Product Guide

WaveShaper® Series A Family of Programmable Optical Processors

FINISAR®

WEB ENABLED

The new WaveShaper® Series A Programmable Optical Processors provide a range of program-mable optical filtering and switching options for optical R&D and production test applications. Based on Finisar's 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.
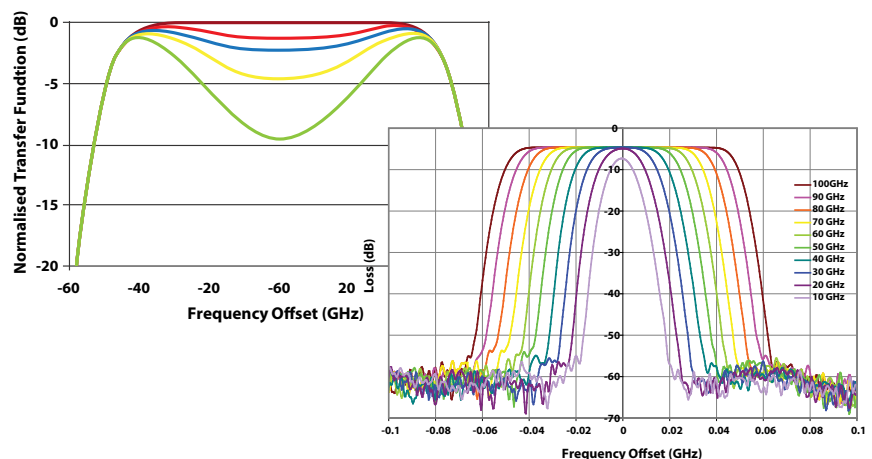
Mux/DeMux and De-/Interleaving

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. As it can operate in both directions, it can be used as a wavelength splitter as well as a combiner.
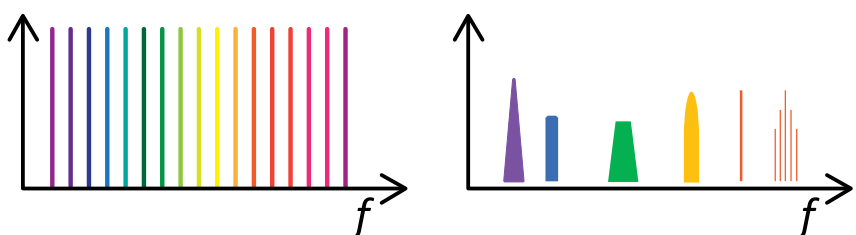
Mux/DeMux

De-/Interleaving


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 verification of 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.
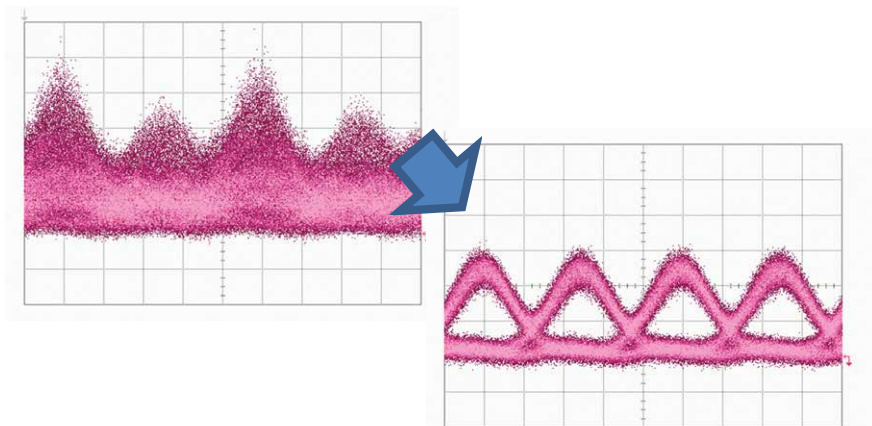
Laser Pulse Compression, Shaping and Generation

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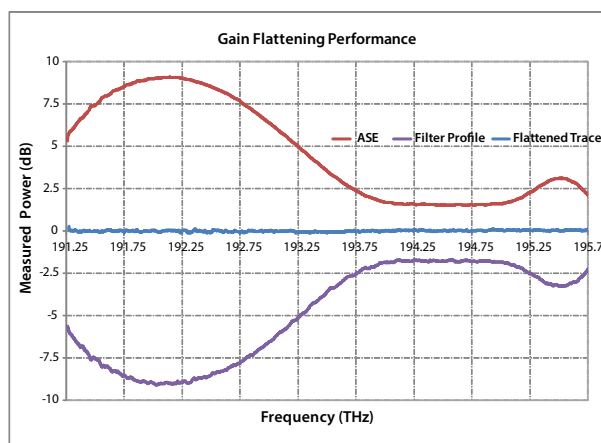
Certain other applications, in particular in the communications area, require specific pulse shapes (like rectangular for example) or particular bit sequences.

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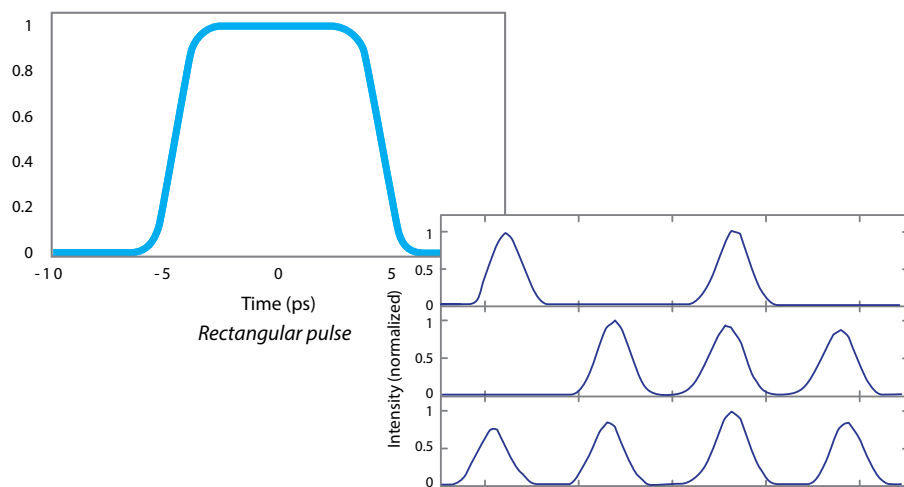
Creation of pulse patterns: pulse sequences of 1010, 0111, 1111 have been created from a single input pulse

Gain Equalization

In Communication system test beds a number of parameters needs to be verified. This includes 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) and therefore allows creation and also compensation of such gain shapes.

Gain Flattening Performance

ASE   Filter Profile   Flattened Trace

Measured Power (dB)

Frequency (THz)

Applications

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.

Programmable Interferometer

In addition to just splitting the power, the phase of the 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).
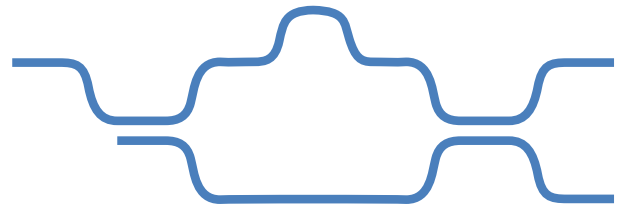
More complex functions, such as the all-optical Discrete Fourier Transform (DFT) filter shown in Figure 4 can also be easily created.

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 1: Splitter

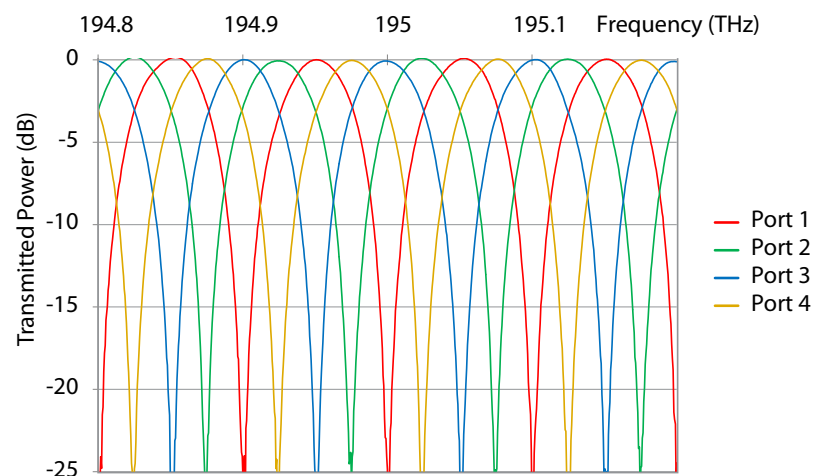*Figure 2: Variable Delay Line Interferometer*

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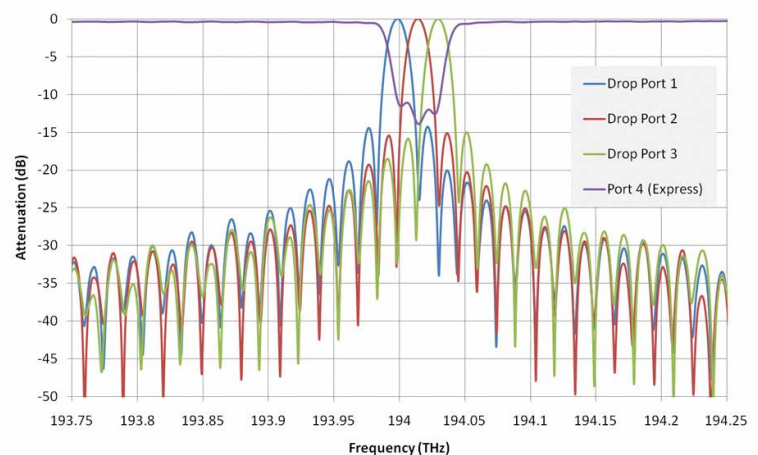

Figure 4: Optical transfer function of an all-optical DFT filter with 15 GHz FSR

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.
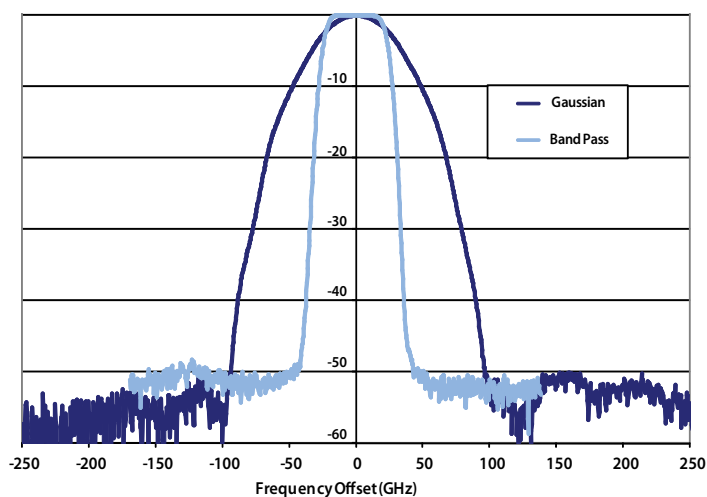
WaveShaper 500A

Programmable Optical Filter

This is an optical filter covering the C-band with arbitrarily programmable attenuation shape. Typical applications include gain equalization, channel selection and channel shaping.
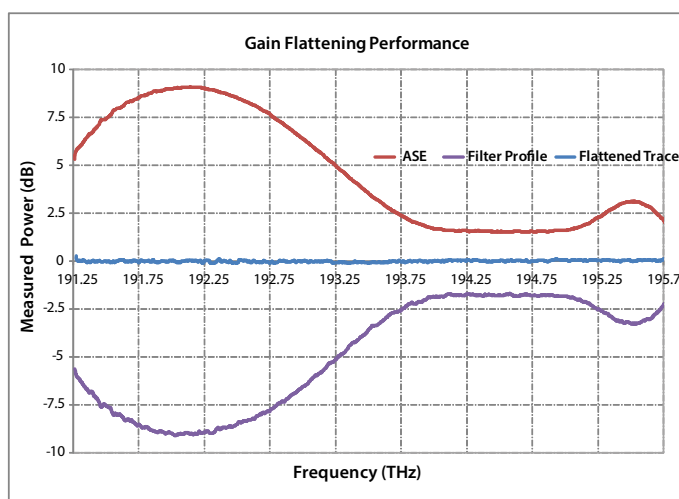
Products

WaveShaper 1000A

Programmable Optical Filter

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 – supports filter bandwidths from 20 GHz to 9 THz. The required filter shape (both amplitude and phase) can be generated by the user and 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.
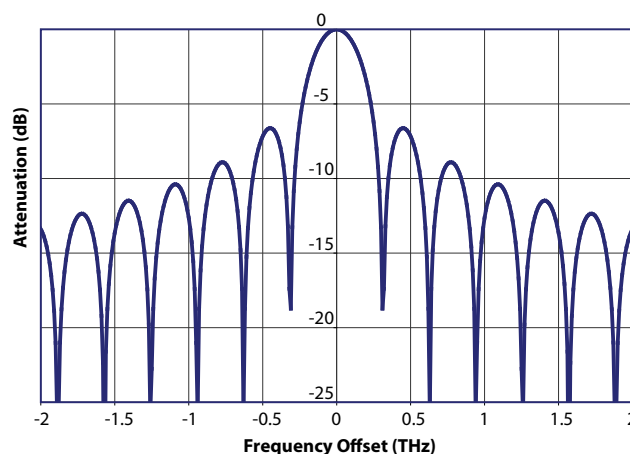
WaveShaper 4000A

Multiport Optical Processor

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

The WaveShaper 1000/SP is a 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.

Finisar also offers a WaveShaper 1000/SP operating in the 1 µm wavelength window for pulsed laser applications. Please find further details on www.finisar.com/instruments.
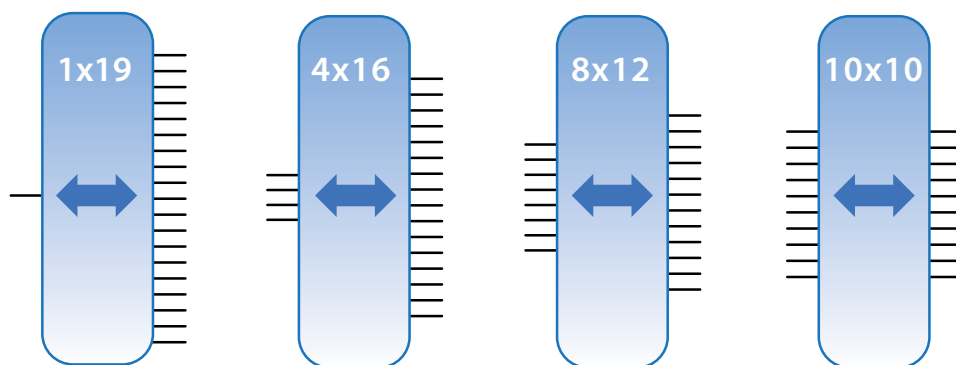
WaveShaper 16000A

Multiport Optical Processor

The WaveShaper 16000A Reconfigurable Optical Processor is a programmable wavelength-selective MxN optical switch and 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.

MxN WSS are key components in next generation colorless, directionless (CD) ROADMs. Finisar's WaveShaper 16000A provides the ability to emulate a Flexgrid™-compatible WSS of various port counts, as well as allowing arbitrary channel control and switching with much higher granularity than the current standards requirements. The WaveShaper 16000A 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 the API ensure that only those filter functions are accepted which do not lead to wavelength contention issues.

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

WaveShaper M-Series

For OEM Applications

The WaveShaper M-Series is the 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.
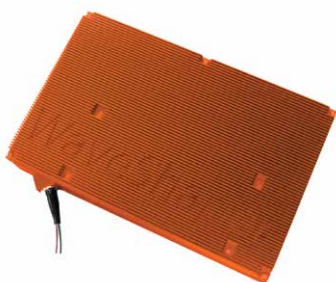
WaveShaper – Graphical User Interface (GUI)

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 the A Series WaveShaper supports the following approaches:

- **Integrated Webserver (Ethernet Interface)**
  The WaveShaper Series A instruments contain an in-built webserver and this 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 version 7 and higher, Linux, OS X, Android, iOS etc. Existing *.wsp and *.ucf files can be used, providing backward compatibility with current filter profiles.

- **WaveManager 3 software package (Ethernet Interface)**
  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 , as well as providing a full device discovery service for networked units.

- **WaveManager 2.7 software package (USB Interface)**
  WaveShaper A Series instruments are fully backward-compatible with the existing WaveManager 2.7 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 2.7 software package can be downloaded from www.finisar.com/instruments.

Loss shape
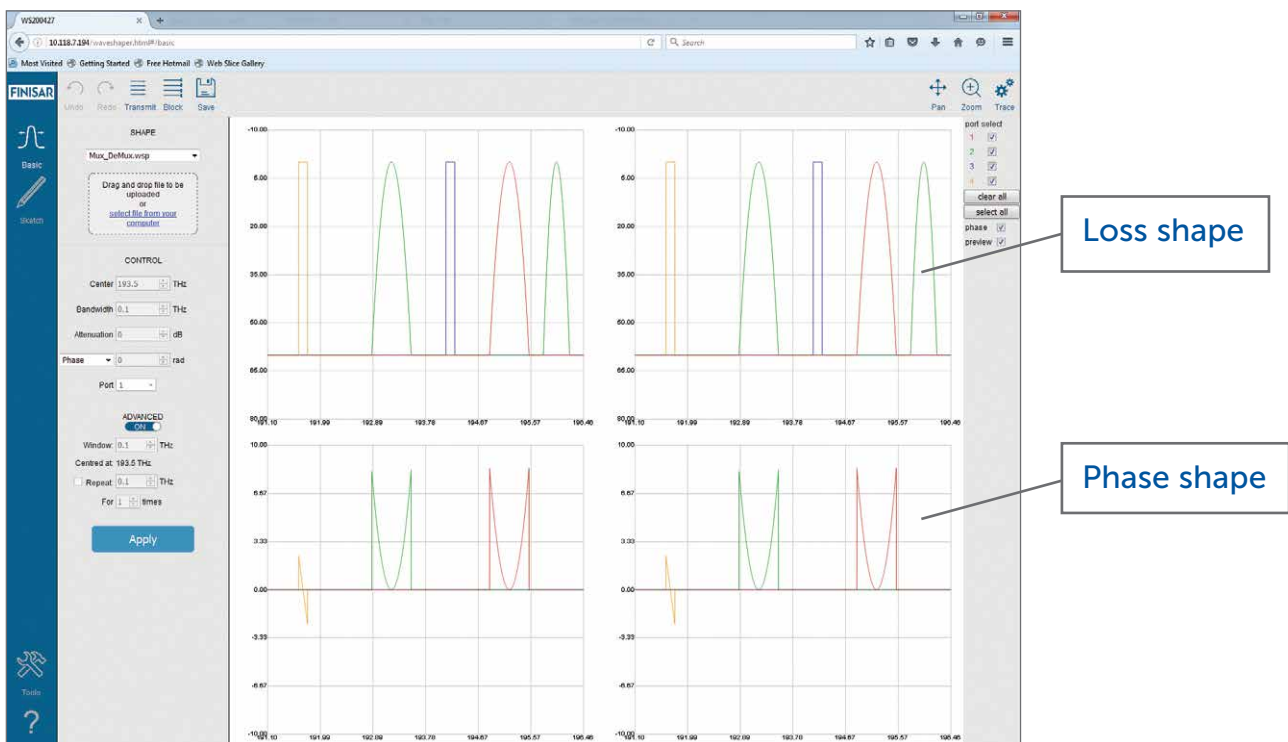
Phase shape

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 the 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.

Loss shape

Group Delay shape
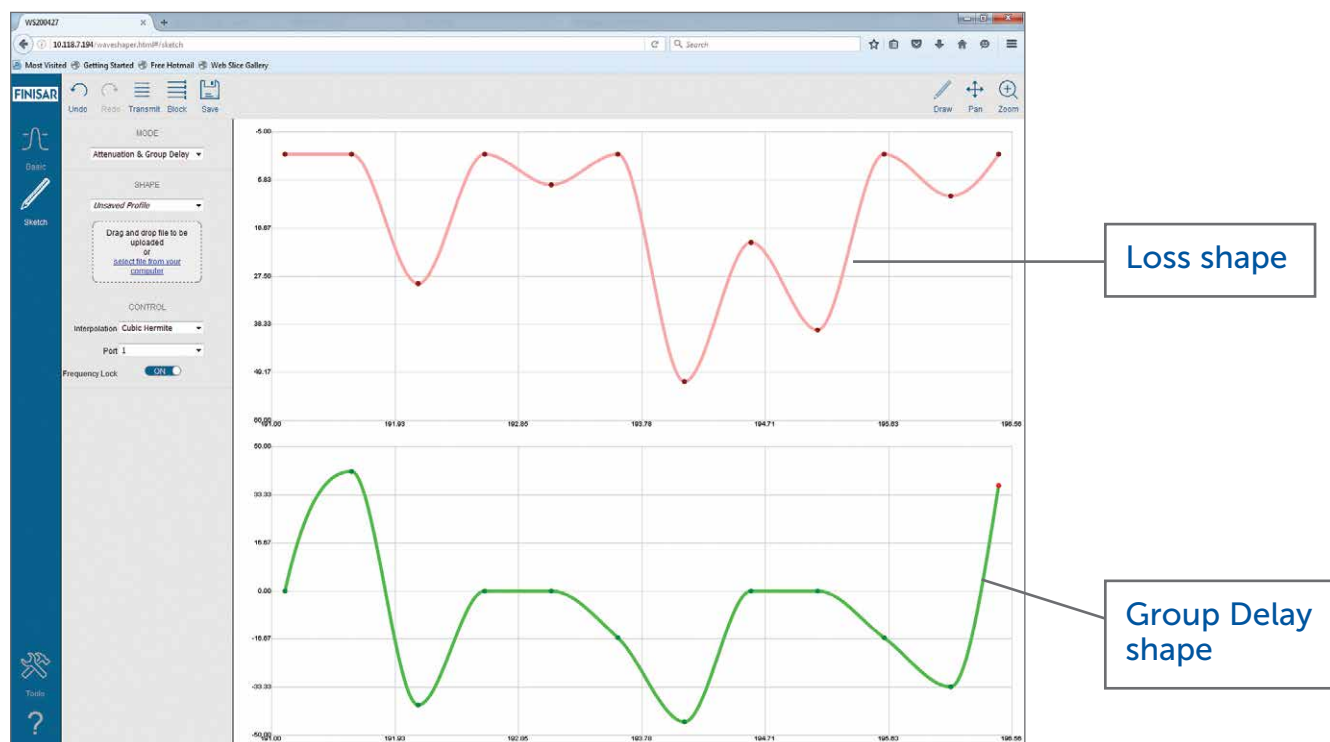
WaveShaper – Application Programming Interface (API)

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.

WaveShaper - How does it work?

The WaveShaper family is based on Finisar's 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.
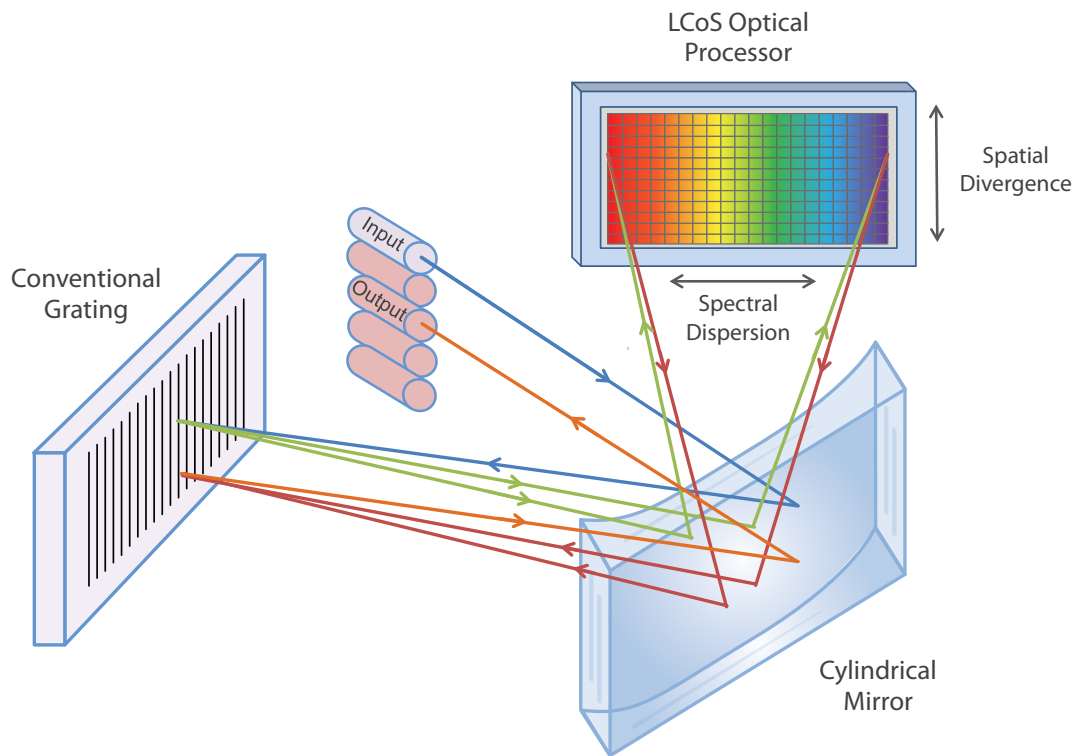
WaveShaper Videos on YouTube

Learn more about the family of WaveShaper instruments by viewing video product demonstrations on Finisar's YouTube channel, available at bit.ly/XdGnTg. Alternatively you may access these videos by searching for "Finisar" and "WaveShaper" on www.youtube.com.

Application Notes

A number of application notes are available on www.finisar.com/instruments. They contain valuable information and guidelines on how to make most use of the WaveShaper instrument:

* Creating Simple Filter Shapes in Excel LabVIEW and MATLAB
* Dispersion Trimming
* Filter Bandwidth Definition
* Group Delay Ripple Compensation
* Pulse Burst Generation
* Automated Gain Flattening

References

1. "Spectral modeling of channel band shapes in wavelength selective switches", Cibby Pulikkaseril, Luke A. Stewart, Michaël A. F. Roelens, Glenn W. Baxter, Simon Poole, and Steve Frisken, Optics Express, Vol. 19, Issue 9, pp. 8458-8470 (2011)
2. "LCOS based WaveShaper technology for optical signal processing and performance monitoring", Schröder, J. et al, Proc OECC 2012, Korea, July 2012
3. "An optical FPGA: Reconfigurable simultaneous multi-output spectral pulse-shaping for linear optical processing", Jochen Schröder; Michaël A. F. Roelens; Liang B. Du; Arthur J. Lowery; Steve Frisken; Benjamin J. Eggleton, Optics Express, Vol. 21, Issue 1, pp. 690-697 (2013)

WaveShaper Specifications

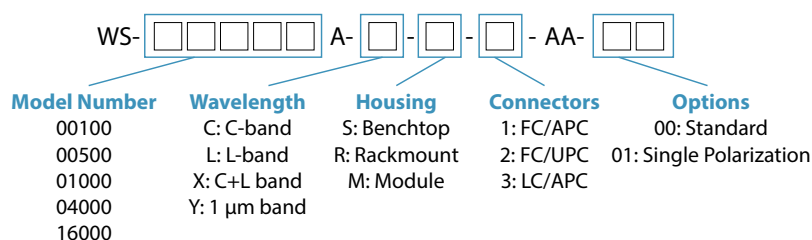| Model		100A	500A	1000A, 4000A	16000A	1000A/SP [Note 1]	1000A/L, 4000A/L	1000A/X, 4000A/X
Optical Ports	Port Configurations	1x1		1x1 (1000) 1x4 (4000)	1x19, 4x16, 8x12, 10x10	1x1	1x1 (1000) 1x4 (4000)	
Filter Control	Operating Frequency Range	191.1 THz to 196.46 THz (1526.0 nm to 1568.7 nm)				191.250 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)	187.275 THz to 196.275 THz (1527.4 nm to 1600.8 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 - 9 THz (0.16 nm - 73.4 nm)
	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						< 6.5 dB
	Insertion Loss Non-Uniformity	0.7 dB					0.7 dB [Note 2]	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	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: Specification is valid over the frequency range of 187.0 to 191.0 THz. From 186.35 to 187.0 THz the insertion loss non-uniformity is <1.0 dB max.

Configuration Guide

	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-X-S-1-AA-00	Programmable Optical Filter	C+L	Benchtop	SM	FC/APC
	WS-01000A-X-M-1-AA-00	Programmable Optical Filter	C+L	Module	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-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-X-S-1-AA-00	Programmable Optical Processor	C+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-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	X: C+L band	M: Module	3: LC/APC	
04000	Y: 1 µm band			
16000				

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