, 25 fs, 10 Hz
266 nm: 150 mJ, 10 ns, 10 Hz
140 mJ, 3 ns, 10 Hz







Acknowledgement
This work was supported by OTKA M36843, TS040759, T33018, OMFB MU-00266/2001 and GVOP-3.2.1.-2004-04-0114/3.0.

Osvay et al., CLEO-Europe 2005

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Ultrafast Spectroscopy

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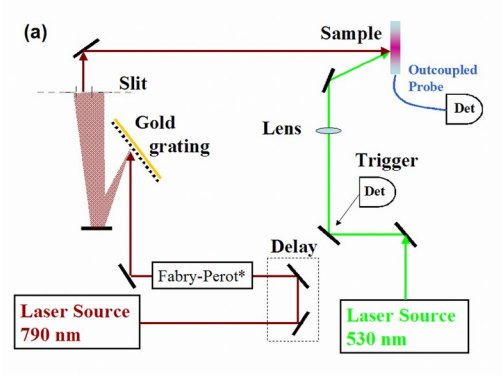
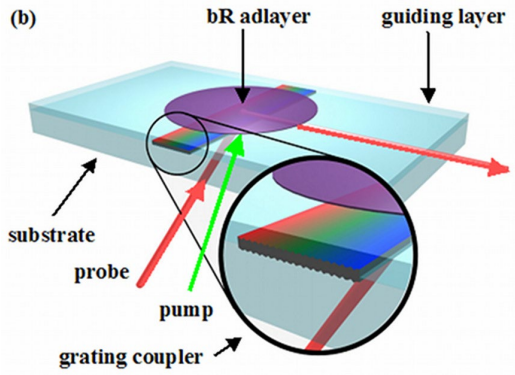
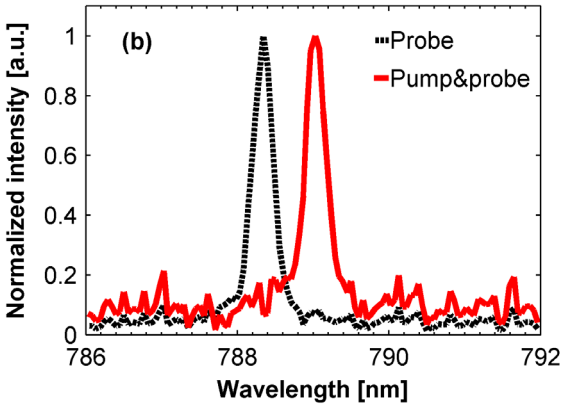
Protein based ultrafast switching

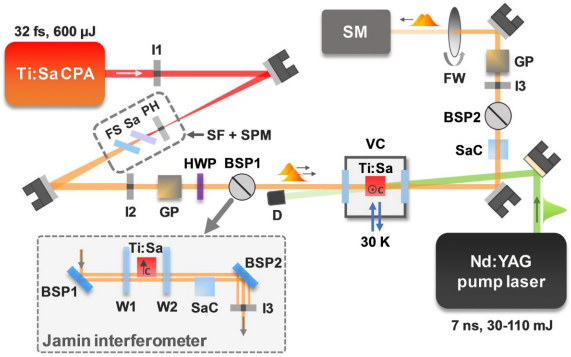


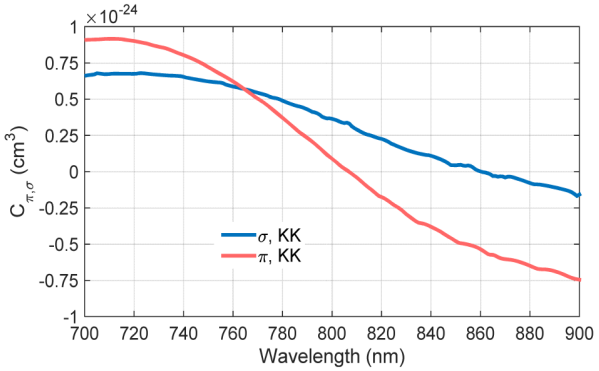


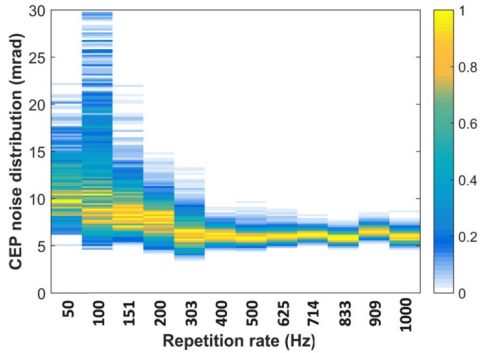


Fabian et al., Opt. Exp. 19 (2011) 18861

Ref. index change and CEP noise in Ti:S upon amplification







Nagymihály et al., Opt. Exp. 25 (2017) 6690

Nagymihály et al., Opt. Exp. 27 (2019) 1226

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Ion Acceleration and Neutron Generation with Few-Cycle Lasers

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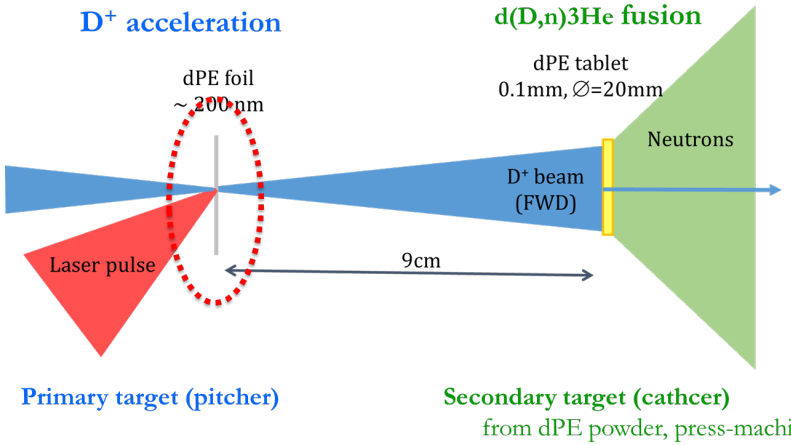
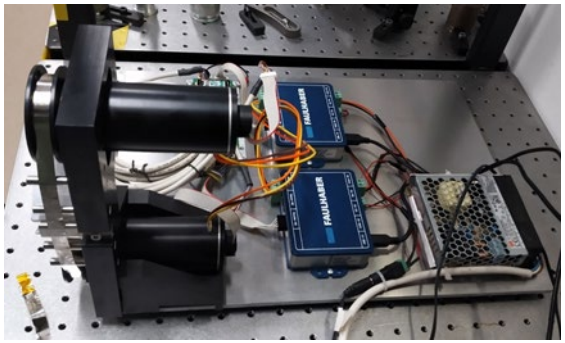
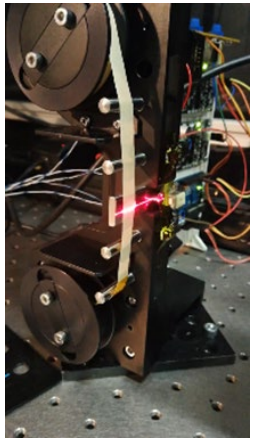


Osvay et al., *in review*

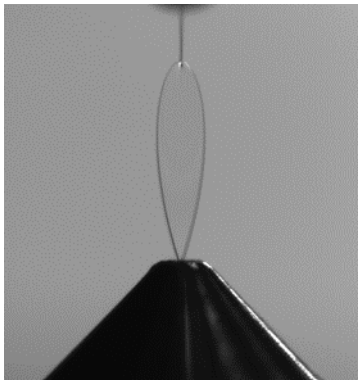
Development of high repetition rate target systems

Tape target





Liquid jet



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Füle et al., in prep

Motivation

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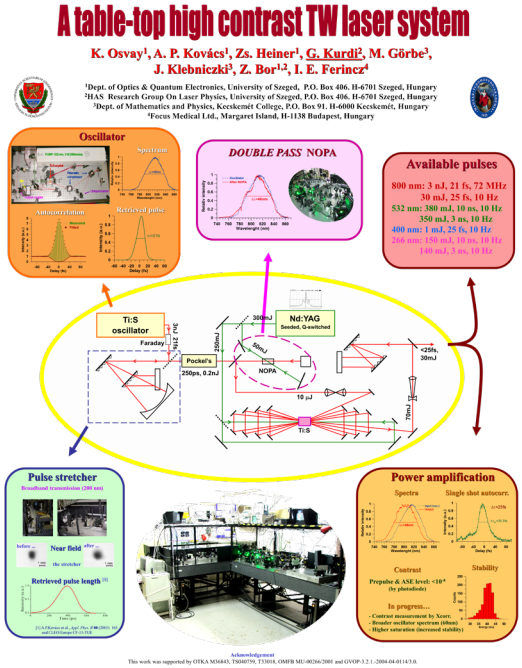

Osvay et al., CLEO-Europe 2005

Upgrade (replacement) of the earlier TW-class laser

- increase the repetition rate 10Hz->**100Hz**
- insert a few-cycle branch -> **sub-10 fs**
- simplified, robust design -> **Dispersion management**

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Laser Block Scheme

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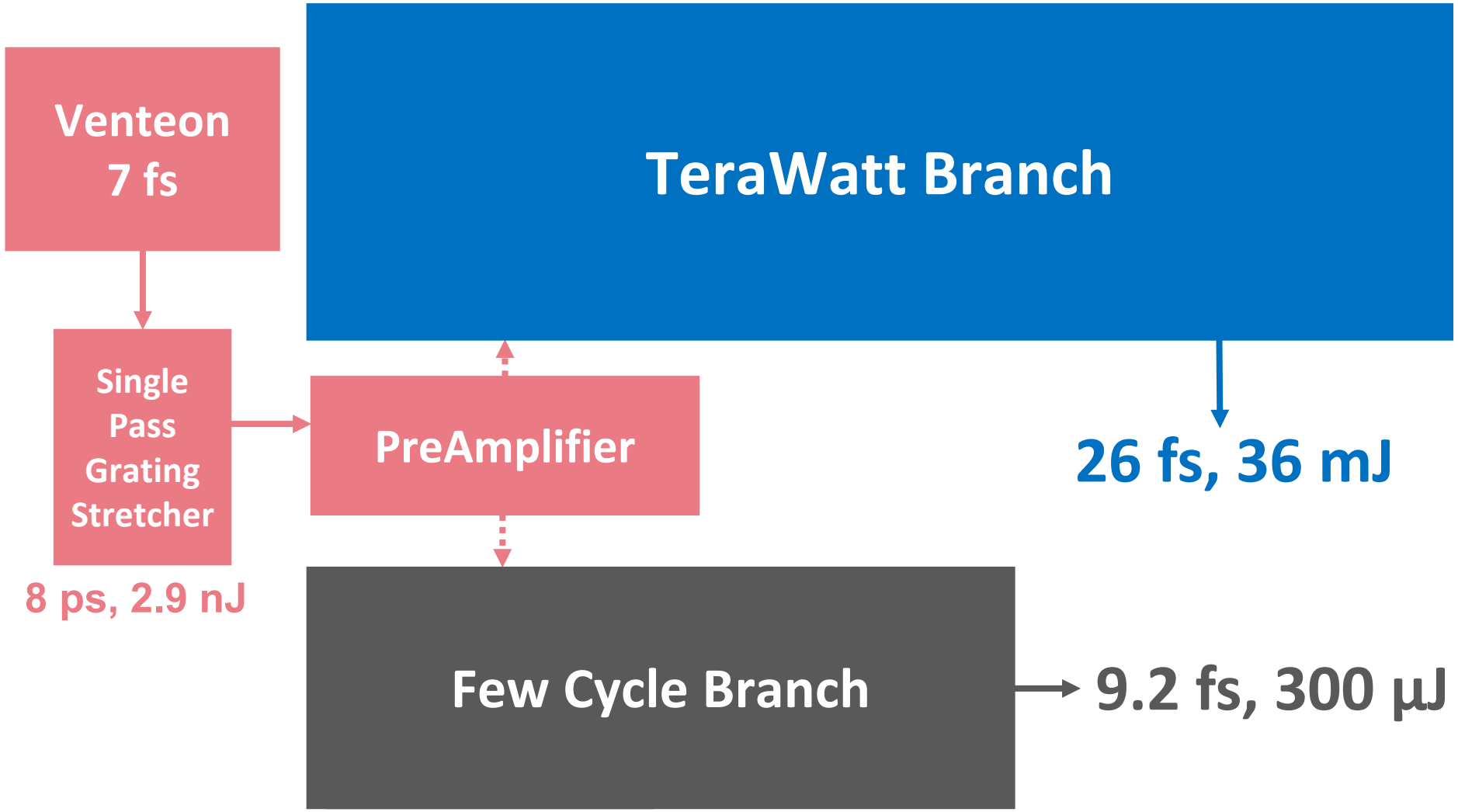

Outline

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Dispersion management

Few Cycle Branch

TW Branch

Recent applications

Summary and outlook

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Dispersion management

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Stretching with "negative" chirp → **Few-cycle branch**

Positive chirp compressor
- Simple
- High throughput (bulk+chirped mirrors)

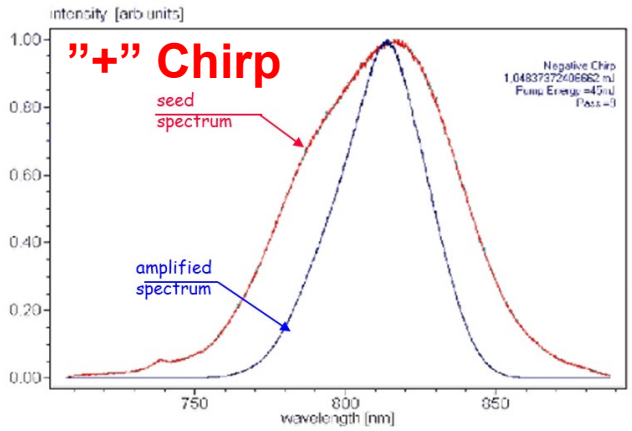
↓

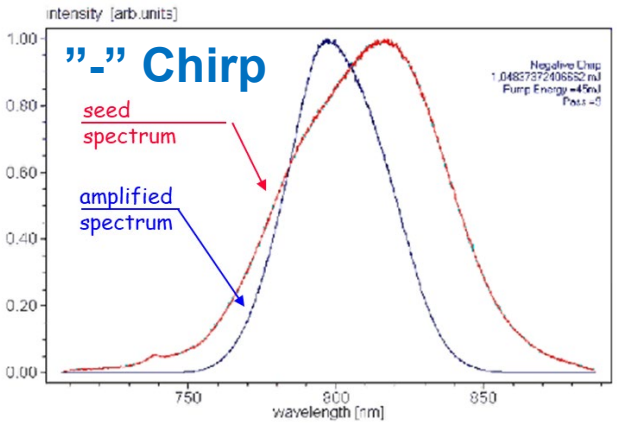
TW branch

Possibility of keeping the bandwidth of the amplified pulses

Negatively and positively chirped pulse amplification

The spectral components of the leading edge of the pulse experiences higher gain (upon saturated amplification)





Kalashnikov et al., IEEE JSTQE 12, 194 (2006)

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Laser Block Scheme

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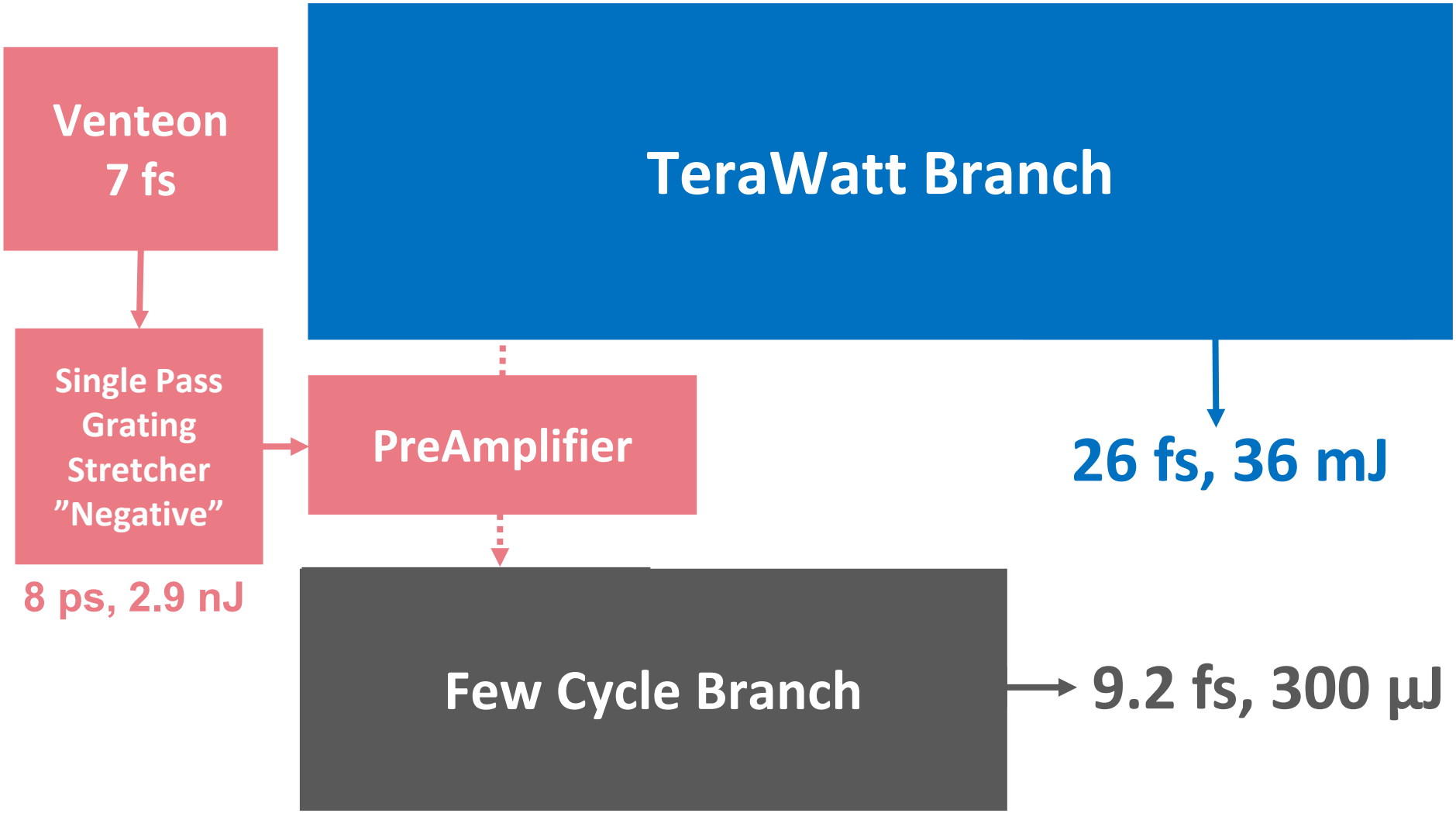

Laser front end

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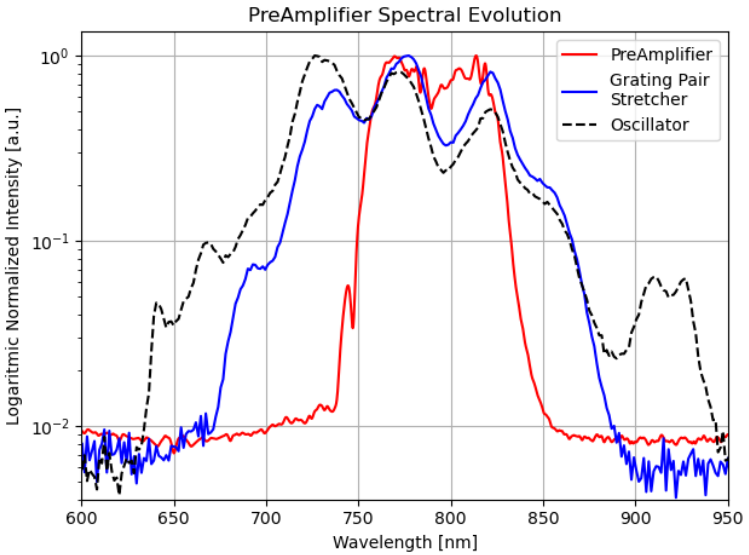
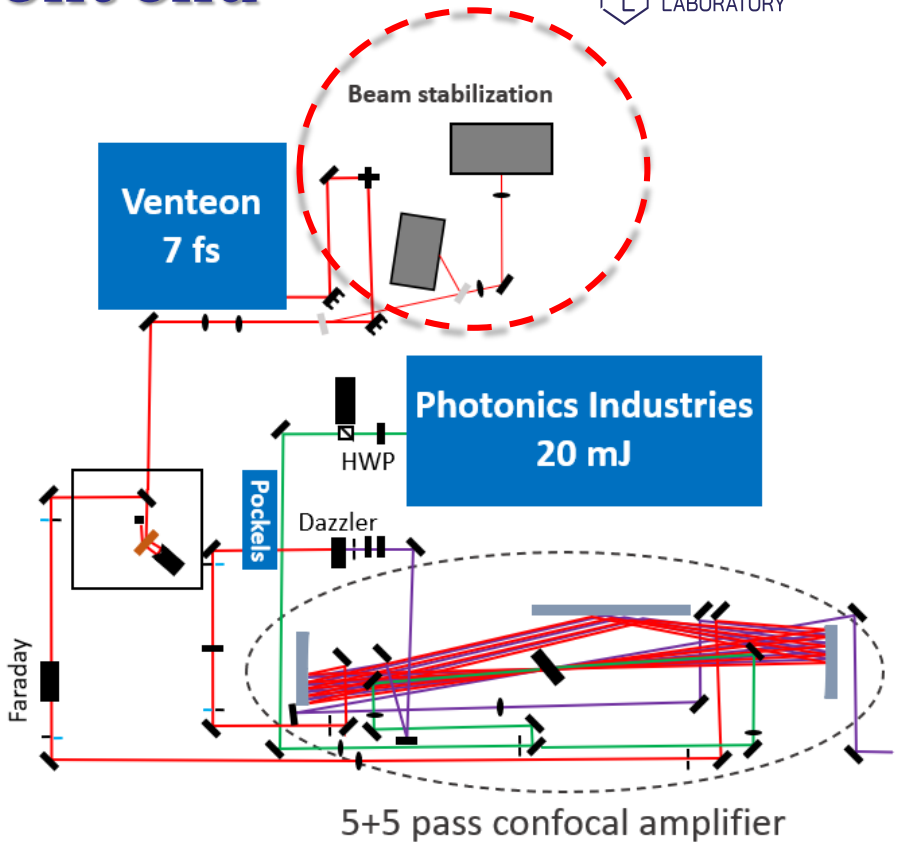
Venteon 7 fs

Single Pass Grating Stretcher

PreAmplifier





Pulse energy: **2.7±0.011 mJ**

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Few Cycle Branch

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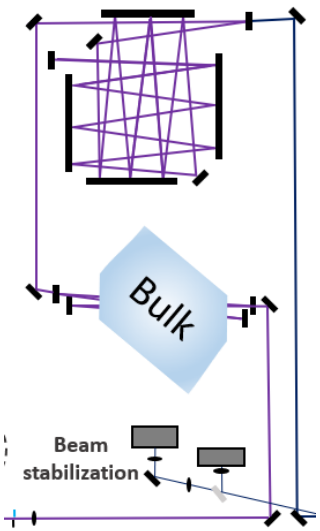
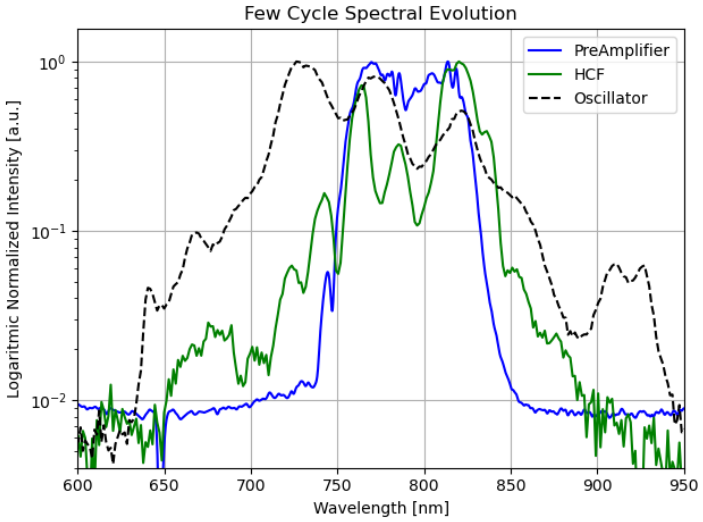
Pulse compressor

Chirped mirrors

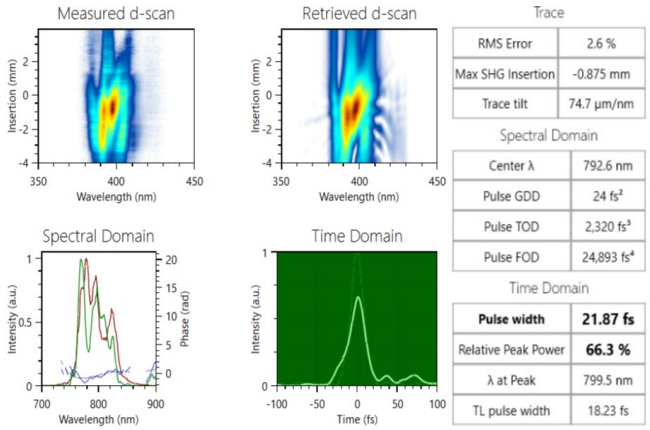


Pulse duration: **22fs**

Pulse energy: **1.15mJ±15µJ**



DScan



Trace	
RMS Error	2.6 %
Max SHG Insertion	-0.875 mm
Trace tilt	74.7 µm/nm

Spectral Domain	
Center λ	792.6 nm
Pulse GDD	24 fs²
Pulse TOD	2,320 fs³
Pulse FOD	24,893 fs⁴

Time Domain	
Pulse width	**21.87 fs**
Relative Peak Power	**66.3 %**
λ at Peak	799.5 nm
TL pulse width	18.23 fs

Hollow Core Fiber Output Parameters

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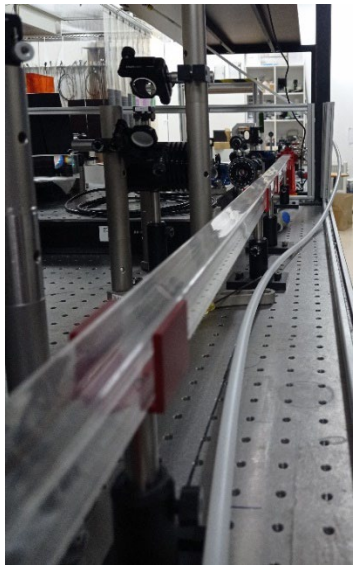
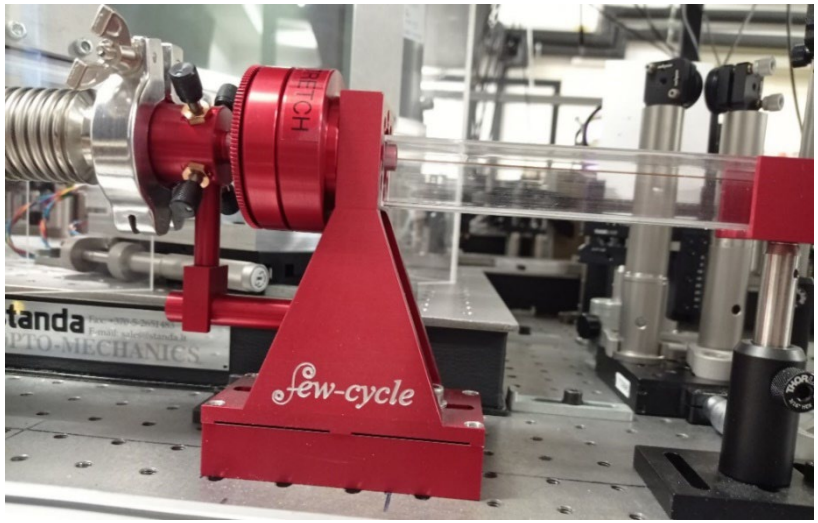
HCF:

- 1.5 m long
- 530 μm diameter
- *Kr* gas at 2 bar





Output energy is **300 μJ** with **7.8 fs pulse duration**

Pulse duration after the **fiber** (**7.8 fs**) is a **calculated** value from the output spectra

Expected pulse duration after 2 pairs of double-angle chirped mirrors is ***sub 10 fs***

TW Branch

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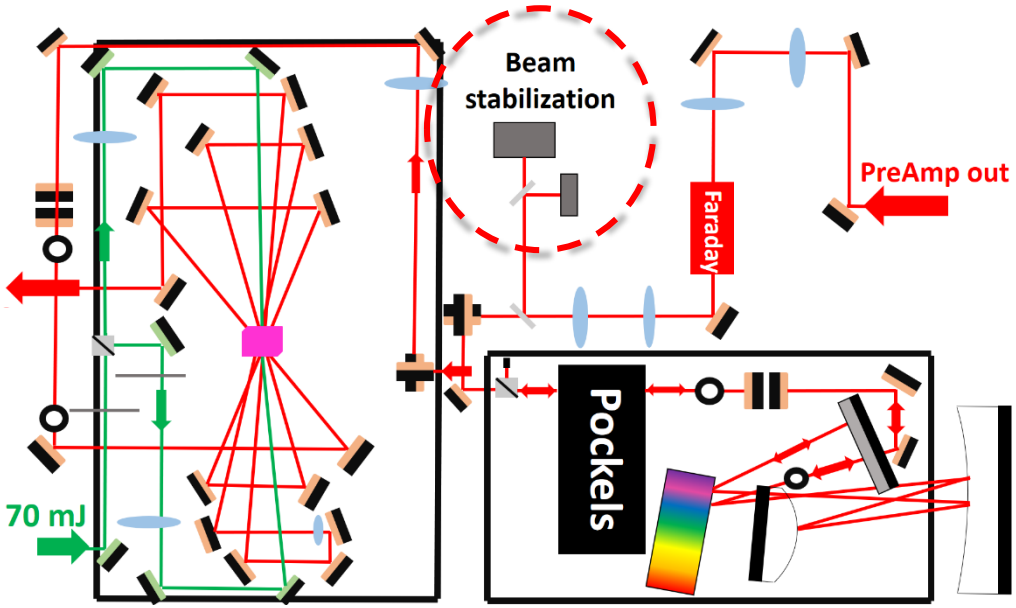
5-pass Booster amplifier:

4.4 mJ± 0.16 mJ



Multi-pass Öffner stretcher

TW Branch

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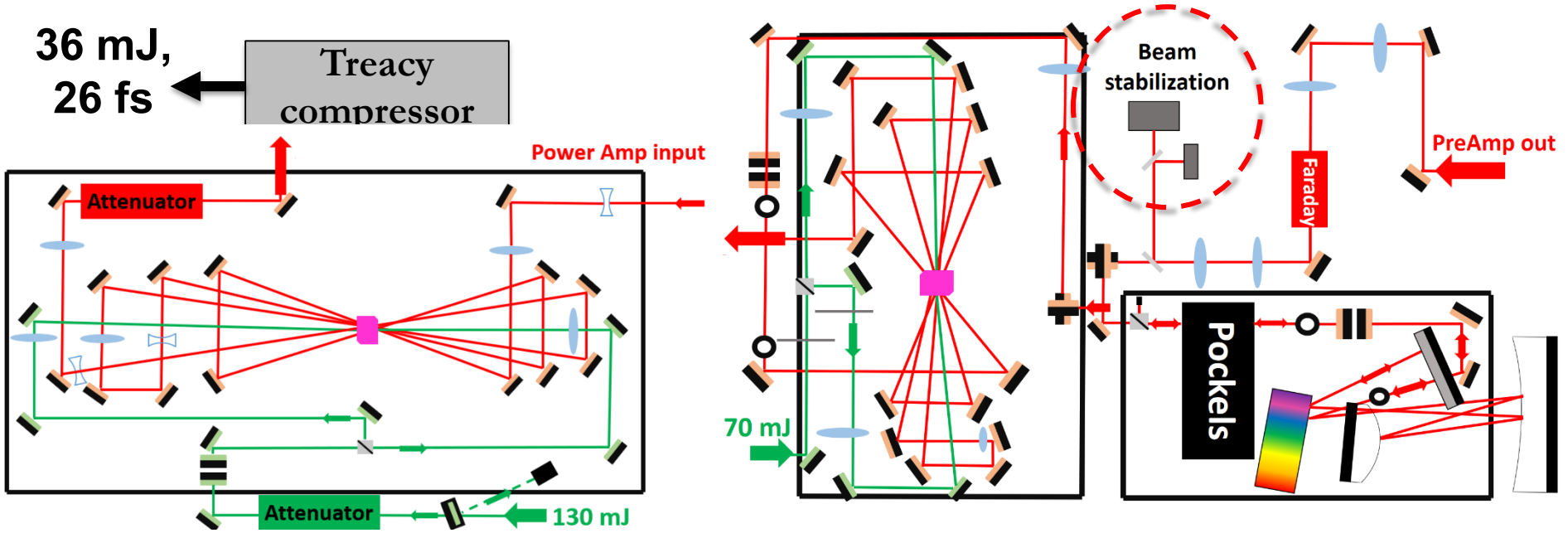
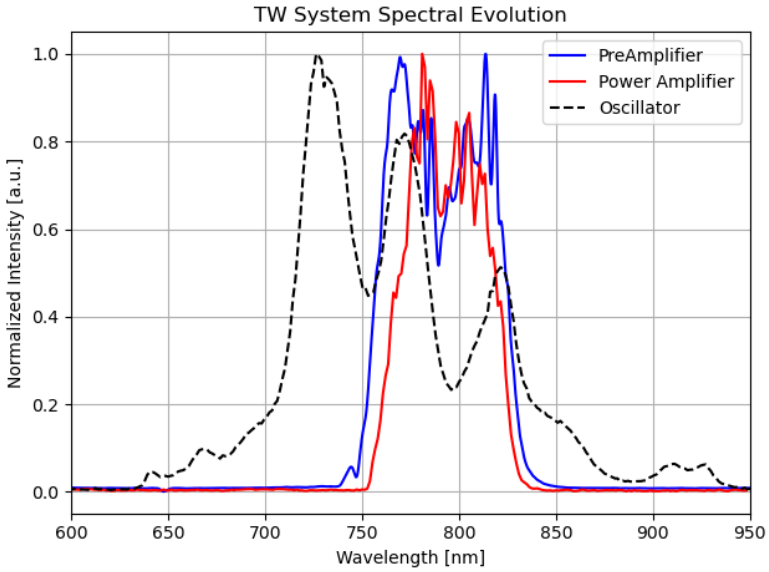


Laser energy: **47.9 mJ± 0.61 mJ**

Tr.limited pulse duration: 24.5 fs



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...waiting for the vacuum (compressor) chamber

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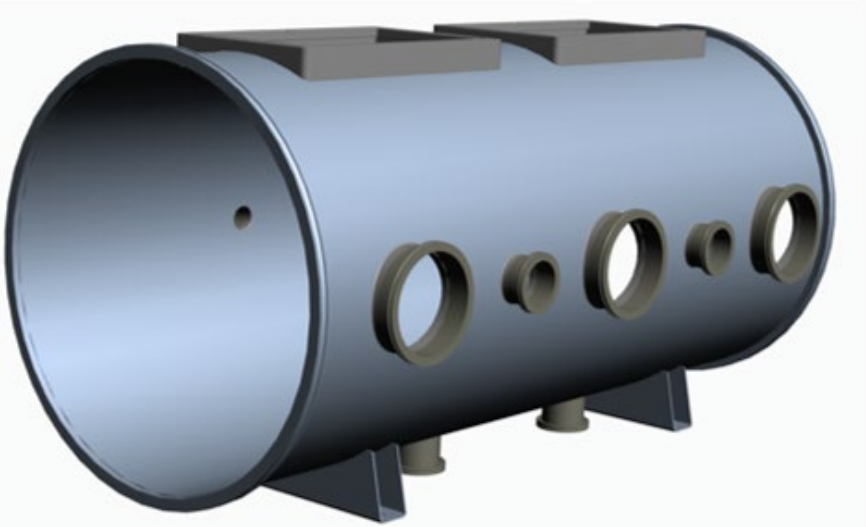
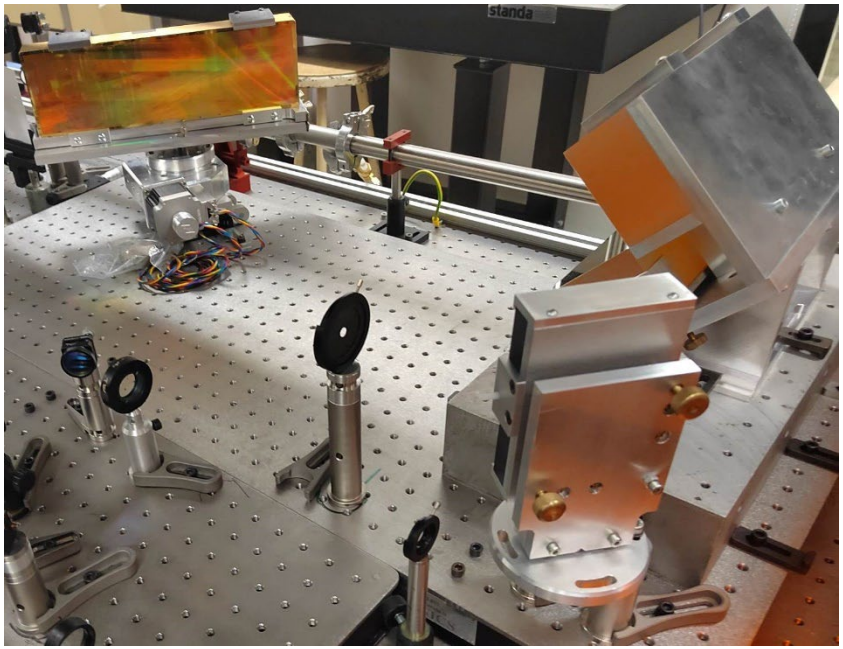
Design of the chamber
(Confirmed delivery Q3 2023)



Treacy-type two-grating **compressor** in air



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Recent Applications of the TW Branch

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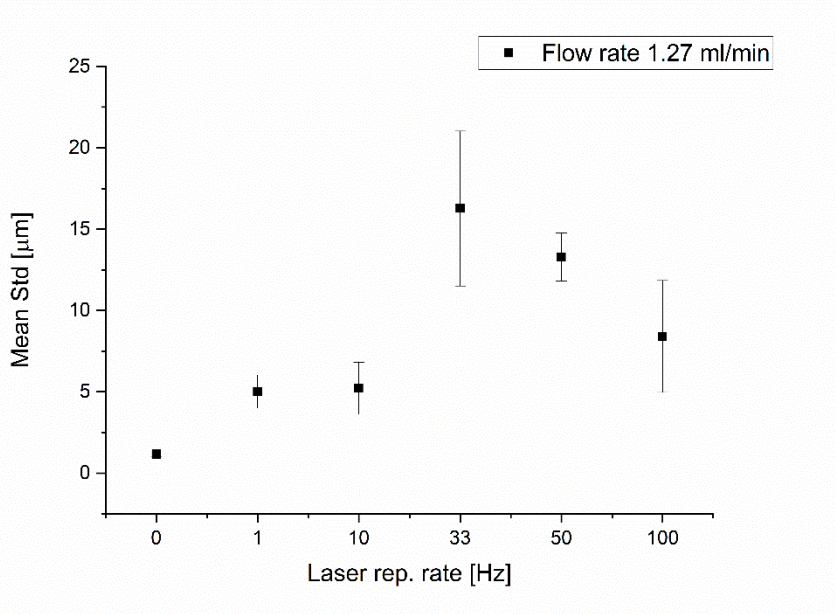
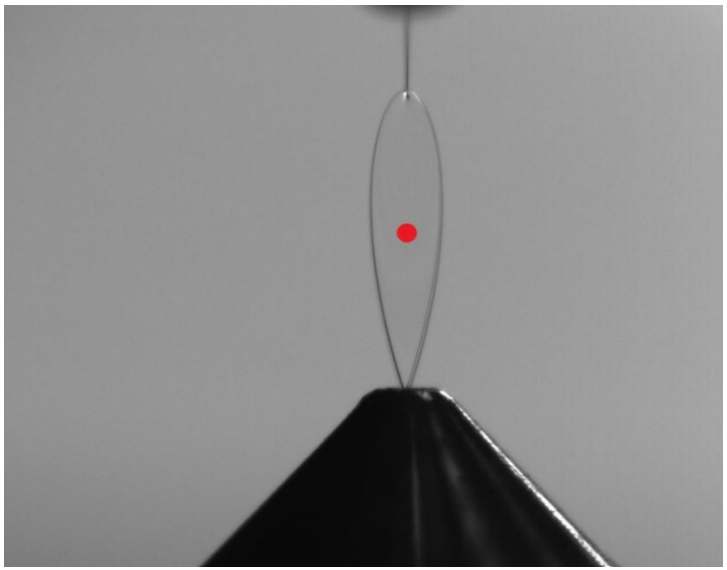
Resonance frequency measurement of an **ultrathin liquid leaf.**

Change of the repetition rate on target:

via mechanical shutter after the preamp (all pump lasers are working at 100Hz)





Füle et al., in prep

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Recent Applications of the Few-cycle Branch

Material Processing with Femtosecond Pulses

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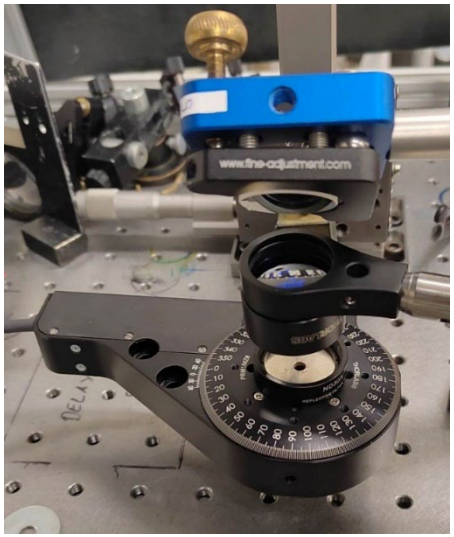
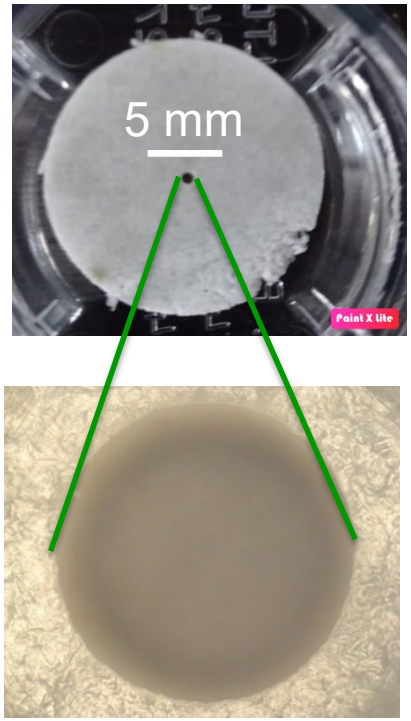
Objects compressed-powder-tablet (C_2D_4, as catcher for neutron generation)
crystalline metal films

Thickness: 0.1-1.3 mm

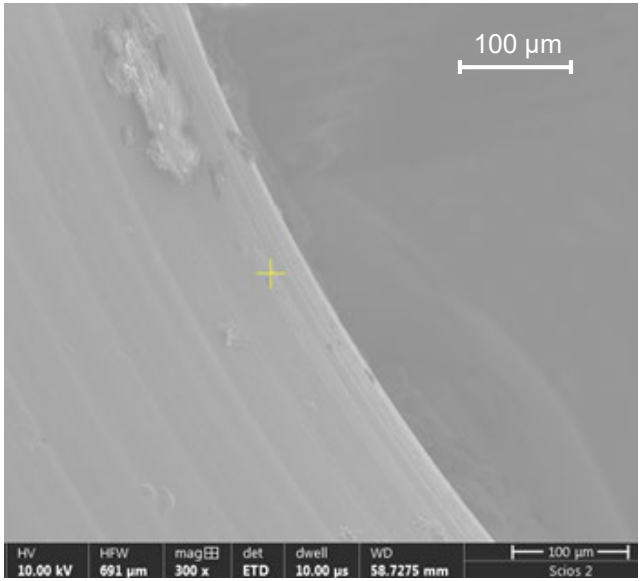
Experimental setup



C_2D_4 tablet



Crystalline metal film



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Fule et al., LiM '23 Somoskoi et al., LiM '23

Summary

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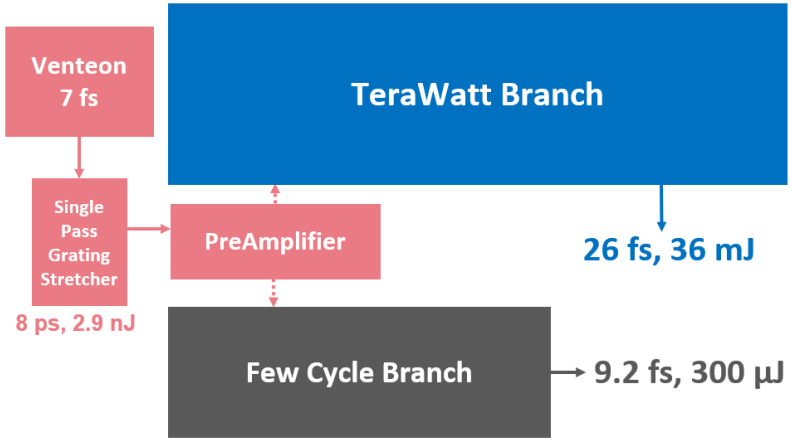
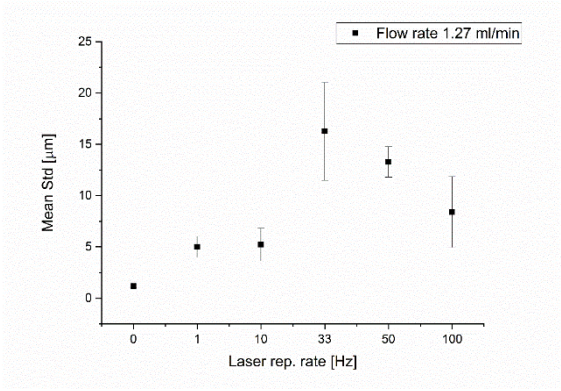
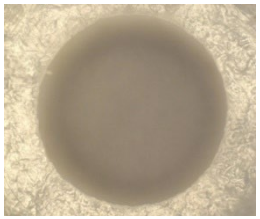
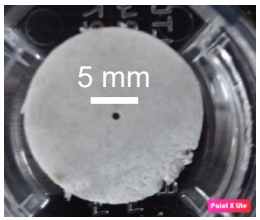
Versatile laser system has been developed with dual branch



Recent applications







Complete the pulse compressor

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Outlook

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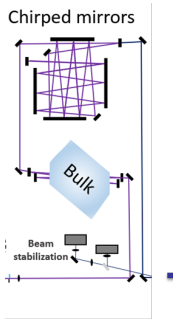
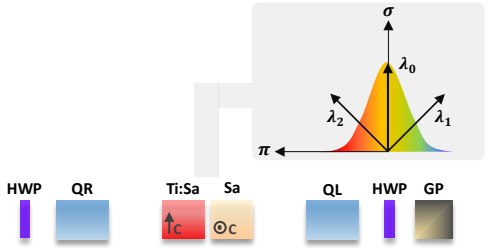
For sub-15 fs, >2 TW pulses

HCF-branch pulses + polarisation encoded amplification



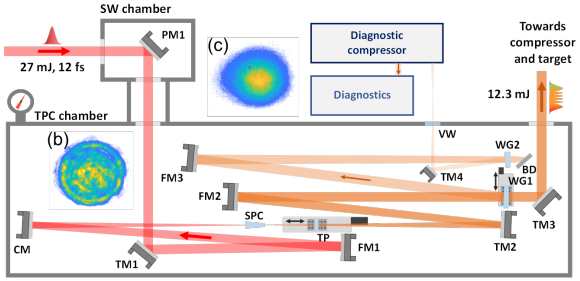
Pulse duration: **22fs**

Pulse energy: **1.15mJ±15μJ**



Cao et al, Las. Phys. Lett. 15, 045003 (2018)

Towards single-cycle energetic pulses – single plate compression



Toth et al, Opt.Lett. 48 (2023) 57

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Thank you for your attention

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