MATERIALS THAT MATTER

II-VI

WaveShaper®

Series A
Family of Programmable Optical Processors

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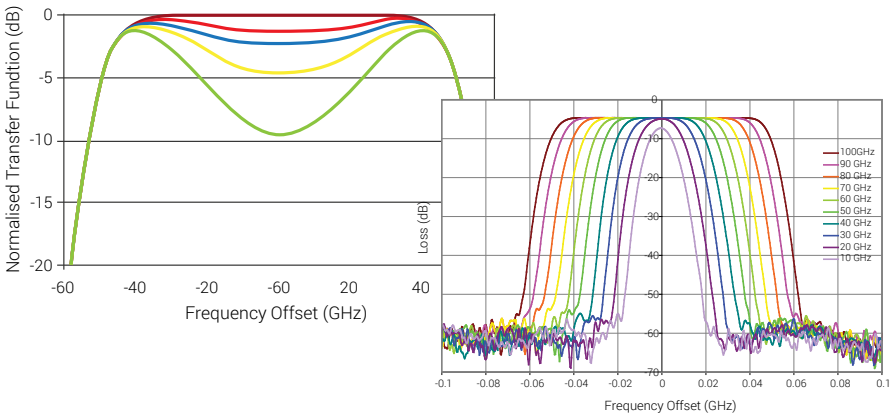
The WaveShaper® Series A Programmable Optical Processors provide a range of programmable optical filtering and switching options for optical R&D and production test applications. With a highly advanced high-resolution, solid-state Liquid Crystal on Silicon (LCoS) optical engine, the WaveShaper family provides extremely fine control of filter characteristics, including center wavelength, bandwidth, shape, dispersion and attenuation. The WaveShaper family is used in a wide variety of applications, including optical communications, pulsed lasers in the medical and material processing area as well as optical sensors.

Applications

Filtering with arbitrary spectral shapes

Filtering with variable bandwidth and with arbitrary spectral shapes is of importance in system test experiments. For example, the influence of cascading of optical filters on the transmission quality can be investigated by programming the resulting filter shape into the WaveShaper.

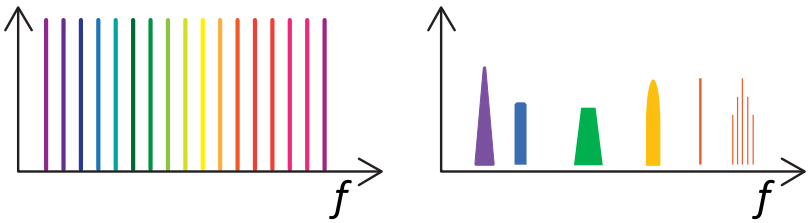


Mux/DeMux and De-/Interleaving

The WaveShaper 4000A can serve as a programmable Multiplexer/Demultiplexer or Interleaver/De-Interleaver. It can incorporate basically any channel spacing, including non-equally spaced channels. It fully supports Flexgrid™, the standard approach to flexible grid network architectures. Since it can operate in both directions, it can be used as a wavelength splitter as well as a combiner.

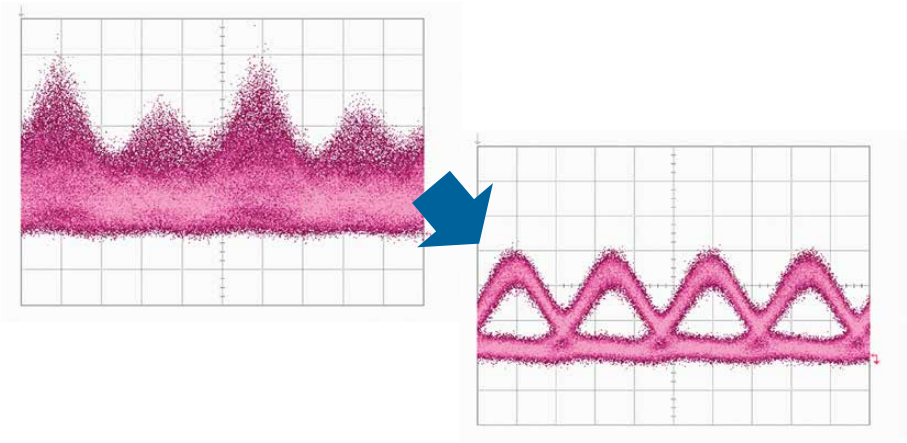
Component and System Loading

Generation of controllable optical combs is key in a variety of module and system test applications. For example, loading an amplifier with a representative power spectrum is required for proper amplifier testing. Similar requirements exist for testing optical systems involving amplified links. The WaveShaper can create individual spectral lines – even with shapes as if they were modulated.



Dispersion Compensation

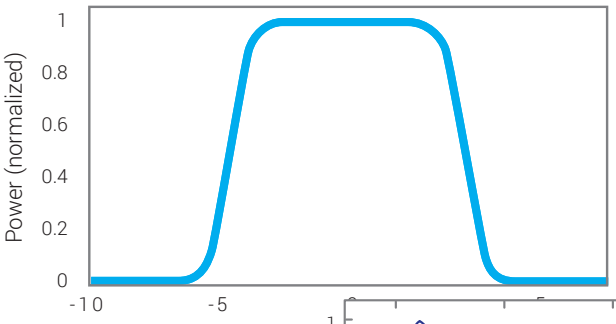
In system testing, verification of dispersion budgets and sensitivity of transmission systems to group delay ripple (and other dispersion imperfections) is of importance. Several members of the WaveShaper family allow setting dispersion values of up to 100 ps/nm (per 50 GHz channel) as well as creating group delay ripple with high spectral frequency.



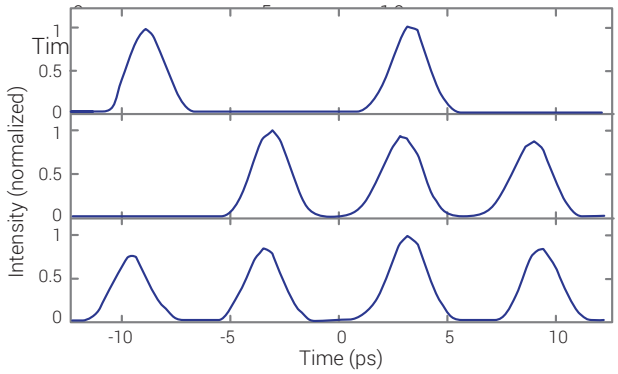
Laser Pulse Compression, Shaping and Generation

Pulsed Lasers are utilized in a large number of medical, material processing, communications and other applications. Several of these applications require very short optical pulses, for example when athermal ablation is required. The WaveShaper 1000/SP allows dynamic compression of optical pulses and therefore enables stable operation of such laser pulses in the femtosecond regime.

Certain other applications, in particular in the communications area, require specific pulse shapes (like rectangular for example) or particular bit sequences.



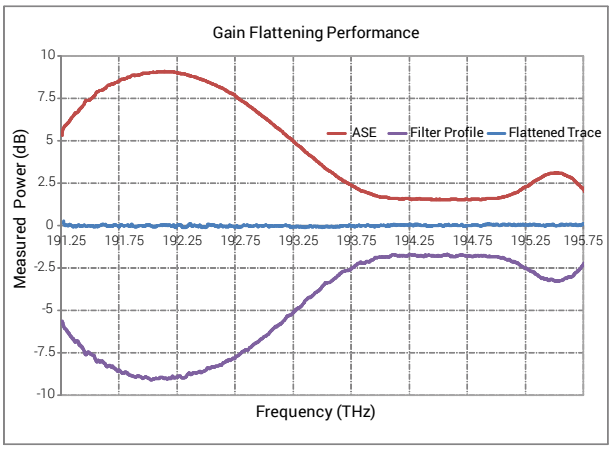
Rectangular pulse



Creation of pulse patterns: pulse sequences of 1010, 0111, 1111 have been created from a single input pulse

Gain Equalization

A number of parameters need to be verified in communication test beds including the tolerance of the transmission system to spectral shapes of the gain. The WaveShaper allows creating such gain shapes with very high resolution (down to 0.01 dB attenuation steps), which allows for creation and compensation of such gain shapes.



Power Splitting and Broadcasting

The WaveShaper 4000 and 16000 both have the ability to split an input signal between multiple output ports. Simple structures like wavelength-dependent couplers and splitters (Figure 1) can be created with user defined coupling ratios and frequency dependencies.

Figure 1: Splitter

Figure 2: Variable Delay Line Interferometer

Programmable Interferometer

In addition to splitting power, the phase of signals in the different ports can also be adjusted. This allows the user to create, on the fly, more complex structures like delay line interferometers (e.g. DPSK-Demodulator – shown in Figure 2) or DQPSK-Demodulators with a variable, easily-programmable, optical transfer function (Figure 3).

More complex functions, such as the all-optical Discrete Fourier Transform (DFT) filter shown in Figure 4 can also be easily created.

These capabilities can be best described as "just like an Optical FPGA", where an optical functional element (component) can be created within a fraction of a second just by uploading a definition table. The ability to easily generate complex interferometric structures simplifies many areas of research which require an arbitrary optical transfer function, including the ability to share (or combine) power between multiple ports.

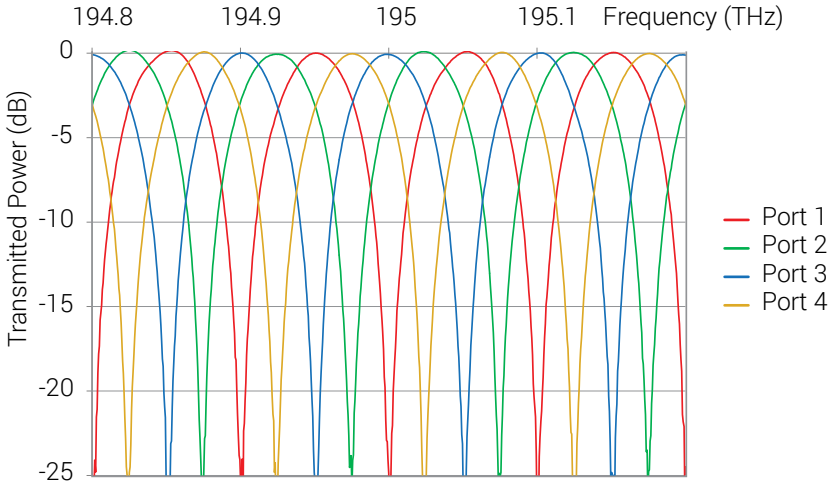


Figure 3: Optical transfer function of a DQPSK demodulator generated in a WaveShaper 4000A using the Fourier processor software

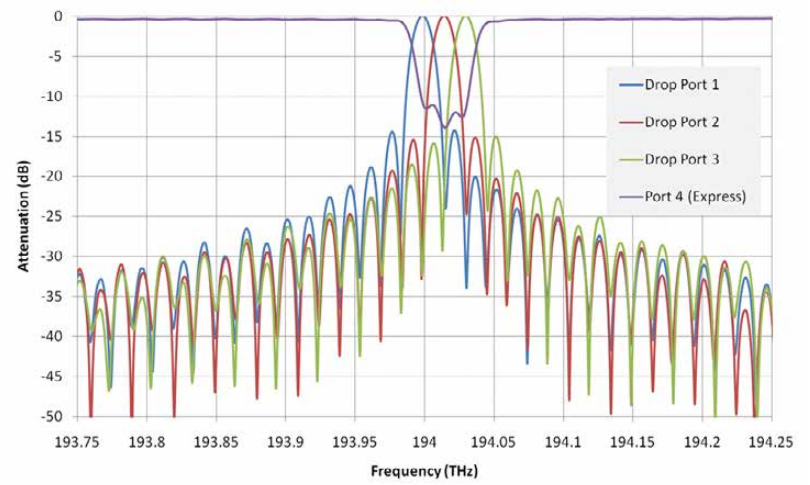
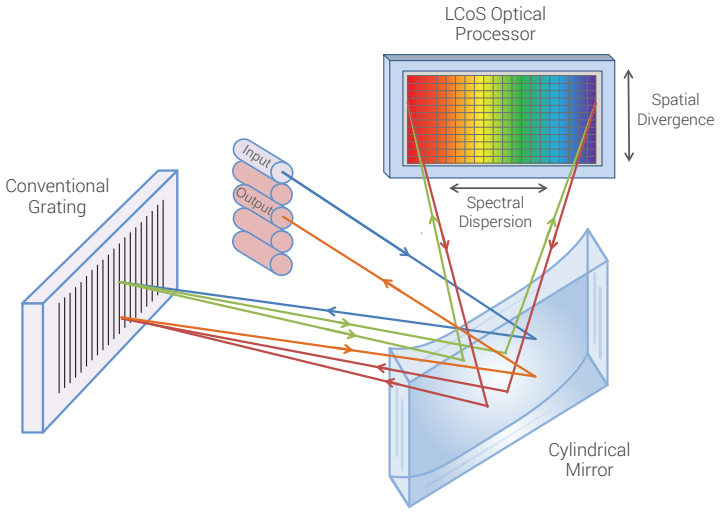


Figure 4: Optical transfer function of an all-optical DFT filter with 15 GHz FSR

Technology - How does it work?

The WaveShaper family is based on advanced Liquid Crystal on Silicon (LCoS) technology. As shown schematically in the figure below, the input signal is dispersed by a conventional grating before its spectral components hit the LCoS optical processor. This LCoS processor consists of a matrix of reflective liquid crystal elements. By applying voltages to these matrix elements, they can add individual phase shifts to the reflected signals which allows beam steering of the signal components hitting the LCoS processor. As the wavelengths are separated on the LCoS chip, the control of each wavelength is independent of all others and can be switched or filtered without interfering with other wavelengths. As a result, the structure offers spectral attenuation, dispersion and optical switching capabilities which are available in the WaveShaper family.

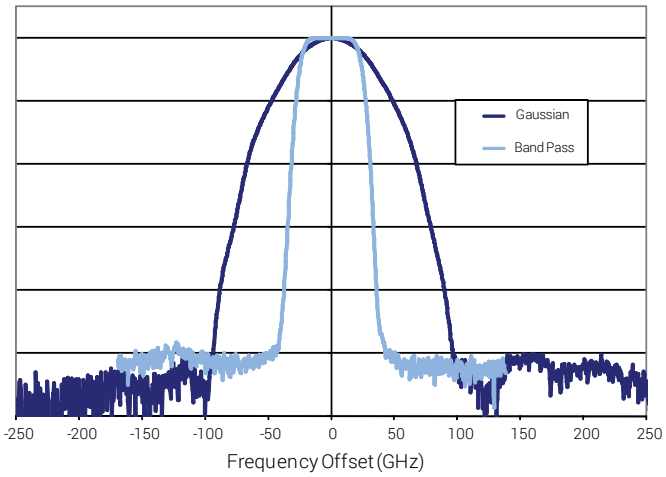


Products

WaveShaper 100A

Tunable Optical Filter

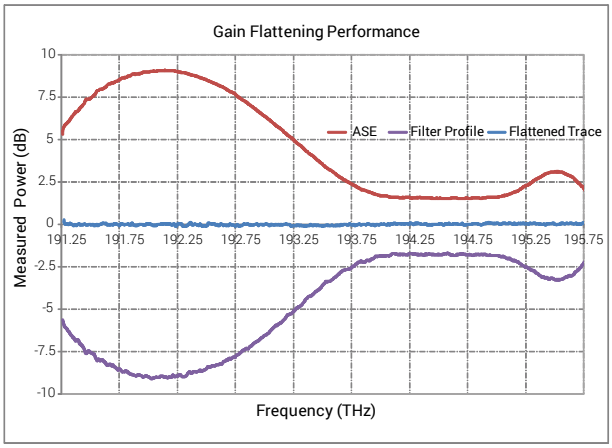
Fully programmable, DWDM tunable optical filter with user-selectable band-pass (flat-top) and Gaussian filter shapes. The filter bandwidth is programmable in 1 GHz increments from 10 GHz up to 1000 GHz, with the center frequency programmable in 1 GHz increments over the whole C- band. Ideal for production test applications.



WaveShaper 500A

Programmable Optical Filter

Optical filter covering the C-band with arbitrarily programmable attenuation shape. Typical applications include gain equalization, channel selection and channel shaping.



WaveShaper 1000A

Programmable Optical Filter

Available for various bands from 1468 nm to 1640 nm

Supports arbitrary user-generated channel and filter shapes. The bandwidth can be set from 10 GHz to about 5 THz with 1 GHz increments for the standard C- or L-band version of the 1000A. The X version (which covers the C+L band) plus the S-band version and the extended L-band version support filter bandwidths from 20 GHz to about 9 THz. The required filter shape (both amplitude and phase) can be generated by the user then loaded into the WaveManager software which translates the user specification into the required optical shape. Band-stop and optical comb filters are also supported as is optical power control over a range of 30 dB for all filter types.

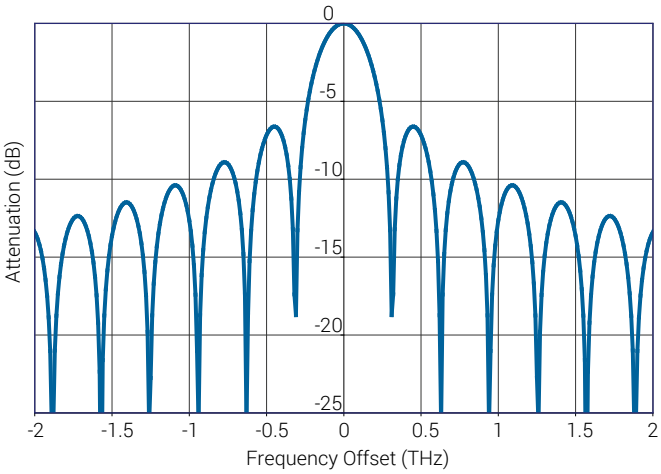
WaveShaper 4000A

Multiport Optical Processor

Available for various bands from 1468 nm to 1640 nm

Extends the capability of the WaveShaper 1000A including the ability to direct different portions of the signal to different output ports with different, arbitrary user-generated channel shapes for each port.

All members of the WaveShaper 4000 family support power splitting, broadcasting and the ability to create programmable interferometers, as described on page 4.



Example filter shapes generated with WaveShaper 1000/4000 programmable optical processor

WaveShaper 1000/SP

Programmable Single Polarization Filter

Polarization maintaining version of the WaveShaper 1000 programmable filter. It transmits and processes the signal which is launched into the slow axis of the input PM fiber. The signal being launched into the fast axis is not transmitted and will be extinguished by more than 20 dB. Covering the entire C-band, the unit allows testing of single-polarization telecommunications components such as lasers and modulators, as well as the creation and shaping of short pulses down to the femtosecond regime in short-pulse fibre lasers.

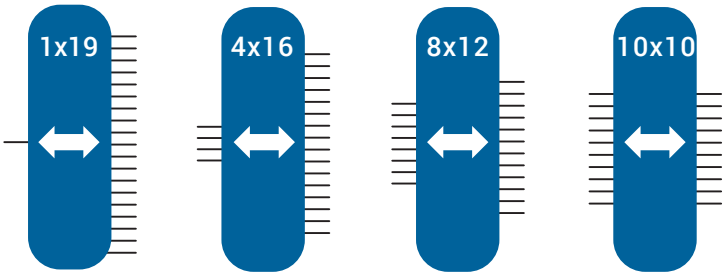
II-VI also offers a WaveShaper 1000/SP operating in the 1 µm wavelength window for pulsed laser applications. For more information, visit www.ii-vi.com/instruments.

WaveShaper 16000A

Reconfigurable Optical Processor

Programmable wavelength-selective MxN optical filter with control of filter shape and phase on each input/output port combination. The instrument has a total number of 20 optical ports. These can be configured by software commands to 1 x 19, 4 x 16, 8 x 12 or 10 x 10. All these port combinations work bi-directional, therefore also 19 x 1, 16 x 4 and 12 x 8 are included.

Covering the entire C-band, the WaveShaper 16000A combines precise control of filter wavelength, bandwidth, shape and phase with the ability to switch and combine multiple signals in an “Add” or “Drop” configuration. The WaveShaper 16000A in a 1x16 configuration also supports power splitting, broadcasting and the ability to create programmable interferometers, as described on page 4.



The WaveShaper 16000A allows arbitrary channel control and switching with high granularity. It has been designed for research and development applications in the advanced optical networking space. It provides key functions which are critical in the areas of elastic and space division multiplexed optical networks as well as software defined optical networking and OFDM.

The WaveShaper 16000 is programmable with user defined filter shapes either through the WaveManager Application Suite which serves as Graphical User Interface (GUI) or through the Application Programming Interface (API).

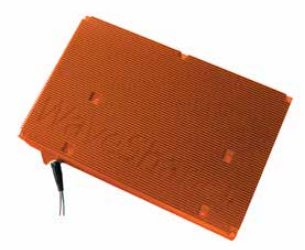
Operating the WaveShaper 16000 in a 4 x 16, 8 x 12 or 10 x 10 configuration is in terms of functionality equivalent to cascading two 1 x N WaveShapers back to back. For example, the 4 x 16 configuration is similar to operating a 4 x 1 WaveShaper and a 1 x 16 WaveShaper back to back. In order to prevent wavelength contention, the signals entering the WaveShaper through the different input ports should not spectrally overlap (one specific wavelength is only used at one input port - other ports receive different wavelengths). Both the GUI and API ensure that only those filter functions are accepted which do not lead to wavelength contention issues.

The programmable and integrated optical functions of the WaveShaper 16000A are highly desirable in next generation optical data center interconnects and high performance computing.

WaveShaper M-Series

For OEM Applications

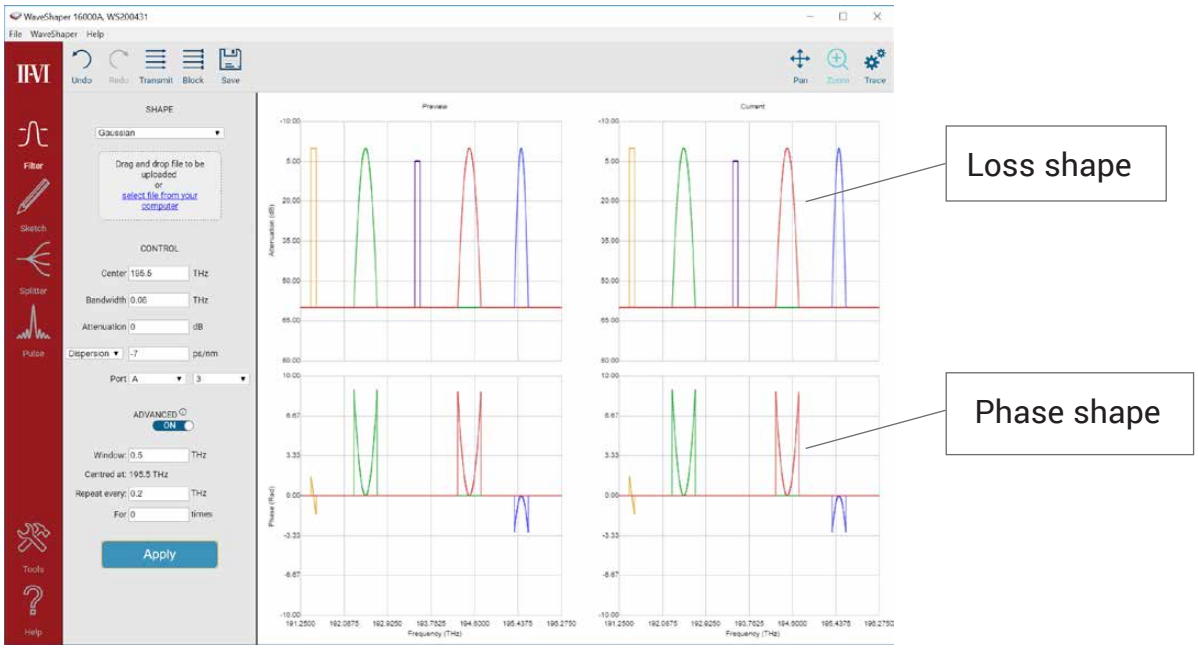
OEM version of the WaveShaper family of programmable optical processors. It is designed for embedding into third party equipment and instrumentation. It provides full WaveShaper functionality but with reduced size. Most of the benchtop WaveShaper models are also available as M-Series module.



Graphical User Interface (GUI)

The WaveShaper A Series instruments are controlled from an external device to select and update the filter shape. Communication with the WaveShaper is via USB or Ethernet interfaces. For the Graphical User Interface (GUI), the A Series WaveShaper supports the following approaches:

- **Integrated Webserver (Ethernet Interface):** The WaveShaper Series A instruments contain an in-built webserver that provides the most flexible approach, as the users client only needs to provide a web browser. No dedicated software or drivers are required. Supported systems include Windows 7 and higher, Linux, OS X, Android, iOS etc. Existing *.wsp and *.ucf files can be used, providing backward compatibility with current filter profiles.
- **WaveShaper App software package (Ethernet Interface):** This package runs on the user's computer and is available for Win 10 systems. It provides the same functionset as operation through the web browser, as well as providing a full device discovery service for networked units.
- **WaveManager 2.7x software package (USB Interface):** WaveShaper A Series instruments are fully backward-compatible with the existing WaveManager 2.7x software. This package runs on the user's computer and is available for Win 7, Win 8.1 and Win 10 systems. It provides the same functionset as operation through the web browser plus it has additional functions supporting power splitting and modeling (which provides a prediction of the real filter curve considering physical limitations). The WaveManager 2.7x software package can be downloaded from www.ii-vi.com/instruments.

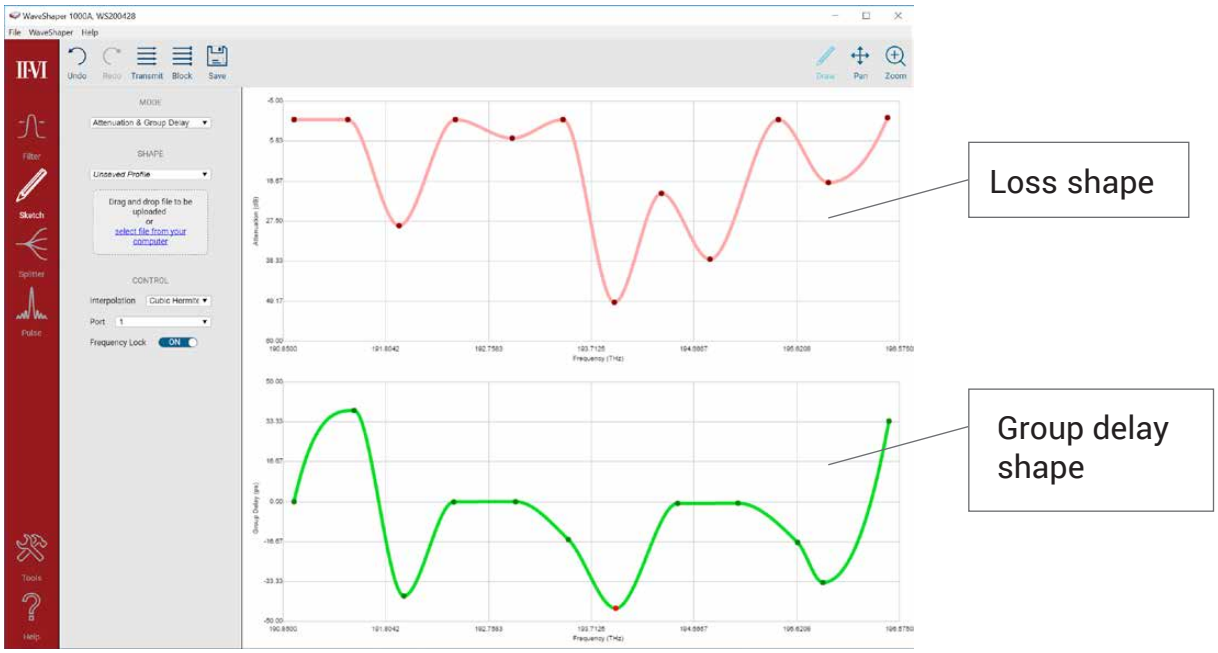


Application Programming Interface (API)

The WaveShaper A Series instruments include a web service API which enables the user to remotely configure the device over an Ethernet connection using HTTP commands from any software programming language. Programming examples are available for LabView, Matlab, Python, Octave, Visual Basic and C#. In addition, a DLL package is available for Windows-based PCs ensuring full backward compatibility ("drop-in replacement") with previous generation WaveShaper units.

WaveSketch

WaveSketch is an exciting capability which enables users of all versions of the WaveShaper 500A, 1000A, 4000A and 16000A to manually create filter shapes using a 'drag and drop' graphical interface. As both the loss and phase (only for 1000A, 4000A and 16000A) of the filter curve are manipulated on screen, the WaveShaper transfer function is updated in real time thus allowing, for example, continuous adjustments to eliminate drift in system test applications. The figure below shows a WaveSketch screenshot in which defined points can be added, deleted or modified as required.



II-VI Knowledgebase

Obtain further application and technical information about the Optical Instrumentation Portfolio including the WaveAnalyzer Family by clicking here: https://ii-vi.com/waveshaper-and-waveanalyzer-knowledgebase

WaveShaper Demonstration on YouTube

Watch product demo at: https://www.youtube.com/user/iiviincorporated

WaveShaper Specifications

Model		100A	500A	1000A, 4000A	16000A	1000A/SP (1)	1000A/L, 4000A/L	New: S-band 1000A/S, 4000A/S	1000A/X, 4000A/X	New: Extended L-band 1000A/XL, 4000A/XL
Optical Ports	Port Configurations	1x1		1x1 (1000) 1x4 (4000)	1x19, 4x16, 8x12, 10x10	1x1	1x1 (1000) 1x4 (4000)			
Filter Control	Operating Frequency Range	191.1 THz to 196.46 THz (1526.0 nm to 1568.7 nm)				191.250 THz to 196.275 THZ (1527.4 nm to 1567.5 nm)	186.2 THz to 191.05 THz (1569.2 nm to 1610.0 nm)	196.2 THz to 204.2 THz (1468.0 nm to 1528.0 nm)	187.275 THz to 196.275 THz (1527.4 nm to 1600.8 nm)	182.8 THz to 191.316 THz (1567.0 nm to 1640.0 nm)
	Filter Bandwidth	10 GHz – 1 THz (0.08 – 8 nm)	10 GHz – 5.36 THz (0.08 – 42.7 nm)			10 GHz - 5 THz (0.08 nm - 40 nm)	10 GHz – 4.85 THz (0.08 – 40.8 nm)	20 GHz - full range (0.16 nm - full range)		
	Filter Shape	Band-pass, Gaussian	Arbitrary							
	Frequency Setting Resolution	±1 GHz (±8 pm)								
	Frequency Setting Accuracy	±2.5 GHz (±20 pm)						± 5 GHz		
	Bandwidth Setting Resolution	±1 GHz (±8 pm)								
	Bandwidth Setting Accuracy	±5 GHz (±40 pm)						± 10 GHz		
	Bandwidth Setting Repeatability	±2.5 GHz (±20 pm)						± 5 GHz		
	Group Delay Control Range	n/a		-25 ps to +25 ps				-15 ps to +15 ps		
	Attenuation Control Range	n/a	0 to 35 dB							
	Attenuation Setting Resolution	n/a	0.01 dB		0.1 dB	0.01 dB				
	Attenuation Setting Accuracy	n/a	±1.0 dB from 0 to 10 dB, ±10 % from 10 to 30 dB							
	Settling Time	<500 ms								
Loss and Dispersion	Insertion Loss	< 5 dB (2)						< 7 dB (3)	< 6.5 dB (3)	< 7 dB (3)
	Insertion Loss Non-Uniformity	0.7 dB					0.7 dB (4)	1 dB		
	Polarization Dependent Loss (PDL)	0.4 dB				n/a	0.4 dB	0.8 dB		
	Differential Group Delay (DGD)	< 0.5 ps				n/a	< 0.5 ps			
	Return Loss	>25 dB								
Optical Power (5)	Max Total Input Optical Power	+27 dBm								
	Max Optical Power per 50 GHz channel	+13 dBm								
Environment	Operating Temperature	Bench-top / Rack-mount instrument: 15 to 35°C Module: 15 to 55°C with airflow of min 1 m / sec across top of module								
	Operating Humidity	10 to 90%								
Electrical	Communications Interface	Ethernet (GbE), USB 2.0								
	Power Consumption	<50 VA								
Mechanical	Connector Interface	FC/APC		FC/UPC, FC/APC	LC/APC	FC/APC				
	Dimensions, weight	Bench-top: 241 mm x 88 mm x 316 mm, 3.8 kg Module: 220 mm x 140 mm x 37 mm, 0.8 kg								

Note (1): Measured on signal in slow axis
Note (2): Valid for Filter Bandwidth settings of 15 GHz and larger. For Filter Bandwidth settings below 15 GHz an additional loss of up to 2 dB may apply.
Note (3): Valid for Filter Bandwidth settings of 25 GHz and larger. For Filter Bandwidth settings below 25 GHz an additional loss of up to 2 dB may apply.
Note (4): Specification is valid over the frequency range of 187.0 to 191.05 THz. From 186.35 to 191.05 THz the insertion loss non-uniformity is 1.0 dB max.
Note (5): Optical signals with spectral components below 600 nm must be avoided.

Configuration Guide

Model	Order Code	Description	Wavelength band	Housing option	Fiber Type	Connector type
WaveShaper 100	WS-00100A-C-S-1-AA-00	Tunable Optical Filter	C	Benchtop	SM	FC/APC
	WS-00100A-C-M-1-AA-00	Tunable Optical Filter	C	Module	SM	FC/APC
	WS-00100A-C-R-1-AA-00	Tunable Optical Filter	C	Rackmount	SM	FC/APC
WaveShaper 500	WS-00500A-C-S-1-AA-00	Programmable Optical Filter	C	Benchtop	SM	FC/APC
	WS-00500A-C-M-1-AA-00	Programmable Optical Filter	C	Module	SM	FC/APC
	WS-00500A-C-R-1-AA-00	Programmable Optical Filter	C	Rackmount	SM	FC/APC
WaveShaper 1000	WS-01000A-C-S-1-AA-00	Programmable Optical Filter	C	Benchtop	SM	FC/APC
	WS-01000A-C-S-2-AA-00	Programmable Optical Filter	C	Benchtop	SM	FC/UPC
	WS-01000A-C-M-1-AA-00	Programmable Optical Filter	C	Module	SM	FC/APC
	WS-01000A-C-R-1-AA-00	Programmable Optical Filter	C	Rackmount	SM	FC/APC
	WS-01000A-L-S-1-AA-00	Programmable Optical Filter	L	Benchtop	SM	FC/APC
	WS-01000A-L-M-1-AA-00	Programmable Optical Filter	L	Module	SM	FC/APC
	WS-01000A-S-S-1-AA-00	Programmable Optical Filter	S	Benchtop	SM	FC/APC
	WS-01000A-X-S-1-AA-00	Programmable Optical Filter	C+L	Benchtop	SM	FC/APC
	WS-01000A-X-S-2-AA-00	Programmable Optical Filter	C+L	Benchtop	SM	FC/UPC
	WS-01000A-X-R-1-AA-00	Programmable Optical Filter	C+L	Rackmount	SM	FC/APC
	WS-01000A-X-M-1-AA-00	Programmable Optical Filter	C+L	Module	SM	FC/APC
	WS-01000A-X-S-1-AA-02	Programmable Optical Filter	Extended L	Benchtop	SM	FC/APC
	WS-01000A-C-S-1-AA-01	Programmable Single Polarization Filter	C	Benchtop	PM	FC/APC
	WS-01000A-C-M-1-AA-01	Programmable Single Polarization Filter	C	Module	PM	FC/APC
WaveShaper 4000	WS-04000A-C-S-1-AA-00	Programmable Optical Processor	C	Benchtop	SM	FC/APC
	WS-04000A-C-S-2-AA-00	Programmable Optical Processor	C	Benchtop	SM	FC/UPC
	WS-04000A-C-M-1-AA-00	Programmable Optical Processor	C	Module	SM	FC/APC
	WS-04000A-C-R-1-AA-00	Programmable Optical Processor	C	Rackmount	SM	FC/APC
	WS-04000A-C-R-2-AA-00	Programmable Optical Processor	C	Rackmount	SM	FC/UPC
	WS-04000A-L-S-1-AA-00	Programmable Optical Processor	L	Benchtop	SM	FC/APC
	WS-04000A-L-M-1-AA-00	Programmable Optical Processor	L	Module	SM	FC/APC
	WS-04000A-S-S-1-AA-00	Programmable Optical Processor	S	Benchtop	SM	FC/APC
	WS-04000A-X-S-1-AA-00	Programmable Optical Processor	C+L	Benchtop	SM	FC/APC
	WS-04000A-X-S-2-AA-00	Programmable Optical Processor	C+L	Benchtop	SM	FC/UPC
	WS-04000A-X-R-1-AA-00	Programmable Optical Processor	C+L	Rackmount	SM	FC/APC
	WS-04000A-X-S-1-AA-02	Programmable Optical Processor	Extended L	Benchtop	SM	FC/APC
	WS-04000A-X-M-1-AA-00	Programmable Optical Processor	C+L	Module	SM	FC/APC
WaveShaper 16000	WS-16000A-C-S-3-AA-00	Reconfigurable Optical Processor	C	Benchtop	SM	LC/APC
	WS-16000A-C-S-4-AA-00	Reconfigurable Optical Processor	C	Benchtop	SM	LC/UPC
	WS-16000A-C-M-3-AA-00	Reconfigurable Optical Processor	C	Module	SM	LC/APC
	WS-16000A-C-R-3-AA-00	Reconfigurable Optical Processor	C	Rackmount	SM	LC/APC

Order Code Key

WS-□□□□□ A-□-□-□-AA-□□

Model Number	Wavelength	Housing	Connectors	Options
00100	C: C-band	S: Benchtop	1: FC/APC	00: Standard
00500	L: L-band	R: Rackmount	2: FC/UPC	01: Single Polarization
01000	S: S-band	M: Module	3: LC/APC	02: X Shifted to Extended L band
04000	X: C+L band		4: LC/UPC	
16000	Y: 1 µm band			

About II-VI

II-VI Incorporated, a global leader in engineered materials and optoelectronic components, is a vertically integrated manufacturing company that develops innovative products for diversified applications in communications, materials processing, aerospace & defense, semiconductor capital equipment, life sciences, consumer electronics, and automotive markets. Headquartered in Saxonburg, Pennsylvania, the Company has research and development, manufacturing, sales, service, and distribution facilities worldwide. The Company produces a wide variety of application-specific photonic and electronic materials and components, and deploys them in various forms, including integrated with advanced software to support our customers. For more information, please visit us at www.ii-vi.com.