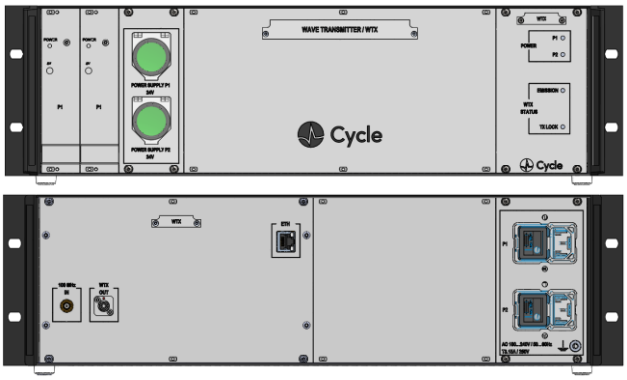
Cycle

WAVE

Stabilized RF over Fiber Link

Lowest noise RF over Fiber transmission



APPLICATIONS

Lowest noise fiber-optic frequency and time signal transfer for applications such as:

- Atomic clock signal distribution such as active or passive H-masers, Cs or Rb clocks
- RF signal distribution in free-electron lasers and particle accelerators
- UTC time realization and distribution
- Reference signal distribution in space telescopes

BENEFITS

- Wide range RF transfer (5/10/100 MHz and [1 GHz – 4 GHz])
- Stability better than state-of-the-art masers
- Modular & configurable
- Synchronous time signals (1PPS, IRIG & NTP)

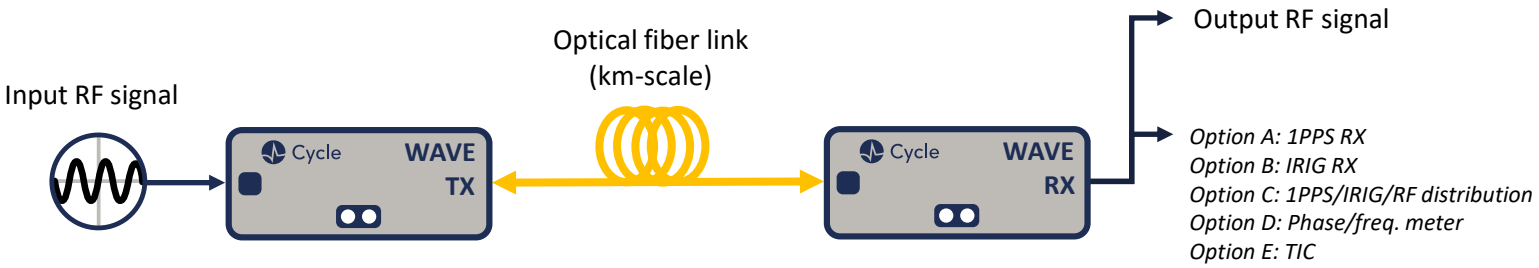
DESCRIPTION

WAVE Link allows precise transmission of frequency and time signals to kilometer distances using optical fibers with stability better than state-of-the-art masers.

It consist of a transmitter (TX) and a receiver (RX) unit, both equipped with advanced Cycle electro-optical modulation and fiber optic delay stabilization technology.

Its modular design enables application-specific configurations, including stable 1PPS, IRIG & NTP transfer, time interval counters, phase/frequency meters, and GNSS tracking and referencing.

SETUP EXAMPLE



Option A: 1PPS TX
Option B: IRIG TX
Option C: 1PPS/IRIG/RF distribution
Option D: Phase/freq. meter
Option E: TIC
Option F: GNSS RX

Cycle GmbH, Hamburg, Germany | +49 40 298486-10 | contact@cyclelasers.com | cyclelasers.com

Cycle

contact@cyclelasers.com

Contact us to discuss your timing and synchronization requirements

SPECIFICATIONS

Parameter	Specification	Comment		
Timing jitter	< 200 fs RMS	integrated residual noise [0.1 Hz – 100 kHz][1]		
Frequency range	5/10/100 MHz and [1 GHz – 4 GHz]	Single frequency at [10 – 13 dBm] input power, not sweeping		
RX outputs	[2 – 4] x SMA type	at [10 – 13 dBm] output power		
Control system interface	TCP/IP	e.g., EPICS or Telnet		
Dimensions, TX + RX	3 U + 3 U	19" rack module, options may increase U		
Residual ADEV	< 1.5E-13 at 1 s < 2E-14 at 10 s < 5E-15 at 100 s < 2E-15 at 1 000 s < 2E-15 at 10 000 s	with active fiber delay stabilization[1]		
Phase noise	**Offset frequency** 1 Hz 10 Hz 100 Hz 1 000 Hz 10 000 Hz 100 000 Hz	**10 MHz carrier** -105 dBc/Hz -130 dBc/Hz -150 dBc/Hz -160 dBc/Hz -160 dBc/Hz -160 dBc/Hz	**100 MHz carrier** -100 dBc/Hz -115 dBc/Hz -125 dBc/Hz -153 dBc/Hz -162 dBc/Hz -163 dBc/Hz	**1 GHz carrier** -95 dBc/Hz -110 dBc/Hz -120 dBc/Hz -140 dBc/Hz -150 dBc/Hz -155 dBc/Hz
Requirements				
Fiber link length	< 1 km	contact Cycle for longer fiber links.		
Fiber link loss	< 10 dB	if higher fiber loss, see option G: EDFA.		
Fiber link reflectance	< -40 dB	APC type fiber connectors are recommended.		
Option A: 1PPS transfer				
Signal level	2.5 V TTL	50 Ω impedance		
Pulse rise and fall times	≤ 1 ns	from 10% to 90% level		
Pulse duration	20 µs – 500 ms	adjustable		
Return loss	30 dB	at signal outputs		
Delay adjustment	10-ns step size	at 100-MHz input		
Timing jitter	< 5 ps RMS	added noise to the RF input		
Option B: IRIG transfer				
Timecode	IRIG-B	contact Cycle for more details.		
Option C: Distribution amplifier				
Frequency distribution	1 x 12	1 input, 12 outputs per module		
1PPS or IRIG distribution	2 x 10	2 switchable inputs, 10 outputs per module		
Option D: Phase/frequency meter				
Input signal	Sine wave	[5 MHz – 100 MHz] frequency and [7 – 10 dBm] power		
Input channels	4 x SMA type	ch1 is reference. Real-time phase, frequency and ADEV at 1-s rate, all combinations of two channels are reported.		
ADEV measurement floor[3]	< 4E-14 at 1 s < 1E-14 at 10 s < 2E-15 at 100 s < 1E-15 at 1 000 s < 1E-15 at 10 000 s			
Option E: Time interval counter				
Input signal	1 PPS	2.5 V TTL at 50 Ω impedance		
Input channels	4 x SMA type	real-time time interval measurements at 1-s rate, all combinations of two channels are reported.		
Resolution	20 ps RMS			
Option F: GNSS tracking & referencing				
GNSS receiver	Furuno GT-100	SMA-type, multi-GNSS receiver optional with a GNSS antenna		
Outputs	1PPS & 10 MHz	SMA-type, synchronized UTC time and frequency output		
Option G: EDFA				
Gain	13 dB	one way, 16 dB total gain in round-trip operation		

[1] TX and RX rack units shall be in a thermally controlled environment (temperature +18 to +24°C, with slope < 0.4°C/h and variation < 1°C pk-pk; humidity < 60 %RH with variation < 10 %RH pk-pk).

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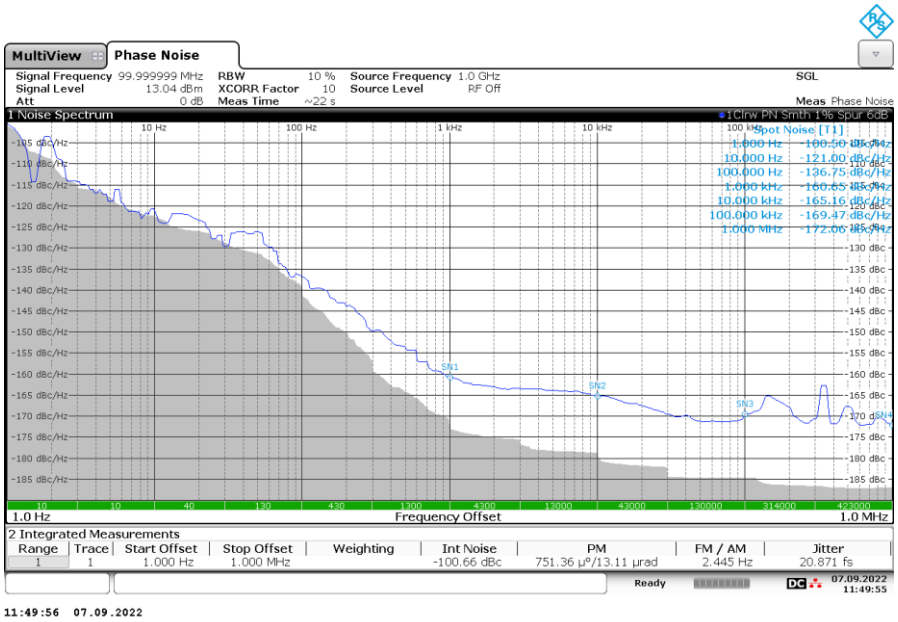
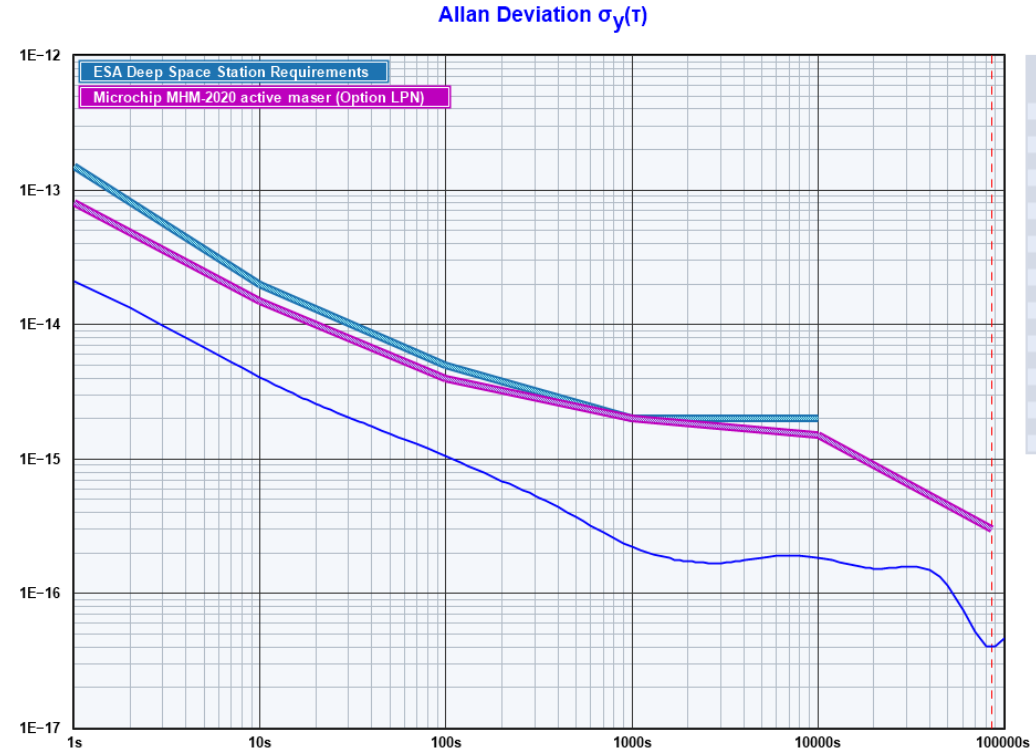
MEASUREMENT DATA

Absolute phase noise measurement at 100 MHz:



Freq. Offset (Hz)	Phase Noise (dBc/Hz)
1	-100.50
10	-121.00
100	-136.75
1 000	-160.65
10 000	-165.16
100 000	-169.47
1 000 000	-172.06

Residual ADEV measurement at 100 MHz:



Tau	Sigma(Tau)
1s	2.09E−14
2s	1.33E−14
4s	7.95E−15
8s	4.76E−15
10s	4.05E−15
20s	2.58E−15
40s	1.74E−15
80s	1.19E−15
100s	1.05E−15
200s	6.88E−16
400s	4.38E−16
800s	2.58E−16
1000s	2.22E−16
2000s	1.75E−16
4000s	1.77E−16
8000s	1.92E−16
10000s	1.85E−16
20000s	1.54E−16
40000s	1.51E−16
80000s	4.08E−17
100000s	4.63E−17

Trace	Notes	Input Freq	Sample Interval	ADEV at 86400s	Duration	Elapsed	Acquired	Instrument
Cycle WAVE Link	100 MHz	100 MHz	1 s	4.09E−17	5d 13h 20m 0s	5d 13h 20m 0s	480000 pts	Digital Phase Detector