



EUROPEAN UNION
European Structural and Investing Funds
Operational Programme Research,
Development and Education



Purchase Contract

entered into pursuant to Section 2079 et seq. of Act No. 89/2012 Coll., the Civil Code (hereinafter the "Civil Code")

I. CONTRACTUAL PARTIES:

1. Buyer:

Fyzikální ústav AV ČR, v. v. i.

(Institute of Physics of the Czech Academy of Sciences, a public research institution)

with its registered office at Na Slovance 2

PSČ 182 21 Praha 8

represented by: RNDr. Michael Prouza, Ph.D. - Director

Registered in the register of public research institutions of the Ministry of Education, Youth and Sports of the Czech Republic

Id. No.: 68378271

Tax Id. No.: CZ68378271

(hereinafter the "Buyer")

and

2. Seller:

OptiXs, s.r.o.

with its registered office at: Křivoklátská 37/3, Letňany,

PSČ 199 00 Praha 9

represented by: Ing. Aleš Jandík, CEO

Id. No.: 02016770

Tax Id. No.: CZ02016770

enrolled in the Commercial Register at the Municipal Court in Prague, section C, enclosure 212818

(Hereinafter the "Seller"; the Buyer and the Seller are hereinafter jointly referred to as the "Parties" and each of them individually as a "Party").

enter, on the present day, month and year, into this Purchase Contract (hereinafter the "Contract")

II. INTRODUCTORY PROVISIONS:

1. The Buyer is the beneficiary of a subsidy from the Ministry of Education, Youth and Sports of the



Czech Republic for the project “Advanced designing of functional materials: From mono – to BI –And TRI- chromatic excitation with tailored laser pulses”, reg. No. CZ.02.1.01/0.0/0.0/15_003/0000445, within the Operational Programme “Research, Development and Education (hereinafter the “**BIATRI Project**”) and HiLASE Centre of Excellence, reg. No: CZ.02.1.01/0.0/0.0/15_006/0000674 (hereinafter „**HiLASE CoE**”).

2. The objective of the BIATRI Project is to create new research team in the field of the advanced designing of functional materials. This team will be managed by the excellent foreign researcher. To secure the quality of the scientific result it is important to build new laser laboratory. Special emphasis will be put on strategic partnership and cooperation with prestigious international partners. The implementation of the BIATRI project would in addition contribute to the increase of the competitiveness of the centre as well as of the region.

The project focuses on the significant upgrade of the current infrastructure towards the new HiLASE centre of excellence. The project is implemented in the close cooperation with the state-of-the-art knowledge institution - British STFC. The extensive knowledge and experiences of the partner contribute to the smooth implementation of upgrades and to the setting of the future operation of the centre. The innovation programme is the necessary prerequisite for the sustainability of the centre as well as for the development of the region.

3. The Seller was selected as the winner of a public procurement procedure announced by the Buyer for the public contract called “Arbitrarily programmable optical filters” (hereinafter the “**Procurement Procedure**”).
4. The Seller acknowledges that the Buyer is not, in connection to the subject matter of this Contract, an entrepreneur, and also that the subject matter of this Contract is not related to any business activities of the Buyer.
5. The documentation necessary for the execution of the Contract is
 - a) *Technical Specifications, which forms an integral part hereof as its Annex 1 (hereinafter the “**TS**”); this TS also formed a part of the tender documentation for the Procurement Procedure in the form of Annex No.3,*
 - b) *The Seller’s bid submitted for the Procurement Procedure, (hereinafter the “**Sellers’s Bid**”); the Sellers’s Bid forms form Annex 2 to this Contract and an integral part hereof.*
6. The Seller represents that it has all the professional prerequisites required for the supply of the Device under the Contract, is authorised to perform the Contract and there are no obstacles on the part of the Seller that would prevent the Seller from fulfilling the Contract. The Seller is aware that the Buyer considers the participation of the Seller in the Procurement Procedure as a confirmation of the fact that the Seller is within the meaning of section 5(1) of the Civil Code capable of acting with due care and diligence that is connected with its profession and that, if the Seller does not act with the due



care and diligence, it shall be to its disadvantage. The Seller shall not exploit its status as a professional nor its market position to the disadvantage of the Buyer and to achieve obvious and unreasonable imbalance in the mutual rights and duties of the Parties.

7. The Parties declare that accept the “risk of changed circumstances” within the meaning of Sec 1765(2) of the Civil Code.
8. The Parties declare that they shall maintain confidentiality with respect to all facts and information they learned in connection with the Contract or during the performance of the Contract, and the disclosure of such facts or information could cause damage to the other Party. This confidentiality provision does not affect duties of Parties with respect to applicable legislation.

III. SUBJECT OF THE CONTRACT:

1. The subject matter of this Contract is the obligation of the Seller to deliver to the Buyer two Arbitrarily programmable optical filters with qualities and technical parameters described in the TS (hereafter the “**Devices**”) in accordance with the terms and conditions of the Contract.
2. The following activities form an integral part of the performance to be provided by the Seller:
 - a) packing and transportation of the Devices to the place of performance, unpacking and checking in the extent specified in the TS,
 - b) preparation of and the handover of the instructions and manuals for users of the Devices,
(The Devices and the activities required under para 2 above are hereinafter referred to as the “**Delivery**”).
3. The Buyer shall take over properly and timely delivered Devices and shall pay the Seller the Purchase Price under the terms and conditions of the Contract.
4. The Seller hereby undertakes, under the terms and conditions hereof, to deliver to the Buyer, properly and in timely manner the Devices, to hand over the Devices to the Buyer and to carry out activities specified in paragraph 2 above. The Seller shall ensure the compliance of the Devices with the Seller’s Bid and with all valid legal, technical and quality standards in the extent specified in the TS, and the Seller shall ensure that the Devices shall have a properly issued and valid CE certificate, if applicable.
5. During the performance of the Contract, the Seller shall cooperate with the Buyer and shall follow the instructions of the Buyer unless such instructions contravene the Contract.

IV. OWNERSHIP TITLE:

The ownership right passes to the Buyer upon the signature of the Handover protocol (as is defined below).



V. PURCHASE PRICE AND PAYMENT TERMS

1. The Purchase Price for the Delivery is the maximum price that cannot be exceeded and is 75.880 USD without value added tax (hereinafter the “**Purchase Price**”). The Seller is VAT payer.
2. Unless provided otherwise in this Contract, all the prices in this Contract are exclusive of value added tax, which shall be paid according to the applicable regulations or international agreements.
3. The Purchase Price includes all the costs related with the performance of the Contract, including the cost of transport of the Devices to the place of delivery, the costs of Verification and Training, the costs of insurance including unloading until the Delivery, licenses, taxes and fees, etc. The Purchase Price is fixed and shall not be changed regardless of the changes of prices or changes in the foreign exchange rates.
4. The Purchase Price shall be paid after the signature of the Handover protocol.
5. The Buyer shall pay the Purchase Price on the basis of an invoice issued by the Seller.
6. Invoices shall be payable within thirty (30) days of the date of their delivery to the Buyer. Invoices will be issued separately for the two projects BIATRI and HiLASE CoE based on the instructions of the Buyer. Payment of the invoiced amount means the date of its remitting to the Seller’s account. In conformity with the applicable tax regulations of the Czech Republic, the tax documents – invoices issued by the Seller hereunder shall include the following details:
 - the business name/designation and registered office of the Buyer
 - the tax identification number of the Buyer
 - the business name/designation and registered office of the Seller
 - the information whether the Seller is VAT payer or not
 - the tax identification number of the Seller
 - the registration number of the tax document
 - the scope and object of the Delivery or Services
 - the date of issue of the tax document
 - the date of the supply or the date of acceptance of the consideration, whichever is earlier, if it differs from the date of issue of the tax document
 - the price
 - the registration number of the Contract, which the Buyer shall communicate to the Seller at his request before the invoice is issued
 - a declaration that the charged price is provided for the purposes of the "Advanced designing of functional materials: From mono – to BI –And TRI- chromatic excitation with tailored laser pulses, reg. No. CZ.02.1.01/0.0/0.0/15_003/0000445” or „HiLASE Centre of Excellence, reg. no: CZ.02.1.01/0.0/0.0/15_006/0000674“

must also comply with any double taxation treaties applicable to the given case.



7. The last invoice in each calendar year must be delivered by the Seller to the Buyer's no later than by December 15 of the given calendar year. If a tax document – invoice does not comply with the payment terms stipulated by the Contract or if it does not comply with the requirements stipulated by law or if it is not delivered to the Buyer by the aforementioned date, the Buyer is entitled to return the tax document – invoice to the Seller as incomplete, or incorrectly issued, for supplementation or issue of a new invoice, as appropriate, within five (5) business days of the date of its delivery to the Buyer. In that case, the Buyer is not in delay in payment of the Purchase price or part thereof or the Price for Services and the Seller shall issue a corrected invoice with a new identical Maturity Period, which shall commence on the date of delivery of the corrected or newly issued tax document – invoice to the Buyer.
8. The Buyer's invoicing details are set out in Art. I hereof.

VI. TIME OF PERFORMANCE OF THE CONTRACT:

1. The Seller shall deliver the Devices to the place of delivery within 12 weeks from the signature of this Contract.
2. The Seller acknowledges that the deadlines stated in this article are of essential importance to the Buyer with respect to the timeline of the BIATRI Project and HiLASE CoE and with respect to the deadline by which both Projects are to be implemented, and that the Buyer could incur damage as a result of failure to meet the above stipulated deadlines.

VII. PLACE OF DELIVERY

The place of delivery shall be HiLASE centrum, Za Radnicí 828, Dolní Břežany in the Central Bohemian Region in the Czech Republic. At the request of the Seller made prior to the transport of the Devices to the place of delivery the Buyer shall inform the Seller of the exact address.

VIII. HANDOVER OF THE DEVICE

1. The Devices shall be at the place of delivery handed over on the basis of handover protocol, which shall contain the following information:
 - identification of the Seller, the Buyer and all subcontractors, if there are any,
 - description of the Devices including the list of individual items of the Devices,
 - the list of defects and deficiencies of the Devices, if there are any, and the deadlines for their removal,
 - the signature and the date of the handover

(hereinafter the “**Handover protocol**”).

2. Instructions and manuals shall be attached to the Handover protocol.



3. The functionality supervision of the Devices shall be made by the Seller prior to the moment of the handover.
4. The delivery of the Devices marks the passage of the risk of damage to the Devices from the Seller on the Buyer; however, this passage of risk of damage does not in any manner prejudice the Seller's liability for damage due to the defects of the Devices.
5. The Buyer shall not be obliged to take over the Devices with defects or deficiencies, regardless of the fact that such defects or deficiencies may not compromise the functionality and use of the Devices. Should the Buyer not exercise its right not to accept the Devices even when manifesting defects or deficiencies, the Parties shall list these in the Handover Protocol, including the manner and deadline for their removal. Should the Parties not specify a deadline for the removal of defects or deficiencies in the Handover protocol, then these must be removed within 14 days from the date of the handover.

IX. WARRANTY

1. The Seller shall provide the warranty for each Device for a period of 12 months.
2. The warranty period shall commence on the date of the signature of the Handover Protocol. However, if the Devices are taken over with defects or deficiencies, the warranty period shall commence on the date of the removal of the last defect or deficiency by the Seller.
3. If the Devices which contains its own warranty documents then the warranty period shall be the period specified in such documents, unless does not exceed the warranty period stipulated in the Contract.
4. The Buyer shall raise a claim for removal of a defect of the Devices without undue delay after discovering the defect, but not later than on the last day of the warranty period, by means of a written notice sent to the Seller's authorised representative for technical matters set out herein (hereinafter the „**Warranty Claim**“). An email is considered to be an adequate way to initiate a Warranty Claim. Warranty Claim sent by the Buyer on the last day of the warranty period shall be deemed to have been made in time.
5. In the Warranty Claim the Buyer shall describe the defect and the manner in which the defect is to be removed. The Buyer is entitled to:
 - request the removal of defects by substitute delivery, or
 - request that the defects are repaired, or
 - request an appropriate discount on the Purchase Price.

The choice among the above specified claims shall be made by the Buyer.



6. The Seller agrees to remove the defects of the Devices free of charge.
7. Defects must be removed within the period of fourteen (14) days from the date, on which the Warranty Claim was notified to the Seller, at the latest, unless the Buyer and the Seller agree otherwise.
8. The Seller shall remove defects of the Devices within periods stated in the Contract also in the instances when the Seller is of the opinion that he is not liable for such defects. In cases when the Seller will not recognize the defect and the Buyer will not agree with such conclusion, the validity of the Warranty Claim shall be ascertained by an expert, which is to be commissioned by the Buyer but on which the Seller also must agree. In the event the expert declared the Warranty Claim as justified, the Seller shall bear the costs of the expert's assessment. If the Warranty Claim is raised unjustly (according to expert's assessment), the Buyer shall reimburse the Seller all reasonably incurred costs associated with removing the defect.
9. The Parties shall execute a record on removal of the defect, in which they shall confirm that the defect was removed. The warranty period shall extend by the time that expires from the date of exercising the Warranty Claim until the defect is removed.
10. In case the Seller fails to remove the defect within the time period set out in the Contract, or within other period as may be agreed by the Parties, or in case the Seller refuses to remedy the defect, the Buyer shall be entitled to have the defect removed at his own cost, and the Seller shall be obliged to compensate the Buyer for all reasonably incurred costs associated with removing the defect within 30 days of the Buyer's request to do so. Under the condition that the repair was professionally done, the scope and length of the warranty remains unaffected by this provision.
11. The warranty shall not cover defects caused by unprofessional handling, non-compliance with the manufacturers' rules of operation and maintenance of equipment accepted by the Buyer from the Seller upon handover, or those of which the Seller advised the Buyer in writing. The warranty shall also not apply to defects caused by intentional conduct.
12. Parties exclude application of the section 1925 (the sentence behind semi-colon) of the Civil Code.
13. The Seller shall provide to the Buyer technical support (consultation of operational, maintenance and other issues regarding the Device) free of charge on the phone no.: +420 607 014 292.

X. CONTRACTUAL PENALTIES

1. In the event the Seller is in delay with performance as stipulated by Art. VI para 1 of this Contract by more than 30 days, the Seller shall pay to the Buyer the contractual penalty in the amount of



- 0.05% of the Purchase Price for each, even commenced day of delay and for every individual case of delay.
2. In the case where the Seller fails to remove defects within the periods stipulated in the Contract, the Seller shall pay to the Buyer a contractual penalty in the amount of 300.00 CZK for each defect on each Device and for each day of delay.
 3. If the Buyer fails to pay the Purchase Price or the Price for Services within the deadlines set out in this Contract, the Buyer shall pay the Seller interest on delay in the amount set forth by the law for each day of delay unless the Buyer proves that the delay with the payment of the Purchase Price was caused by late release of the funds by the provider of the support.
 4. The obliged party must pay any contractual penalties to the entitled party not later than within 15 calendar days of the date of receipt of the relevant claim from the other party.
 5. Payment of the contractual penalties pursuant to this article shall in no way prejudice the Buyer's right to claim compensation for damage incurred by the Buyer as a result of the Seller's breach of obligations to which the penalty applies.
 6. Total amount of contractual penalties, which the Buyer is entitled to enforce pursuant to this Contract, shall not exceed 10 % of the Purchase Price.

XI. TERMINATION OF THE CONTRACT

1. This Contract may be terminated by completing the performance required hereunder, by agreement of the Parties or by withdrawal from the Contract on the grounds stipulated by law or in the Contract.
2. The Buyer is entitled to withdraw from the Contract without any penalty if any of the following events occur:
 - a) The provider of the subsidy or any other control body determines that the expenditures or part of the expenditures incurred on the basis of this Contract are ineligible; or
 - b) The financial subsidy for implementation of the BIATRI Project or HiLASE CoE is withdrawn from the Buyer;
 - c) The Seller has materially breached the obligations imposed thereon by the Contract, specifically i) by being delayed with the performance hereunder by more than 3 months, or ii) Devices fails to meet technical parameters and qualities or other requirements defined in the TS;
 - d) Insolvency proceedings are initiated against the Seller's assets,
 - e) should it become apparent that the Seller provided information or documents in the Seller's bid, which are not true and which could, therefore, influence the outcome of the Procurement Procedure leading to the conclusion of this Contract (Section 223(2)(b) of the Act No. 134/2016 Coll., on public procurement).



3. The Seller is entitled to withdraw from the Contract in the event of material breach of the Contract by the Buyer and in case of events outside the control of the Seller (e.g. natural disasters, etc.).

XII. REPRESENTATIVES OF THE PARTIES

1. The Seller has appointed the following authorised representatives for communication with the Buyer in relation to the subject of performance hereunder:

In technical matters: Ing. Aleš Jandík, jandik@optixs.cz, +420 607 014 292

2. The Buyer has appointed the following authorised representatives for communication with the Seller in relation to the subject of performance hereunder:

In technical matters: Martin Smrž, Ph.D., e-mail: martin.smrz@hilase.cz

XIII. CHOICE OF LAW

1. This Contract and all the legal relationships arising out of it shall be governed by the laws of the Czech Republic.
2. Any disputes arising out of this Contract or legal relationships connected with the Contract shall be resolved by the Parties amicably. In the event that a dispute cannot be resolved amicably within sixty (60) days, the dispute shall be resolved by the competent court in the Czech Republic based on application of any of the Parties.

XIV. FINAL PROVISIONS

1. The Contract with all annexes represents the entire and complete agreement between the Buyer and the Seller.
2. The Parties agree that the Seller shall not be entitled to set off any part of its receivable, or receivable of its sub-debtor against the Buyer or any of his receivables, unless this Contract stipulates otherwise. The Seller shall not be entitled to assign any receivable arising in connection herewith to a third party. The Seller shall not be entitled to assign any rights or obligations arising to him hereunder or any of its parts to third parties.
3. The Seller shall:
 - duly archive all written material prepared in connection with the execution of this Contract and to provide access to the Buyer to these archived documents until 2027. The Buyer shall be



- entitled to take possession of these documents after ten years from the completion of the Contract from the Seller free of charge;
- cooperate during financial inspections carried out in accordance with Act 320/2001 Coll., on Financial Inspections, as amended, i.e. to allow the Managing Authority of the Operational Program Research, Development and Education (hereinafter the “**Sponsor**”) to access also those portions of the bid submitted within the Procedure, the Contract, Orders and related documents which may be protected by special legal regulation, given that all requirements set forth by legal regulation with respect to the manner of executing such inspections will have been observed; the Seller shall bind any of its sub-contractors to comply with this obligation accordingly.
4. In the event that any of the provisions of this contract shall later be shown or determined to be invalid, putative, ineffective or unenforceable, then such invalidity, putativeness, ineffectiveness or unenforceability shall not cause invalidity, putativeness, ineffectiveness or unenforceability of the Contract as a whole. In such event the Parties undertake without undue delay to subsequently clarify any such provision using Sec 553(2) of the Civil Code, or to replace after mutual agreement such invalid, putative, ineffective or unenforceable provision of the Contract by a new provision, that in the extent permitted by the laws and regulations of the Czech Republic, relates as closely as possible to the intentions of the Parties to the Contract at the time of creation hereof.
 5. This Contract becomes valid and effective as of the day of its execution by the authorised persons of both Parties.
 6. This Contract may be changed or supplemented solely in writing.
 7. The Parties agree to publish the full text of this Contract, including its annexes, in the Register of Contracts pursuant to Act No. 340/2015 Coll., on Special Conditions for the Effectiveness of Certain Contracts, the Disclosure of These Contracts and the Register of Contracts (Act on the Register of Contracts).
 8. This Contract is drawn up in English language in four (4) counterparts, each of which is deemed to be the original. Each Party to the Contract shall receive two (2) counterparts.
 9. The following Annexes form an integral part of the Contract:
Annex No. 1: Technical Specifications;
Annex No. 2: The Seller’s Bid;
- In case of any discrepancies between this Contract and its annexes, the provisions of this Contract shall prevail. In case of any discrepancies between Annex No. 1 and the other annexes of this Contract, the provisions of Annex No. 1 shall prevail.
10. The Parties, manifesting their consent with the entire the Contract, affix their signatures below.



EUROPEAN UNION
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Operational Programme Research,
Development and Education



MINISTRY OF EDUCATION,
YOUTH AND SPORTS

Buyer

Signature: _____

Name: RNDr. Michael Prouza, Ph.D.

Position: director

Date: 31.7.2017

Seller

Signature: _____

Name: Ing. Aleš Jandík

Position: CEO

Date: 21.7.2017



ANNEX NO. 1
Technical specifications

Arbitrarily programmable optical filters parameters	
Light modulator type	Liquid crystal-based programmable filter
Quantity	2
Working wavelength range	Min 1020 - 1060 nm
Pulse filter shape	arbitrary amplitude and phase transfer func.
Attenuation control range	Min 0 - 25 dB
Attenuation setting spectral resolution	≤ 0.01 nm
Minimal selectable filter bandwidth	0.5 nm or less
Bandwidth setting resolution	≤ 0.01 nm
Input/output radiation coupling	SM or PM fiber-coupled input and output
Group delay range	± 13 ps
Allowed laser pulse repetition rate	0 - 50 MHz
Communication interface	USB, Ethernet
Control software	Labview drivers, Matlab and C++ control
Housing	Benchtop product
Warranty	12 months



EUROPEAN UNION
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MINISTRY OF EDUCATION,
YOUTH AND SPORTS

ANNEX NO. 2
The Seller's Bid

Product Guide

WaveShaper® Series A
Family of Programmable
Optical Processors

FINISAR®



WEB ENABLED

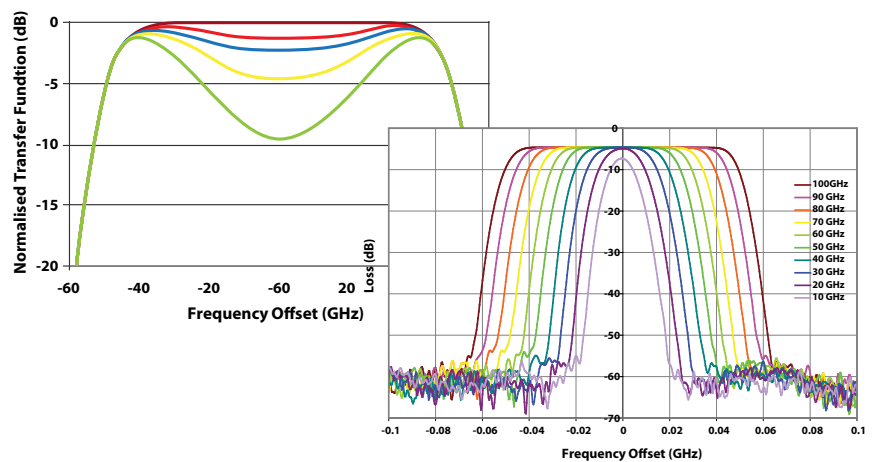
WaveShaper®—Family of Programmable Optical Processors

The new WaveShaper® Series A Programmable Optical Processors provide 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

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

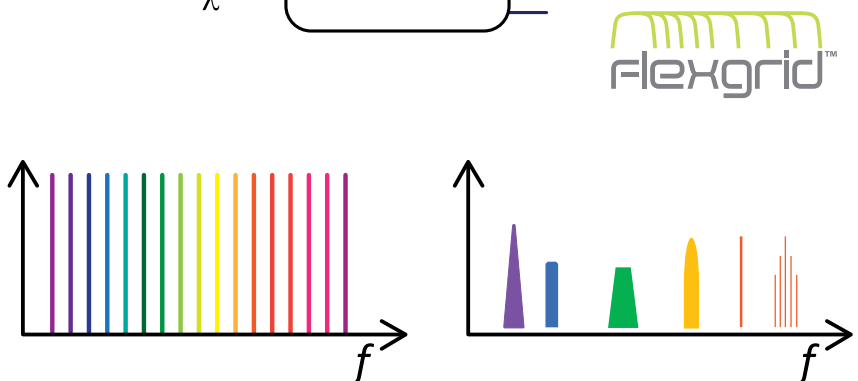


De-/Interleaving



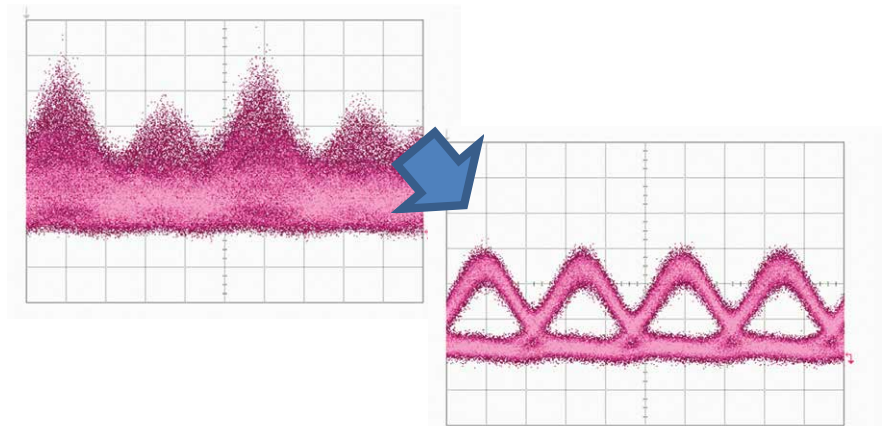
Component and System Loading

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

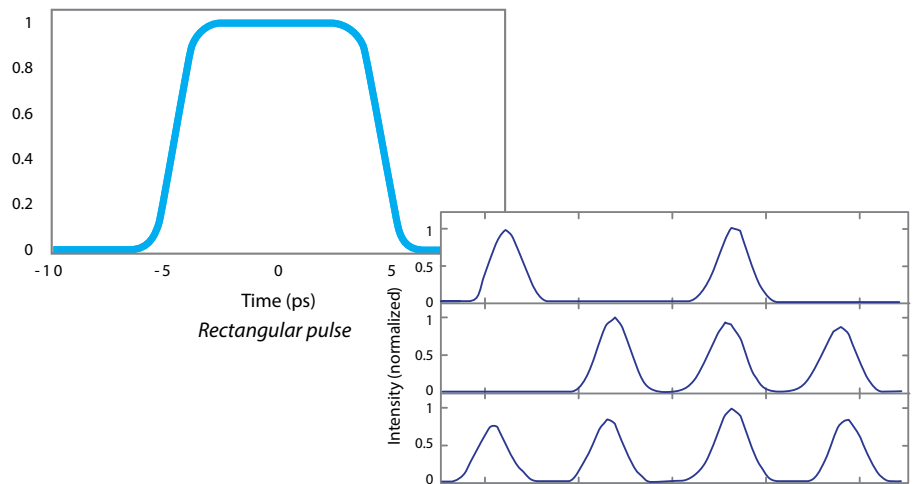
In system testing, verification of dispersion budgets and verification of sensitivity of transmission systems to group delay ripple (and other dispersion imperfections) is of importance. Several members of the WaveShaper family allow setting dispersion values of up to 100 ps/nm (per 50 GHz channel) as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

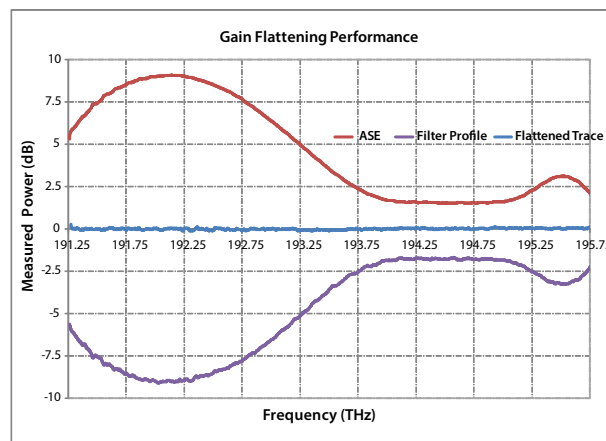
Certain other applications, in particular in the communications area, require specific pulse shapes (like rectangular for example) or particular bit sequences.



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

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

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).

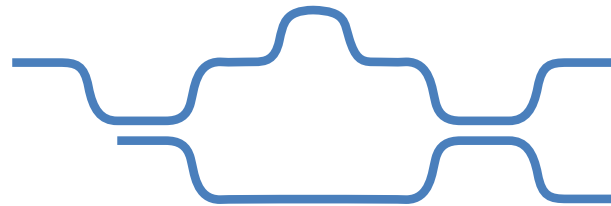


Figure 2: Variable Delay Line Interferometer

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.

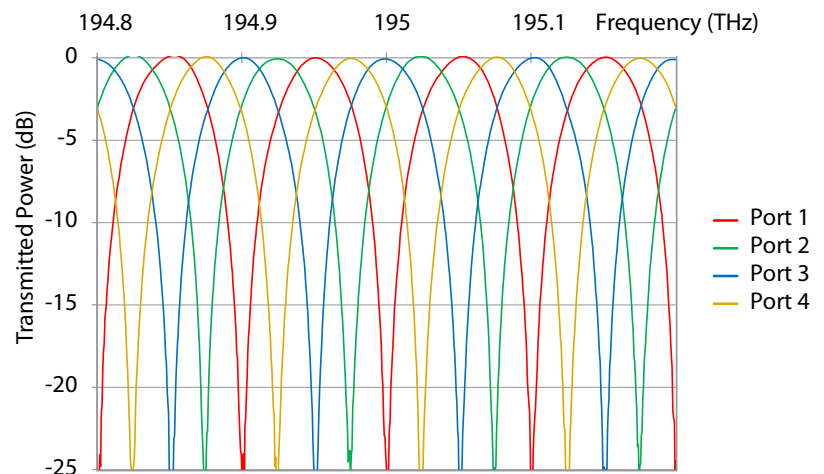


Figure 3: Optical transfer function of a DQPSK demodulator generated in a WaveShaper 4000A using the Fourier processor software

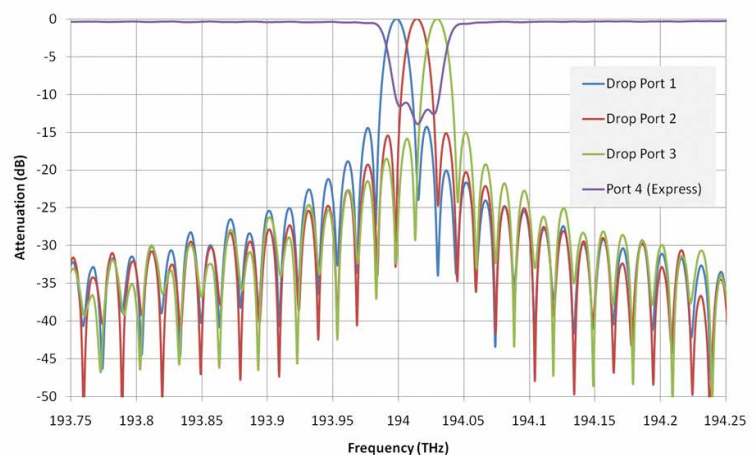


Figure 4: Optical transfer function of an all-optical DFT filter with 15 GHz FSR

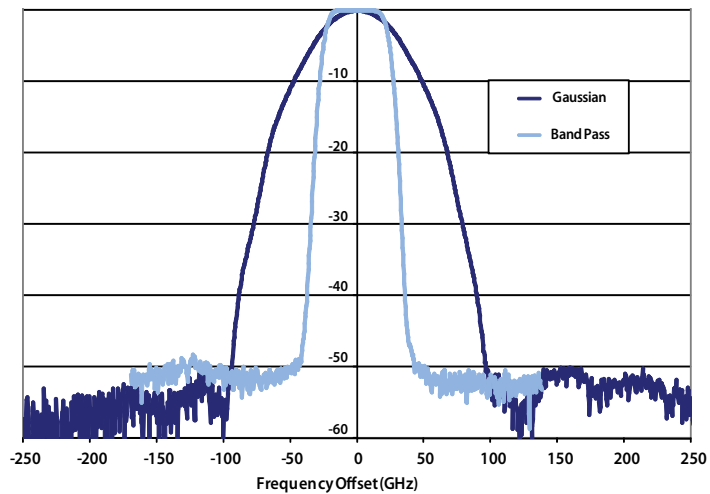
Products



WaveShaper 100A

Tunable Optical Filter

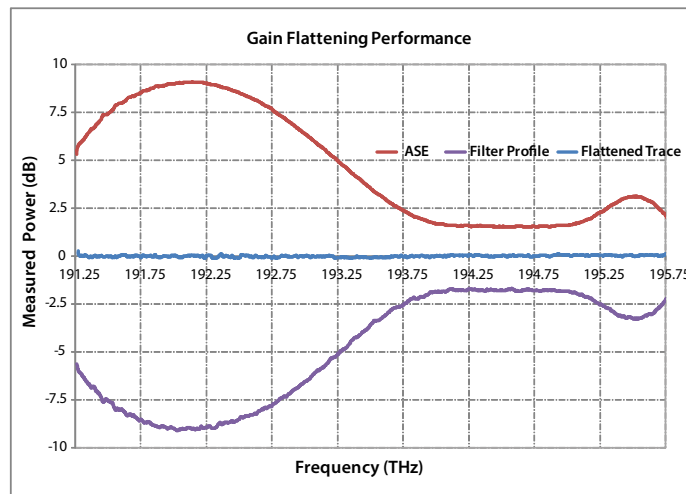
Fully programmable, DWDM tunable optical filter with user-selectable band-pass (flat-top) and Gaussian filter shapes. The filter bandwidth is programmable in 1 GHz increments from 10 GHz up to 1000 GHz, with the center frequency programmable in 1 GHz increments over the whole C-band. Ideal for production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

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 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.



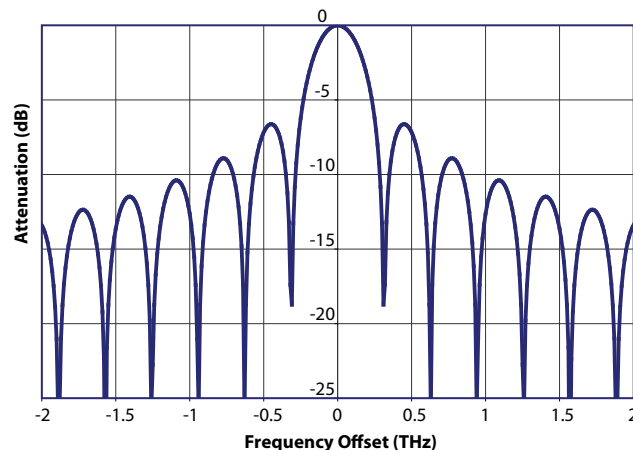
WaveShaper 4000A

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

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.

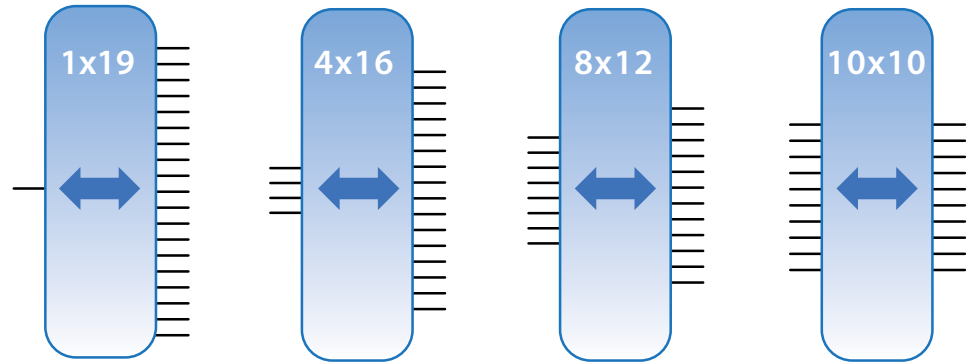
Products



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.



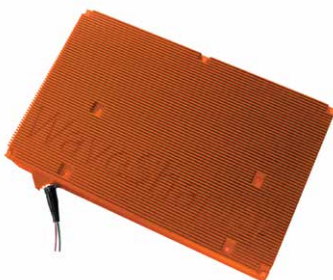
Covering the entire C-band, the WaveShaper 16000A combines precise control of filter wavelength, bandwidth, shape and phase with the ability to switch and combine multiple signals in an "Add" or "Drop" configuration. The WaveShaper 16000A in a 1x16 configuration also supports power splitting, broadcasting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

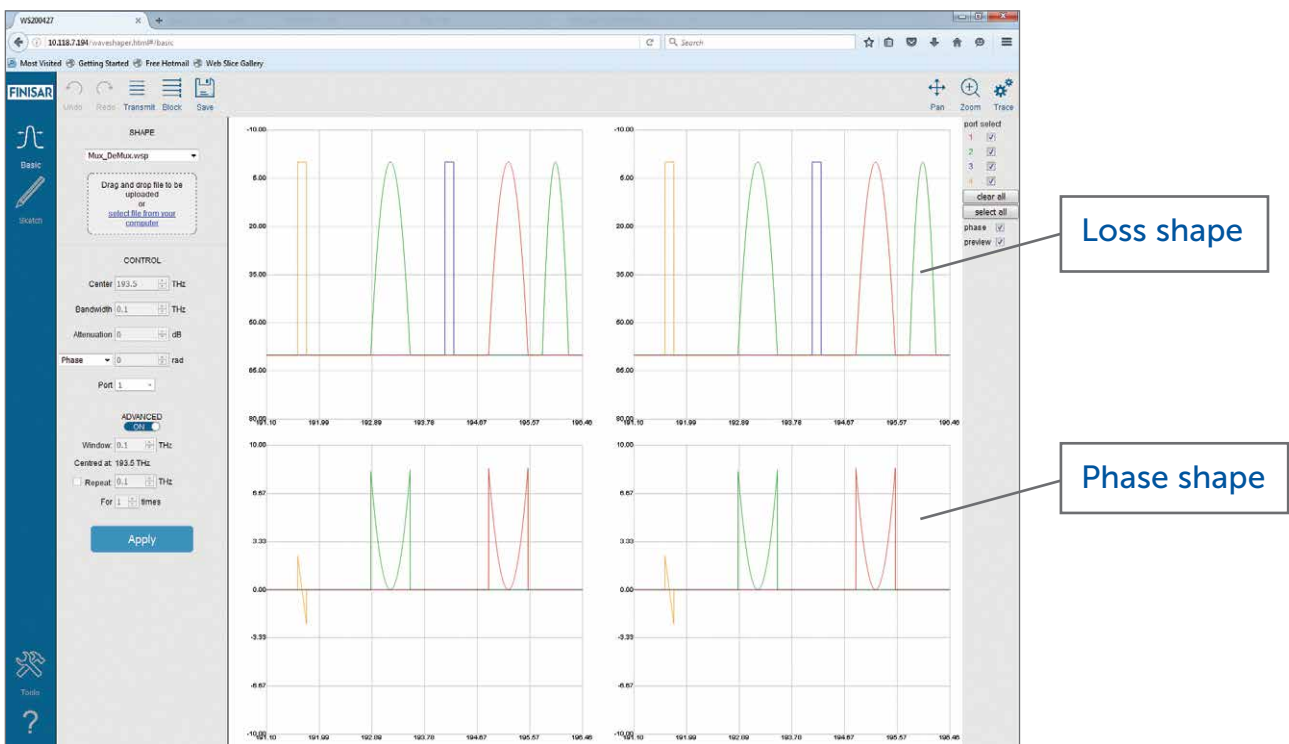
The WaveShaper Series A instruments contain an in-built webserver and this provides the most flexible approach, as the users client only needs to provide a Web browser. No dedicated software or drivers are required. Supported systems include Windows version 7 and higher, Linux, OS X, Android, iOS etc. 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.

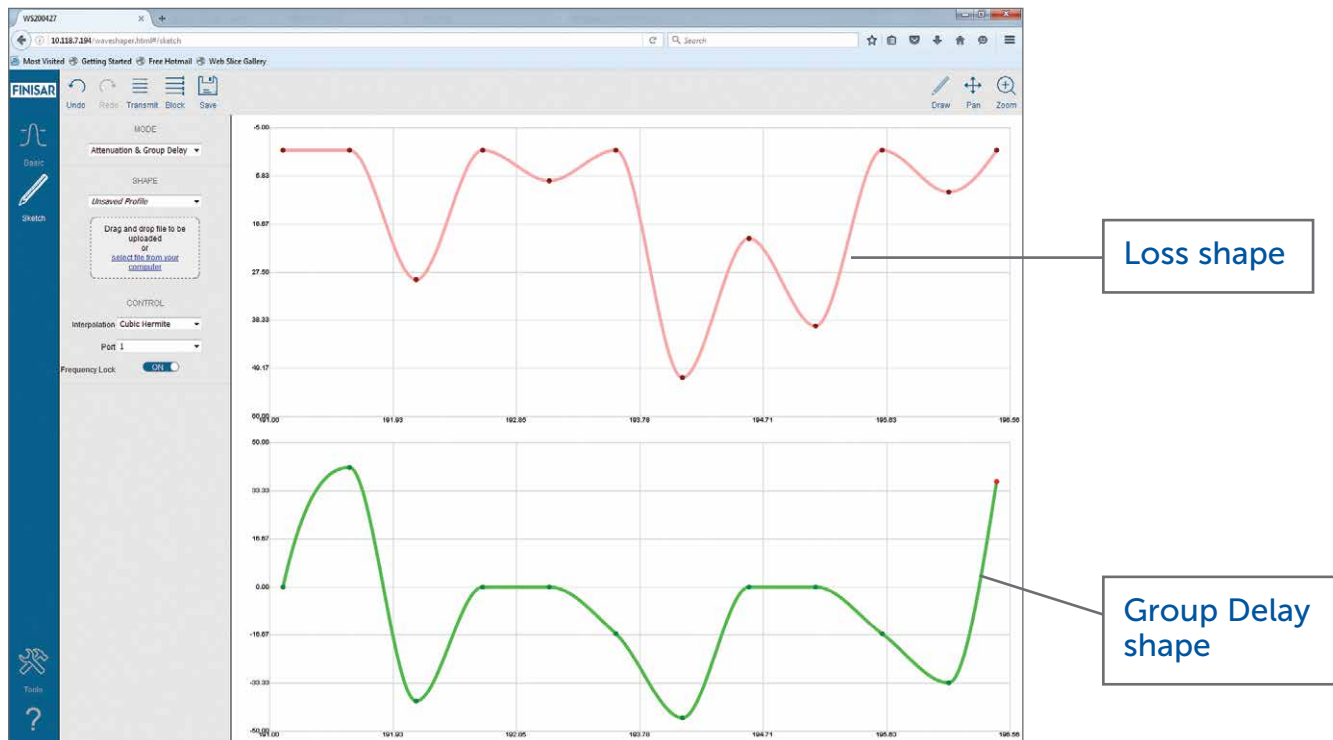
- **WaveManager 2.7 software package (USB Interface)**

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.



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.

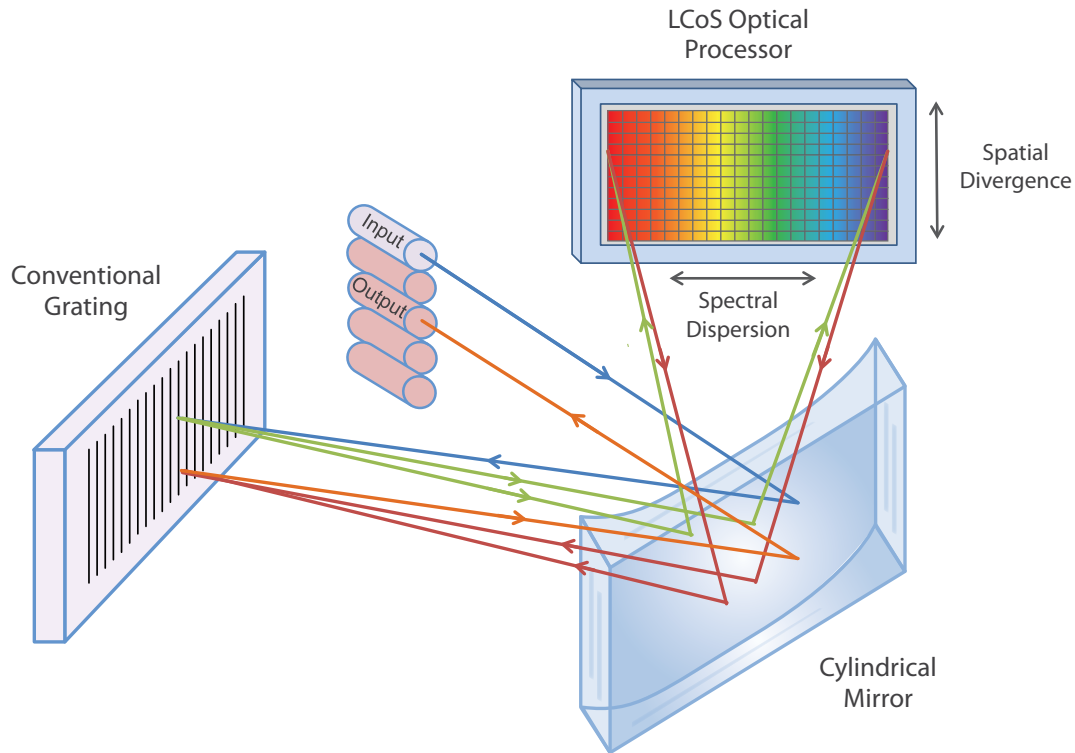


WaveShaper – Application Programming Interface (API)

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 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

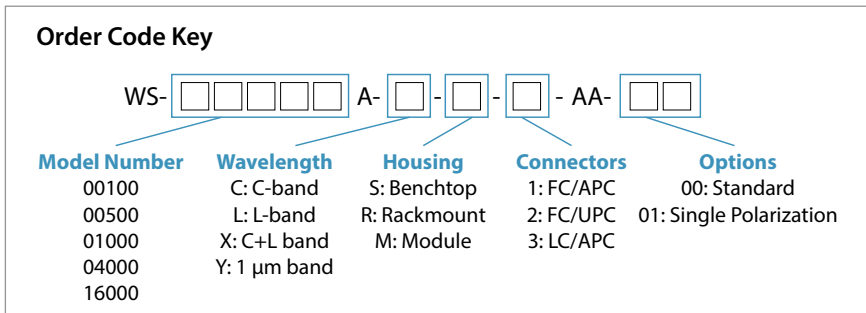
Model		100A	500A	1000A, 4000A	16000A	1000A/SP ^{Note 1}	1000A/L, 4000A/L	1000A/X, 4000A/X	
Optical Ports	Port Configurations	1x1		1x1 (1000) 1x4 (4000)	1x19, 4x16, 8x12, 10x10	1x1	1x1 (1000) 1x4 (4000)		
Filter Control	Operating Frequency Range	191.1 THz to 196.46 THz (1526.0 nm to 1568.7 nm)				191.250 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



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