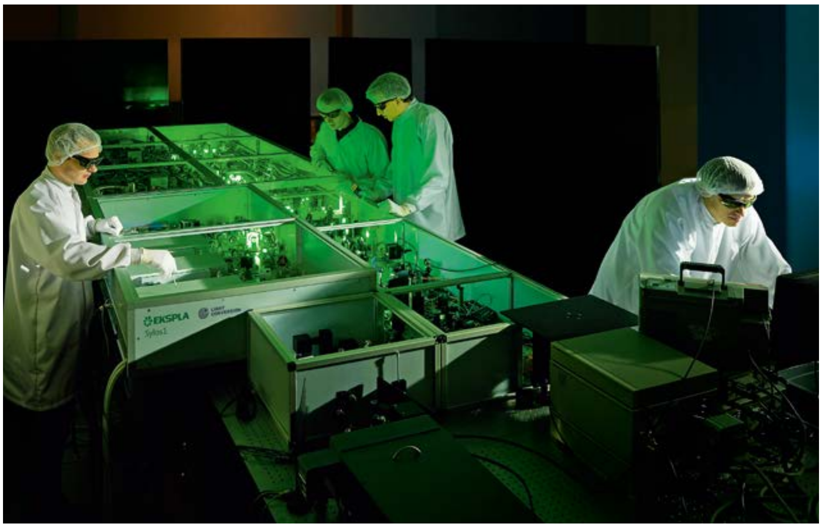
Multi TW Few cycle OPCPA systems

UltraFlux Custom



Unique OPCPA based laser system, providing ~5 terawatts of output power at 1 kHz repetition rate has been designed and built for ELI-ALPS facilities located in Szeged, Hungary

Since their invention, lasers have been extremely effective to improve our understanding of the molecular and atomic structure of matter and the associated dynamical events. However, laser pulse energy was not enough to probe deeper – into nucleons and their components the quarks or to dissociate the vacuum. A new type of large-scale laser infrastructure specifically designed to produce the highest peak power and focused intensity was established by the European Community: the Extreme Light Infrastructure (ELI). ELI was designed to be the first exawatt class laser facility, equivalent to 1000 times the National Ignition Facility (NIF) power. Producing kJ of power over 10 fs, ELI will afford wide benefits to society ranging from improvement of oncology treatment, medical and biomedical imaging, fast electronics and our understanding of aging nuclear reactor materials to development of new methods of nuclear waste processing.

The facility will be based on four sites. Three of them are implemented in the Czech Republic, Hungary and Romania.
ELI-ALPS based in Szeged (Hungary), one of the three pillars of the Extreme Light Infrastructure, will further deepen knowledge in fundamental physics by providing high repetition rate intense light pulses on the attosecond timescale. Current technological limitations will be overcome by use of novel concepts. The main technological backbone of ELI-ALPS will be optical parametric chirped-pulse amplification (OPCPA) of few-cycle to sub-cycle laser pulses. Pumped by dedicated all-solid-state short-pulse (ps-scale) sources and their (low-order) harmonics, this approach will be competitive with conventional (Ti:Sapphire laser based) femtosecond technology in terms of pumping efficiency and will dramatically outperform previous technologies in terms of average power, contrast, bandwidth, and – as

FEATURES

- *Driven by low maintenance cost diode-pumped and industry-tested Yb:KGW and Nd:YAG lasers running at 1 kHz repetition rate*
- *> **120 W** average power combined with > **15 TW** peak power, along with sub-250 mrad carrier-envelope phase stability (CEP) and **sub-8 fs** pulse duration at a center wavelength of **900 nm***
- *Amplified Spontaneous Emission (ASE) – free, passively CEP stabilized pulses have excellent stability of output parameters over 24 hours of continuous operation*
- *Despite its unique set of specifications, it is still a table-top system*
- *A sophisticated self-diagnostic system allows hands-free operation and output specification stability all day long without operator intervention*

APPLICATIONS

- *Fundamental frontier particle physics research*
- *Nuclear Photonics*
- *High harmonic generation*
- *Attosecond pulse generation*
- *Wake field particle acceleration*
- *X-ray generation*

a consequence – degree of control of the generated radiation. The ELI-ALPS laser architecture will consist of three main laser beamlines, operating at different regimes of repetition rates and peak powers: High Repetition Rate (HR): 100 kHz, > 5 mJ, ≤ 6 fs, Single Cycle (SYLOS): 1 kHz, > 120 mJ, ≤ 8 fs, High Field (HF): 10 Hz, 34 J, ≤ 17 fs.

The Single Cycle Laser SYLOS2A (the first stage of the SYLOS project), which employs OPCPA technology developed at Vilnius University, has been designed and manufactured by a consortium of two Lithuanian companies – Ekspla and Light Conversion.

The consortium won SYLOS1 procurement SYLOS2A upgrade tenders. The system was installed in 15 May 2019 and produces Carrier Envelope Phase (CEP) stabilized, 6.6 fs laser pulses with a peak power of > 4.5 TW and an average power of 35 W at 1 kHz repetition rate. To the best of our knowledge, this is currently the highest average power produced by a multi-TW few-cycle OPCPA system.

Despite of its uniqueness and extremely high power, the current state of SYLOS laser system already sets a new standard of reliability in ultrafast laser technology.

On 25 of November 2020, ELI-ALPS (Extreme Light Infrastructure Attosecond Light Pulse Source) facility and consortium between EKSPLA and Light Conversion, signed a contract for building a new laser system, called SYLOS3 for ELI-ALPS. A new system will deliver unique parameters, never before achieved in a commercially available system: 15 TW peak power at 1 KHz repetition rate and 8 femtoseconds pulse duration. Compared to SYLOS2A system (4.5 TW, 6.36 fs, 1 kHz) , already installed at ELI-ALPS, new system will provide more than 3 times higher peak and average power.

'The ELI-ALPS SYLOS3 laser system is planned to generate coherent X-ray radiation through gas and surface higher order harmonic generation, as well as electron acceleration in order to serve various experiments.'

– mentioned Adam Börzsönyi, Head of Laser Sources Division at ELI-ALPS.

– 'One of the many applications is the generation of attosecond pulses for attosecond metrology. The beamlines operated with the SYLOS laser are designed for user operation and demands high stability of operation with high up-time. These tasks will be of top priority when designing and developing the SYLOS3 system.'

Due to the exceptionally large XUV/X-ray energy this system opens up the route to nonlinear XUV and X-ray science as well as 4D imaging and industrial, biological and medical applications.

The main object of ELI-ALPS (Extreme Light Infrastructure Attosecond Light Pulse Source) project is creating a unique European research center, providing the international research community with laser pulses and secondary sources. The Szeged facility will stand out from the institutes producing the highest intensity laser pulses at 1 kHz pulse repetition rate in the world.

SPECIFICATIONS

Model	UltraFlux FF401k-F8-CEP	UltraFlux FF1201k-F8-CEP
MAIN SPECIFICATIONS [1]		
Output energy	40 mJ	120 mJ
Peak pulse power	> 5 TW	> 15 TW
Pulse repetition rate	1 kHz	1 kHz
Wavelength [2]	900 nm	900 nm
Pulse duration	≤ 8 fs (≤ 3 cycles)	≤ 8 fs (≤ 3 cycles)
Pulse energy stability [3]	≤ 1 %	≤ 1 %
Long-term power drift [4]	± 1.5 %	± 1.5 %
CEP stability	≤ 250 mrad	≤ 250 mrad
Beam spatial profile	Super-Gaussian [5]	Super-Gaussian [5]
Beam diameter	~ 50 mm	~ 100 mm
Beam pointing stability [6]	≤ 20 μrad	≤ 20 μrad
Strehl ratio [7]	> 0.7	> 0.7
Temporal contrast [8]		
APFC (within ± 50 ps)	10^6 : 1	10^6 : 1
Pre-pulse (≤ 50 ps)	10^{11} : 1	10^{11} : 1
Post-Pulse (>50 ps)	10^8 : 1	10^8 : 1

UltraFlux Custom

Model	UltraFlux FF401k-F8-CEP	UltraFlux FF1201k-F8-CEP
PHYSICAL CHARACTERISTICS [9)]		
Laser head size (W×L×H mm)	9000 × 5000 × 1200	9000 × 9000 × 1200
Umbilical length	up to 10 m	up to 5 m
OPERATING REQUIREMENTS [10)]		
Electrical power	208, 380 or 400 V AC, three-phase, 50/60 Hz [11)]	208, 380 or 400 V AC, three-phase, 50/60 Hz [11)]
Power consumption [12)]	≤ 40 kVA	≤ 60 kVA
Water supply	≤ 30 l/min, 2 Bar, max 15 °C	≤ 40 l/min, 2 Bar, max 15 °C
Operating ambient temperature	22 ± 2 °C	22 ± 2 °C
Storage ambient temperature	15 – 35 °C	15 – 35 °C
Relative humidity (non-condensing)	≤ 80 %	≤ 80 %
Cleanness of the room	ISO Class 7	ISO Class 7

1) Due to continuous improvement, all specifications are subject to change without notice. The parameters marked 'typical' are indications of typical performance and will vary with each unit we manufacture. Presented parameters can be customized to meet customer's requirements.

2) Central wavelength is calculated as the power-weighted mean frequency from measured spectrum in frequency domain.

3) Under stable environmental conditions, normalized to average pulse energy (RMS, averaged from 30 s).

4) Measured over 8 hours period after 30 min warm-up when ambient temperature variation is less than ±2 °C.

5) Super-Gaussian spatial mode of 6-11th order in near field.

6) Beam pointing stability is evaluated as movement of the beam centroid in the focal plane of a focusing element (RMS, averaged from 30 s).

7) Strehl ratio of > 0.7 is achieved with deformable mirror option.

8) Pulse contrast is only limited by amplified parametric fluorescence (APFC) in the temporal range of ~90 ps which covers OPCPA pump pulse duration and is better than 10^6 : 1. APFC contrast depends on OPCPA saturation level. Our OPCPA systems are ASE-free and pulse contrast value in nanosecond range is limited only by measurement device capabilities (third-order autocorrelator). There are no pre-pulses generated in the system and post-pulses are eliminated by using wedged transmission optics.

9) System sizes are preliminary and depend on customer lab layout and additional options purchased.

10) The laser and auxiliary units must be settled in such a place void of dust and aerosols. It is advisable to operate the laser in air conditioned room, provided that the laser is placed at a distance from air conditioning outlets. The laser should be positioned on a solid worktable. Access from one side should be ensured.

11) Voltage fluctuations allowed are +10 % / -15 % from nominal value.

12) Required current rating can be calculated by dividing power rating by mains voltage. Power rating is given in apparent power (kVA) for systems with flash lamp power supplies and in real power (kW) for systems without flash lamp power supplies where reactive power is neglectable.

OPTIONS

Option	Description	Comment
-F8	Short Pulse option reduces output pulse duration to ≤ 8 fs	Wavelength tunability not available with 'F8' option
-CEP	CEP stabilization to ≤ 250 mrad	Passive and active CEP stabilization
-DM	'Deformable Mirror' option for Strehl ration improvement to > 0.7	
-ps out	Additional narrow spectra ps output that is optically synchronized to main system output	Can be simultaneous and non-simultaneous to the main system output

PERFORMANCE

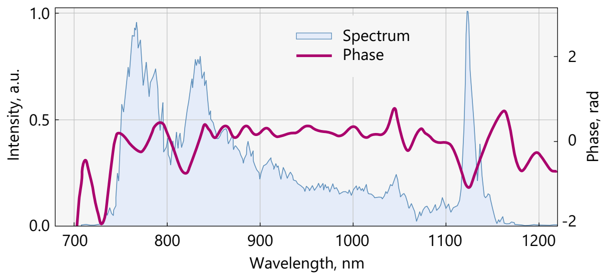


Fig 1. Typical output spectra and spectral phase of UltraFlux FF401k-F8-CEP-DM system

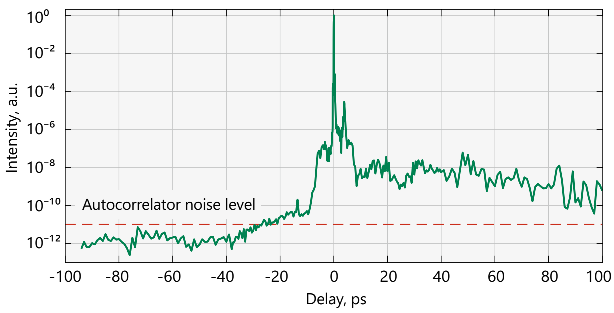


Fig 2. Typical temporal contrast of UltraFlux FF401k-F8-CEP-DM system

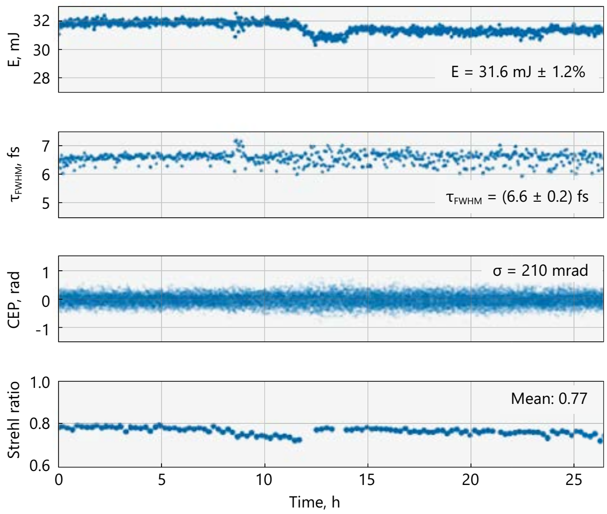


Fig 3. Typical long-term energy, pulse duration, CEP and Strehl ratio stability of UltraFlux FF401k-F8-CEP-DM system

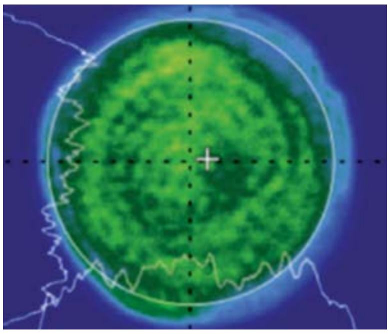


Fig 4. Typical UltraFlux FF401k-F8-CEP-DM near field beam profile

Fig 5. Typical external view of UltraFlux FF401k-F8-CEP-DM system (ELI-ALPS, SYLOS2A system)

ORDERING INFORMATION

UltraFlux FF(1)(2)-(3)

Model

Energy level:
40 → 50 mJ
100 → 100 mJ

Pulse repetition rate:
100 → 100 Hz
1k → 1 kHz

Additional options:
- F8 → output pulse duration to ≤ 8 fs
- CEP → CEP stabilization to ≤ 250 mrad
- DM → Deformable Mirror' option for Strehl ration improvement to > 0.7
- ps out → Additional ps output that is optically synchronized to main system output.