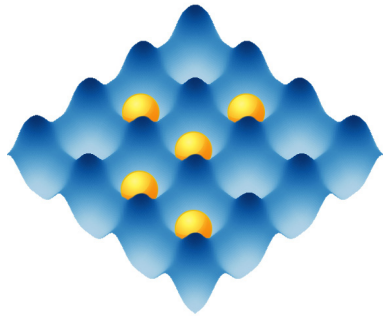


FC1500-ULN^{plus}

Ultra Low Noise Optical Frequency Comb for Optical Lattice Clocks



The FC1500-ULN^{plus} Ultra Low Noise Optical Frequency Comb brings the system performance to the next level. Additional hardware, optimized components and engineering ingenuity resulted in a perfect flywheel for transferring frequency stability between two or more user-defined frequencies at the 10^{-19} level. This exceeds the stability of any optical oscillator demonstrated to date, and transcends the stability requirement for optical clocks.

The ability to measure sub- 10^{-18} level frequency shifts can be relevant for applications such as optical clocks in quantum sensing and fundamental physics. Our all polarization maintaining figure 9[®] mode locking technology together with high bandwidth actuators (>1 MHz) for both the carrier-envelope offset frequency and the repetition rate guarantee ultimate performance.

The performance is proven in an out of loop comparison between two independent ULN^{plus} optical frequency combs, which is integral part of the quality check during factory acceptance of each system. Thus Menlo guarantees and proves by measurement that the outstanding spectral purity of the oscillator is transferred perfectly to the desired wavelength for every system delivered.

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NEW

KEY SPECIFICATIONS

- Comb Spacing 250 MHz
- Accuracy 1×10^{-18} ($\tau > 100$ s)
- Stability: 5×10^{-18} in 1 s, 5×10^{-19} in 1000 s
- Operational Range from 500 nm to 2 μ m
- Integrated Phase Noise < 80 mrad [1 Hz-2 MHz]

APPLICATIONS

- Optical (Lattice) Clocks
- Clock comparisons (via fiber networks)
- Transfer of CW Laser Stability to Full Comb Spectrum from 500 nm to 2 μ m

FEATURES

- High Repetition Rate
- High Bandwidth > 1 MHz Actuators for CEO and Repetition Rate
- Fully stabilized and qualified HMP-VIS/NIR at custom wavelength (500 nm to 2 μ m)
- Turnkey Metrology System. Fully automated, including data evaluation software, designed for continuous operation

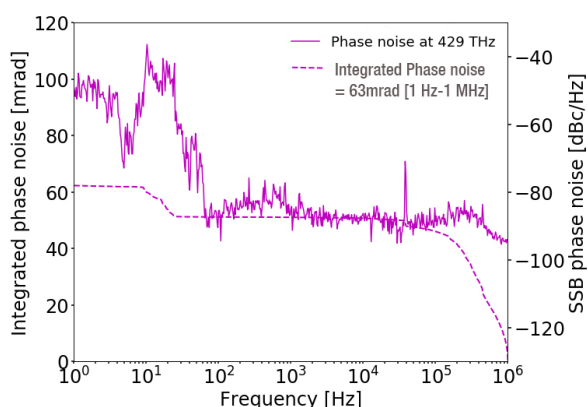
OPTIONS

Complete Solution with Modular Extensions

Menlo Systems Optical Frequency Combs are complete solutions. The modular system architecture allows for easy additions of more functionality to an existing system. Multiple extensions can be combined in a system.

- **M-NIR:** Extension Package
- **M-VIS:** Extension Package
- **HMP:** High Power Measuring Port
- **P250 PM Pulse EDFA:** Erbium-doped Fiber Amplifier
- **M-780:** High Power output around 780 nm
- **BDU:** Beat Detection Unit
- **LLE-SYNCR0:** Laser Locking Electronics
- **Microwave:** Ultrastable RF Output
- **GPS:** -based 10 MHz Frequency Reference
- **WLM-NIR /WLM-VIS:** Integrated Wavelength Meters

Phase Noise of Comb-Comb Comparison at 698 nm



Analysis of the out of loop beat signal between two ULN^{plus} combs at the Strontium clock transition frequency:

The extremely low phase noise proves that the spectral purity is transferred to the target wavelength, which makes the ULN^{plus} a unique clockwork for Strontium and other optical lattice clocks.

FC1500-ULN^{plus}

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Ultra Low Noise Optical Frequency Comb for Optical Lattice Clocks

SPECIFICATIONS

FC1500-ULN^{PLUS}

Comb Spacing	250 MHz
Accuracy	1×10^{-18} for $\tau > 100\text{s}^*$
Stability [▲]	5×10^{-18} in $1\text{s}^{*\Delta}$, 5×10^{-19} in $1000 \text{s}^{*\Delta}$
Integrated Phase Noise	$<80 \text{ mrad}$ [1 Hz-2 MHz]
Linewidth	$<1 \text{ Hz}^{*\diamond}$
Tuning Range of Spacing Between Individual Comb Lines	$>4 \text{ MHz}$
Tuning Range of CEO Frequency	$>250 \text{ MHz}$
Laser Outputs	five fiber-coupled, linearly polarized, PM output ports, 1560 nm
Spectral Range	$>25 \text{ nm}$ (500-1050 nm with M-VIS, 1050-2100 nm with M-NIR)
Average Output Power	$>10 \text{ mW}$ from each laser port ($>100 \text{ mW}$ with M-VIS, $>200 \text{ mW}$ with M-NIR)
CW Laser Inputs	approx. 1 mW optical power required, wavelength user-defined in the 500-2100 nm range (more upon request)

[▲]spectral purity transfer between fundamental and a user-defined wavelength in the 500-2100 nm range, ^{*}phase lock to optical reference, ^Δmodified Allan deviation (λ -type counter, timebase 1ms), [◆]limited by resolution bandwidth of analyzer

SPECIFICATIONS USING THE FC1500-ULN (NOVA AND PLUS) IN THE TRANSFER OSCILLATOR SCHEME**:

Accuracy	1×10^{-18} ($\tau > 100 \text{ s}$)
Stability	8×10^{-18} in 1 s, 5×10^{-20} in 1000 s

**see Ref. 1 and Ref. 2 for further details

Ref. 1: Benkler, E., Lipphardt, B., Puppe, T., Wilk, R., Rohde, F., Sterr, U., End-to-end topology for fiber comb based optical frequency transfer at the 10^{-21} level. *Optics Express* 2019, Vol. 27, Issue: 25.

Ref. 2: <https://www.menlosystems.com/products/optical-frequency-combs/menlo-systems-frequency-comb-technology>

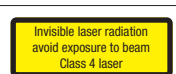
REQUIREMENTS

Input Requirements	cw optical reference, power level approx. 1 mW (see Menlo ORS datasheet) 10 MHz frequency reference, power level +7 dBm
Operating Voltage	100/115/230 VAC
Frequency	50 to 60 Hz
Power Consumption	$<500 \text{ W}$, $<3\text{kW}$ including chiller
Cooling Requirements	closed cycle chiller included
Operating Temperature	$22 \pm 5 \text{ }^\circ\text{C}$
Optical Unit Dimensions/Weight	706 x 716 mm, approx. 80 kg (Standard system configuration)
Control Electronics Dimensions/Weight	600 x 800 mm, approx. 140 kg (Standard system configuration)

ORDERING INFORMATION

Product Code	FC1500-ULNplus
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Please call for pricing. Specifications are subject to change without notice. Custom modifications are available, please inquire.



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