FC1500-Quantum

Complete solution for Quantum 2.0 applications

MenloSystems

The FC1500-Quantum provides exquisite low noise comb and CW light over a wide frequency range in a fully rack-mounted system. It is the all-in-one ultra-stable frequency comb-based solution for your Quantum 2.0 application. Whether you are building an ion/neutral atom-based quantum computer, a quantum optical clock, or an atom interferometry experiment, Menlo tailors your system according to your requirements and delivers the optical engine to operate your physics experiments. The system consists of an ultra-stable cavity stabilized laser with sub-Hz linewidth from Menlo's Optical Reference System (ORS) line, an ultra-low-noise optical frequency comb (FC1500-ULN or SmartComb) and as many CW lasers as required for your experiment.

The unique patented Menlo comb technologies allow the transfer of spectral purity, narrow linewidth, and high stability of the ORS throughout the entire comb spectrum, and enable the down-division to the RF domain without any loss of phase coherence. The purity transfer is future proof, with the residual comb phase noise being orders of magnitude below the highest stability optical reference demonstrated to date. These features enable the minimization of the Dick effect in optical clocks, high phase coherence to maximize optical and microwave qubit fidelities, and last but not least, 24/7 cycle-slip-free and drift-compensated laser operation. The FC1500-Quantum is ready to enable and enhance your state-of-the-art Quantum Application.

APPLICATIONS

- Complete Solution for Sr, Yb, Ca, Sr^+, Yb^+, Ba^+, Ca^+, Others
- Quantum Computing, Sensing and Simulation
- Optical Atomic Clocks Operation and RF Down-conversion and Time Scale Realization
- Atom Interferometry
- Laboratory Master Reference for Sub-Hz Control of multiple CW Lasers

FEATURES

- Complete Solution, ready to be interfaced with the Physics Package
- Up to 250 MHz Repetition Rate for ample flexibility on Target CW Laser Frequencies
- High-fidelity Spectral Purity Transfer from Optical Reference to CW Lasers
- Integration of CW Lasers from Various Providers
- CW Output Power from mW to W Level
- Fully Rack-mounted
- Full Remote Control

KEY SPECIFICATIONS

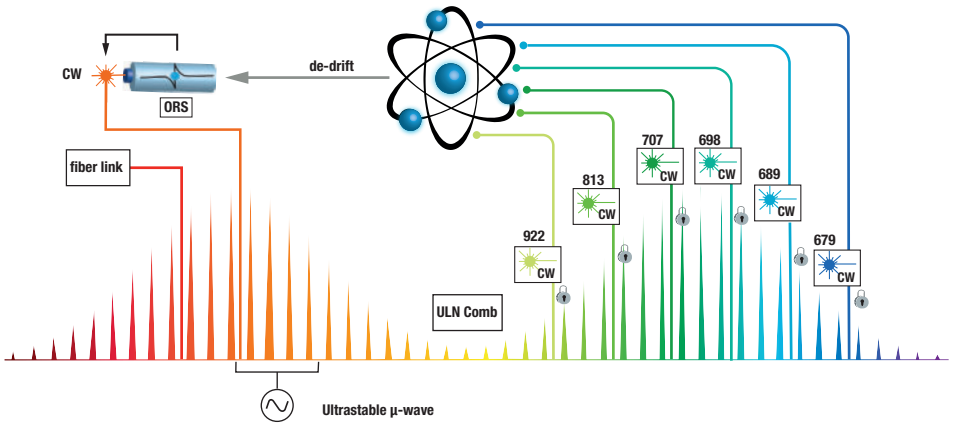
- Absolute Stability down to $<7 \times 10^{-16}$ (1 s)
- Long-term Stability defined by User-provided Precision Spectroscopy Signal or SI-traceable GPS Receiver Signal (Adaptive De-drifting)
- Ultra-stable µWave/RF Output Signals, Phase coherent to the Optical Reference
- Up to 24 Channels dead-time free Lambda-frequency Counters for Precision Measurement
- OEM Wavemeter for Laser Wavelengths Tuning and Monitoring

ADDITIVE VALUES

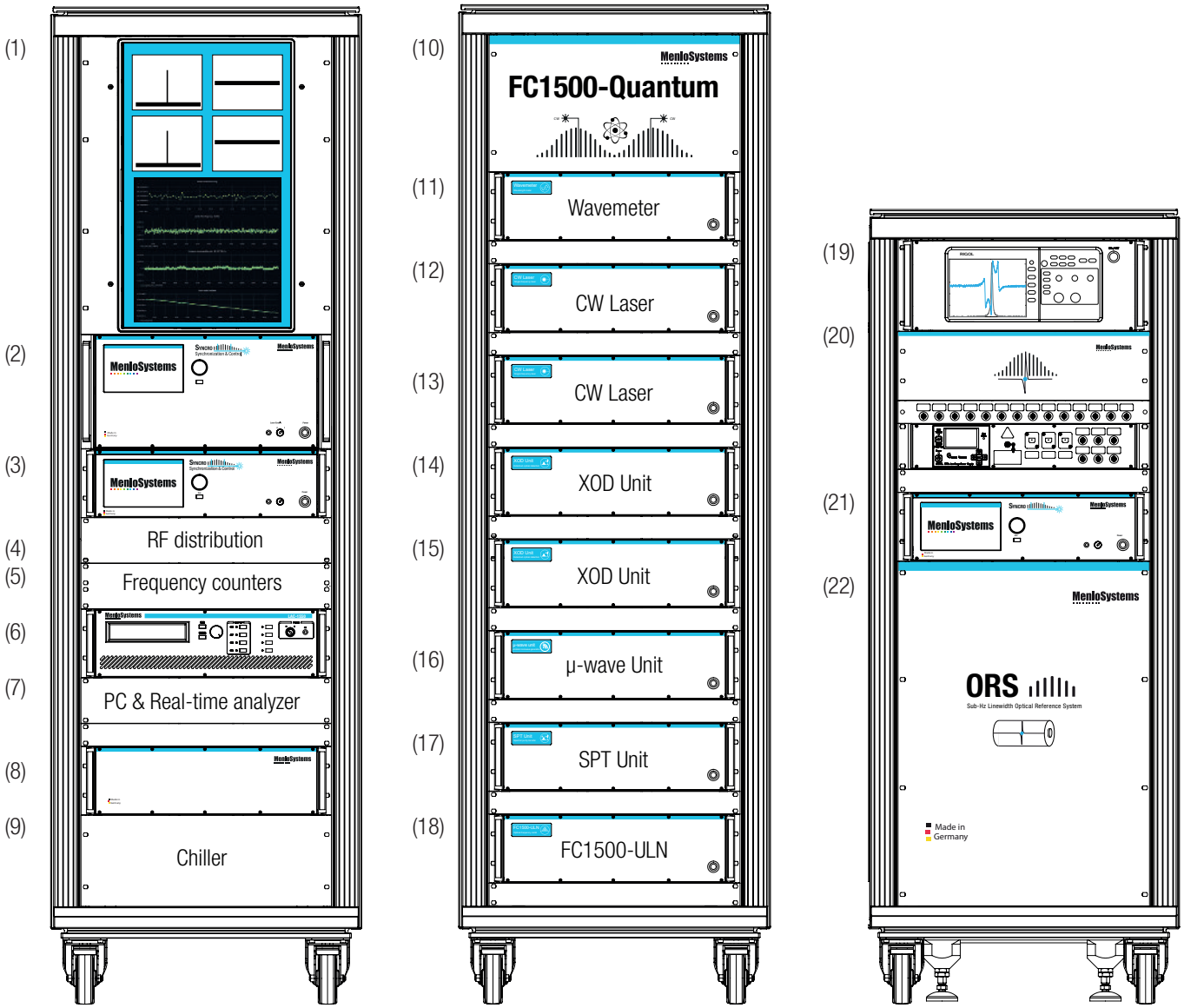
- Scalability of Optical Power without loss of Fidelity
- Metrological Fiber-link Network ready

SYSTEM SCHEME – FC1500-QUANTUM

Exemplary system for neutral strontium



Technology protected by patents US7026594, DE10044404, US7804863, US8995796, US8873601, JP4668423, JP5615397, CN103311780



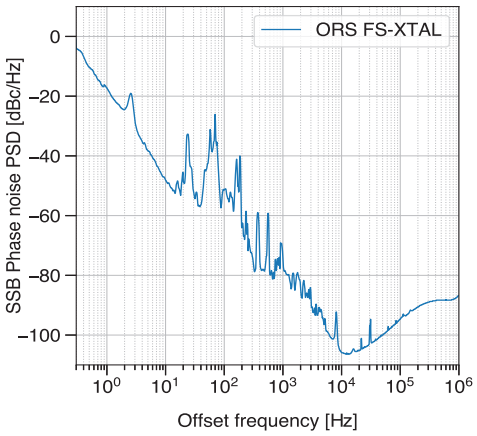
FC1500-QUANTUM

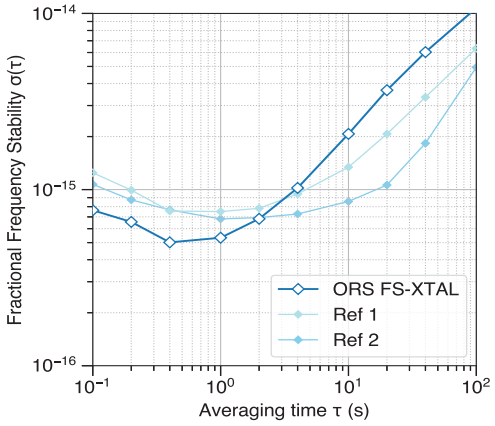
ELECTRONICS RACK		OPTICS RACK		OPTICAL REFERENCE SYSTEM RACK	
(1)	24” touchscreen for full system control and monitoring	(10)	Additional space for further units	(19)	Oscilloscope
(2)	SYNCRO 5-HU control electronics for CW lasers and Fiber noise cancellers	(11)	Wavemeter (up to 8 channels)	(20)	Ion getter pump controller
(3)	SYNCRO 3-HU control electronics for frequency comb	(12)	CW lasers (up to 4 ECDLs or 2 High Power Lasers)	(21)	SYNCRO PDH locking electronics and ultra-low-RIN laser with driver
(4)	Radio frequency reference distribution	(13)	CW lasers (up to 4 ECDLs or 2 High Power Lasers)	(22)	High-finesse Fabry-Perot cavity in vacuum assembly on active anti-vibration platform
(5)	Frequency counter (up to 24 dead-time free channels, Lambda-type)	(14)	Extended Optical Detection frequency comb extensions*		
(6)	Pump diode drivers and controllers	(15)	Extended Optical Detection frequency comb extensions		
(7)	PC with real-time signal analyzer	(16)	Ultrastable photonic µ-wave and radio frequency unit		
(8)	Power supply, Interlock, DC/DC converters	(17)	Spectral Purity Transfer ultra-high stability frequency comb extension*		
(9)	Chiller for optics rack units cooling	(18)	Ultra-low-noise frequency comb and f-2f interferometer.		

*The XOD is composed by an erbium-doped fiber amplifier and non-linear fibers for the generation of comb lines at the target frequency ranges (from 500 nm up to 2.1 um) and beat detection units for generation of RF beat notes. The SPT unit is similar to the XOD, but has means to ensure even higher stability at longer timescales and may include the most critical CW laser and Fiber Noise Canceller to deliver the sub-Hz and long-term stable light to the Physics package.

OPTICAL REFERENCE SYSTEM

Frequency stability in the mid-10^{-16} level at 1 s

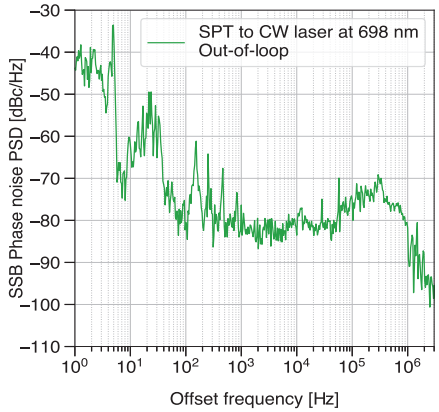


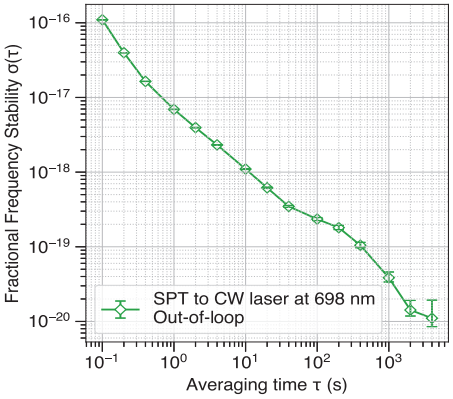


The rack-mounted ORS of the FC1500-Quantum is characterized in terms of single-sideband optical phase noise power spectral density and fractional frequency stability. Menlo Systems carries on detailed analysis for each system to guarantee ultimate performance and uninterrupted operation. A three-cornered hat technique is used to provide absolute noise analysis of the ORS.

ULTRA-LOW-NOISE SPECTRAL PURITY TRANSFER

Comprehensive out-of-loop qualifications of Spectral Purity transfer before shipping

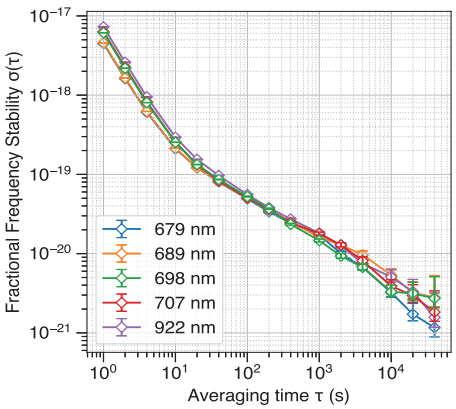




The ultra-low-noise frequency comb is qualified against a reference system. The Spectral Purity Transfer performance is analyzed for short-term phase noise performance and long-term fractional frequency stability, to ensure negligible additive noise. Here, the residual phase noise of an ECDL at 698 nm in the FC1500-Quantum is measured against a reference system, proving the exquisite transfer of phase-coherence from the optical reference system to the high Q-factor clock transition in neutral Strontium.

PHASE LOCK LOOPS STABILITY OF 5 CW LASERS

Ultra-stable phase lock loops ensuring negligible additive noise to the CW Lasers



We believe in fully phase-locked systems, being the only path for phase-coherently transfer the purity from one specific optical frequency to all frequencies. Here the robustness of our phase-lock-loops is measured, demonstrating the negligible additive noise and the full control of the disciplined CW lasers.

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SPECIFICATIONS	FC1500-QUANTUM
Optical Reference System (ORS) FSR	1.2 GHz or 3 GHz (Refer to ORS product lines)
Optical Reference Stability	<5 x 10^{-15} at 1s, down to <7 x 10^{-16} at 1s^{r} (ORS option dependent)
Residual ORS Phase Noise PSD	<-5 dBc/Hz at 1 Hz;<-50 dBc/Hz at 100 Hz,<-80 dBc/Hz at 10 kHz (ORS option dependent)
ORS Spurious	<-20 dBc (ORS-XTAL)
Comb Spacing (FSR)	250 MHz, 125 MHz or 100 MHz^{t}
Fractional Comb Stability (modADEV)[1]	<1 x 10^{-17} at 1 s, <5 x 10^{-18} at 100 s^{t}
Fractional Comb Accuracy (relative)[1]	<1 x 10^{-18} for t > 100 s^{t}
Residual Comb lines Phase Noise PSD[1]	< -40 dBc/Hz at 1 Hz; <-60 dBc/Hz at 100 Hz, <-90 dBc/Hz at 10 kHz
Comb Linewidth	<1 Hz (with Menlo ORS)
CW Laser Spectral Range	Ultraviolet to Infrared (OEM integrated or user provided)
CW Laser Power	From mW to Watt level (application and laser dependent)
PLLs Behavior	Cycle-slip free for weeks at a time for all phase-lock-loops¥

[1]The comb stability, accuracy and phase noise are qualified by upper-limit measurements against a reference when both combs are phase-locked to an ORS. The absolute accuracy is given by either the user physics-package or the RF reference (e.g., GPS signal).△ORS-type and system configuration dependent. ♦Comb-type and system configuration dependent. ¥Enables continuous phase-coherent measurements and uninterrupted spectral purity transfer.

OPTIONS	
Reference System	Menlo Systems **ORS, ORS-Compact, ORS-Mini**
Frequency Comb	Menlo Systems **FC1500-250-ULN, FC1500-ULN^{PLUS}, SmartComb**
Optical Comb Extensions 500 – 2100 nm Each comb extension is tailored for optimum signal-to-noise ratio	**XOD:** eXtended Optical Detection unit Comprise high SNR integrated beat detection unit for CW laser phase locking **SPT:** Spectral Purity Transfer Unit For ultra-high stability operation – relevant for supporting state-of-art optical clocks and beyond
Embedded Electronics	Modular Menlo Systems **SYNCRO** Electronics for phase-locking, signal amplification and distribution. Up to 8 or 12 CW laser controls per 5U SYNCRO unit (laser-type dependent).
CW Lasers	**ECDLs** and amplified systems, **DFB-fiber lasers, Ti:Sapphire** and other **DPSS lasers (we select the optimal solution for your application)**
Others	**FNC:** Fiber noise canceller for ultra-narrow linewidth signal delivery to user Physics package; **Microwave:** Ultra-stable RF and Microwave outputs; **GPS:** 10 MHz Frequency reference with SI-traceability GPS receiver; **WLM-NIR / WLM-VIS:** Rack-integrated wavemeter (configuration dependent)

REQUIREMENTS	
Operating Voltage	100/115/230 VAC
Frequency	50 to 60 Hz
Power Consumption	~1 kW (configuration dependent)
Cooling Requirements	closed cycle chiller included (rack-mount or separate)
Operating Temperature	22 ± 5 °C
Dimensions/Weight	3×19” racks, each approx. 140 kg (configuration dependent)

ORDERING INFORMATION	
Product Code	FC1500-Quantum

Please call for pricing. Specifications are subject to change without notice. Custom modifications are available, please inquire.

Invisible laser radiation
avoid exposure to beam
Class 4 laser

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