



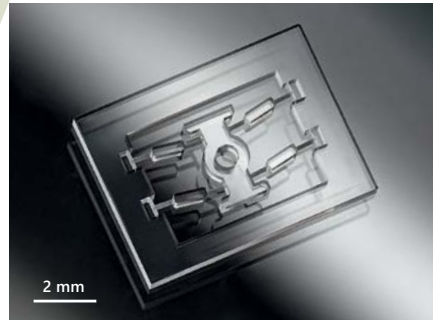
Material processing examples

Made with **FemtoLux** laser

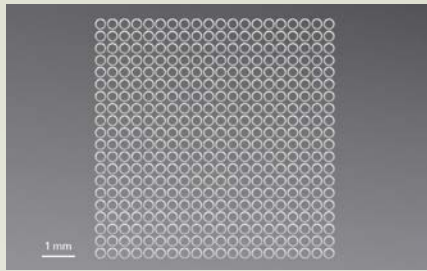
Glass

Processing glass substrates presents significant challenges due to their fragility and susceptibility to cracking under excessive thermal loads.

Femtosecond lasers are ideal for processing glass substrates due to their ultra-short pulse duration that minimizes thermal accumulation, resulting in superior quality.



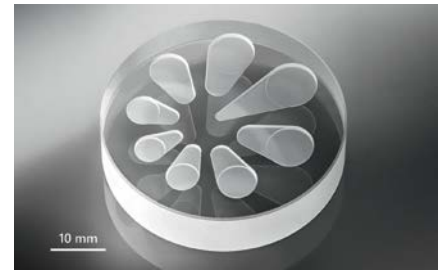
Femtosecond laser induced selective etching of bistable switch. Courtesy of Femtika.



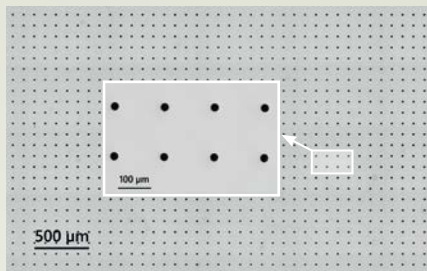
300 µm hole drilling in thin borosilicate glass. Courtesy of FTMC.



Fused-silica milling. Courtesy of FTMC.



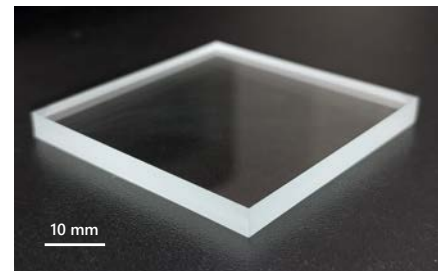
UVFS milling. Courtesy of FTMC.



GHz burst assisted percussion drilling of high aspect ratio holes in EXG glass. Courtesy of Akoneer.



Bottom-up milling of fused-silica glass. Courtesy of FTMC.

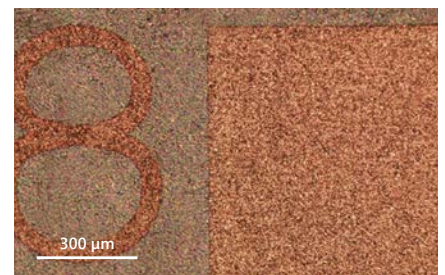


Laser-based Bessel beam scribing of soda-lime glass. Courtesy of FTMC.

Polymer

Polymers are widely used in various applications, including automotive, medicine, and consumer electronics. However, due to their inherent property of low heat conductivity, polymers are quite sensitive to heat.

Femtosecond lasers, with their very short pulse durations, offer a solution to this problem by enabling the precise machining of polymers while preserving process quality.



Insulation layer removal from PCB. Courtesy of FTMC.

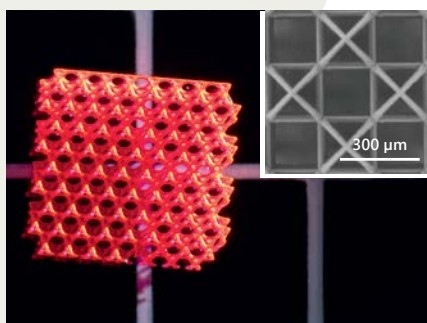


Photo-polymerization. Courtesy of Femtika.

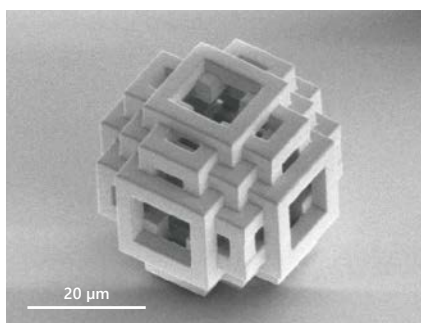
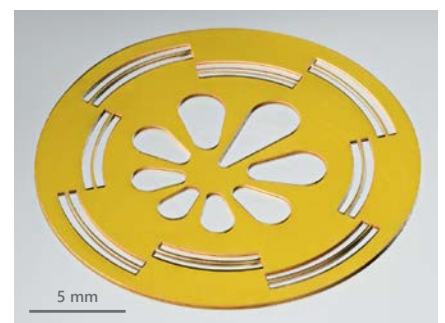


Photo-polymerization. Courtesy of WOP.



Polymeide cutting. Courtesy of FTMC.

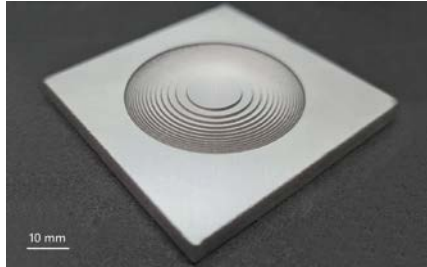
Material Processing Examples

Metal

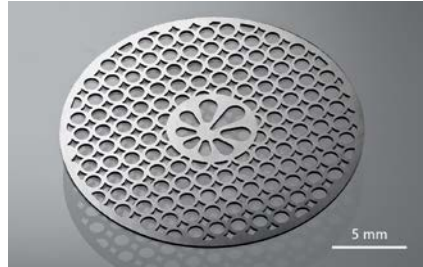
Femtosecond lasers enable the production of complex shapes and features, while also providing the capability to perform black/white marking and coloring without the need for chemical additives.



Stainless steel cutting. Courtesy of FTMC.



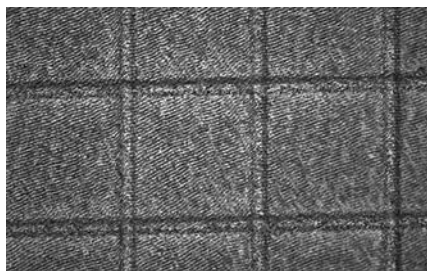
Laser milled aluminium Fresnel lens mould, diameter 35 mm. Courtesy of FTMC.



Stainless steel cutting. Courtesy of FTMC.



Black marking of tweezers. Courtesy of FTMC.



Grid surface texturing with LIPSS of nitinol. Courtesy of UNIMORE.



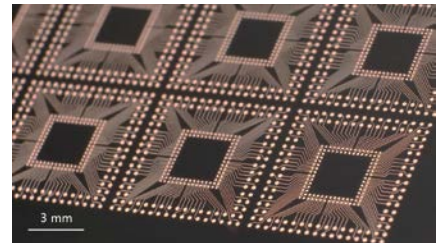
Nitinol stent cutting. Courtesy of Vactronix Scientific



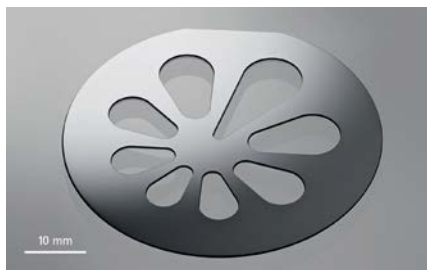
Stainless steel coloring with GHz burst feature. Courtesy of Akoneer.

Other materials

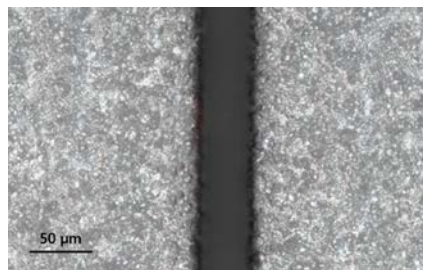
Femtosecond lasers, with pulse durations in the hundreds of femtoseconds, generate high intensities that make it possible to process almost material. Complex 3D structures, as well as non-conventional shapes can be obtained.



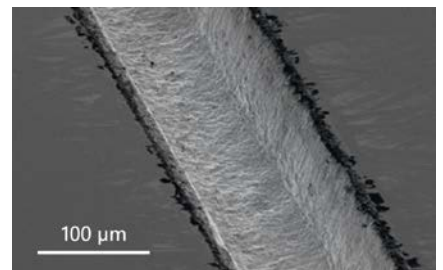
SSAIL technology on PI. Courtesy of Akoneer.



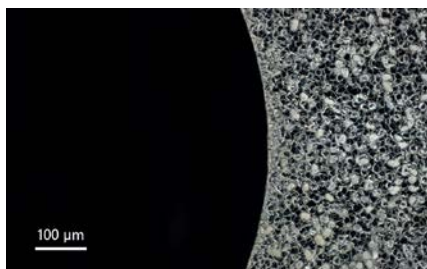
Crystalline silicon cutting. Courtesy of FTMC.



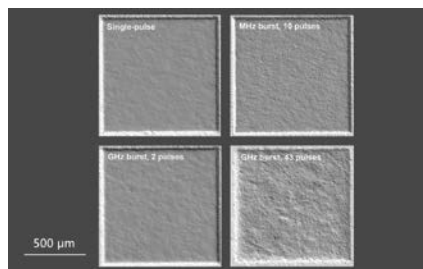
50 µm depth groove formation in ceramic. Courtesy of FTMC.



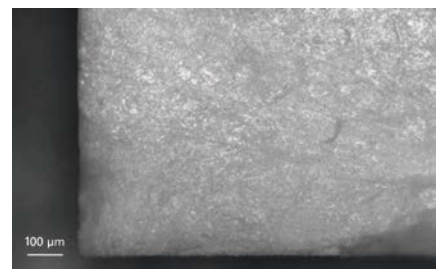
Groove formation in GaAs in water environment. Courtesy of FTMC.



Crystalline silicon cutting. Courtesy of FTMC.



Optical 3D profilometer image showing milled square patterns in aluminum oxide ceramics.



Heat-sensitive organic material cutting. Courtesy of FTMC.

fs

Industrial
Femtosecond
Lasers

FemtoLux

Reliability Redefined

A reliable &
versatile tool for
micromachining

- / Glass, sapphire and ceramics
micro processing
- / Microelectronics manufacturing
- / Glass intra volume structuring
- / Micro processing of different
polymers and metals
- / LCD, LED, OLED drilling,
cutting and repair



Industrial Dry Cooled Femtosecond Laser

FemtoLux

Designed from the get-go for maximum reliability, seamless integration and non-stop 24/7/365 zero maintenance operation with innovative "dry" cooling.

The FemtoLux femtosecond laser has a tunable pulse duration from <350 fs to 1 ps and can operate in a broad AOM controlled range of pulse repetition rates from a single shot to 4 MHz.

The maximum pulse energy is more than 300 μJ operating with single pulses and can reach more than 750 μJ in burst mode, ensuring higher ablation rates and processing throughput for different materials.

The FemtoLux beam parameters will meet the requirements of the most demanding materials and micro-machining applications.

Innovative laser control electronics ensure simple control of the FemtoLux laser by external controllers that could run on different platforms, be it Windows, Linux or others using REST API commands.

This makes easy integration and reduces the time and human resources required to integrate this laser into any laser micromachining equipment.

Seamless User Experience

Easy integration – remote control using REST API via RS232 and LAN.

Reduced integration time – demo electronics is available for laser control programming in advance.

Easy and quick installation – no water, fully disconnectable laser head. Can be installed by the end-user.

Easy troubleshooting – integrated detectors and constant system status logging.

No periodic maintenance required.

Zero
maintenance

"Dry"
cooling

Features

Typical max output power
50 W at 1030 nm,
20 W at 515 nm,
10 W at 343 nm

Typical max output energies
> 300 μJ at 1030 nm,
> 50 μJ at 515 nm,
> 25 μJ at 343 nm

Up to 1 mJ high energy version available

MHz, GHz, MHz+GHz burst modes

> 750 μJ in a burst mode

< 350 fs – 1 ps

Pulse duration extension
up to 1 ns

Single shot – up to 4 MHz
(AOM controlled)

Pulse-on-demand (PoD),
with jitter as low as 20 ns
(peak-to-peak)

<0.5% RMS power long term
stability over 100 hours

$M^2 < 1.2$

Beam circularity > 0.85



Learn more
about FemtoLux
www.ekspla.com

“Dry” Cooling

Direct Refrigerant Cooling System

The FemtoLux laser employs an innovative cooling system and sets new reliability standards among industrial femtosecond lasers. No additional bulky and heavy water chiller is needed.

The chiller requires periodic maintenance – cooling system draining and rinsing and water and particle filter replacement. Moreover, water leakage can cause damage to the laser head and other equipment. Instead of using water for transferring heat from a laser head, the FemtoLux laser uses an innovative Direct Refrigerant Cooling method.

The refrigerant agent circulates from a PSU-integrated compressor and condenser, to a cooling plate via armored flexible lines.

The entire cooling circuit is permanently hermetically sealed and requires no maintenance.

Benefits

Military-grade reliability

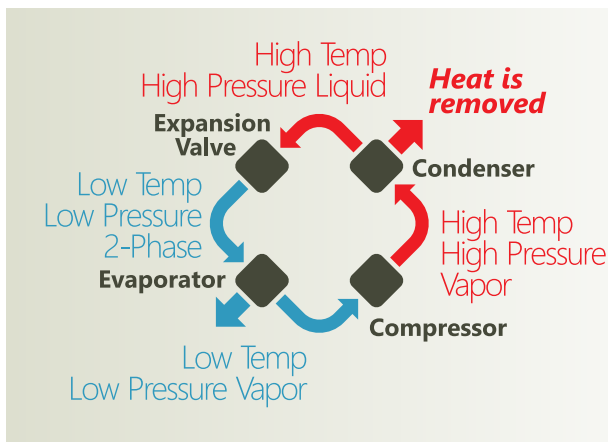
Permanently hermetically sealed system **>90,000 hour MTBF**

No maintenance

High cooling efficiency

>45% lower power consumption compared to water cooling equipment

Compact and light



Compressor picture. Courtesy of Aspen Systems Inc.

Simple & Reliable Cooling Plate Attachment

The cooling plate is detachable from the laser head for more convenient laser installation. The laser cooling equipment is integrated with the laser power supply unit into a single 4U rack-mounted housing with a total weight of 15 kg.

Detachable cooling plate

Integrated cooling equipment with the laser power supply



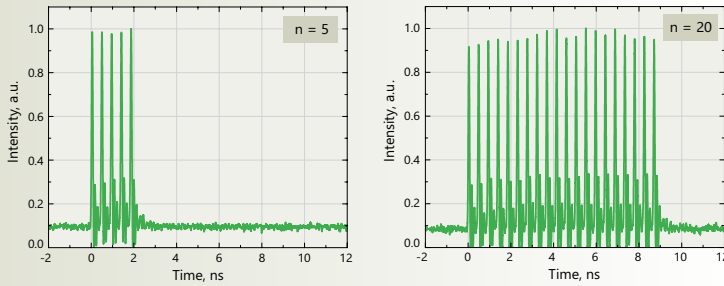
Simple and reliable cooling plate attachment

GHz Burst Option

Patent-Pending Method
for Ultra-High Rate Bursts

Short GHz burst

Fig 1. Measured 2.2 GHz intra-burst PRR burst of pulses containing a different number of pulses of equal amplitudes at 31.5 W average output power



Long GHz burst

Fig 2. Measured 2.2 GHz pre-shaped bursts of 1000 pulses at 233 kHz burst repetition rate for the desired rectangular-like burst shape

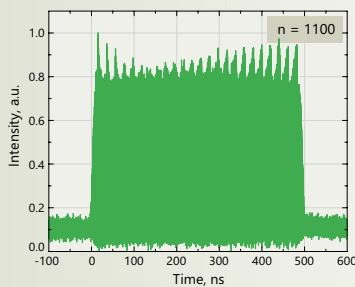
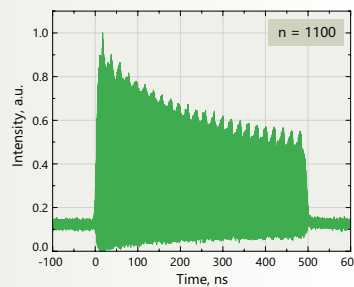


Fig 3. Measured 2.2 GHz non-pre-shaped bursts of 1100 pulses at 233 kHz burst repetition rate



MHz + GHz burst mode

Fig 4. Measured 4 bursts of 50 MHz BRR containing 4 pulses of 2.5 GHz intra-burst PRR

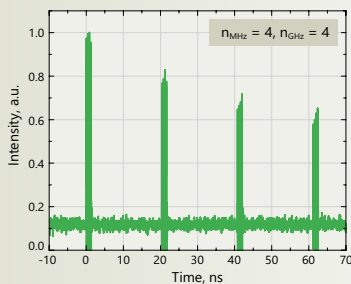
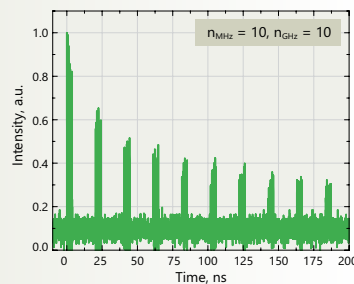


Fig 5. Measured 10 bursts of 50 MHz BRR containing 10 pulses of 2.5 GHz intra-burst PRR



Benefits

The Femtolux laser can operate in the **single-pulse** mode, **MHz burst** mode, **GHz burst** mode, and **MHz + GHz burst** mode.

The burst formation technique based on the use of the AFL is a very versatile method as it allows to overcome many limitations encountered by other fiber- and/or solid-state-based techniques.

Any desired intra-burst PRR can be achieved independently from the initial PRR of the master oscillator

Identical pulse separation inside the GHz bursts is maintained

Short- and long-burst formation modes can be provided.

/ A short burst is up to about 10 ns burst width (from 2 to tens of pulses in the GHz burst).

/ A long burst is from ~20 ns up to a few hundred ns in burst width (from tens to thousands of pulses in the GHz burst)

MHz+GHz burst mode

An adjustable amplitude envelope of the GHz bursts is provided

No pre/post pulses in GHz burst. Pure GHz bursts

Ultrashort pulse duration is maintained inside the bursts

A new versatile patent-pending method to form ultra-high repetition rate bursts of ultrashort laser pulses.

The developed method is based on the use of an all-in-fiber active fiber loop (AFL). A detailed description of the invention can be found on:

[1] Andrejus Michailovas, and Tadas Bartulevičius. 2021 Int. patent application published under the Patent Cooperation Treaty (PCT) WO2021059003A1.

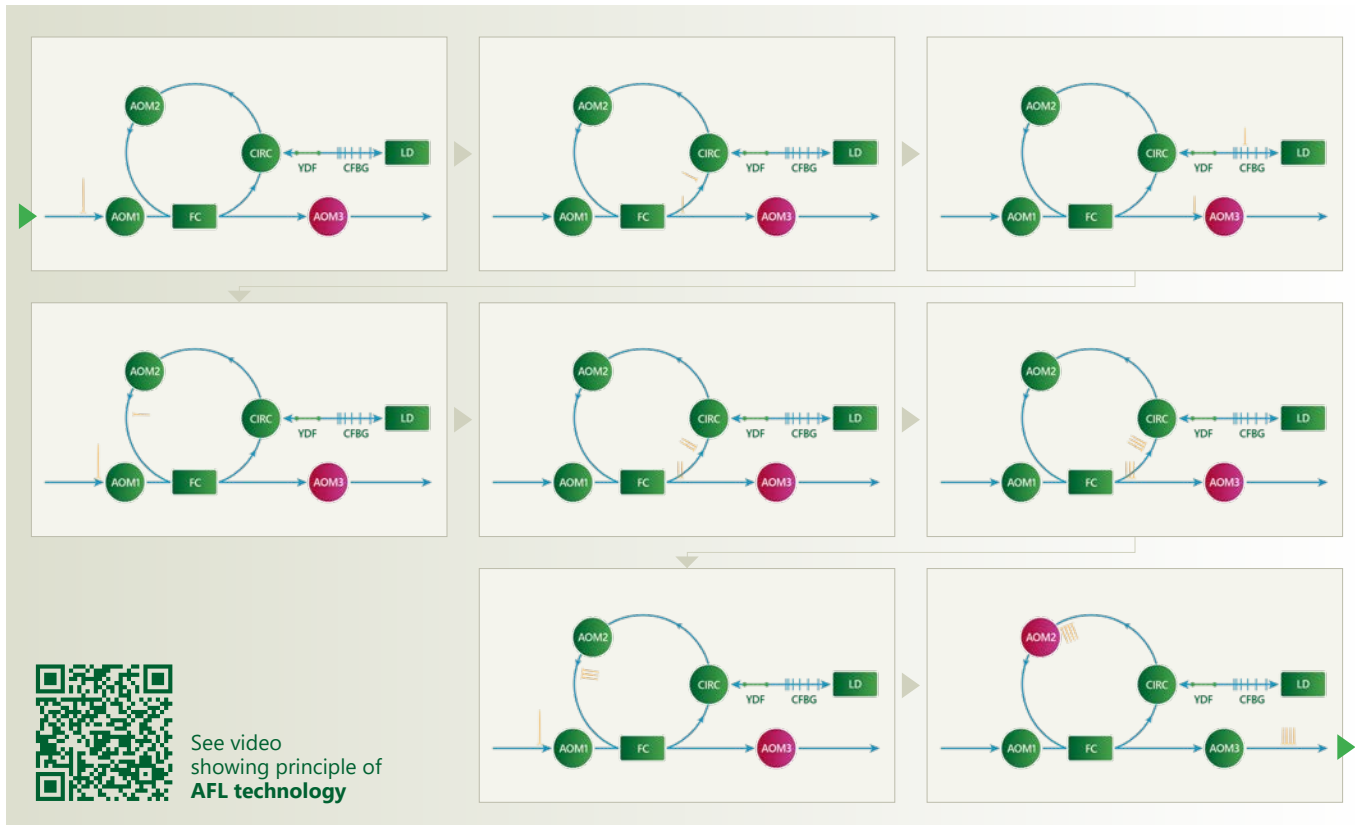
[2] Tadas Bartulevičius, Mykolas Lipnickas, Virginija Petrauskienė, Karolis Madeikis, and Andrejus Michailovas, (2022), "30 W-average-power femtosecond NIR laser operating in a flexible GHz-burst-regime," Opt. Express 30, 36849-36862.

Specifications

Burst repetition rate	up to 650 kHz	
Intra-burst pulse repetition rate ¹⁾	2 GHz	
GHz burst mode	short	long
GHz burst length	0.5 – 10 ns	20 – 500 ns
Number of pulses ²⁾	2 – 20	40 – 1000
Shape	square, rising, falling	falling, pre-shaped ³⁾
MHz + GHz burst mode		
Number of pulses in MHz burst	2 – 10	
Number of pulses in GHz burst ²⁾	2 – 20	

¹⁾ Custom intra-pulse PRR is available upon a request.
²⁾ Depends on the intra-pulse PRR.
³⁾ For more information, please inquire sales@ekspla.com.

Principle of AFL Technology

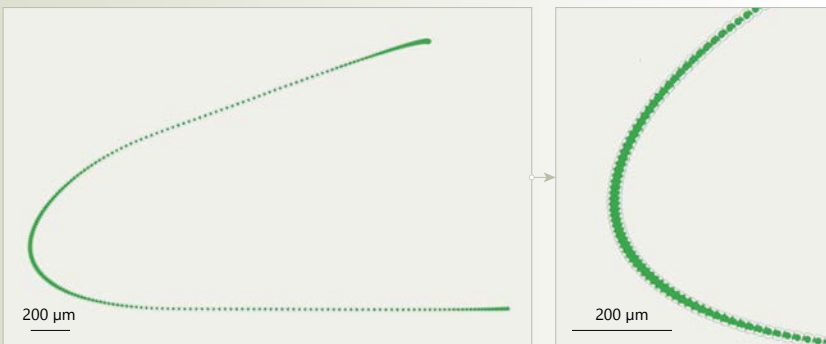


Pulse-on-Demand (PoD)

Traditional laser triggering techniques struggle to maintain equally spaced pulses at high speeds (Fig.1, 2). Pulse-on-demand feature tackles this challenge and enables high-speed micromachining (Fig. 3).

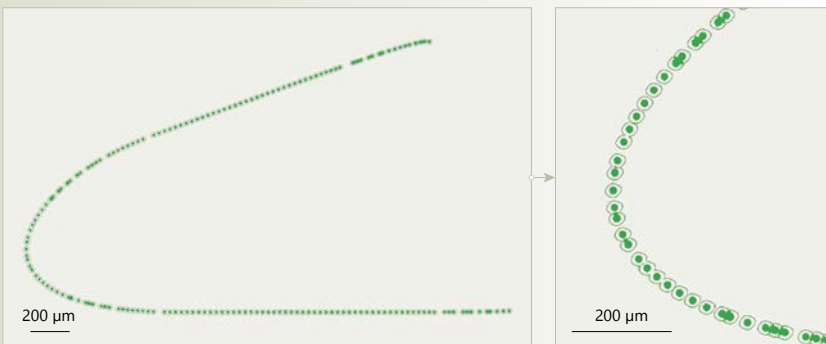
Time based laser triggering

Fig 1. Complex shape scanned with time based laser triggering mode with a pulse repetition of 200 kHz and scanning speed of 6 m/s. The scanning started from the top right to the bottom right area. Overlapping pulses result in an overheated area.



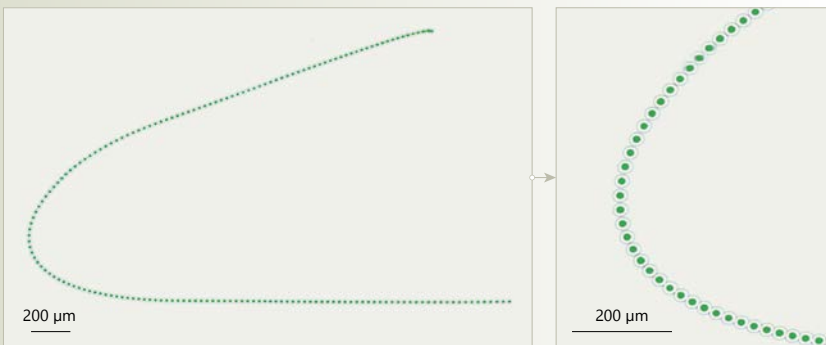
Position based laser triggering

Fig 2. Complex shape scanned with position based laser triggering mode with a pitch of 30 µm and scanning speed of 6 m/s. The scanning started from the top right to the bottom right area. Jitter of tens of µs results in random pulse spacing.



Pulse-on-demand (PoD)

Fig 3. Complex shape scanned with pulse-on-demand (PoD) and position based laser triggering mode with a pitch of 30 µm and scanning speed of 6 m/s. The scanning started from the top right to the bottom right area. PoD feature preserves equidistant pulse spacing at high speeds.



Benefits

Jitter lower than 20 ns ensures consistent and equidistant pulse spacing for high-speed micromachining

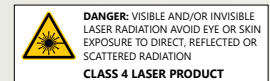
Adjustable repetition rate for processing complex geometries

Faster processing speeds, increased productivity

PoD feature enables the laser to fire a pulse only when required, rather than at a constant rate, enabling precise control over the laser's output and resulting in higher efficiency, accuracy and quality.

This capability is especially valuable in various micromachining applications where a high processing speed, constant energy, and accuracy are essential. To follow complex curvature at high speed and to maintain equidistant spacing it is necessary to ensure that the repetition rate of the pulses is adjusted. To achieve these requirements, it is necessary to ensure that the repetition rate of the pulses is adjusted to follow complex curvature at high speed and to maintain equidistant spacing. One may try to use position based laser triggering but, due to laser system limitations, the jitter will be from several µs to tens of µs, which will result in random spacing of the pulses. On the other hand, the usage of time based laser triggering results in overheat areas, due to excessive overlap of pulses. The FemtoLux laser has the pulse-on-demand feature with jitter as low as 20 ns (peak-to-peak), and it can therefore tackle all the challenges and maximize process efficiency, precision and quality at high speed.

Model	FemtoLux 30	FemtoLux 50
Main specifications		
Central wavelength	fundamental	1030 nm
	with second harmonic option	515 nm
	with third harmonic option	343 nm
Pulse repetition rate (PRR) ²⁾	200 kHz – 4 MHz	100 kHz – 2 MHz
Pulse repetition frequency (PRF) after frequency divider	PRF = PRR / N, N=1, 2, 3, ... , 65000; single shot	
Average output power	at 1030 nm ³⁾	> 27 W (typical 30 W)
	at 515 nm	> 11 W ⁴⁾
	at 343 nm	> 6 W ⁴⁾
Pulse energy	at 1030 nm	> 100 µJ or 1 mJ ⁶⁾
	at 515 nm	> 55 µJ ⁴⁾
	at 343 nm	> 30 µJ ⁴⁾
Number of pulses in MHz burst ⁸⁾	2 – 10	
Maximal energy in burst mode ⁹⁾	> 450 µJ	> 750 µJ
Power long term stability (Std. dev.) ¹⁰⁾	< 0.5 %	
Pulse energy stability (Std. dev.) ¹¹⁾	< 1 %	
Pulse duration (FWHM) @ 1 MHz	tunable, < 350 fs ¹²⁾ – 1 ps ¹³⁾	tunable, < 400 fs ¹²⁾ – 1 ps ¹³⁾
Optional pulse duration extension	tunable, up to 1 ns	
Beam quality	M ² < 1.2 (typical < 1.1)	
Beam circularity, far field	> 0.85	
Beam divergence (full angle)	< 1 mrad	
Beam pointing thermal stability	< 20 µrad/°C	
Beam diameter (1/e ²) @ 1030 nm	2.5 ± 0.4 mm @ 65 cm	
Polarization	vertical	
Triggering mode	internal / external	
Pulse output control	frequency divider, pulse picker, burst mode, packet triggering, power attenuation, pulse-on-demand ¹⁴⁾	
Control interfaces	RS232 / LAN	
Length of the umbilical cord	3 m, detachable. Custom length option available	
Laser head cooling type	dry (direct refrigerant cooling through detachable cooling plate)	
Physical characteristics		
Laser head (W × L × H)	434 × 569 × 150 mm	
Power supply unit (W × L × H)	449 × 496 × 184 mm	
Operating requirements		
Mains requirements	100 – 240 V AC, single phase, 50/60 Hz	
Maximal power rating	800 W	
Operating ambient temperature	18 – 27 °C	
Relative humidity	10–80 % (non-condensing)	
Air contamination level	ISO 9 (room air) or better	
<p>¹⁾ Due to continuous improvement, all specifications are subject to change without notice. Parameters marked typical are not specifications. They are indications of typical performance and will vary with each unit we manufacture. All parameters are specified for a shortest pulse duration. Unless stated otherwise, all specifications are measured at 1030 nm and for basic system without options.</p> <p>²⁾ When frequency divider is set to transmit every pulse. Fully controllable by integrated AOM.</p> <p>³⁾ At 1 MHz.</p> <p>⁴⁾ At 200 kHz.</p> <p>⁵⁾ At 400 kHz.</p> <p>⁶⁾ Other combinations of energy and repetition rate available.</p> <p>⁷⁾ At 100 kHz.</p> <p>⁸⁾ Oscillator frequency ~50 MHz, ~20 ns separation between pulses.</p> <p>⁹⁾ MHz burst mode or MHz+GHz burst mode at 50 kHz PRR.</p> <p>¹⁰⁾ Over 100 h after warm-up under constant environmental conditions.</p> <p>¹¹⁾ Under constant environmental conditions.</p> <p>¹²⁾ At PRR > 500 kHz. At PRR < 500 kHz shortest pulse duration is < 400 fs.</p> <p>¹³⁾ Custom pulse duration by request. For example – fixed 50 fs available.</p> <p>¹⁴⁾ Optional feature. Jitter < 20 ns. Trigger-to-pulse delay < 1 µs.</p>		



Performance of FemtoLux 50

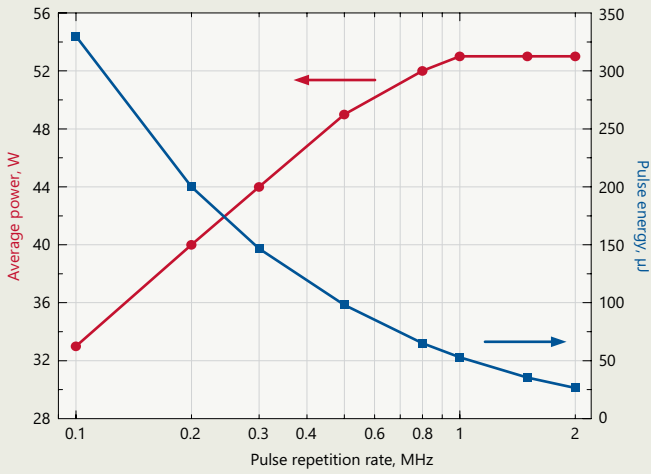


Fig 1. Typical dependence of output power and pulse energy of FemtoLux 50 laser at 1030 nm on pulse repetition rate

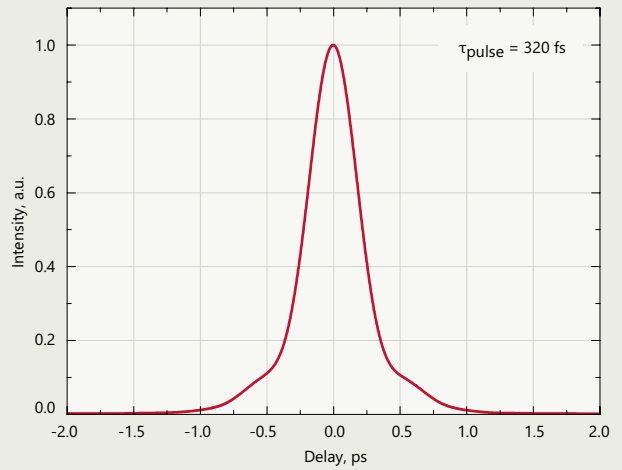


Fig 2. Typical FemtoLux 50 laser output pulse autocorrelation function at 1030 nm @ 1 MHz

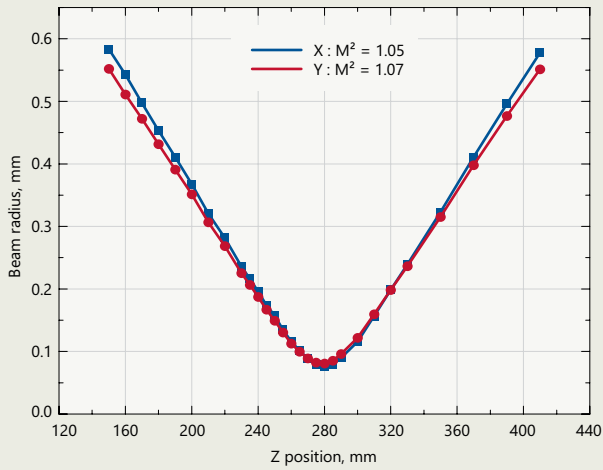


Fig 3. Typical M^2 measurement of FemtoLux 50 laser at 1030 nm

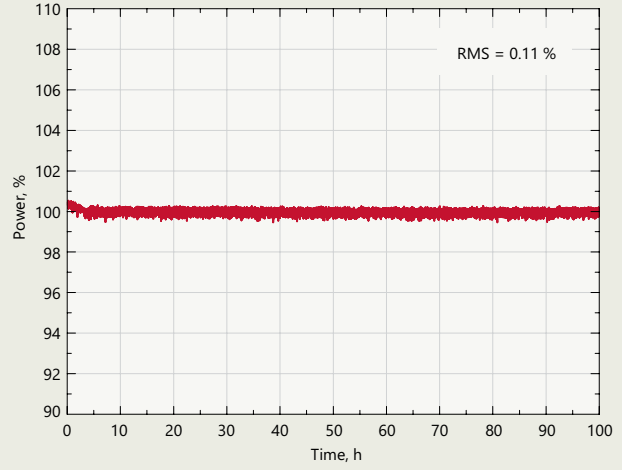


Fig 4. Typical long term average power stability of FemtoLux 50 laser at 1030 nm under constant environmental conditions

Performance of FemtoLux 30

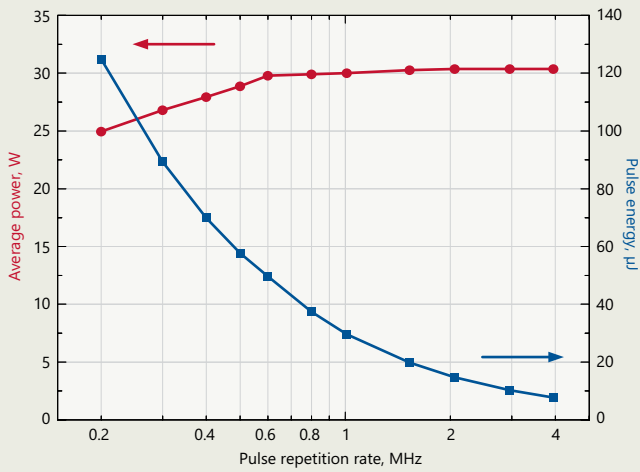


Fig 5. Typical dependence of output power and pulse energy of FemtoLux 30 laser at 1030 nm on pulse repetition rate

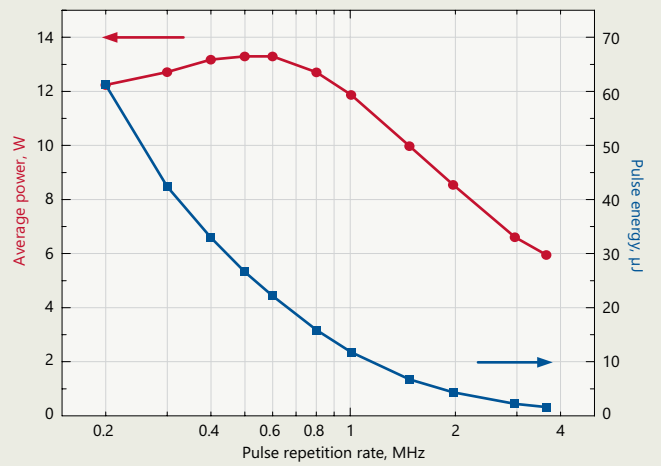


Fig 6. Typical dependence of output power and pulse energy of FemtoLux 30 laser at 515 nm on pulse repetition rate

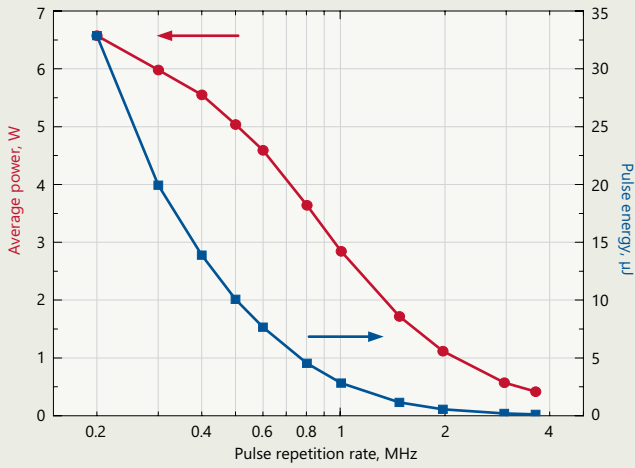


Fig 7. Typical dependence of output power and pulse energy of FemtoLux 30 laser at 343 nm on pulse repetition rate

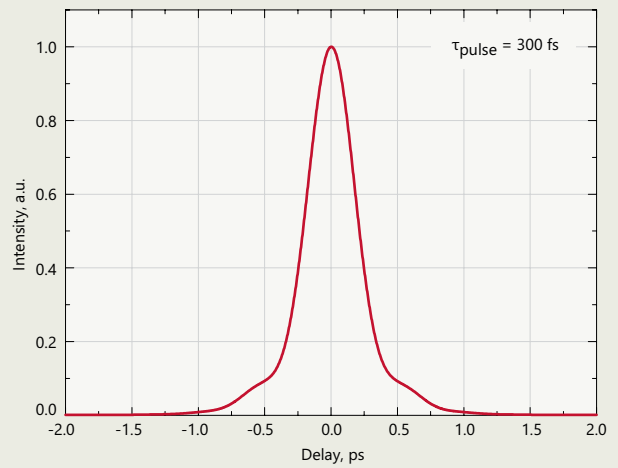


Fig 8. Typical FemtoLux 30 laser (at 1030 nm) output pulse autocorrelation function

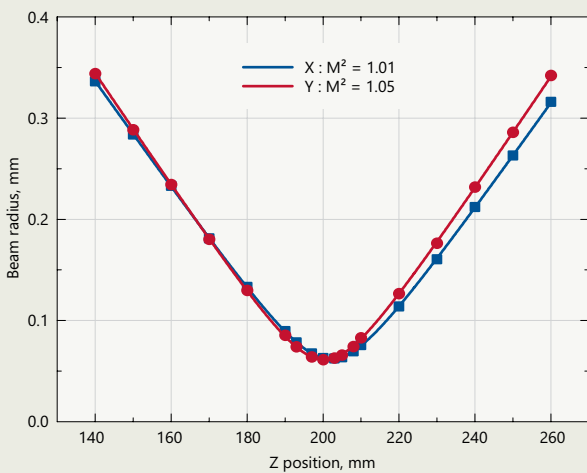


Fig 9. Typical M^2 measurement of FemtoLux 30 laser at 1030 nm

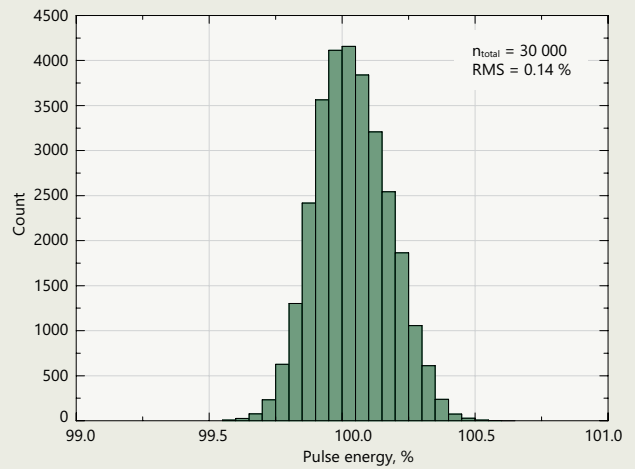


Fig 10. Typical pulse-to-pulse energy stability of FemtoLux 30 laser at 200 kHz over 30 000 pulses. RMS was calculated by using a set of mean values of 10 consecutive laser shots

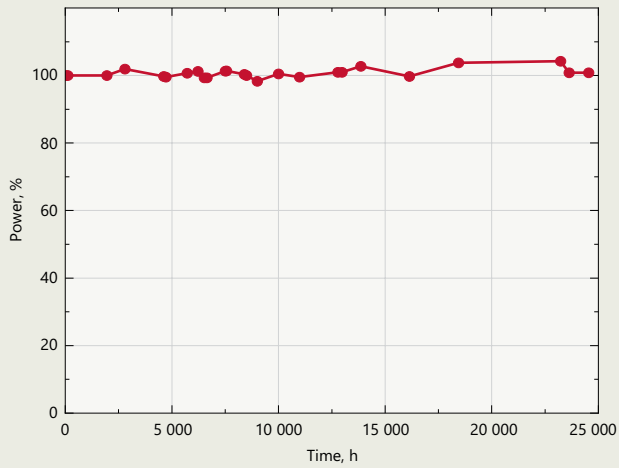


Fig 11. Long-term average power stability of the FemtoLux 30 laser at 1030 nm under constant environmental conditions over an extended duration of 25,000 hours

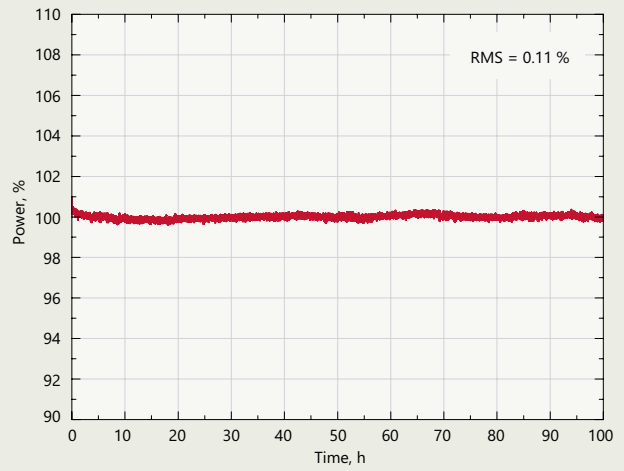


Fig 12. Typical long term average power stability of FemtoLux 30 laser at 1030 nm under constant environmental conditions

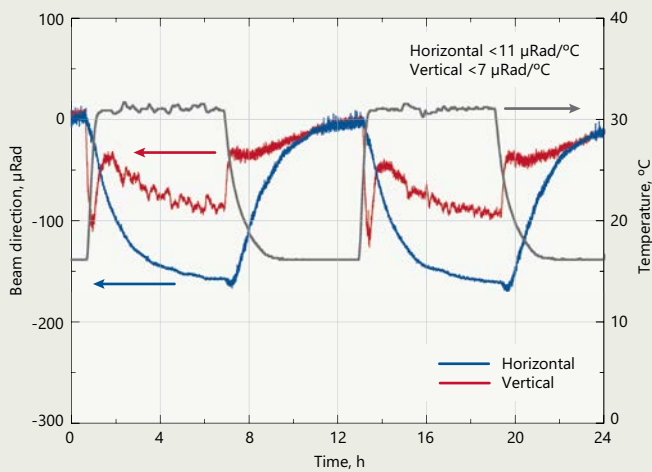


Fig 13. Typical beam direction stability of FemtoLux 30 under harsh environmental conditions

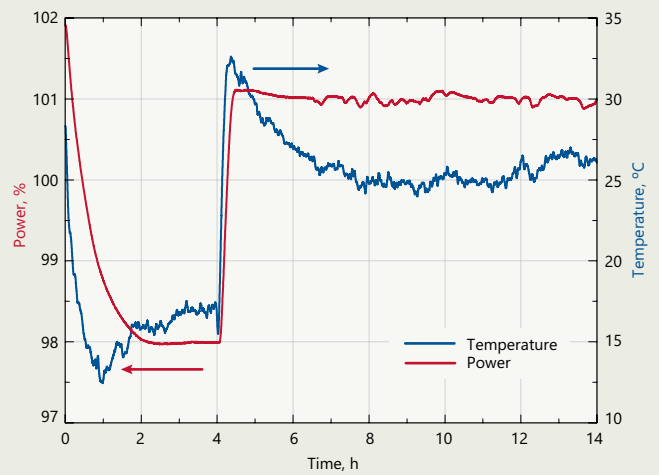


Fig 14. Average output power dependence of FemtoLux 30 laser on ambient temperature at 1030 nm



FemtoLux with harmonics module and power supply

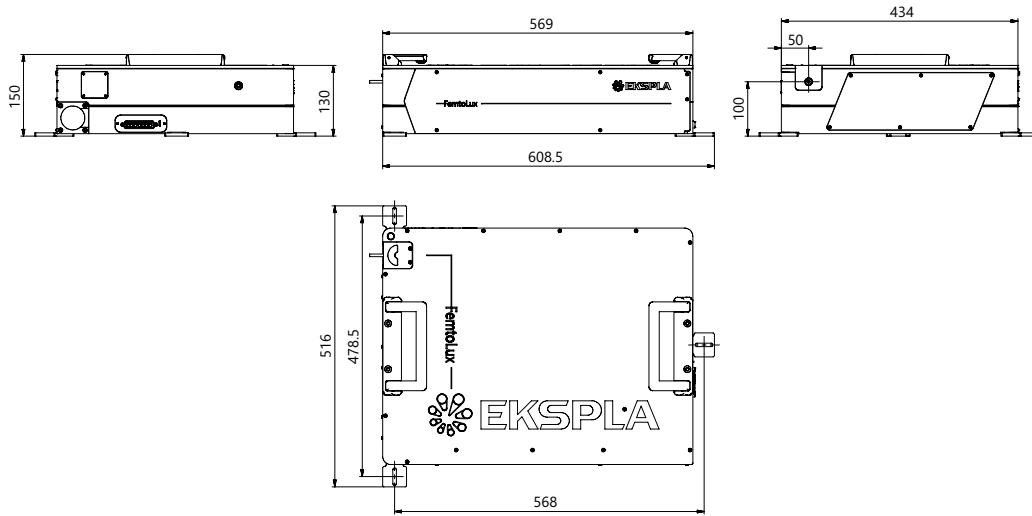


Fig 11. FemtoLux laser head outline drawing

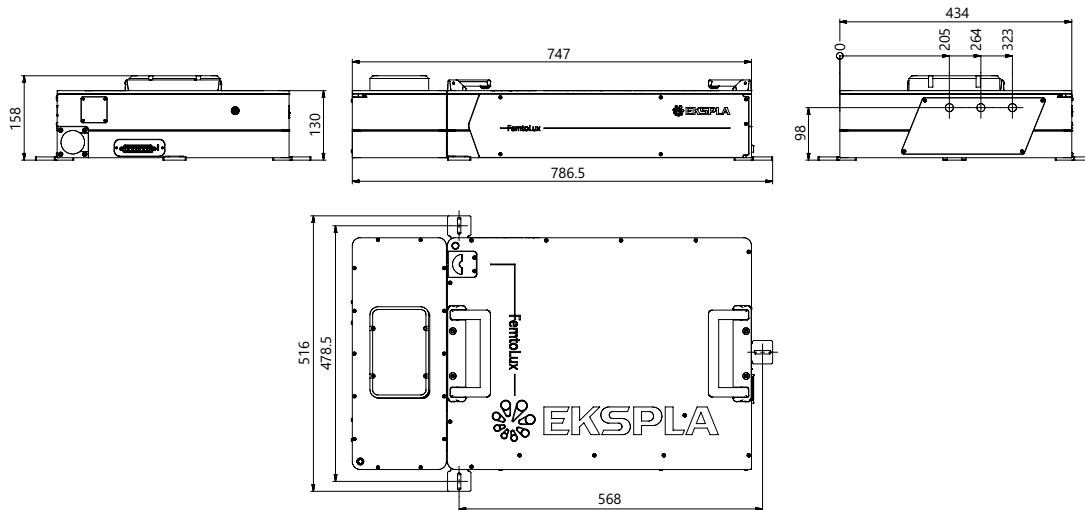


Fig 12. FemtoLux with harmonics module. Laser head outline drawing

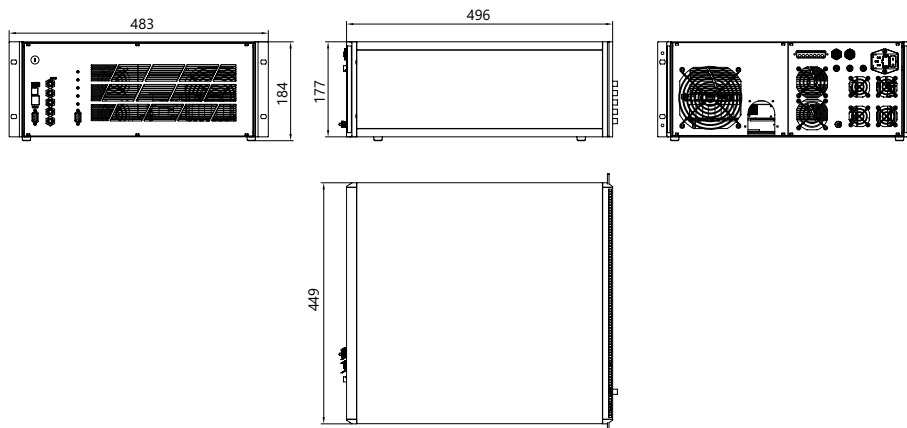


Fig 13. Power supply outline drawing

Laser control application

Ekspla Control Application is a software tool intended for day-to-day routine operation control. It is used to control the laser in API level through LAN or RS-232 communication types, the control capabilities are stored in the laser system itself, software is self-adaptive to the system, one application can be used with multiple systems and can run on different platforms – be it Windows, Linux or others using REST API commands.

