BOMPD

Balanced Optical Microwave Phase Detector

Optical-to-microwave timing detection with attosecond resolution and ultra-low drift

DESCRIPTION

BOMPD enables ultra-precise measurement of timing jitter between an optical pulse train and a RF signal. Its opto-electronic architecture provides amplitude-insensitive detection, eliminating AM-to-PM conversion and ensuring a pure timing error signal.

By directly linking optical and RF domains in an interferometer, BOMPD generates a baseband signal proportional to timing error, enabling high-resolution characterization and feedback control beyond conventional electronic phase detectors.

With the optional ESYNC module, the system becomes a complete opto-electronic synchronization solution, enabling low-noise locking between optical and microwave sources with residual timing jitter and drift below 20 fs RMS, or photonic generation of RF signals referenced to an optical oscillator.

BENEFITS

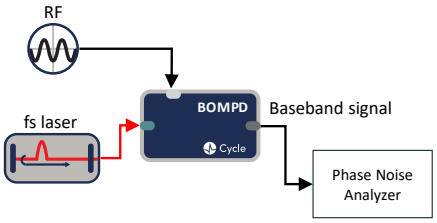
- Attosecond-level timing jitter resolution
- Exceptional long-term stability & ultra-low drift
- High timing sensitivity (> 0.2 mV/fs) for precise measurement and control
- Ultra-stable bias control and < 20 fs RMS timing jitter & drift with ESYNC

APPLICATIONS

- Synchronization between ultrafast lasers and microwave signals
- Photonic microwave generation
- Synchronization between ultrafast lasers and relativistic electron beams
- Electron bunch timing in free-electron lasers
- RF over fiber distribution

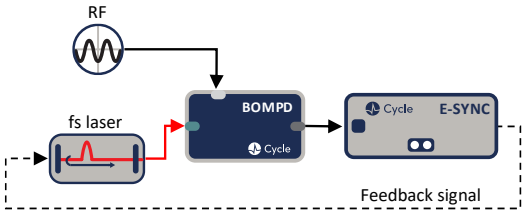
SETUP EXAMPLES

Timing jitter characterization



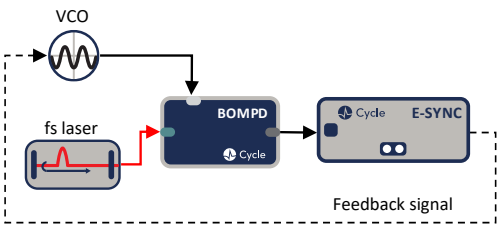
BOMPD inputs/outputs	
Input 1	RF (SMA)
Input 2	Optical (PM fiber)
Output	Baseband signal proportional to relative timing jitter

Femtosecond laser to RF synchronization



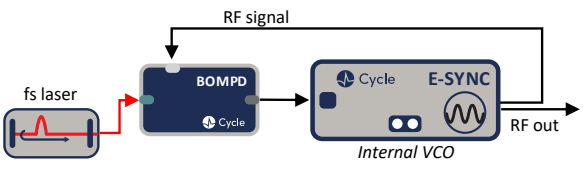
ESYNC inputs/outputs	
Input	Baseband signal proportional to relative timing jitter
Output	Feedback signal for laser intracavity actuators

RF to femtosecond laser synchronization



ESYNC inputs/outputs	
Input	Baseband signal proportional to relative timing jitter
Output	Feedback signal for a voltage-controlled oscillator

Photonic microwave generation



ESYNC inputs/outputs	
Input	Baseband signal proportional to relative timing jitter
Output 1	Internal VCO RF to BOMPD
Output 2	Synchronized VCO RF output

SPECIFICATIONS

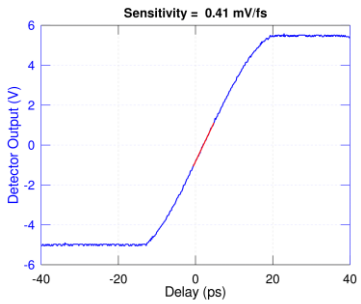
Parameter	Specification	Comment
Detector specifications		
Timing sensitivity	> 0.2 mV/fs	main balanced output with 1 MΩ load impedance
Timing noise floor	< 5 fs RMS	integrated noise floor [1 Hz - 100 kHz]
Timing resolution	< 0.1 fs RMS	integrated noise floor within 1 Hz bandwidth above 100 Hz
Detector bandwidth	> 100 kHz	3-dB signal bandwidth
Dimensions (H x W x L)	225×150×100 mm^3	dimensions of the optical detector head
Option ESYNC: Electronic Synchronization Unit		
Timing jitter	< 20 fs RMS	integrated residual noise [35 µHz – 100 kHz], i.e., for 8 hours[1]
Control unit type	Cycle ESYNC	provides auto search, lock and feedback control functions
Control unit dimensions	3 U	19” rack module
Control system interface	EPICS	via TCP/IP
Integrated feedback	included	applied either to a VCO or a slave laser’s actuators
Auto lock	included	via graphical user interface on a computer
Input specifications		
Optical input wavelength	800 ± 30 nm 1030 ± 30 nm 1550 ± 40 nm	center wavelength
Optical input power	< 5 mW	average optical power coupled in PM fiber
Pulse repetition rate	10 MHz – 1.3 GHz	
Harm. RF input frequency	200 MHz – 20 GHz	shall be a harmonic of pulse repetition rate, contact Cycle for frequencies higher than 20 GHz.
Harm. RF input power	+13 to +18 dBm	contact Cycle for lower input power.

[1] with appropriate laser inputs, 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).

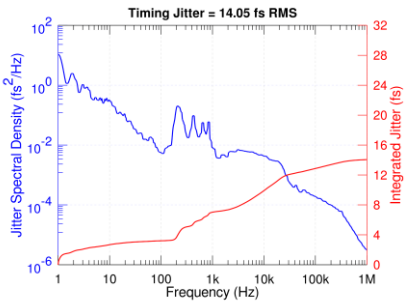
MEASUREMENT DATA

BOMPD and ESYNC performance locking an 800-nm mode-locked laser (Ti:Sa) to a microwave at 5712 MHz.

Timing sensitivity



Out-of-loop timing jitter



Out-of-loop timing drift