Product Guide

WaveShaper Family of Programmable Optical Processors

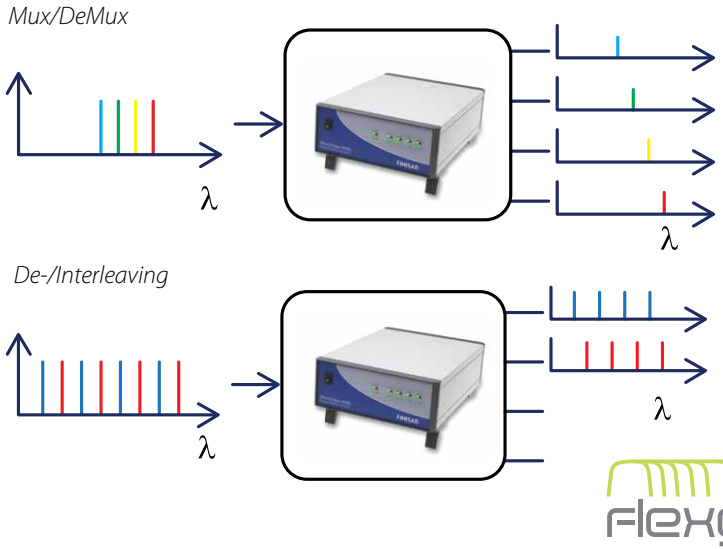
FINISAR®

The WaveShaper™ family of Programmable Optical Processors provides a range of programmable 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

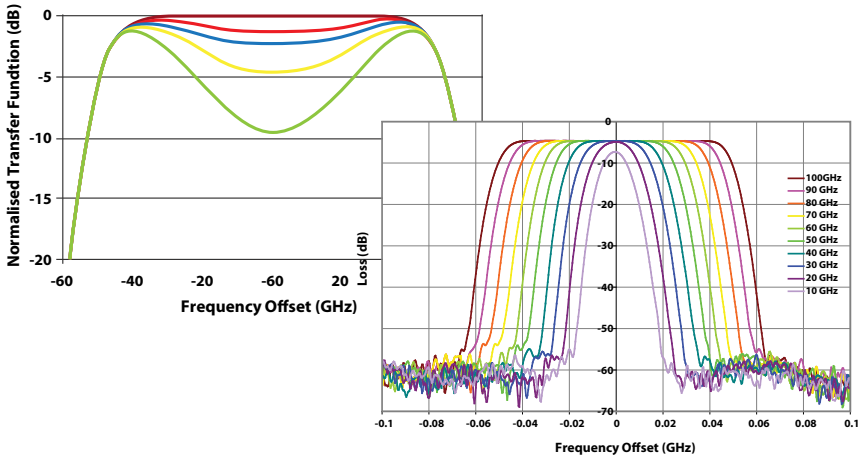
Mux/DeMux and De-/Interleaving

The WaveShaper 4000S 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 new 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.



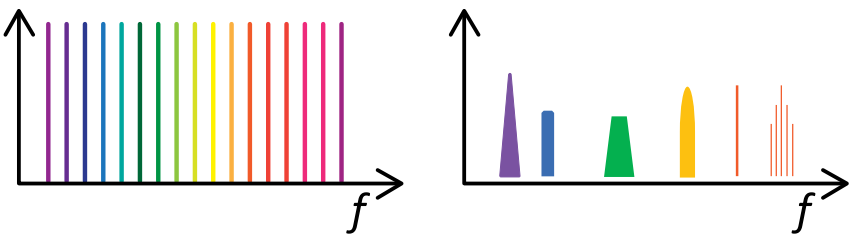
Filtering with arbitrary spectral shapes

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.



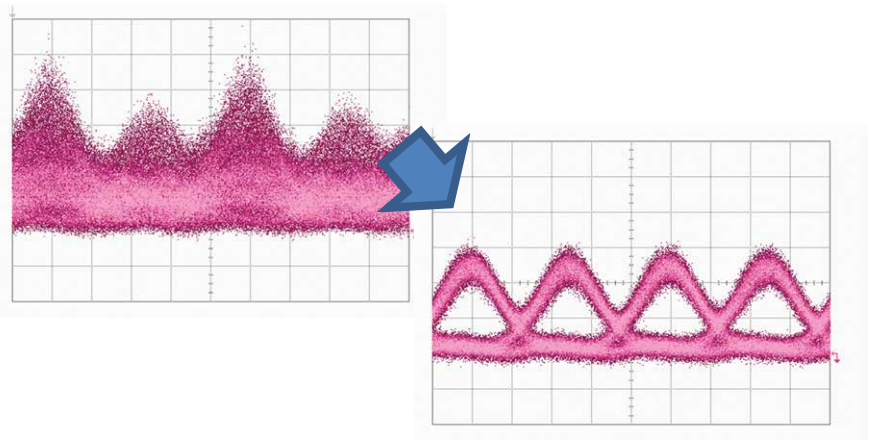
Optical Comb Generation

Generation of 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

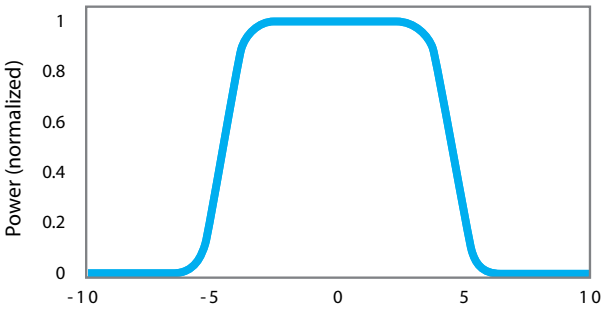
In system testing, verification of dispersion budgets and verification of sensitivity of transmission systems to group delay ripple (and other dispersion imperfections) is of importance. Several members of the WaveShaper family allow setting dispersion values of up to 100 ps/nm (per 50 GHz channel) as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



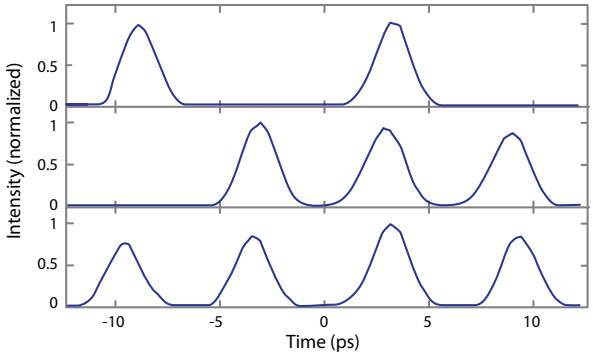
Laser Pulse Compression, Shaping and Generation

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.



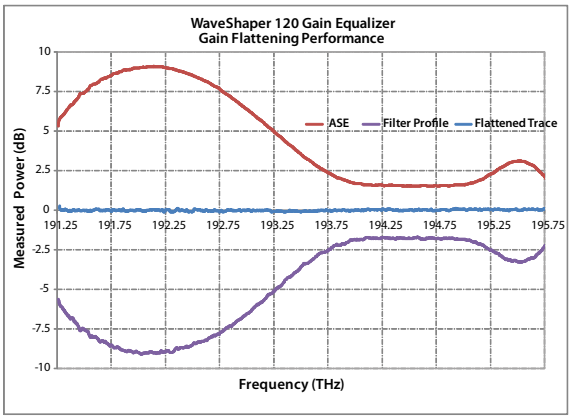
Rectangular pulse



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.



Applications

Fourier Processing

Fourier processing is available in the WaveShaper 4000 and in the WaveShaper 16000 and allows the user 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. 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.

The Fourier Processing algorithms have been developed with the support of leading edge research groups (see e.g. Reference 3 on page 10). The capabilities of Fourier processing on the WaveShaper 4000 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. Fourier processing is built into the WaveManager Application Suite and supported on all new WaveShaper 4000 and WaveShaper 16000 programmable optical processors. Upgrades are available for existing units.

Figure 1: Splitter

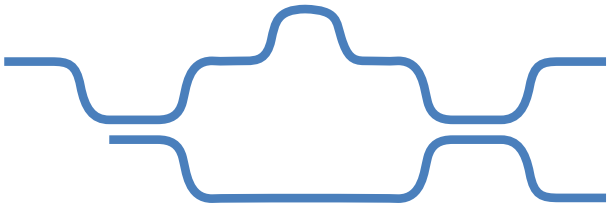


Figure 2: Delay Line Interferometer

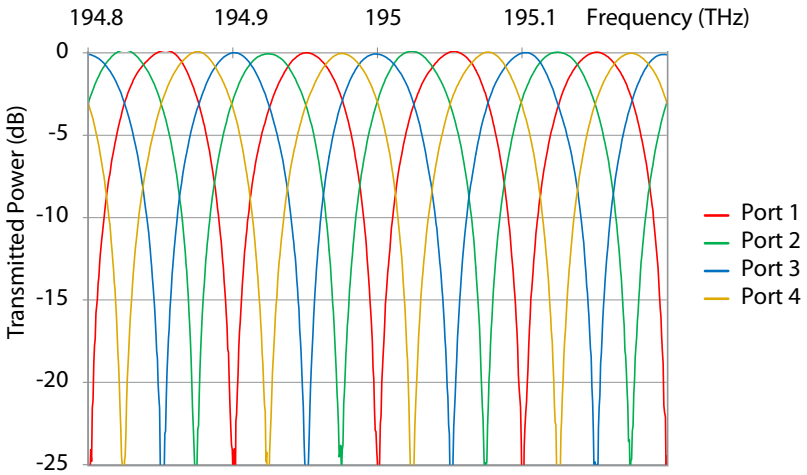


Figure 3: Optical transfer function of a DQPSK demodulator generated in a WaveShaper 4000S using the Fourier processor software

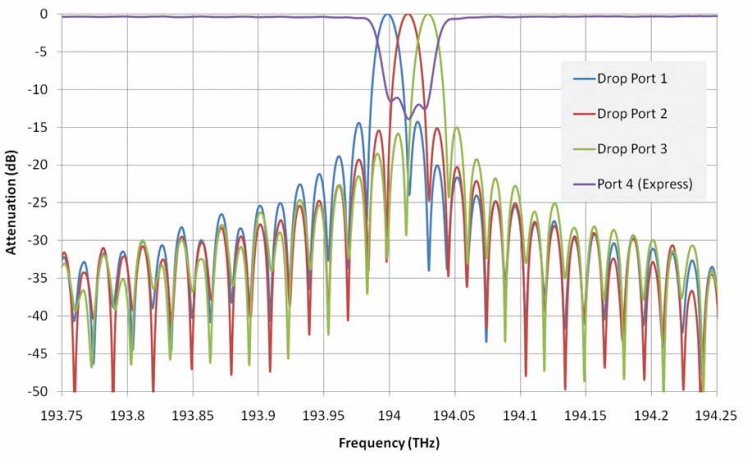
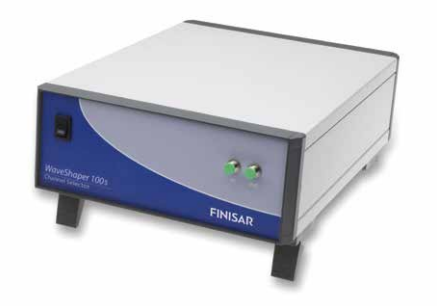


Figure 4: Optical transfer function of an all-optical DFT filter with 15 GHz FSR

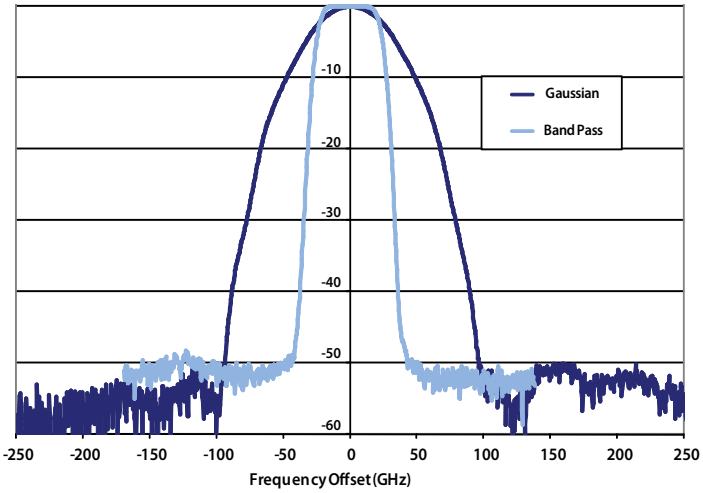
Products



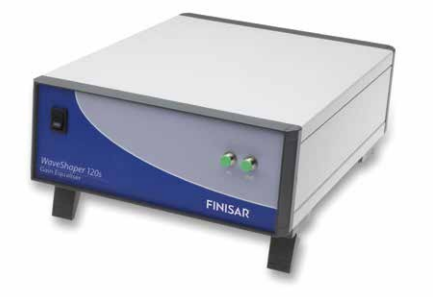
WaveShaper 100S

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.

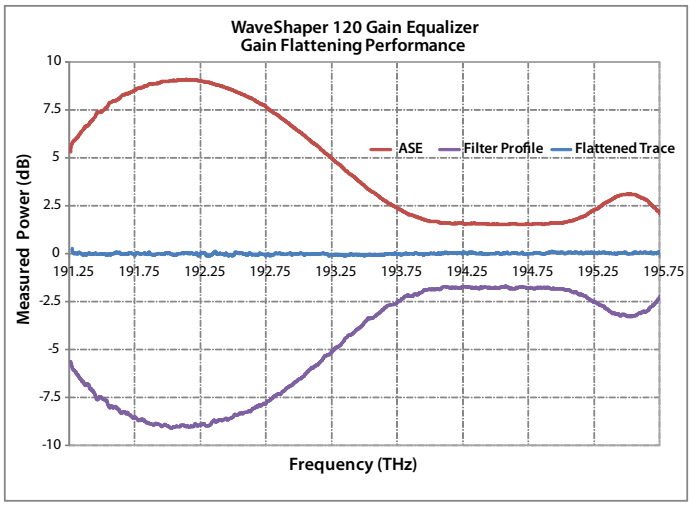


WaveShaper 120S

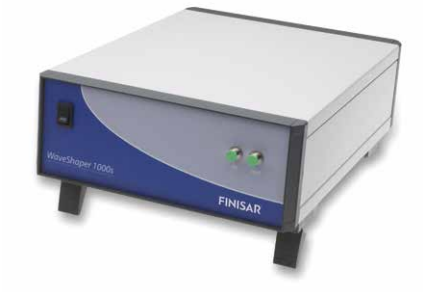


Gain Equalizer

Programmable equalizer which allows arbitrary attenuation shapes with 0.01 dB resolution in the range of 0 -10 dB over the whole C- band. Optimized for gain flattening of high-performance EDFAs. Gridless operation for next-generation transmission system development.



Products



WaveShaper 1000S

Available for C-, L- and C+L band

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 1000S. 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.

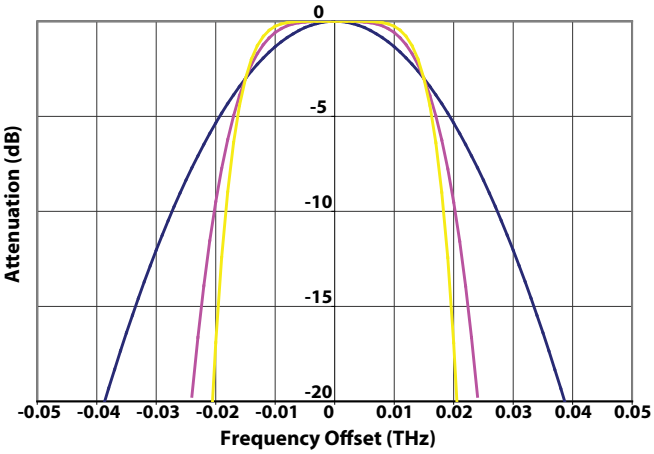
WaveShaper 4000S

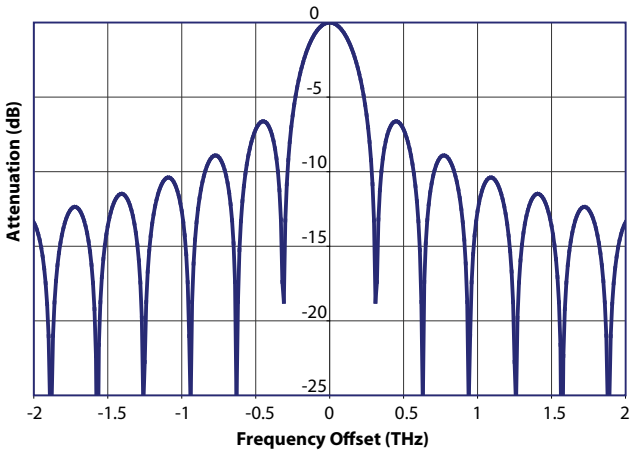
Available for C-, L- and C+L band

Multiport Optical Processor

Extends the capability of the WaveShaper 1000S 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 Fourier processing. This new function allows splitting the signal at one wavelength between multiple output ports, as described in more detail on page 4.





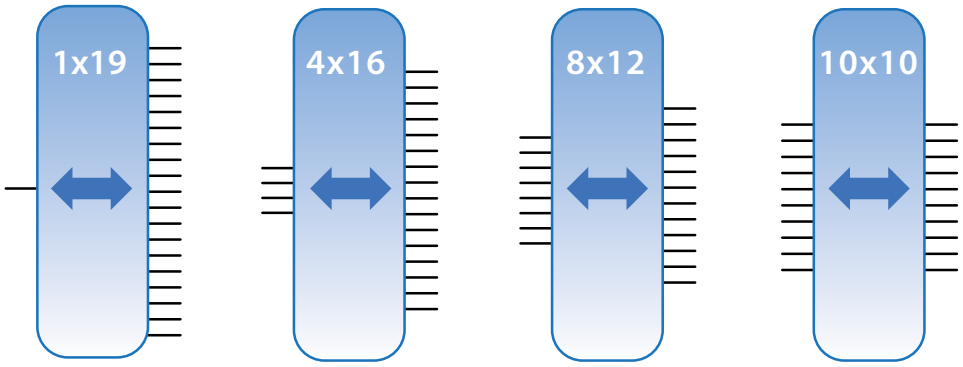
Example filter shapes generated with WaveShaper 1000/4000 programmable optical processor

Products

WaveShaper 16000S

Multiport Optical Processor

The WaveShaper 16000S Multiport 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.



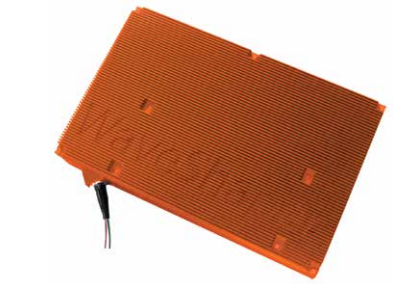
Covering the entire C-band, the WaveShaper 16000S combines precise control of filter wavelength, bandwidth, shape and phase with the ability to switch and combine multiple signals in an "Add" or "Drop" configuration. The WaveShaper 16000S also supports Fourier processing in a 1x16 configuration.

MxN WSS are key components in next generation colorless, directionless (CD) ROADMs. Finisar's WaveShaper 16000S 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 16000S 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 1 x 4 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 shall 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 16000S 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 (S-Series) models are also available as M-Series module.

Products

WaveShaper 1000S/SP

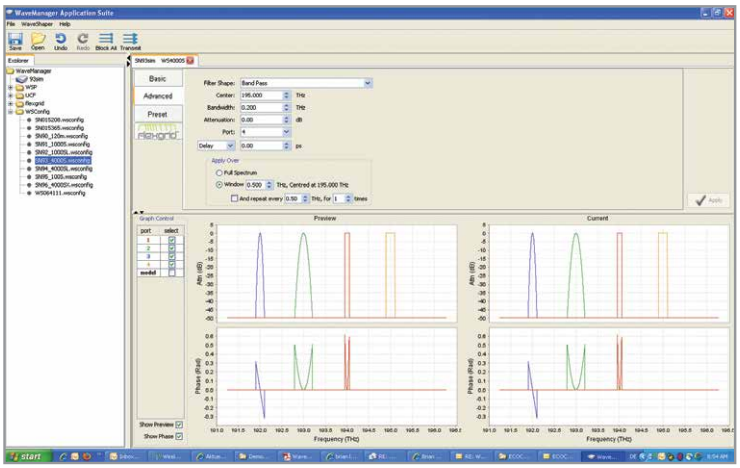
Programmable Single Polarization Filter

The WaveShaper 1000S/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 1000S/SP operating in the 1 µm wavelength window for pulsed laser applications. Please find further details on www.finisar.com/instruments.

Extended Warranty

Most WaveShaper instruments are available with an extended warranty package. This package has to be purchased at the time of the purchase of the instrument and extends the standard warranty coverage of the first year also to the second and the third year. Please ask your sales representative in case this is of interest to you.

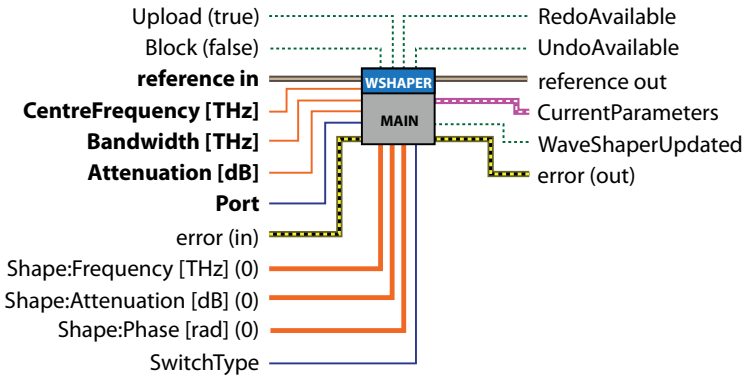


WaveManager Software

Easy-to-use User Interface

All members of the WaveShaper family can be controlled through the WaveManager Application Suite which provides an intuitive user interface for real-time control of up to four separate WaveShapers. The Flexgrid™ option simplifies the emulation of flexible bandwidth WSS for advanced network development.

The WaveManager software package can be downloaded from www.finisar.com/instruments.



Full API plus LabVIEW™ Drivers

For Test Automation

Control software is also provided for both Windows and Unix (Linux) which allows full control of all aspects of the WaveShaper functionality. A common API across all operating systems makes it easy to integrate the WaveShaper functionality into the users system. LabVIEW™ drivers are provided as well as bindings for common programming and scripting languages such as C, Visual Basic, Python, etc.

WaveSketch

WaveSketch is an exciting capability which enables users of all versions of the WaveShaper 120, 1000, 4000 and 16000 to manually create filter shapes using a 'drag and drop' graphical interface. As both, the loss and the phase (only for 1000, 4000 and 16000) of the filter curve is manipulated on the 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 on the right shows a WaveSketch screenshot in which defined points can be added, deleted or modified as required. The filter shapes generated in WaveSketch can be saved in the WaveShaper *.wsp format and then re-used in either WaveSketch or WaveManager. WaveSketch is part of the installation package of the WaveManager Application Suite.

Screenshot of WaveSketch application showing user-defined filter shape created by the WaveSketch drag and drop interface

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.

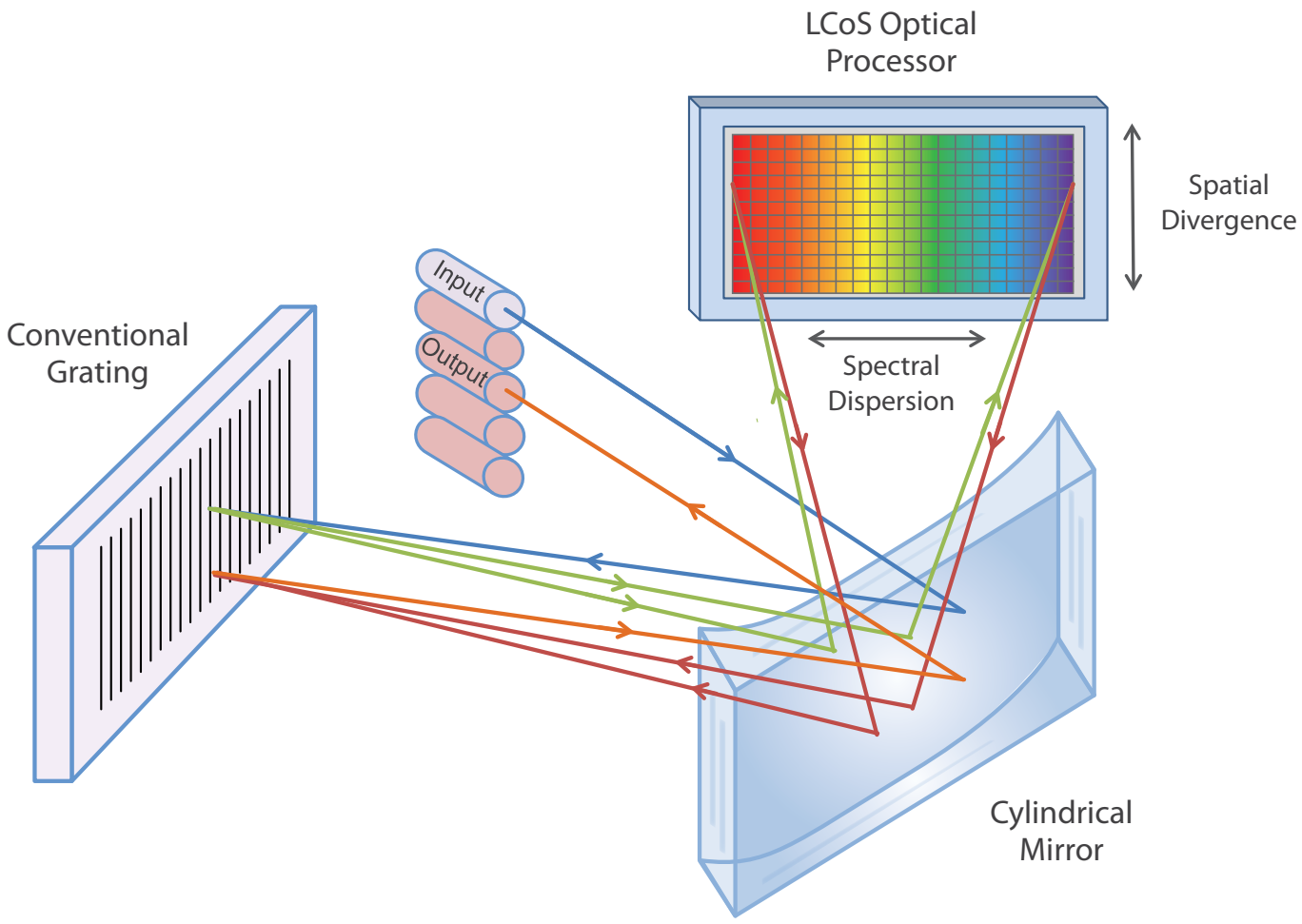
Application Notes

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

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.



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

Specifications guaranteed except where stated as typical (typ).

Model		120M, 120S	100M, 100S	1000S, 1000M 4000S, 4000M	16000S	1000S/L, 1000M/L 4000S/L, 4000M/L	1000S/X, 1000M/X 4000S/X, 4000M/X	1000S/SP, 1000M/SP Note 1
Filter Control Note 2	Operating Frequency Range	191.250 THz to 196.275 THz (1527.4 nm to 1567.5 nm)		191.250 THz to 196.275 THz (1527.4 nm to 1567.5 nm)		186.350 THz to 191.000 THz (1569.6 nm to 1608.7 nm)	187.275 THz to 196.275 THz (1527.4 nm to 1600.8 nm)	191.250 THz to 196.275 THZ (1527.4 nm to 1567.5nm)
	Filter Bandwidth	5 THz	10 GHz - 1000 GHz	10 GHz - 5 THz (0.08 – 40 nm)		10 GHz - 4.65 THz (0.08 - 35 nm)	20 GHz to 9 THz	10 GHz – 5 THz
	Filter Shape	Arbitrary	Band-pass, Gaussian	Arbitrary				
	Frequency Setting Resolution	±1 GHz (±8 pm)						
	Frequency Setting Accuracy	±2.5 GHz (±20 pm)					± 5 GHz	±2.5 GHz
	Bandwidth Setting Resolution	n/a	±1 GHz (±8 pm)					
	Bandwidth Setting Accuracy	n/a	±5 GHz (±40 pm)				± 10 GHz	±5 GHz
	Bandwidth Setting Repeatability	n/a	±2.5 GHz (±20 pm)				± 5 GHz	±2.5 GHz
	Group Delay Control Range	n/a		-25 ps to +25 ps			-15 ps to +15 ps	-25 ps to +25 ps
	Attenuation Control Range	0 to 10 dB	n/a	0 to 35 dB				
	Attenuation Setting Resolution	0.01 dB	n/a	0.01 dB				
	Attenuation Setting Accuracy	±1.0 dB	n/a	±1.0 dB from 0 to 10 dB, ±10 % from 10 to 30 dB				
	Settling Time	<500 ms						
Optical Ports	Connector Interface	FC/PC, FC/APC			LC/APC	FC/PC, FC/APC		FC/APC
	Port Configurations	1x1		1x1 (1000) 1x4 (4000)	1x19, 4x16, 8x12, 10x10	1x1 (1000) 1x4 (4000)		
Loss	Insertion Loss	6.5 dB (typ. 4.5 dB)						
	Insertion Loss Non-Uniformity	0.7 dB (typ. 0.5 dB)				0.7 dB (typ. 0.5 dB) Note 3	1 dB (typ)	0.7 dB (typ. 0.5 dB)
	PDL	0.7 dB (typ. 0.3 dB)					1 dB (typ)	n/a
	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	15 to 35 ºC						
	Operating Humidity	10 to 90 %						
Electrical	Communications Interface	USB 2.0						
	Power Consumption	<50 VA						

Note 1: Measured on signal in slow axis
Note 2: Measured over 60 GHz passband on a 100 GHz flat-top filter unless specified.
Note 3: 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	Connector type
WaveShaper 100S	WS-AA-0100S-ZZ-H	Tunable Optical Filter	C	Benchtop	FC/APC
	WS-AA-0100S-RM-H	Tunable Optical Filter	C	Rackmount	FC/APC
WaveShaper 120S	WS-AA-0120S-ZZ-H	Programmable Gain Equalizer	C	Benchtop	FC/APC
	WS-AA-0120S-RM-H	Programmable Gain Equalizer	C	Rackmount	FC/APC
WaveShaper 1000S	WS-AA-1000S-ZZ-H	Programmable Optical Filter	C	Benchtop	FC/APC
	WS-AA-1000S-ZZ-F	Programmable Optical Filter	C	Benchtop	FC/UPC
	WS-AA-1000S-LB-H	Programmable Optical Filter	L	Benchtop	FC/APC
	WS-AA-1000S-LB-F	Programmable Optical Filter	L	Benchtop	FC/UPC
	WS-AA-1000S-XB-H	Programmable Optical Filter	C+L	Benchtop	FC/APC
	WS-AA-1000S-RM-H	Programmable Optical Filter	C	Rackmount	FC/APC
	WS-AA-1000S-SP-H	Programmable Single Polarization Filter	C	Benchtop	FC/APC
WaveShaper 4000S	WS-AA-4000S-ZZ-H	Multiport Optical Processor	C	Benchtop	FC/APC
	WS-AA-4000S-ZZ-F	Multiport Optical Processor	C	Benchtop	FC/UPC
	WS-AA-4000S-LB-H	Multiport Optical Processor	L	Benchtop	FC/APC
	WS-AA-4000S-XB-H	Multiport Optical Processor	C+L	Benchtop	FC/APC
	WS-AA-4000S-RM-H	Multiport Optical Processor	C	Rackmount	FC/APC
WaveShaper 16000S	WS-AA-16000S-ZZ-D	Multiport Optical Processor	C	Benchtop	LC/APC
	WS-AA-16000S-RM-D	Multiport Optical Processor	C	Rackmount	LC/APC

Configurations for the M-Series of instruments and further configurations of the S-Series of instruments are available upon request.

Technology Innovator.
Broad Product Portfolio.
Trusted Partner.

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