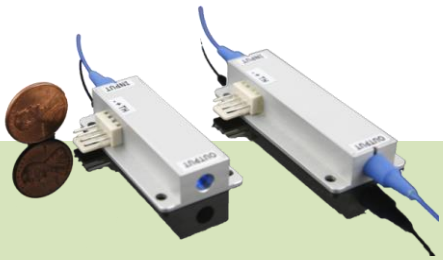
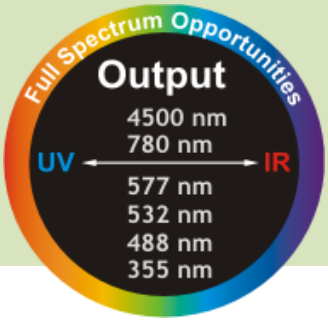
PPLN Optical Mixers





Compact, Robust and Maintenance-free optical frequency converters for full-spectrum applications

Your trusted value co-creation partner

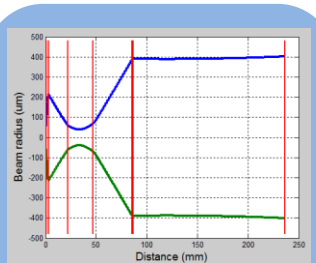
HCP
HC PHOTONICS CORP.

HC Photonics provides a compact, robust and maintenance-free module for optical wavelength conversion called “Mixer”. Integrated with Periodically-Poled nonlinear crystals (e.g. PPLN or PPLT bulk or waveguide chips) as well as optics and electronics, the mixer provides high conversion efficiency from UV to mid-IR. Numerous successful cases are applied in Quantum, Industrial Productivity, Bio & Medicine, Spectroscopy & Environment, Space & Defense, Science & Research, etc.

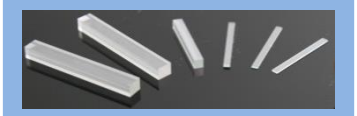
Your innovations

The success of HCP product does not come easy. Every single device is examined microscopically. At design phase, optical beam path simulation is performed with the nonlinear crystal for optimal parameters, including the conversion efficiency and other beam characteristics. Moving forward to engineering development phase, the mixers are set to go through a variety of reliability tests, i.e. thermal/humidity cycling, ingress protection examination, and vibration/shock verification in compliance with Telcordia standard. Among the key tasks is the perfection of final touch before delivery. Environmental qualifications, such as temperature cycling, drop and vibration test are performed on each mixer to ensure the quality.

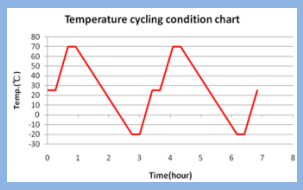
Simulation



Integration



Qualification Test



Temperature cycling
Damp Heat
Dry Heat
IPXX
Shock
Vibration

With these strict quality criteria, we believe our precision alignment capability and photonics packaging technology could surely meet all requirements from innovative ideas to volume production.

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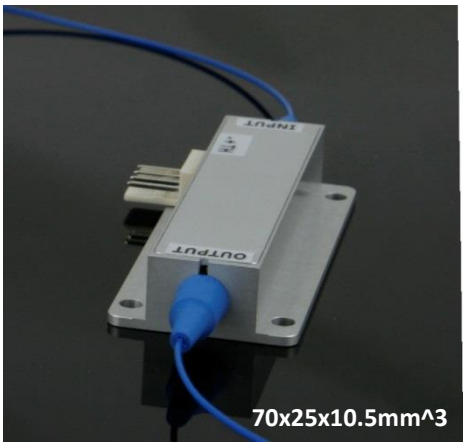
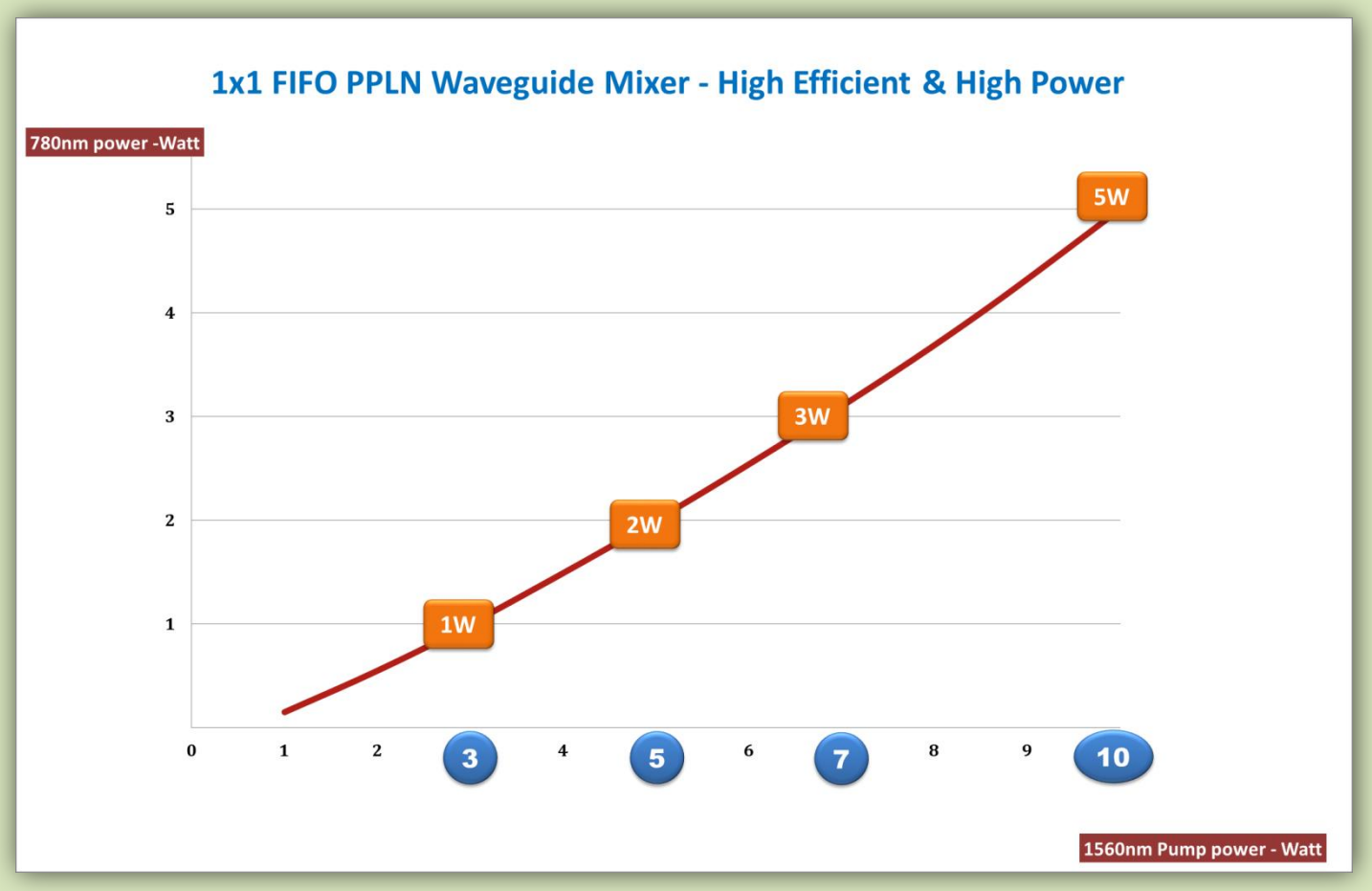
1x1 FIFO Waveguide Mixer



NEW Telecom band SHG

- High efficiency (up to 50%)
- High power (up to **5W** out of PM fiber)
- Compact/Robust package (~18 cc only)
- Custom Wavelengths upon request
- Fiber delivery (FIFO, Fiber-In & Fiber-Out)
- **Commercial volume**

Waveguide solutions with high power endurance in compact footprints have been in great demand constantly. HCP aims to turn the light into something feasible and affordable. Thus countless efforts are merged into the commercialized 5W waveguide mixers. This breakthrough not only obscures the line between waveguide and bulk chip solution, but inspires even more in the territory of photonic application!



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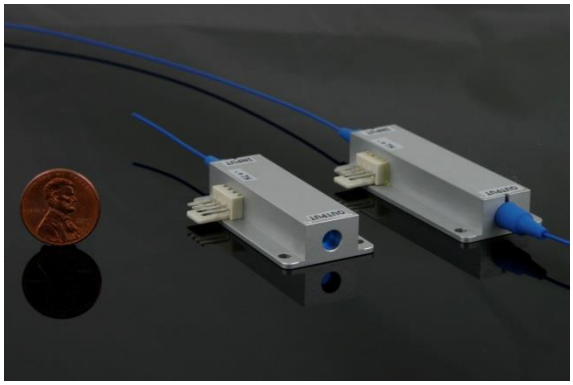
Waveguide Mixer

Standard 1x0 & 1x1 Mixer



- High efficiency (up to 50%)
- High power (up to **5W** out of PM fiber)
- Compact/Robust package
- Custom Wavelengths upon request
- Fiber delivery (FIFO, Fiber-In & Fiber-Out)
- **Commercial volume**

PPLN waveguide mixer is made with **PPLN waveguide chips** for various lasers from continuous wave (CW) to ultrafast pulse. Via different nonlinear frequency conversion processes (e.g. SHG, SFG, DFG…), the PPLN waveguide mixer provides the output wavelength from UV to mid-IR with superb conversion efficiency and exceptional high power up to Watts level.

What makes HCP waveguide mixers stand out is the technique of fiber butt-coupling. Unlike the typical application for low power only, our unique design breaks the confinement of technical barrier and push ahead the power handling capability to Watts level while remaining compact and robust. 5W out of single mode PM780 fiber with 10W pump at 1560nm CW is the spotlight you definitely cannot miss!

Best-seller

	Waveguide Mixer – SHG					
Series	**B**	**G**	**Y**	**O**	**R**	**T**
Range (nm)	450-495	495-560	560-580	580-620	620-700	700-800
Best seller, λ *1	**488nm**	**532nm** **555nm**	**561nm**	**589nm**	**628nm**	**775nm** **780nm**
Overall Efficiency*2	80%/W	120%/W	105%/W	90%/W	80%/W	50%/W
Fiber output*2	Yes, ~80% coupling efficiency from waveguide to single mode PM fiber					

1. The wavelengths of the best sellers are within +/- 0.5 nm typically. Custom wavelengths are available upon request.
2. The listed overall efficiency is baseline for volume production and refers only for low power regime with single longitudinal mode input. In general, the efficiency could be doubled with multi-longitudinal mode lasers e.g. **180%/W for 1064 nm SHG to 532 nm**. High power application are also available for further discussion.

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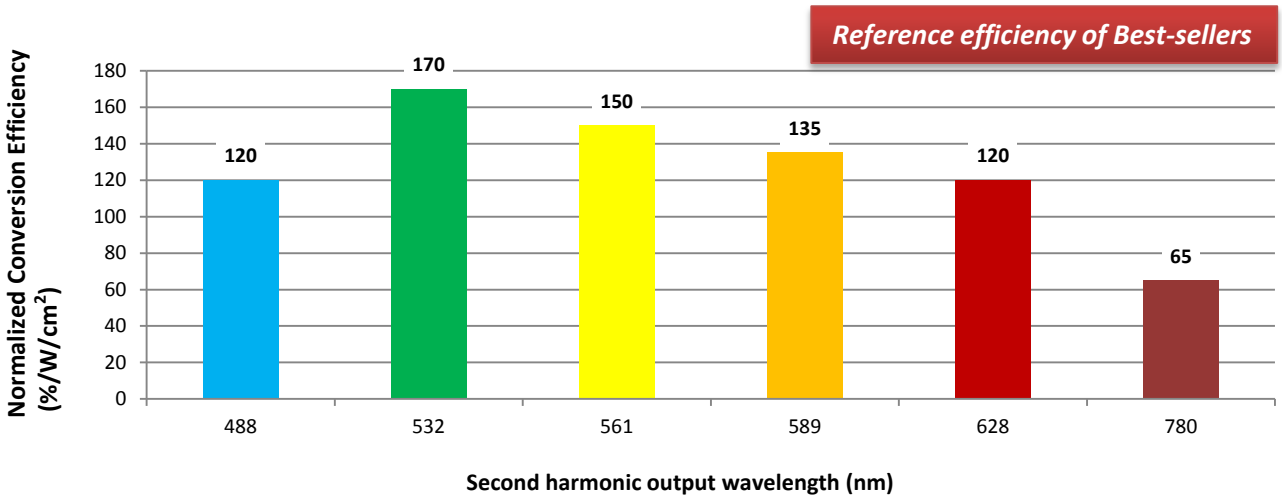
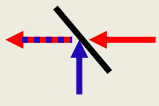
Specifications



Optics	unit	Spec.		
		Minimum	Typical	Maximum
Beam quality, M^2				≤1.2
Output beam (TEM00) ellipticity			1.2-2.0	
Output polarization state			Vertical or Horizontal, PER>20dB	
Back reflection for IR wavelength	dB		-40	
Fiber coupled output	%	75	80	
Mechanics	**unit**	**Spec.**		
		Minimum	**Typical**	**Maximum**
Typical housing dimension (LxWxH)	mm		60x25x10.5, 70x25x10.5(fiber-out)	
Beam height	mm		5.25+/-0.5	
Electrics	**unit**	**Spec.**		
		Minimum	**Typical**	**Maximum**
Electrical connector			Molex (4P)	
Typical thermoelectric cooler			3.9V, 1.7A maximum, Qc = 4.9W	
Environment	**unit**	**Spec.**		
		Minimum	**Typical**	**Maximum**
Storage temperature (no humidity)	˚C	-20	-	70
Operating ambient temperature range	˚C	10	25	35
Operating rel. humidity (non condensing)	%RH	10	-	85
Restriction of hazardous substances directive (RoHs)			Declaration of Conformity to 2011/65/EU	

Options:

Wavelength Combiner

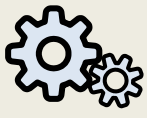


A free space module combines arbitrary optical wavelengths into waveguide mixer with low insertion loss.

Filter Module

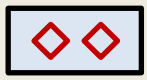
The filter module with free space/fiber input & output removes the undesired wavelengths for up to 100dB between residual pump and converted signal.

Control unit



A control unit allows to set and read the crystal temperature for phase-matching optimization. Photodiode signal can also be viewed at power monitoring option.

Fiber adaptor package



The waveguide mixers could be integrated into a housing that provides FC/APC fiber adaptor interface with collimation optics. Simply plug & play, life is just that easy!

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Bulk Mixer

Standard 1x0 & 1x1 Mixer

- High output power
- Excellent beam quality
- Robust package
- Broad wavelength selection
- Fiber delivery

PPLN bulk mixer is made with **PPLN bulk chips** for various lasers from continuous wave (CW) to ultrafast pulse. Via different nonlinear wavelength conversion processes (e.g. SHG, SFG, DFG…etc), the PPLN bulk mixer provides the polarization maintained output from UV to mid-IR with output power up to few Watts either in free space or with optical fiber.

Best-seller

Five color series corresponding to the different wavelength range are our Best-sellers. They are designed for specific application such as laser microscopy or atom trapping. Detailed specifications are shown below. Alternatives are also available upon request.

	Bulk Mixer – SHG [*1]				
Color	**B**	**G**	**Y**	**O**	**R**
Range (nm)	450-495	495-560	560-580	580-620	620-800
Best seller, λ [*2]	473nm, **488nm**	515nm, **532nm,** 543nm	**561nm**	**589nm,** 594nm	**775nm, 780nm,** 785nm
Power[*3] (max)	1W	2W	3W	4W	6W
Pump	Diode	Diode/Yb&Yb+/Raman lasers			Diode/Er laser

1. Second-Harmonic Generation (SHG)
2. The wavelengths are within +/- 0.5 nm. Other custom wavelengths are open for discussion.
3. SHG power is pump dependent. Typical output coupling efficiency from chip to single mode PM fiber is >80%. Higher efficiency is also achievable. Please contact us with your pump conditions (power, linewidth, pulse width, repetition rate...) for further evaluation.

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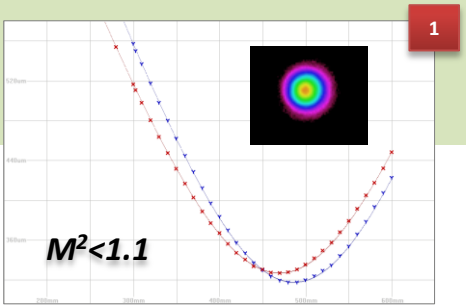
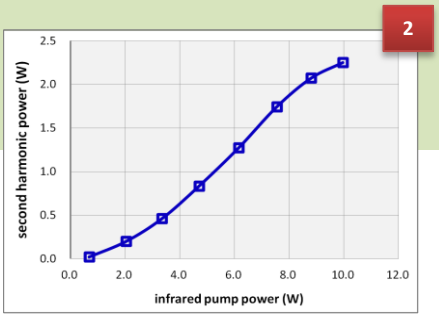
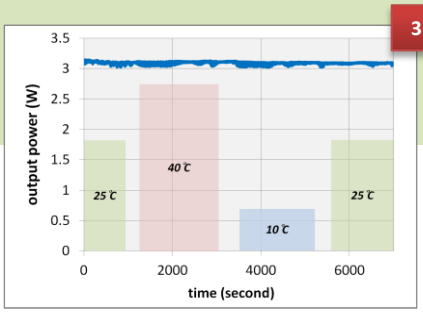
Specifications

Optics	unit	Spec.		
		Minimum	Typical	Maximum
Beam quality, M^2				≤1.2
Reference diameter of collimated output beam	mm	0.9	1	1.1
Output beam (TEM00) ellipicity	%			≤10
Residual IR/output power rejection ratio	dB			-40
Output polarization state		Horizontal, PER>20dB		
Back reflection for IR wavelength	dB		-45	-42
Fiber coupled output	%		75	
Mechanics	**unit**	**Spec.**		
		Minimum	**Typical**	**Maximum**
Typical housing dimension (L*W*H)	mm	150x50x35		
Beam height	mm	18.9±0.5		
Statistic beam angle	mrad	-7.5	0	7.5
Electrics	**unit**	**Spec.**		
		Minimum	**Typical**	**Maximum**
Electrical connector		Hirose HR 10G-10R-10P(73)		
Thermoelectric cooler		3.2V, 4A maximum, Qc = 6.9 W		
Environment	**unit**	**Spec.**		
		Minimum	**Typical**	**Maximum**
Storage temperature (no humidity)	°C	-20	-	70
Operating ambient temperature range	°C	10	25	35
Operating rel. humidity (non condensing)	%RH	10	-	85
Restriction of hazardous substances directive (RoHs)		Declaration of Conformity to 2011/65/EU		



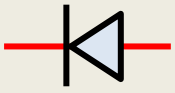




(**1**) The typical beam quality of collimated output from the bulk mixer
(**2**) The typical power scaling curve of the second harmonic generation from the bulk mixer-G at 532nm
(**3**) Environmental temperature cycling(10-40 ˚C) before delivery

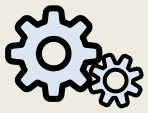
Options:

Power Monitoring



Photodiode for the output power monitoring with a voltage signal Vpd (typically 3V at maximum output power) allows auto-power control (APC) mode operation.

Control unit



A control unit allows to set and read the crystal temperature for phase-matching optimization. Photodiode signal can also be viewed at power monitoring option.

Filter Module

The filter module with free space/fiber input & output removes the undesired wavelengths for up to 100dB between residual pump and converted signal.

Customer Inspiration

We are open to discuss the possibility of integrating other components. Don't hesitate to contact us and share your innovative ideas!

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Cavity Mixer

- Cavity enhanced for higher efficiency
- Wavelength from UV/Visible to NIR/MIR
- Fiber delivery optional
- Wavelength tunable up to few-hundred nm
- Convenient, compact and robust

Cavity configuration is an alternative way to enhance nonlinear frequency conversion. To fit with all kinds of applications, we have developed a cavity mixer platform which provides users-friendly interface. With this platform structure, it can be easily transformed to external pump OPO (EP-OPO), Intra-cavity OPO (IC-OPO), Intra-cavity SFG (IC-SFG), Intra-cavity DFG (IC-DFG) etc. They are widely applied for generating NIR signal wavelengths between 1.4-2 um and MIR idler wavelengths between 2.3-4.5 um.

Best-seller

ICOPO-B & ICOPO-TB series are optical parametric oscillator (OPO) mixers, particularly designed for ultra-low input power. The intra-cavity structure utilizes the high circulating power in the cavity so as to reach the threshold efficiently. With accumulation of years-experience, now HCP proudly presents the series of 3 different wavelength ranges together with software and controller!

Parameter	unit	ICOPO-B[1] & ICOPO-TB[2]
Signal/Idler Wavelength	nm	α series: 1560-1880/2500-3300 β series: 1495-1640/3000-3700 γ series: 1440-1510/3600-4080
Signal/Idler Output Power	mW	α series: 250/100 β series: 250/90 γ series: 200/70
Linewidth	GHz	300
Beam Quality		TEM00, Signal M2<1.2, Idler M2<1.5
Polarization		Linear, >20dB

1. ICOPO-B: broad bandwidth (few nm), specific wavelength within α,β,γ range could be designed
2. ICOPO-TB: tunable (few hundred nm)

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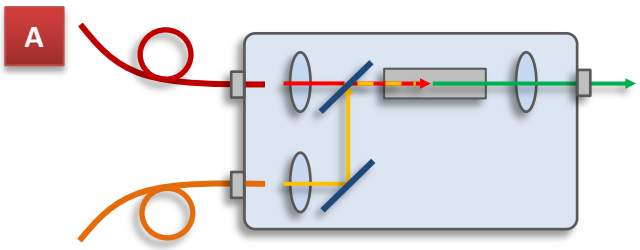
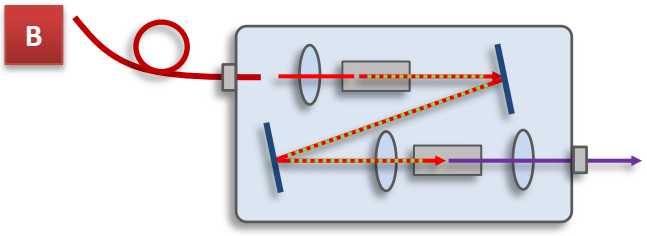
2x0/2x1 Mixer



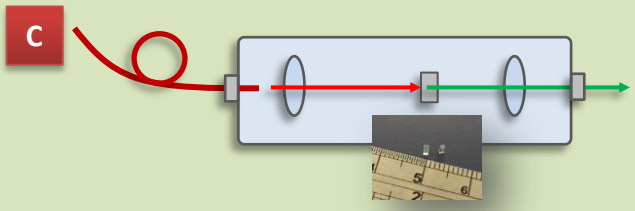
Sum frequency generation (SFG)
Difference frequency generation (DFG)
Optical parametric amplification (OPA)

Cascaded Mixer

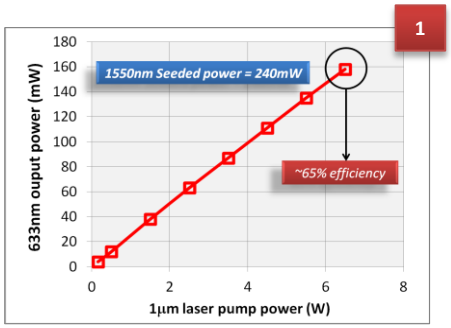


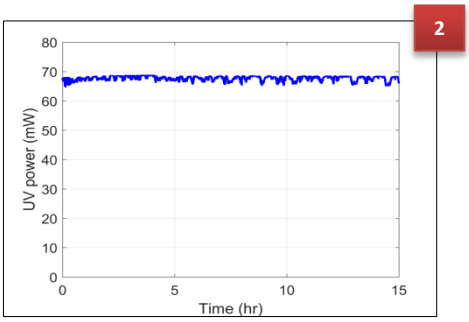
Third-harmonic generation (THG)
Fourth-harmonic generation (FHG)

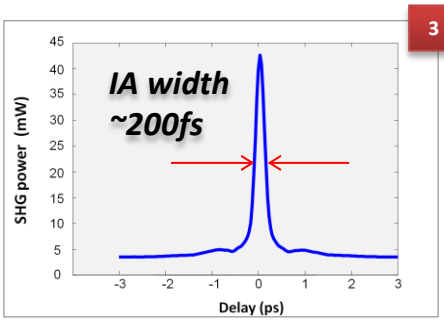
Ultrafast mixer



(**A**) 2x0/2x1 Mixer configuration goes with two fiber-coupled input, out with either free-space converted beam or fiber-coupled. The free-spaced optical design inside the module can reduce loss of beam combination.
(**B**) Cascaded Mixer configuration includes two frequency conversion stages, e.g. one sum-frequency generation(SFG) followed by a SHG, which is equivalent to frequency tripling(THG).
(**C**) An ultrafast mixer with tiny crystal inside enables to convert a broad spectrum of ultrafast pulses.







(**1**) 1550nm and 1064nm lasers are combined to generate 633nm output by sum-frequency generation (SFG) 2x0 mixer. 633nm output power vs. pump source is shown in depiction (1).
(**2**) UV (355nm) is tripled from 3.5W infrared by our third harmonic generation (THG) cascaded mixer. The stability (measured power vs. time)is shown in depiction (2).
(**3**) 780nm ultrashort pulse was doubled from an ultrafast erbium-doped fiber laser by SHG ultrafast mixer with >50% conversion efficiency. Measured correlation trace is shown in depiction (3).

How to select YOUR mixer?

1. Check the nonlinear conversion configuration you would like to proceed (e.g. SHG, SFG, DFG, OPO/OPG, SPDC…etc.)

2. Select the corresponding mixer type as well as the optional parts for specified application.

-1x0: fiber in, free-space out
-1x1: fiber in, fiber out
-2x0: 2 fibers in, free-space out
-2x1: 2 fibers in, 1 fiber out

3. Contact HC Photonics directly or the local representative for further information about mixers with custom options.

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Ver. Sep-22

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United Kingdom
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photonicsolutions.co.uk

HC PHOTONICS CORP.

HCPHOTONICS.COM
service@hcphotonics.com (T)+886-3-666 2123
F4, No.2, Technology Road V, Hsinchu City 30078, Taiwan