VENTEON ULTRAFAST FEMTOSECOND LASER DATA SHEET

ULTRASHORT PULSE OSCILLATORS

Novanta develops photonics solutions specializing in cutting-edge components and sub-systems for laser-based diagnostic, analytical, micromachining and fine material processing applications. Powerful lasers, coupled with advanced beam steering and intelligent sub-systems incorporating software and controls, deliver extreme precision and performance, tailored to our customers' demanding applications.

RELIABLE AND ROBUST

The venteon range of femtosecond oscillators uses ultra-short pulse laser technology and offers the shortest commercially available pulses at <5 fs (FTL), bandwidths >380 nm and average powers >900 mW. The compact monolithic design is optimized for low pump thresholds and contains an integrated pump laser. With long operational lifetimes, these instruments are highly reliable and extremely robust. All venteon oscillators show an exceptional stability (Fig. 1) and beam shape (Fig. 2).

The venteon cavity exclusively uses DCM mirrors that are created by ion beam sputtering techniques to ensure unsurpassed phase control and pulses that approach the theoretical values available. Laser Quantum supports clarity in reporting pulse duration and we always detail whether our figures are theoretical values based on Fourier transform calculations, or actual measured durations using SPIDER technology and instrumentation.

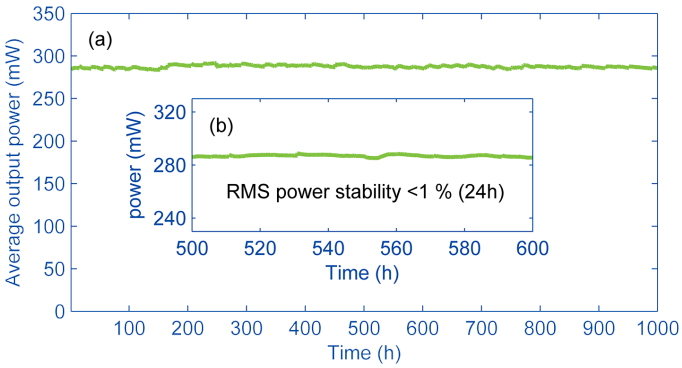


Fig. 1 Exceptional stability of the venteon ultra oscillator resulting from the optimized thermal and mechanical design.

Few cycle femtosecond pulses - venteon family

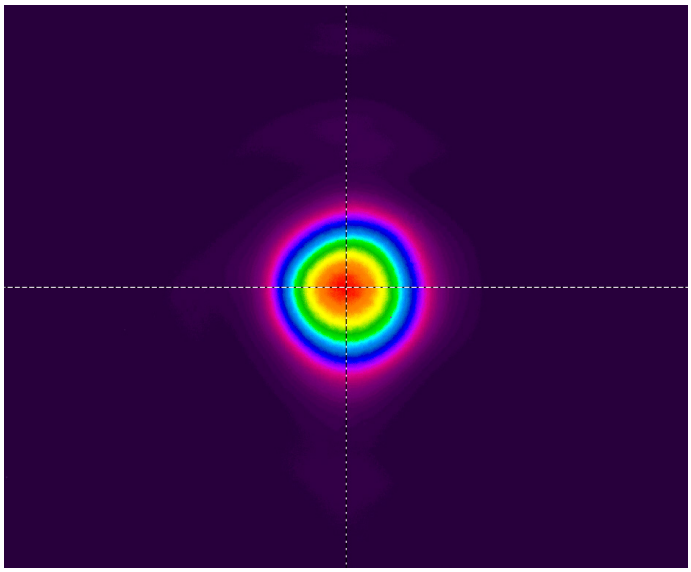


Fig. 2 Typical beam profile of the venteon ultra oscillator measured with a CCD camera.

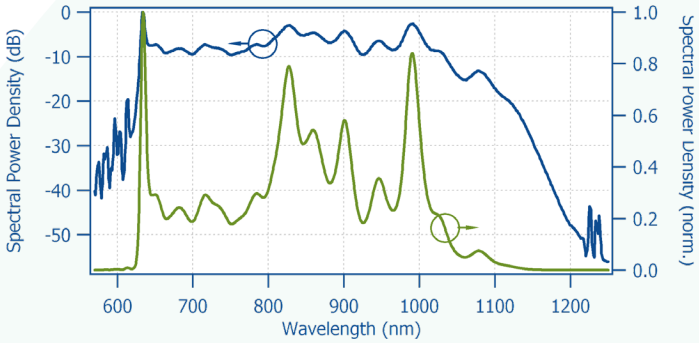
VENTEON POWER

The venteon power femtosecond oscillator has been optimized to provide high output power at measured pulse durations less than 8 fs. The venteon power can be supplied with CEP stabilized performance or state-ready for a CEP upgrade. It can also be equipped with a piezo transducer/linear actuator that allows for resonance free repetition rate locking to a suitable radio frequency reference source with locking bandwidths of up to 30 kHz.

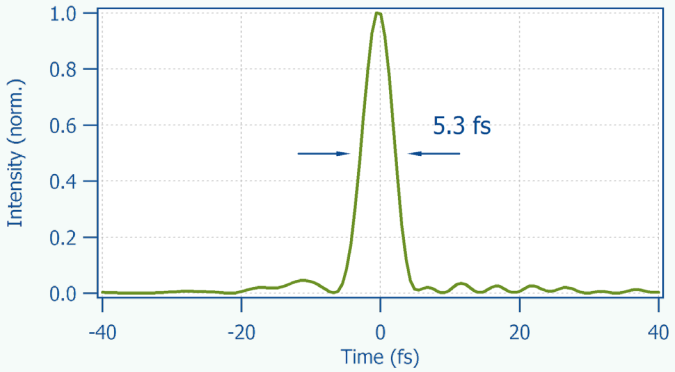
VENTEON ULTRAFAST FEMTOSECOND LASER

VENTEON ULTRA

The venteon ultra femtosecond oscillator delivers >240 mW of <5.5 fs short pulses with an unrivaled spectral bandwidth ranging from 600 nm to 1200 nm specified with <5.5 fs @-10 dBc. Due to this octave spanning output spectrum, the venteon ultra can be used for direct CEP stabilization without any additional spectral broadening. The venteon ultra can be upgraded to a fully CEP stabilized laser, or with the necessary components to allow CEP upgrade at a later date.



Typical venteon ultra spectrum spanning from >600 nm up to 1200 nm. This spectrum supports the shortest pulses commercially available and is ideally suited e.g. for a direct CEP stabilization.



Typical venteon ultra pulse of <5.5 fs, measured with a venteon SPIDER.

OPTIONS AND UPGRADES

Pulse train monitoring

An integrated high bandwidth (>10 GHz) photodiode can be used for repetition rate monitoring and to supply a signal to a TL-1000 unit or external electronics.

Repetition rate control

Control of the repetition rate and active feedback is enabled by cavity mirrors mounted on piezoelectric actuators, enabling rapid feedback and long-term drift control simultaneously. In combination with the TL1000 repetition rate stabilization unit, timing jitter <100 fs can be achieved. Alternatively, the piezos can be driven by customer supplied electronics.

Active locking of repetition rate and pulse timing

The TL-1000 is an optional supporting unit that enables tight phase-locking of the repetition rate to an external reference with a residual timing jitter <100 fs.

CEPLoQTM technology for the venteon CEP5

CEPLoQ™ technology directly modulates the pump power to maintain phase stabilization without the use of an AOM. This leads to faster and more stable responses. The venteon family is compatible with Laser Quantum's software that allows connection to its support team for monitoring laser performance, diagnosing opportunities and carrying out laser optimization.

Pump power modulation

Modulation access to the pump power with a bandwidth of >100 kHz and modulation depth up to ±1% is provided for feedback purposes.

	venteon power	venteon ultra
Photodiode Option	X	X
Repetition Rate Stabilization Option	X	X
CEP Stabilization	X	X
CEP-Zero Stabilization		X

VENTEON ULTRAFAST FEMTOSECOND LASER SPECIFICATIONS

Specification*	venteon power	venteon ultra
Average Power Output	> 560 mW	> 240 mW
Center Wavelength[1]	780 nm ± 30 nm	830 nm ± 30 nm
Pulse Energy (@ 80 MHz)	> 7 nJ	> 3 nJ
Spectral Bandwidth (@ -10 dBc)	> 200 nm	> 380 nm
Pulse Duration (Measured)[2]	< 8 fs	< 5.5 fs
Pulse Duration (FTL)	< 7.5 fs	< 5 fs
RMS Noise[3]	< 0.1%	
Beam Diameter[4]	0.8 mm ± 0.3 mm	
Divergence	< 3 mrad	
M^2	< 1.2	
Power Stability (RMS within 24 hours)	< 1%	
Repetition Rate[5]	80 MHz	
Polarization Direction	Horizontal	
Polarization Ratio	> 100:1	
Operating Temperature	21° C ± 3° C	
Warm-Up Time	< 20 Minutes	
Weight (Head Only)	33 kg	

**Laser Quantum operates a continuous improvement programme which can result in specifications being improved without notice.*

1 Measured as the spectral centroid.

2 Achieved using optional extra cavity dispersion compensation.

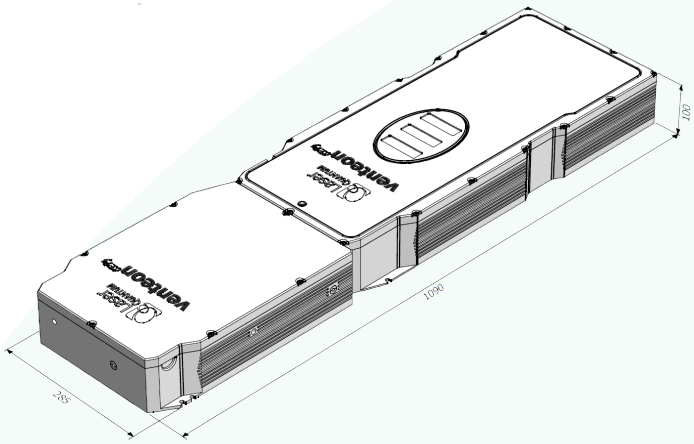
3 Noise bandwidth 1 Hz to 1 MHz.

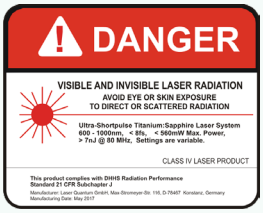
4 FWHM beam diameter at laser exit.

5 Repetition rate accuracy +/-100 kHz. Other repetition rates available upon request.

VENTEON ULTRAFAST FEMTOSECOND LASER

DIMENSIONS (mm)



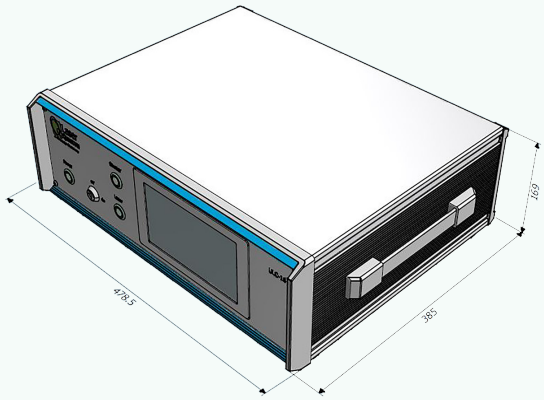


Drawings are for illustrative purposes only, please contact us for complete engineer's drawings

ADDITIONAL INFORMATION

- Weight (head only): 33 kg
- Cooling system included
- 2 years/5000 hours (PSU 'on' time) full specification warranty

POWER SUPPLY UNIT



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VENTEON CEP5 ULTRAFAST FEMTOSECOND LASER

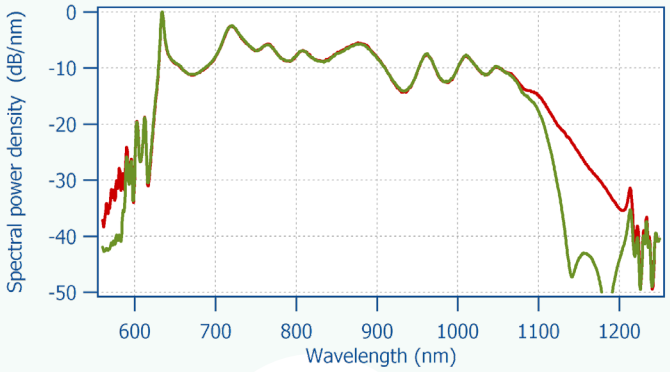
VENTEON CEP5

The venteon ultra oscillator directly delivers Fouriertransform limited (FTL) pulse durations well below 5.5 fs. The corresponding octave-spanning spectrum is sufficiently broad for direct CEP stabilization of the pulses without any additional spectral broadening by either a PCF or PPLN device.

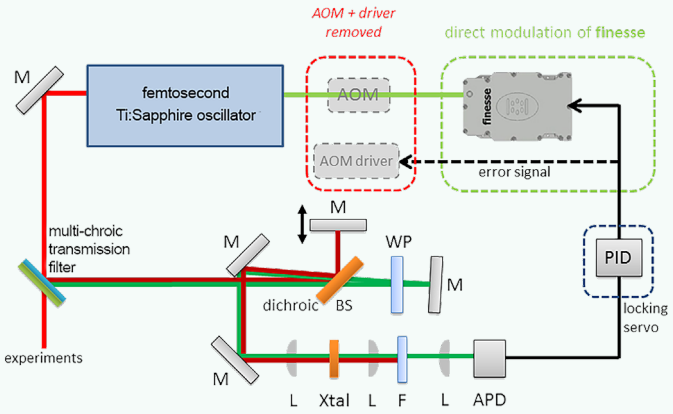
In the venteon f-to-2f interferometer, f- and 2f components are spectrally filtered from the octavespanning spectrum for f-to-2f beating, leaving more than 220 mW output power and <5.5 fs FTL pulse duration available for subsequent experiments. This is the most natural, direct and reliable approach for realizing a CEP stabilization without distorting the laser output beam and giving an excellent long-term locking performance.

In addition to the advantage of direct f-to-2f beating, the feedback signal for CEP stabilization can be directly applied to the pump laser using CEPLoQ™ technology rather than an acousto-optic modulator placed before or after the oscillator. This is achieved by directly controlling a ±1% power modulation of the pump laser, covering a range of DC to 1 MHz with better than 90 degrees phase behavior up to 700 kHz, leading to a more stable locking bandwidth than traditional methods.

The combination of these two innovative technologies delivers a CEP stabilized laser using the most direct and natural scheme possible today, with <6 fs pulses in an unaffected high quality output beam within a compact housing that requires minimal maintenance.



venteon ultra oscillator output spectrum (red) and CEP- stabilized output spectrum (green) of the venteon CEP5 laser. Spectral wings are filtered and used for CEP-stabilization.



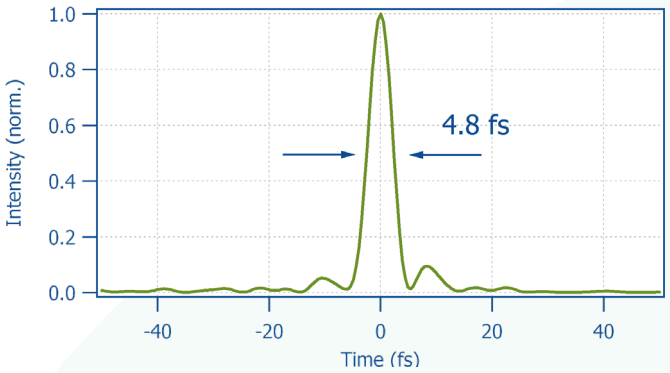
Schematic of CEP5 locking scheme with pump laser using CEPLoQTM technology.

TYPICAL VENTEON CEP5 DATA

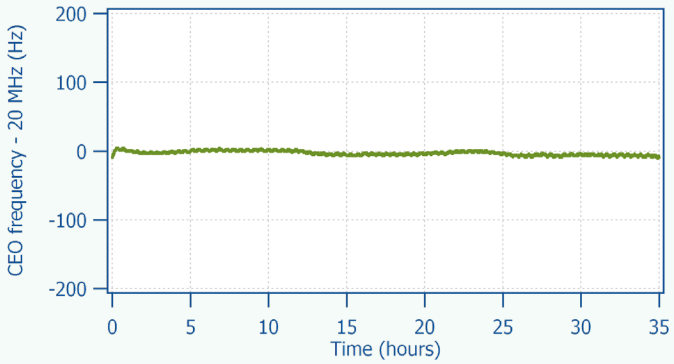
The modular realization of the venteon CEP5 laser allows for an easy separation of venteon ultra oscillator and venteon f-to-2f module. If CEP stabilization is not required, the venteon f-to-2f interferometer module can be detached and the full oscillator characteristics can be used for experiments. This ensures the maximum flexibility for many ultrafast applications.

Laser Quantum supports clarity in reporting pulse duration and detailing whether our figures are theoretical values based on Fourier transform calculations or actual measured durations using SPIDER technology and instrumentation. In the case of the venteon CEP5 laser, the Fourier transform specification is < 5.5 fs, with a measured pulse of 6 fs. The small difference between these two values demonstrates the excellent phase control of the laser.

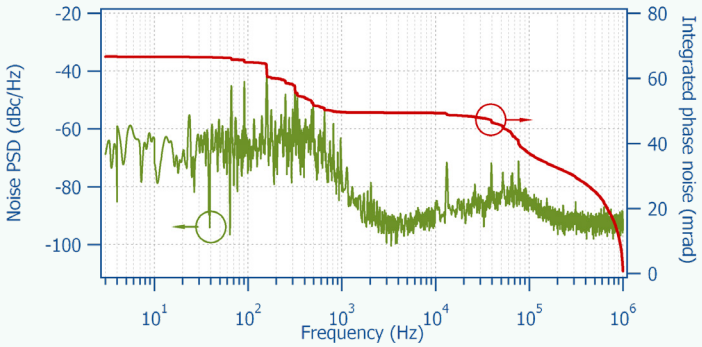
VENTEON CEP5 ULTRAFAST FEMTOSECOND LASER



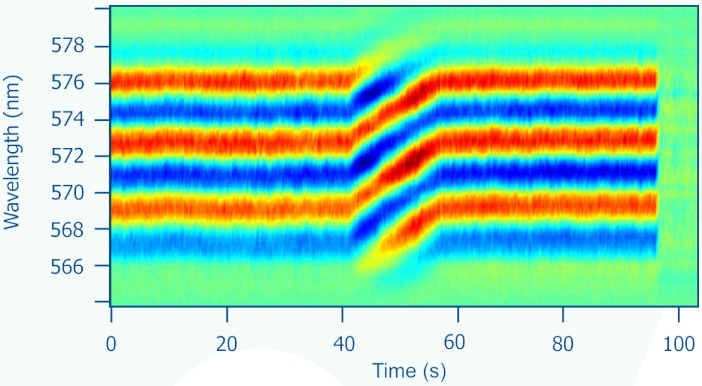
Typical venteon CEP5 output pulse, measured with SPIDER after external pulse compression.



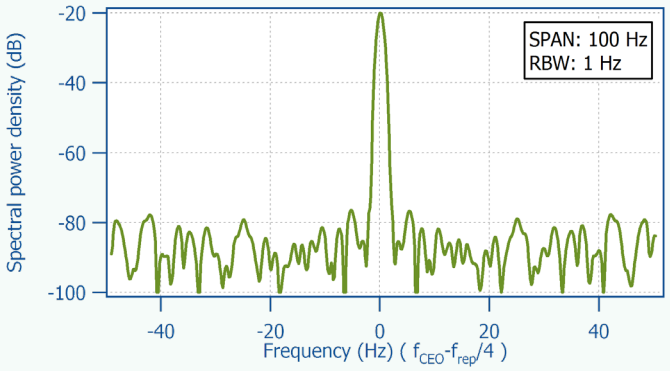
Long-term tracking of the carrier envelope offset frequency, locked to a quarter of the repetition rate. Automated dispersion control enables the venteon CEP5 to operate CEP locked over several days.



Integrated phase noise of the carrier envelope offset beat signal featuring 68 mrad (1 MHz - 3 Hz).



Out-of-loop measured interference of 1011 oscillator pulses proving an excellent CEP-lock. The CEP is tuned by inserting glass wedges in the extra-cavity beam, as shown in the middle part of the picture.



Zoomed-in stabilized carrier envelope offset signal featuring 1 Hz resolution bandwidth.

OPTIONS AND UPGRADES

The venteon CEP5 can be ordered with a CEPzero option to stabilize the carrier-envelope-offset frequency to zero, generating a pulse train with constant CE phase (versus every fourth in standard configuration). This system allows for field sensitive experiments at full oscillator power and repetition rate without the need for sophisticated pulse picking.

RELATED SYSTEMS

The venteon dual laser represents the ideal front-end for broadband few-cycle OPCPA applications. The spectral bandwidth of this laser allows for the generation of broadband (<5.5 fs) pulses as a signal for a NOPA stage and additionally provides sufficient pulse energy for seeding an Yb-based amplifier pump stage. The pulses are provided by two separate output ports and are intrinsically self-synchronized with ultra-low timing jitter. If a CEP stabilized laser system is required for realizing a CEP-stable OPCPA, the venteon dual laser system can be ordered with a CEP option featuring the CEP5 stabilization technology and performance.

PST option: Preparation for repetition rate stabilization, including a slow and fast piezo motor unit to add fine control of cavity length and repetition rate.

TL-1000 timing stabilization: Locking electronics, photodiode, RF analyzer and oscilloscope needed for full timing stabilization of the laser system (requires PST option).

VENTEON ULTRAFAST FEMTOSECOND LASER SPECIFICATIONS

Specification*	venteon CEP5
Average Power Output	> 220 mW
Center Wavelength[1]	830 nm ± 30 nm
Pulse Energy (@ 80 MHz)	> 2.75 nJ
Spectral Bandwidth (@ -10 dBc)	> 300 nm
Pulse Duration (Measured)[2]	< 6 fs
Pulse Duration (FTL)	< 5.5 fs
RMS Noise[3]	< 0.05%
Beam Diameter[4]	1.2 mm ± 0.3 mm
Divergence	< 3 mrad
M^2	< 1.2
Power Stability (RMS within 24 hours)	< 1%
Repetition Rate[5]	80 MHz
SNR for fceo-Beat (@ 100 kHz RBW)	> 30 dB (> 27 dB with CEP Zero Option)
CEP Phase Noise[6]	< 100 mrad (< 150 mrad with CEP Zero Option)
Polarization Direction	Horizontal
Polarization Ratio	> 100:1
Operating Temperature	21° C ± 3° C
Warm-Up Time	< 20 Minutes
Weight (Head Only)	30 kg

**Laser Quantum operates a continuous improvement programme which can result in specifications being improved without notice.*

1 Measured as the spectral centroid

2 Achieved using optional extra cavity dispersion compensation

3 Noise bandwidth 1 Hz to 1 MHz

4 FWHM beam diameter at laser exit

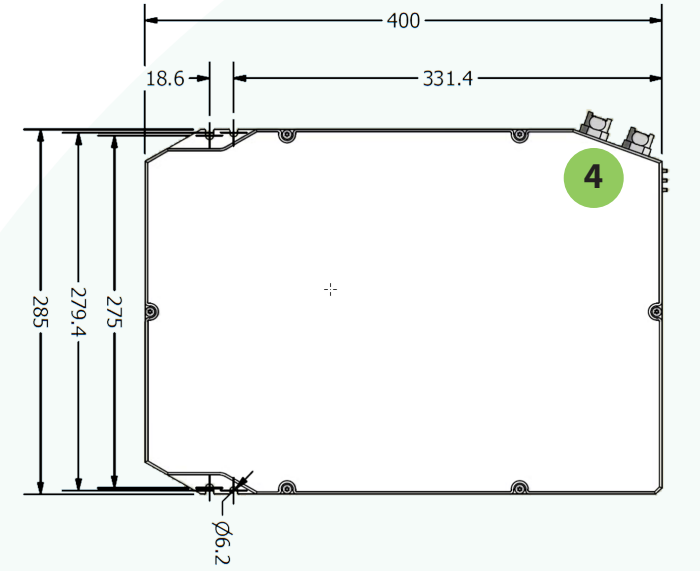
5 Repetition rate accuracy +/-100 kHz. Other repetition rates available upon request

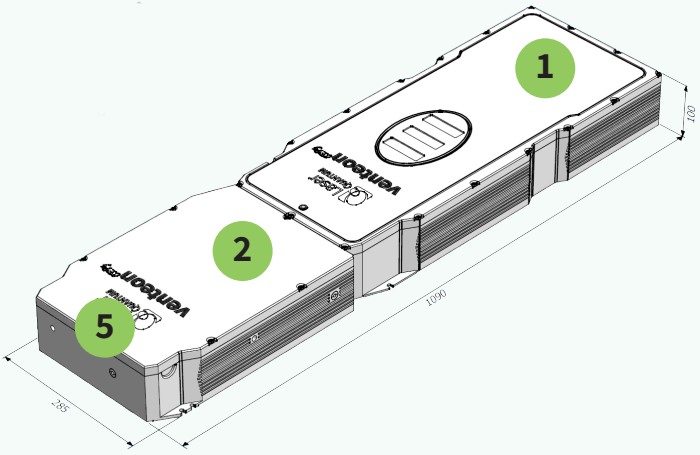
6 Noise bandwidth 3 Hz to 1 MHz derived from RF side-band analysis

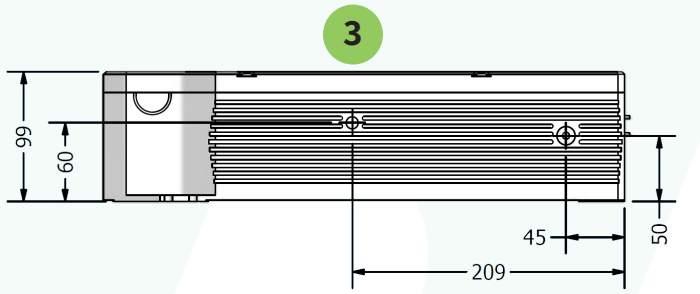
VENTEON CEP5 ULTRAFAST FEMTOSECOND LASER

DIMENSIONS (mm)

1 - venteon oscillator
2 - venteon module
3 - Broadband output
4 - Electrical and water connections
5 - Alternate front-side outputs (choose upon order)







Drawings are for illustrative purposes only, please contact us for complete engineer's drawings

ADDITIONAL INFORMATION

- Weight (head + f-to-2f module only): 47 kg
- Cooling system included
- 2 years/5000 hours (PSU 'on' time) full specification warranty
- Locking electronics included
- All required measurement equipment included (oscilloscope, RF analyzer)
- CEPLoQ™ technology that directly modulates the pump power to maintain phase stabilization without the use of an AOM, allowing faster responses than the traditional method.
- The venteon CEP5 laser system features a set of remote control capabilities including remote starting, adjustment and dispersion control. Together with the provided user-control software, the laser system can be handled, monitored and maintained on a day-to-day basis without manual intervention. Upon installation, our service engineers will provide detailed training on the laser system and all associated components. If service is required, the user control software allows our service engineers to connect to the laser system to remotely check and optimize the laser, ensuring speedy and efficient help and support.

VENTEON DUAL ULTRAFAST FEMTOSECOND LASER

VENTEON DUAL

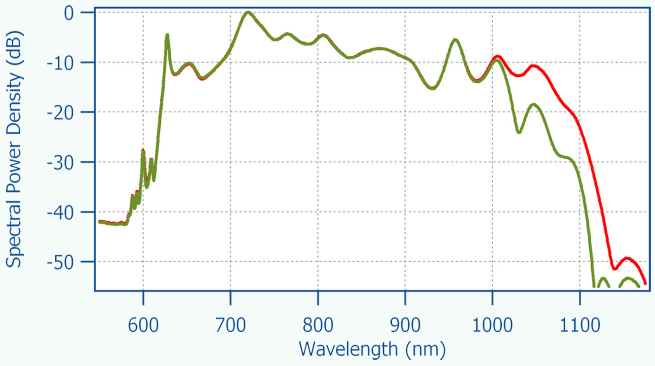
The venteon dual represents the ideal front end for broadband few-cycle Optical Parametric Chirped Pulse Amplifier (OPCPA) applications. The spectral bandwidth of this laser allows for the generation of broadband (<6 fs) pulses as a signal for a subsequent NOPA stage and provides additional sufficient pulse energy for seeding an Yb-based amplifier pump stage. The pulses are delivered by two separate output ports and are intrinsically self-synchronized with ultra-low timing jitter.

The first output provides the broadband signal pulses and a duration <6 fs. The pulses can be optionally CEP stabilized with the typical performance of the venteon CEP5 laser systems.

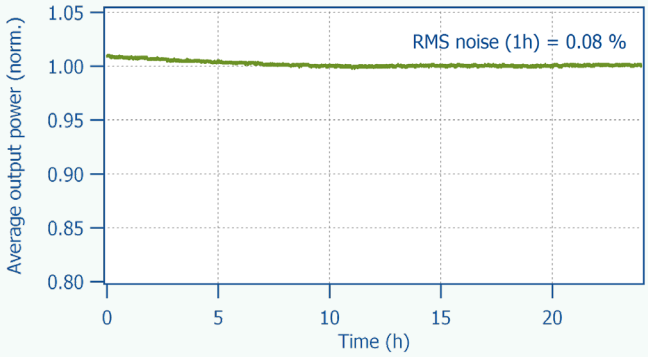
The second output at 1030 nm delivers - without any additional broadening - 625 pJ in a spectral bandwidth of approx. 10 nm (FWHM) and is ideally suited as a narrow-band seed for pump amplifiers. This output can be optionally ordered pre-amplified, delivering pulses with an energy >1 nJ.

Laser Quantum supports clarity in reporting pulse duration and detailing whether our figures are theoretical values based on Fourier transform calculations or actual measured durations using SPIDER technology and instrumentation. In the case of the venteon dual, the Fourier transform specification is <5.5 fs, with a measured pulse of <6 fs. The small difference between these two values demonstrates the excellent phase control of the laser.

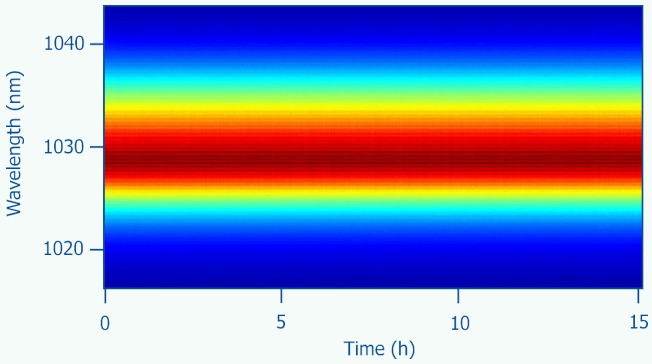
TYPICAL VENTEON DUAL DATA



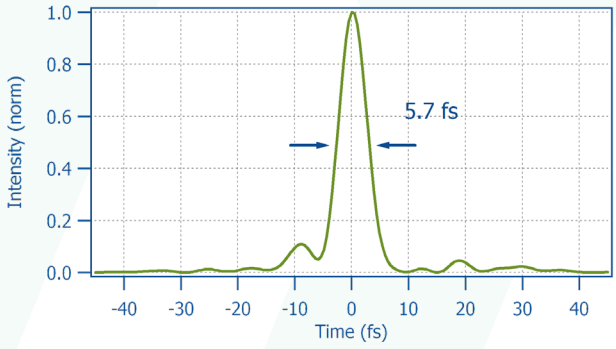
Typical venteon dual usable output spectrum (green) and spectrum without filtering for the 1030 nm seed radiation (red).



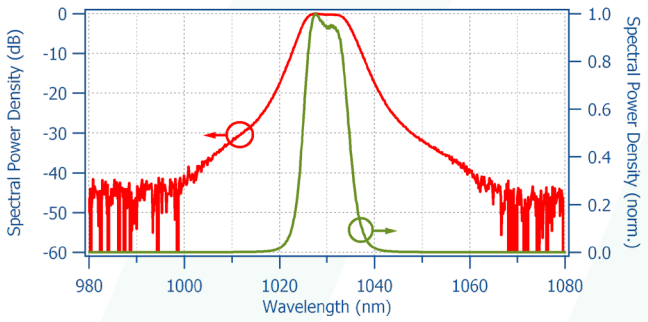
Long-term track of the broadband output of the venteon dual laser system shown for 24 hours.



Spectral stability of the 1030 nm seed output shown for 15 hours. The measurement was performed using a single mode fiber.



Typical SPIDER-measured few-cycle pulse emitted by a venteon dual laser system.



1030 nm seed spectrum as provided by a venteon dual laser system with applied bandpass filter centered @1030 nm, shown on logarithmic scale (red) and linear scale (green).

VENTEON DUAL ULTRAFAST FEMTOSECOND LASER SPECIFICATIONS

Specification*	venteon Dual
Average Power Output	> 220 mW
Center Wavelength[1]	830 nm ± 30 nm
Pulse Energy (@ 80 MHz)	> 2.75 nJ
Spectral Bandwidth (@ -10 dBc)	> 300 nm
Pulse Duration (Measured)[2]	< 6 fs
Pulse Duration (FTL)	< 5.5 fs
RMS Noise[3]	< 0.1%
Beam Diameter[4]	1.2 mm ± 0.3 mm
Divergence	< 3 mrad
M^2	< 1.2
Power Stability (RMS within 24 hours)	< 1%
Repetition Rate[5]	80 MHz
1030 nm Output Average Power[6]	> 0.5 mW
1030 nm Output Pulse Energy[6]	> 6.25 pJ
1030 nm Output Pulse Duration (FTL)	< 250 fs
1030 nm Output RMS Noise[3]	0.5%
Polarization Direction	Horizontal
Polarization Ratio	> 100:1
Operating Temperature	21° C ± 3° C
Warm-Up Time	< 20 Minutes
Weight (Head Only)	33 kg

**Laser Quantum operates a continuous improvement programme which can result in specifications being improved without notice.*

1 Measured as the spectral centroid

2 Achieved using optional extra cavity dispersion compensation

3 Noise bandwidth 1 Hz to 1 MHz

4 FWHM beam diameter at laser exit.

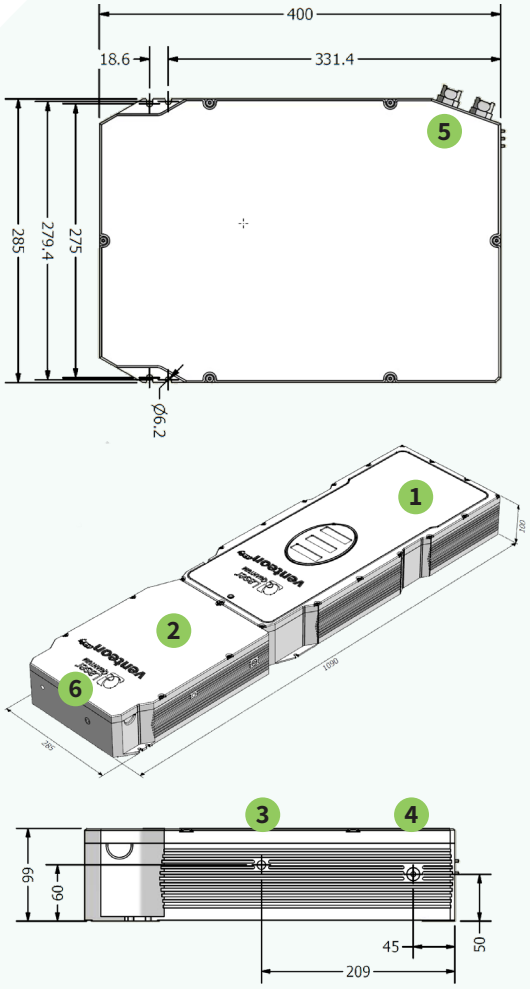
5 Repetition rate accuracy +/-100 kHz. Other repetition rates available upon request.

6 Measured after single mode fiber coupling.

VENTEON DUAL ULTRAFAST FEMTOSECOND LASER

DIMENSIONS

1 - venteon oscillator
2 - venteon module
3 - Broadband output
4 - Fiber-coupled 130 nm output
5 - Electrical and water connections
6 - Alternate front-side outputs (choose upon order)



Drawings are for illustrative purposes only, please contact us for complete engineer's drawings

ADDITIONAL INFORMATION

- Weight (head + f-to-2f module only): 47 kg
- Cooling system included
- 2 years/5000 hours (PSU 'on' time) full specification warranty

OPTIONS AND UPGRADES

- **CEP ready:** Incorporates pump laser and components to allow future CEP stabilization upgrade.
- **CEP upgrade:** Upgrade to CEP stabilized output, including f-to-2f interferometer. (Requires CEP ready option). Average output power will reduce to 180 mW; specifications for CEP lock similar to CEP5 laser system.
- **PST option:** Preparation for repetition rate stabilization, including a slow and fast piezo motor unit to add fine control of cavity length and repetition rate.
- **TL-1000 timing stabilization:** Locking electronics, photodiode, RF analyzer and oscilloscope needed for full timing stabilization of the laser system (requires PST option).

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