OPCPA as an amplifier technology for high repetition rate 100 TW-class lasers

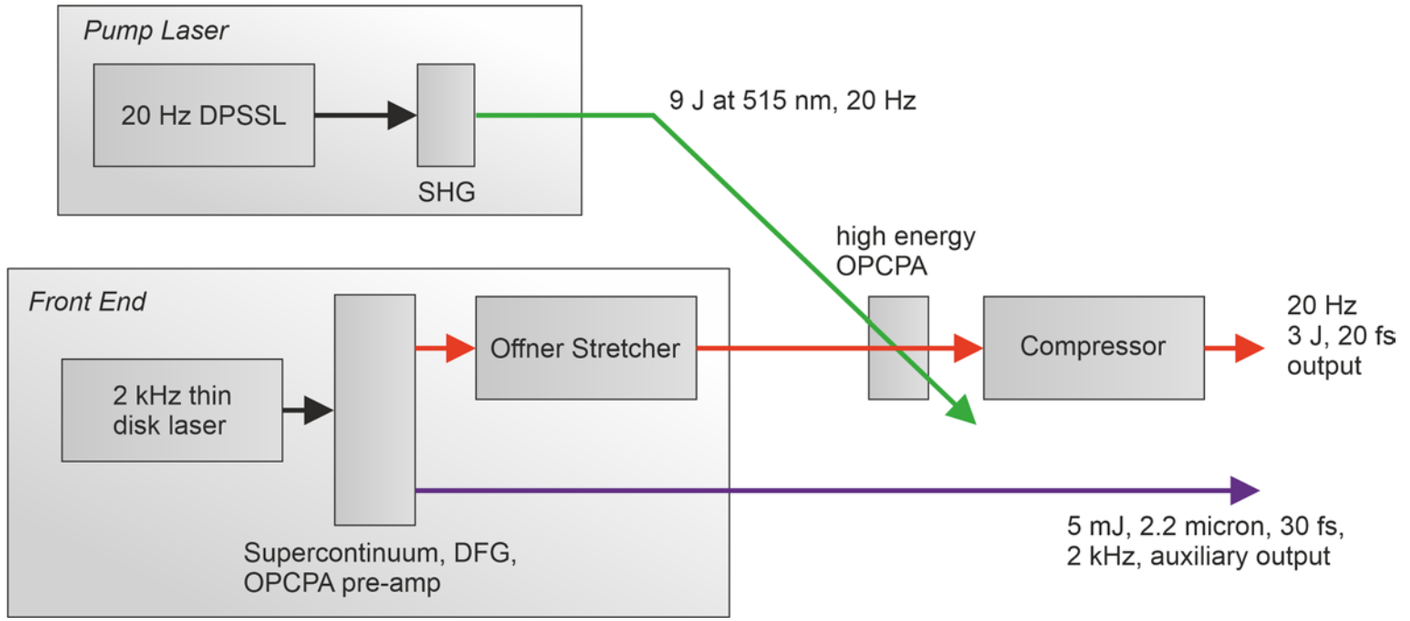
Speaker: Jonathan Tyler Green

ELI – Beamlines Laser Center

L2-DUHA 50 Hz 100 TW OPCPA system

High Repetition rate 20 – 50 Hz, 100 TW laser with an auxiliary mid-IR output designed for driving LWFA

The core technology of the laser relies on Yb:YAG DPSSL-pumped OPCPA



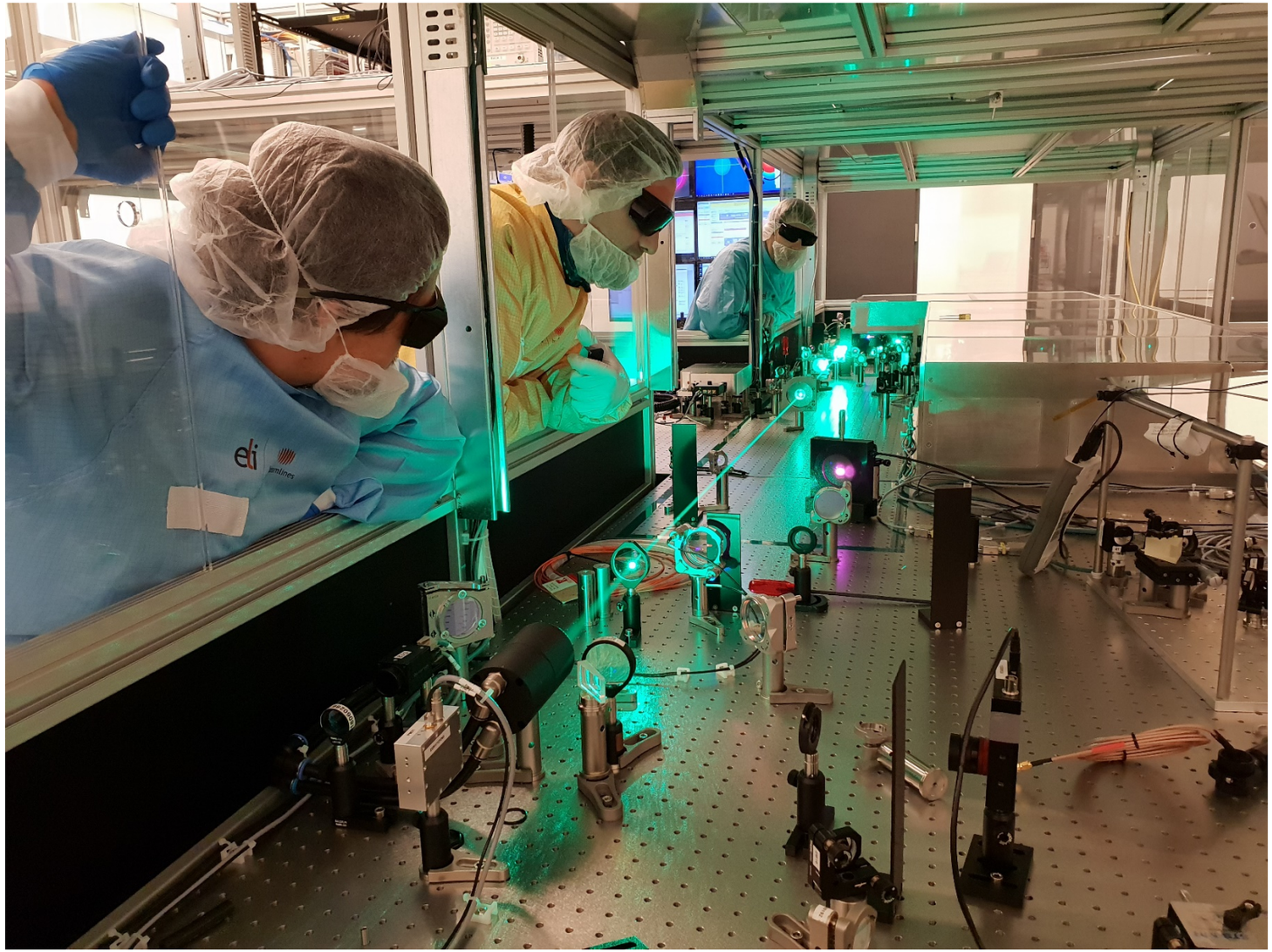
Optical Parametric Chirped Pulse Amplification

Advantages of OPCPA:

- No quantum defect
- Just a single pass of the seed pulse required
- Broad and flat/shapeable amplification bandwidth
- No ASE

Disadvantages

- More sensitive to quality of pump profile and wavefront
- Precise temporal synchronization required

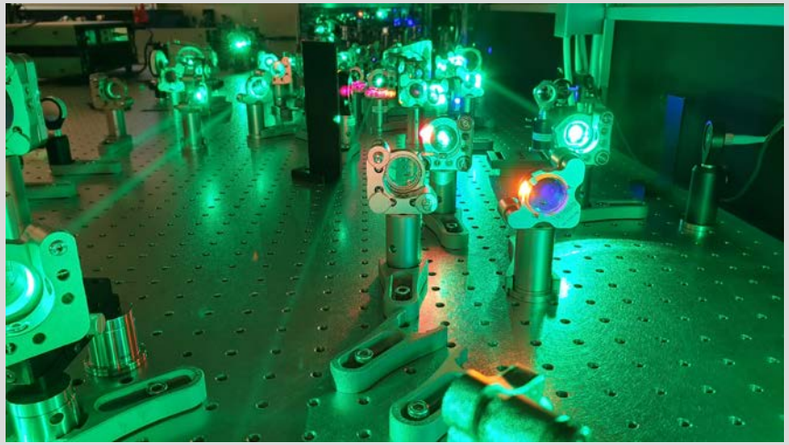


OPCPA at ELI-Beamlines

L1-Allegra: 50 mJ, 1 kHz, 15 fs

(Planned: 100 mJ, 1 kHz, 15 fs)

F-SYNC auxiliary probe beam: >10mJ, 1kHz, <20fs



L4-Aton Front End: 4 J, 5 Hz, 170 fs

L2-DUHA: 3 J, 50 Hz, < 25 fs

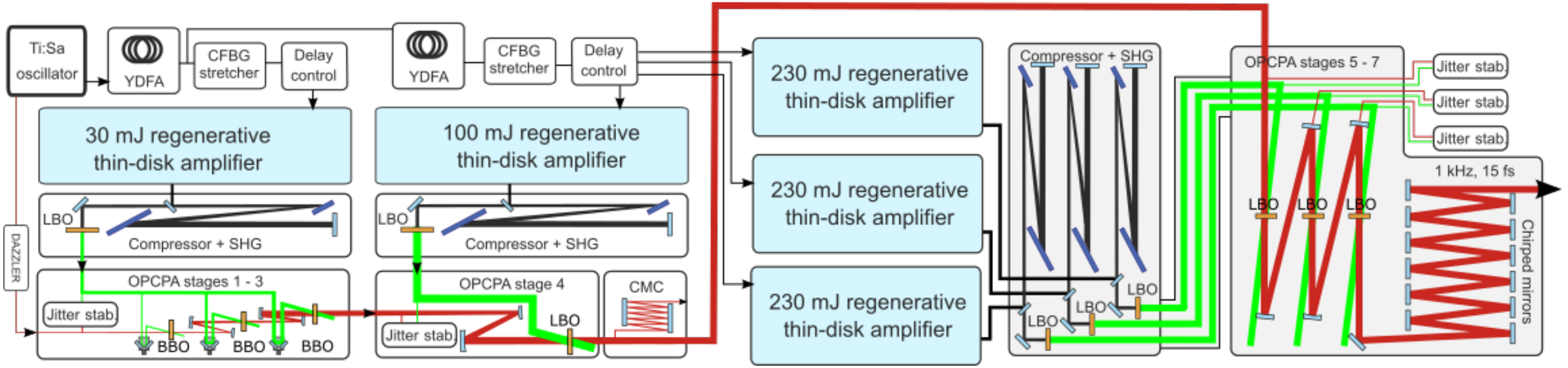
L1 – ALLEGRA 1 kHz OPCPA system

Design parameters: >5 TW, 15 fs, 100 mJ, 1 kHz

Currently demonstrated: >3TW, 15 fs, >55 mJ, 1 kHz

Optically synchronized 5 thin-disk pump lasers
Total available pump power @515 nm >370 W

7 OPCPA stages based on BBO and LBO crystals
>62 mJ OPCPA output (~16% pump-to-signal efficiency)
>55 mJ output after compression



L1 – ALLEGRA 1 kHz OPCPA system

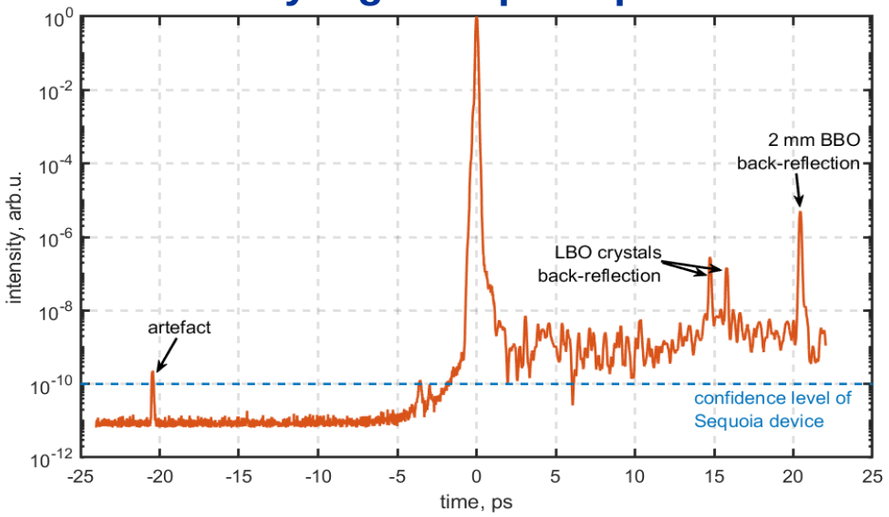
Routine operation for users

- >50 mJ / <15 fs pulses @ 1 kHz available
- 70 mJ later in 2022
- 100 mJ end 2023 (multipass thin-disk pump)

F-SYNC: auxiliary beam in construction

- 10 mJ /<15 fs / 1 kHz mid 2023 available for experiments
  <100 fs (10 fs or better expected)
  synchronization with the L1 main beam

Picosecond OPCPA architecture: inherently high temporal pulse contrast



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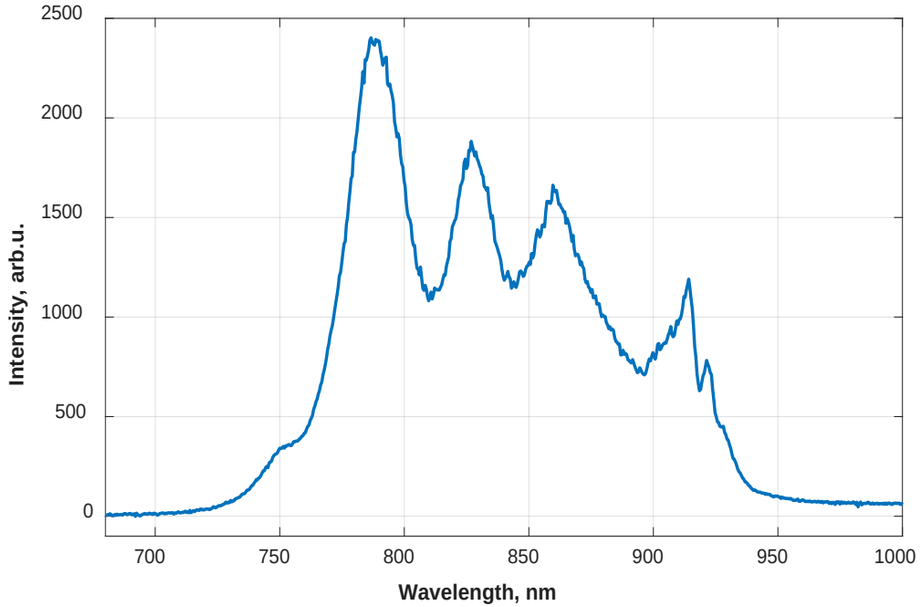
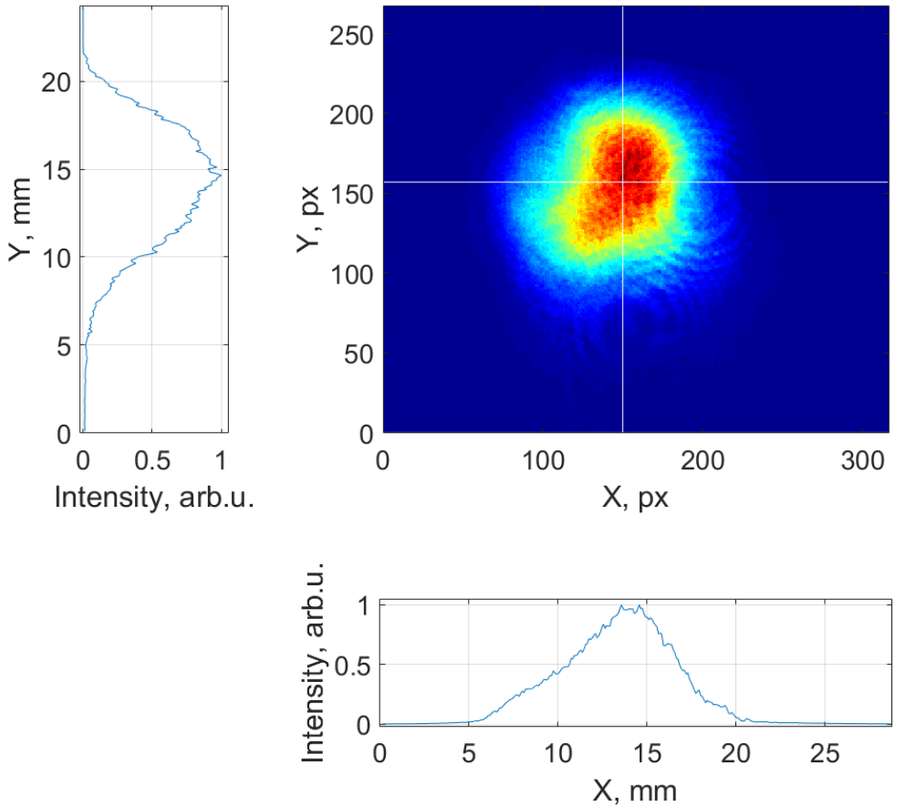
Evropské strukturální a investiční fondy
Operační program Výzkum, vývoj a vzdělávání
MINISTERSTVO ŠKOLSTVÍ, MLÁDEŽE A TĚLOVÝCHOVY

L1 – ALLEGRA 1 kHz OPCPA system

>55 mJ after compression
~15 fs pulse duration
>3.5 TW peak power

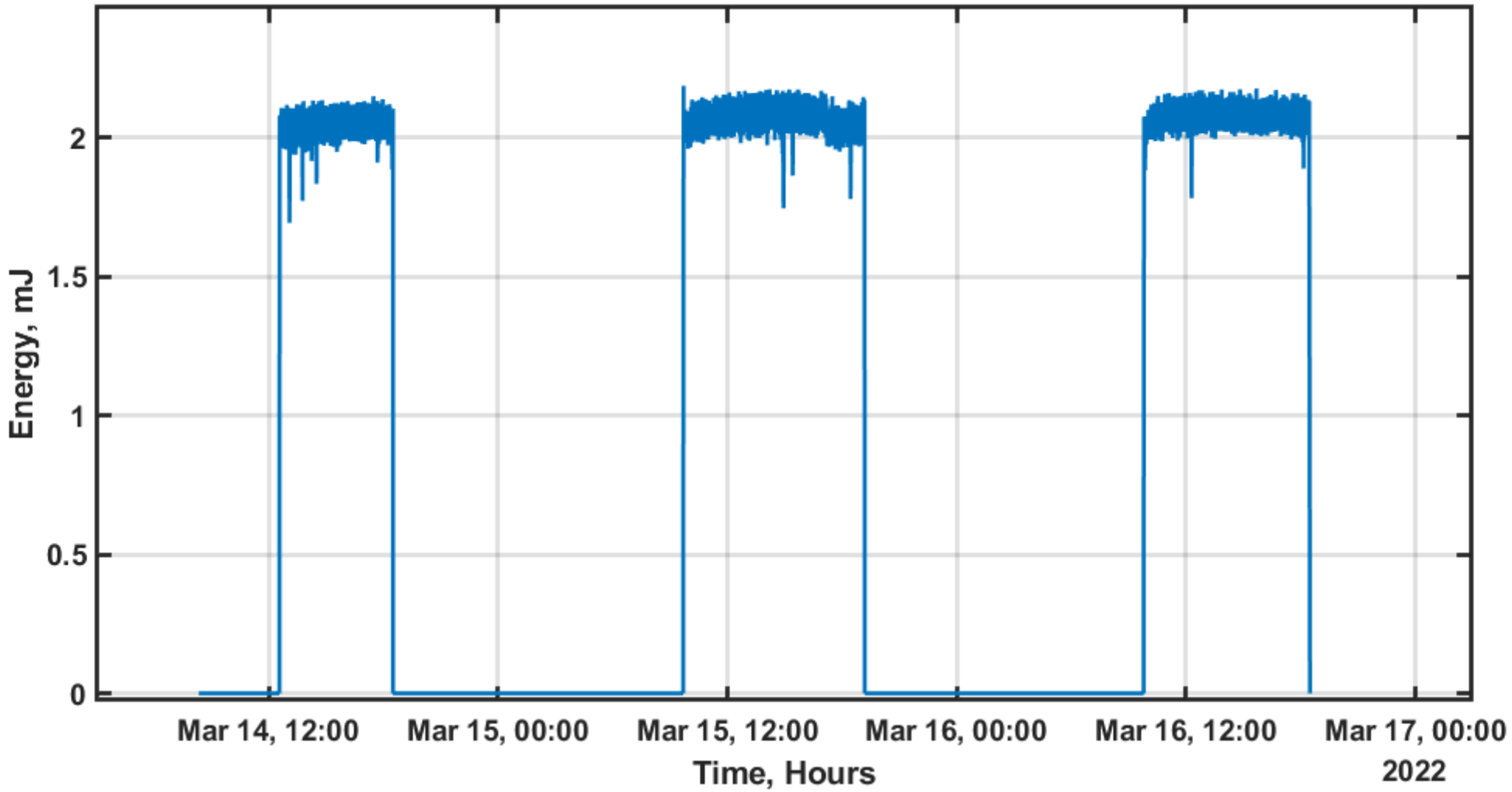


Beamprofile after compression



L1 – ALLEGRA 1 kHz OPCPA system

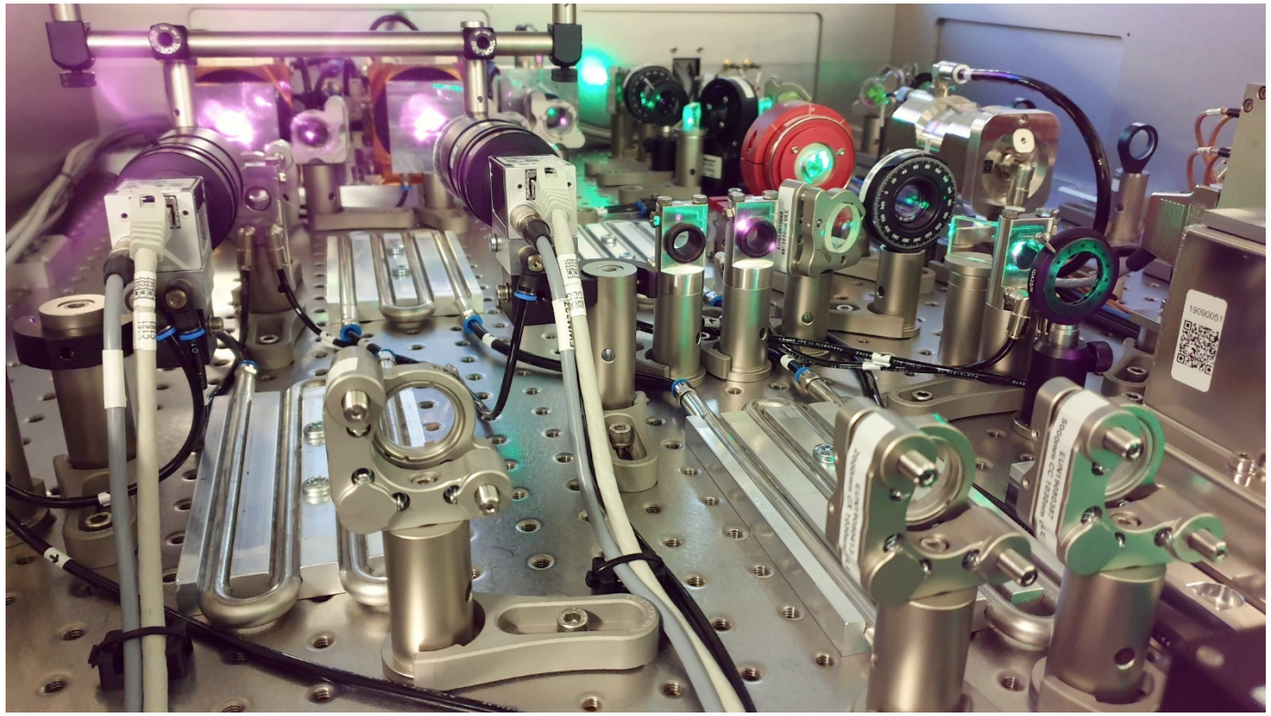
Standard daily performance of the L1-Allegra OPCPA front end



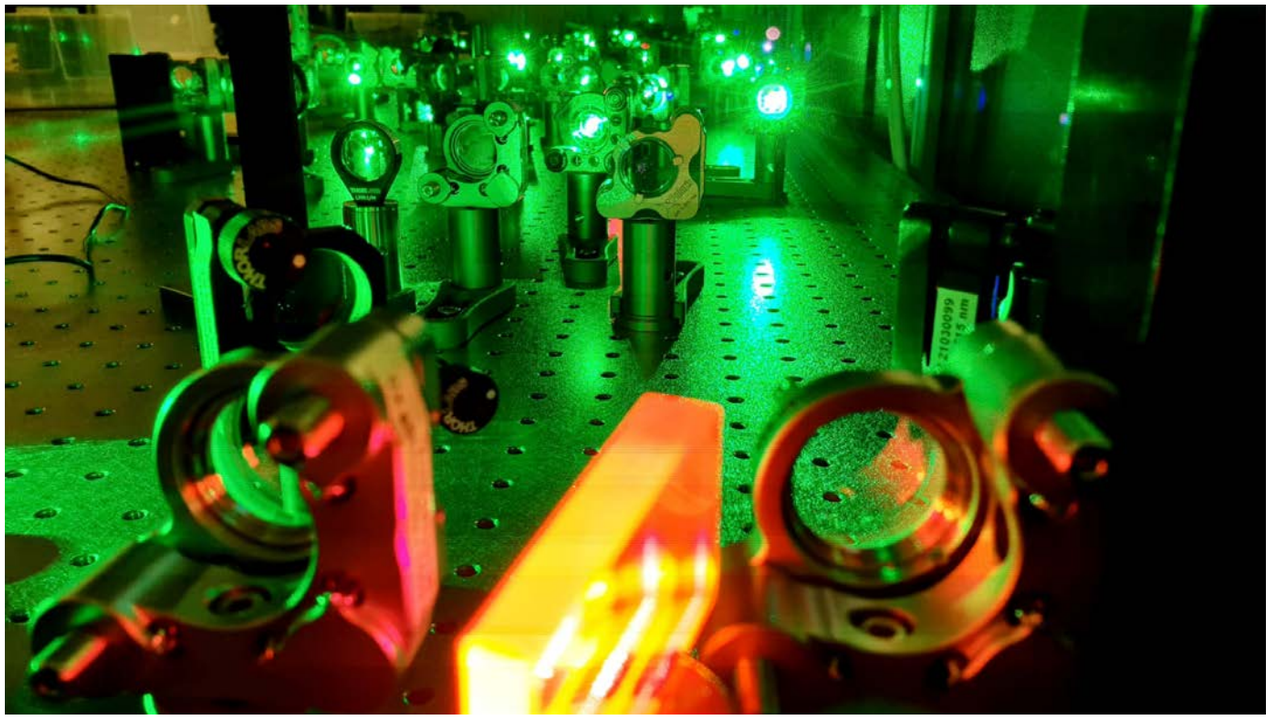
F-SYNC Auxiliary probe beam for L1-Allegra

10 mJ, 1 kHz, 15 fs auxiliary pulse train synchronized to L1-Allegra with arbitrarily long programmable delay

Thin disk pump laser



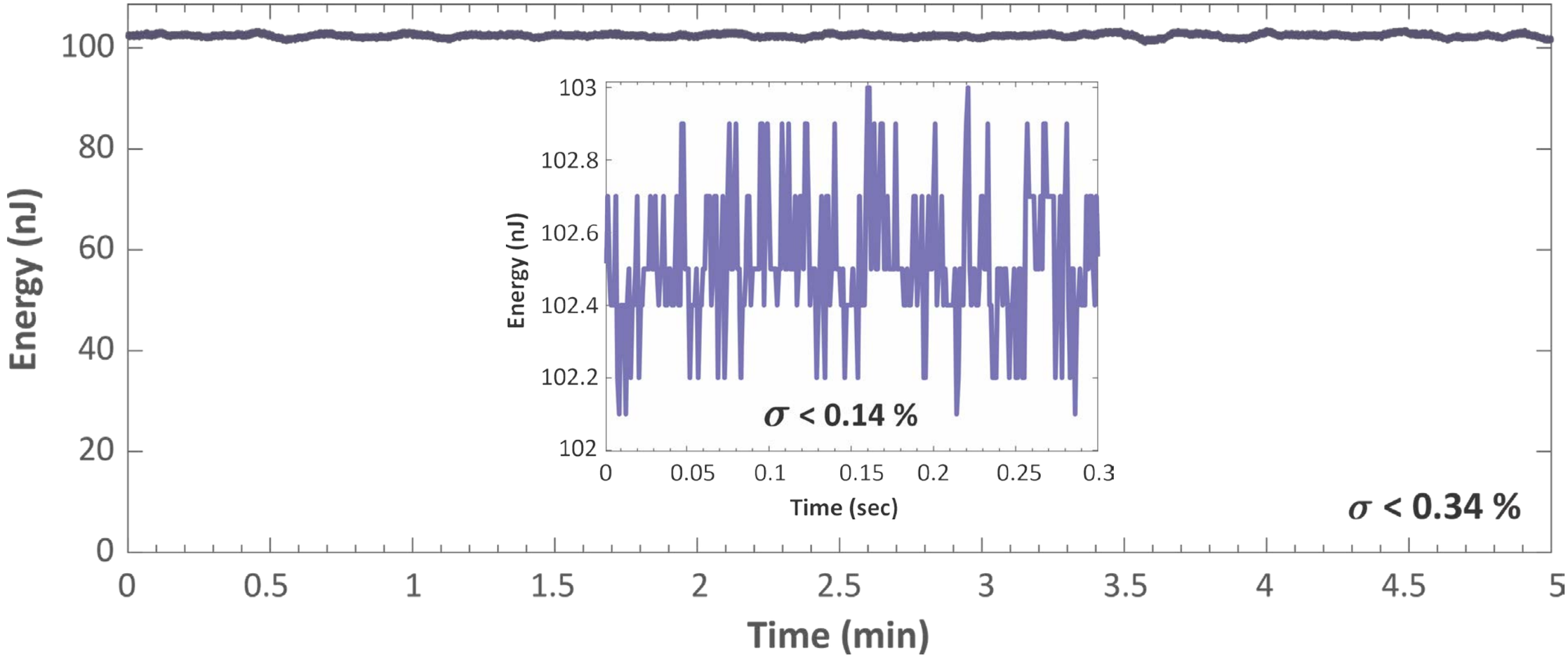
Picosecond OPCPA seeded by continuum



J. Novak, et al., “Dual-output kilohertz pump laser for high-energy picosecond OPCPA," Opt. Lett. **47**, 4869 (2022)

F-SYNC Auxiliary probe beam for L1-Allegra

- Stability of pump 0.77% → Stability of continuum 0.34%



L. Indra, et al., "Picosecond pulse generated supercontinuum as a stable seed for OPCPA," Opt. Lett. **42**, 843-846 (2017)

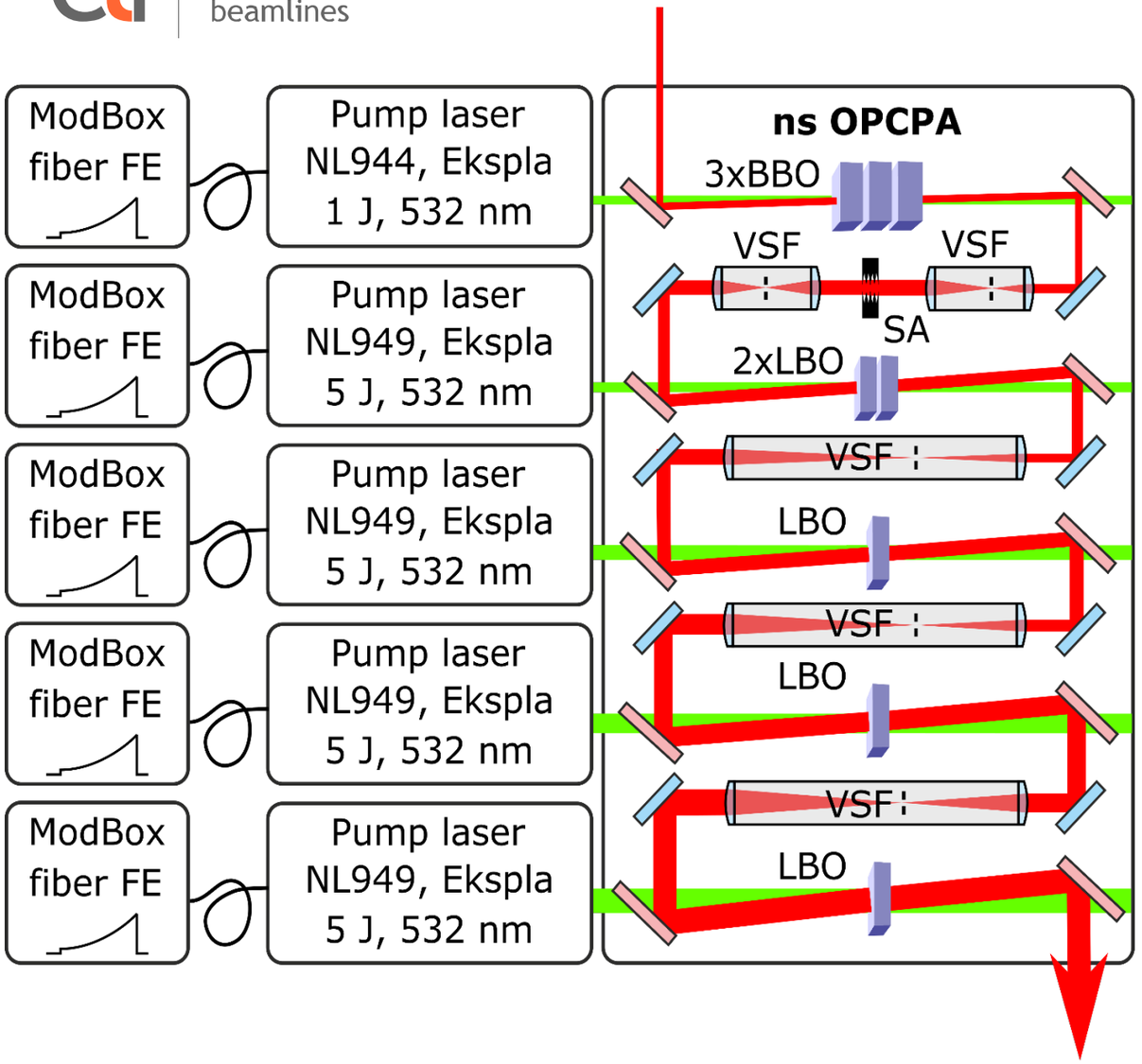
A. Špaček, et al., "Stability mechanism of picosecond supercontinuum in YAG," Opt. Express **28**, 20205-20214 (2020)

Front end for L4-Aton 10 PW laser

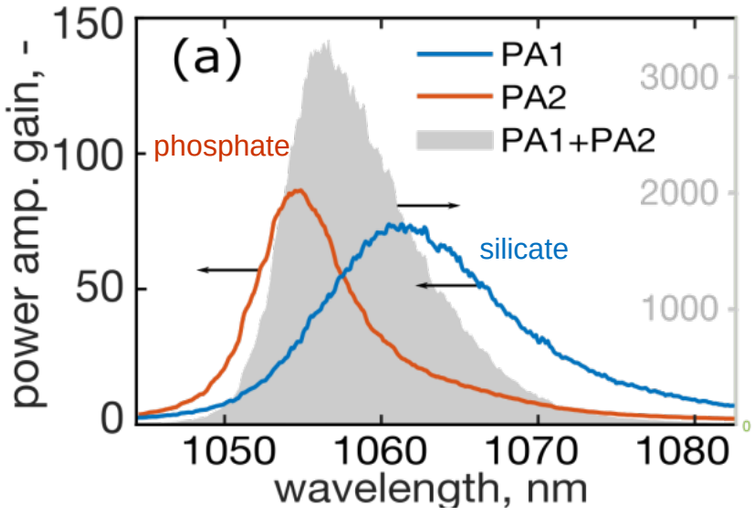
L4-Aton Front End

ELI played a major role in the development of the 5Hz, 4J nanosecond OPCPA front end for the 10PW L4-Aton Laser.

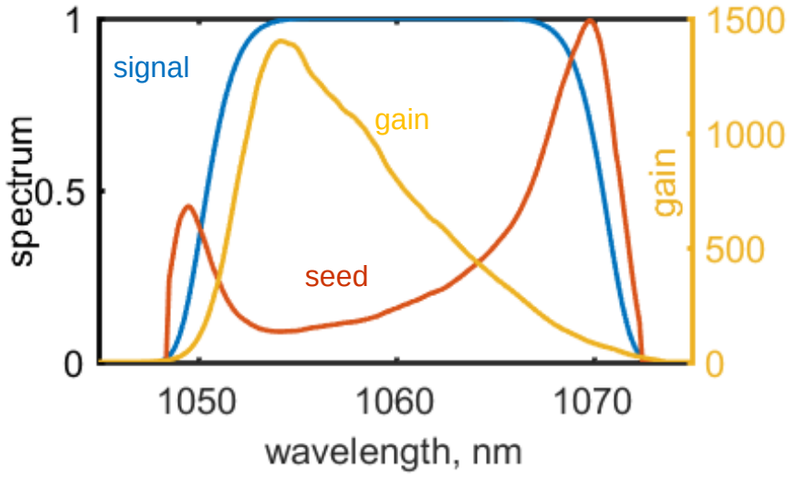
Front end for L4-Aton 10 PW laser



Power amplifier gain



Seed ≈ 1/Gain



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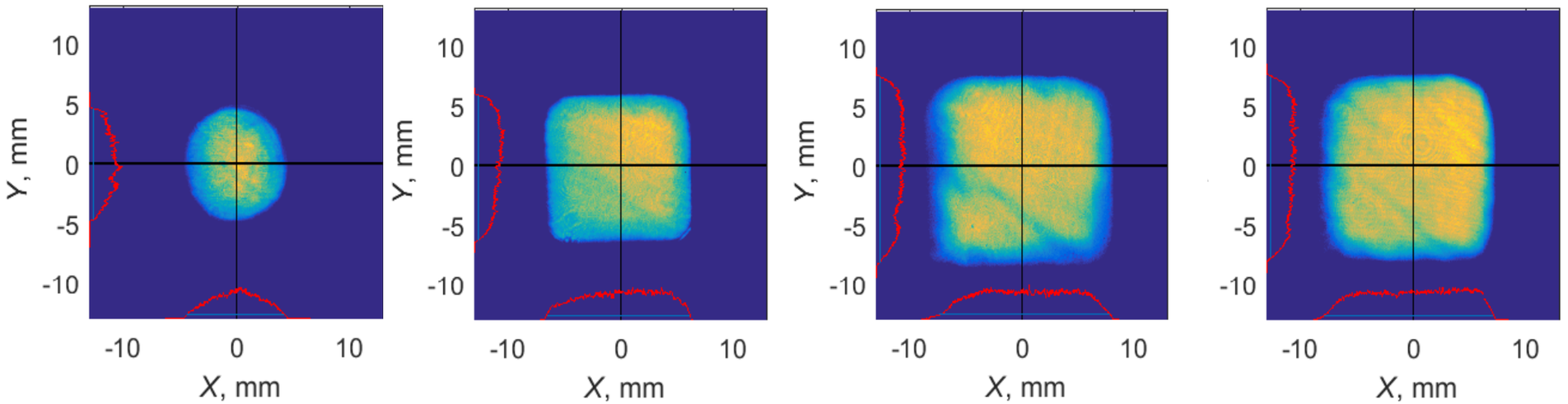

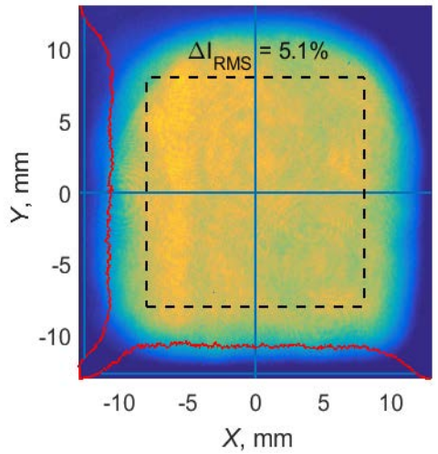

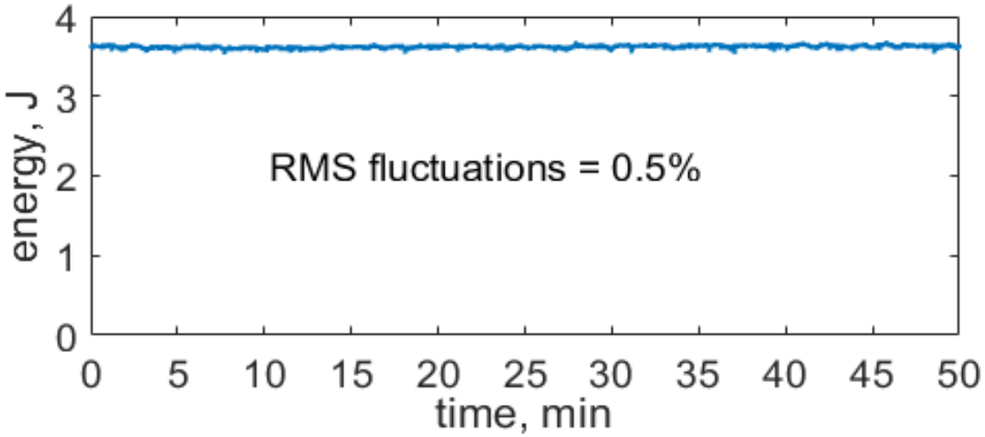

F. Batysta, et al., “Spectral pulse shaping of a 5 Hz, multi-Joule broadband optical parametric chirped pulse amplification front end for a 10 PW laser system," Opt. Lett. **43**, 3866-3869 (2018)

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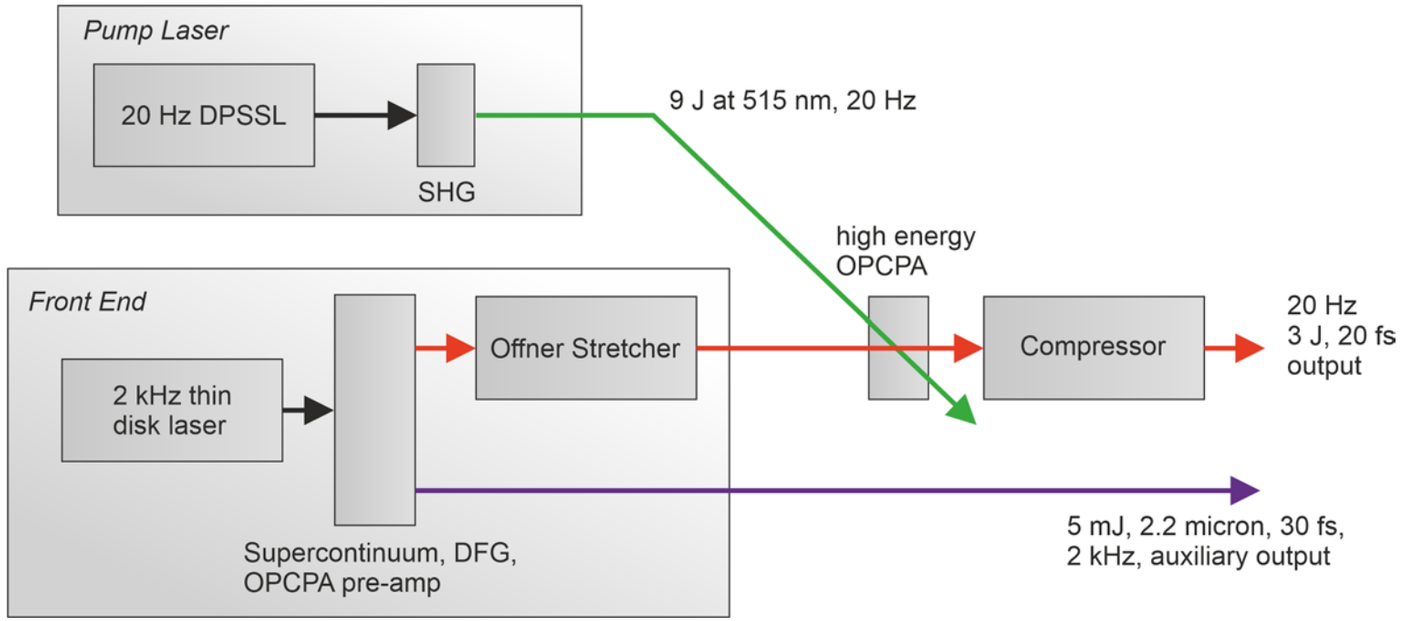
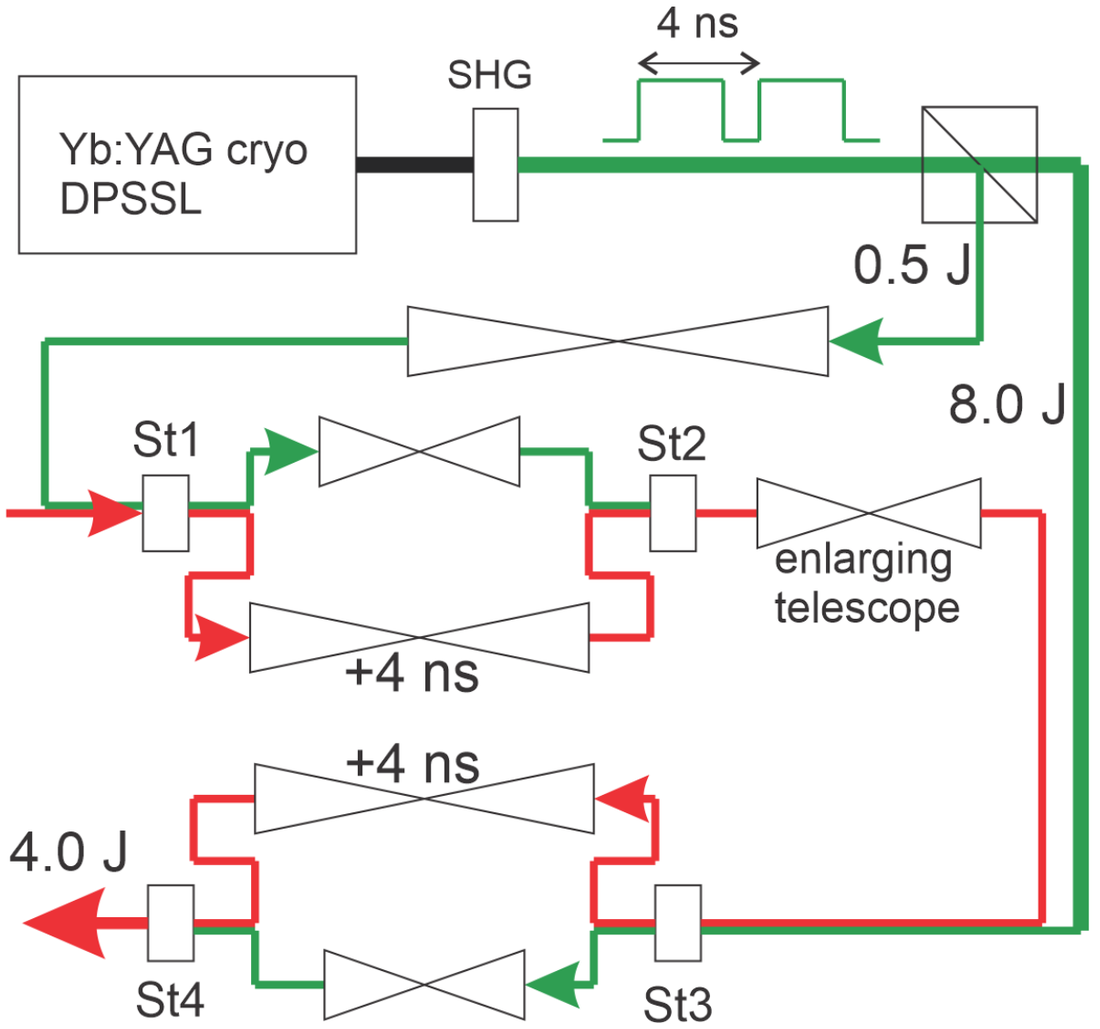


High Energy ns-OPCPA

Stage (crystal type)	Crystal Length (mm)	Pump Energy (J)	Pump Diameter (mm)	Pump Intensity (MW/cm^2)	Signal Output Energy (J)	Signal Output Intensity (MW/cm^2)
1 (BBO)	20	0.250	7.5	217	0.06	150
2 (BBO)	6	0.250	7.5	217	0.15	279
3 (LBO)	25	4	29	232	2.0	158
4 (LBO)	13	4	29	232	**4.0**	302



Conclusions

ELI-Beamlines would like to investigate the potential for using DPSSL pumped OPCPA as a driver for LWFA

1. The development of the L2-DUHA 50 Hz demonstrator is based proven technology; cryo cooled Yb:YAG multislab and OPCPA technology heavily based on previous experience at ELI.

2. The laser is being designed with the application in mind from the beginning in terms of attention to stability, reliability, and laser parameters.