Covesion Ltd

Engineering on your wavelength

MADE IN BRITAIN

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version 8.1

Company Profile

MgO:PPLN is ideal for cutting-edge laser applications due to its high effective nonlinear coefficient; allowing for high efficiency frequency conversion across multiple different mechanisms. Magnesium doped, periodically poled lithium niobate (MgO:PPLN) supports a wide range of applications including quantum optics, frequency doubling of CW & pulse lasers; mid-infrared generation; atom cooling; terahertz generation and biomedical imaging. The addition of MgO:PPLN waveguides to the Covesion product range allows our customers to exploit greater conversion efficiencies and save on unnecessary pump sources within their applications.

Covesion researches, develops and manufactures MgO:PPLN crystals, waveguide, component and system for highly efficiency non-linear frequency conversion.

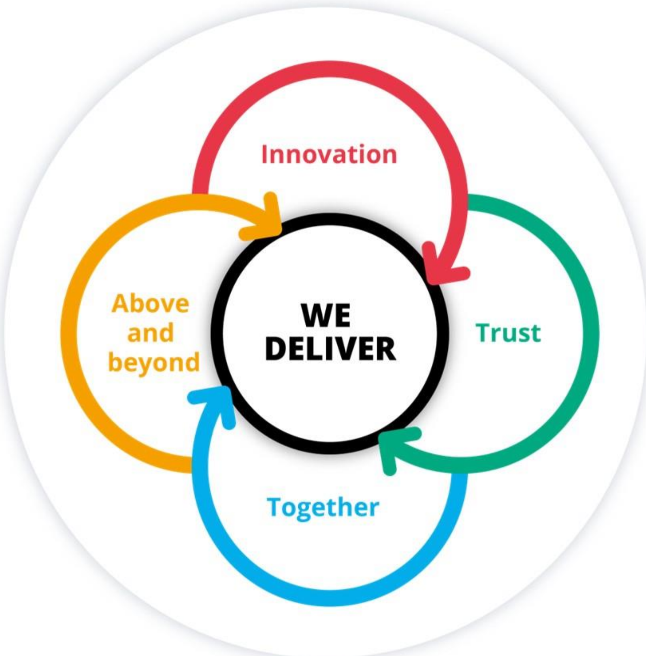
With over 20 years' experience and technical knowledge, the team of engineers at Covesion are perfectly placed to provide you with the support you need for designing a system to generate visible and IR light. Covesion offers advice on all aspects of PPLN technology, from crystal length to optical mounting, aiming to deliver the ideal MgO:PPLN system for your application.

We have an unrivalled international reputation for our products, built upon our team's many years' experience in the manufacture of PPLN frequency conversion products, selling to both R&D and OEM customers. We stock crystals and waveguides as well as designing and manufacturing custom chips for specific customer applications.

Covesion values:

WE DELIVER

- **Together**
- **Above and beyond**
- **Trust**
- **Innovation**



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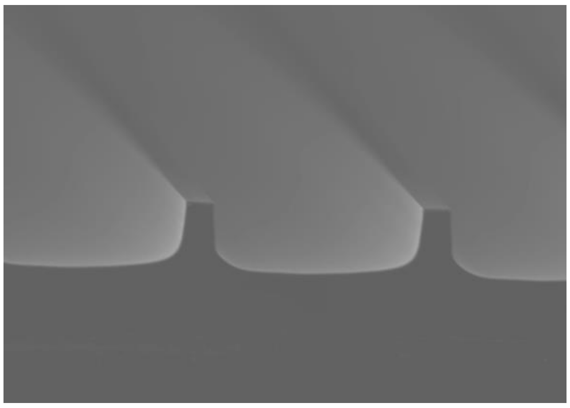
Introduction

MgO:PPLN for efficient wavelength conversion



Covesion Ltd is a UK manufacturer of Periodically Poled Lithium Niobate (PPLN) materials, including **Magnesium Doped Periodically Poled Lithium Niobate** (MgO:PPLN or PPMgO:LN) bulk crystal and waveguide.

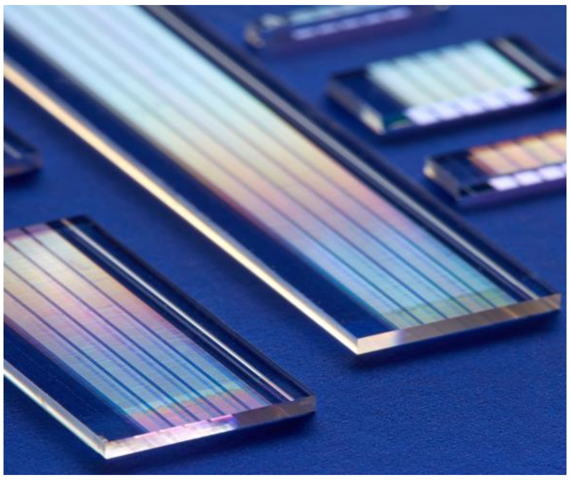
MgO:PPLN are nonlinear optical crystals for high efficiency wavelength conversion in the 460nm – 5100nm range. Our proprietary PPLN poling process creates high fidelity grating periods from 4.5µm to 33µm+ and is ideal for high volume manufacture.

We provide off-the-shelf crystals as well as custom crystals: from R&D requests to high volume OEM designs. Our team of PPLN engineers provide technical consultation and advice to assist in finding the right solution for your application.

Covesion's optical engineers have designed a range of PPLN crystal clips, ovens, temperature controllers and mounting accessories, providing a **complete PPLN system** for easy integration into your optical arrangement.

Whether you are building a PPLN system for scientific research or prototype development, Covesion offers a complete PPLN solution designed for quick and simple integration with your laser arrangement.

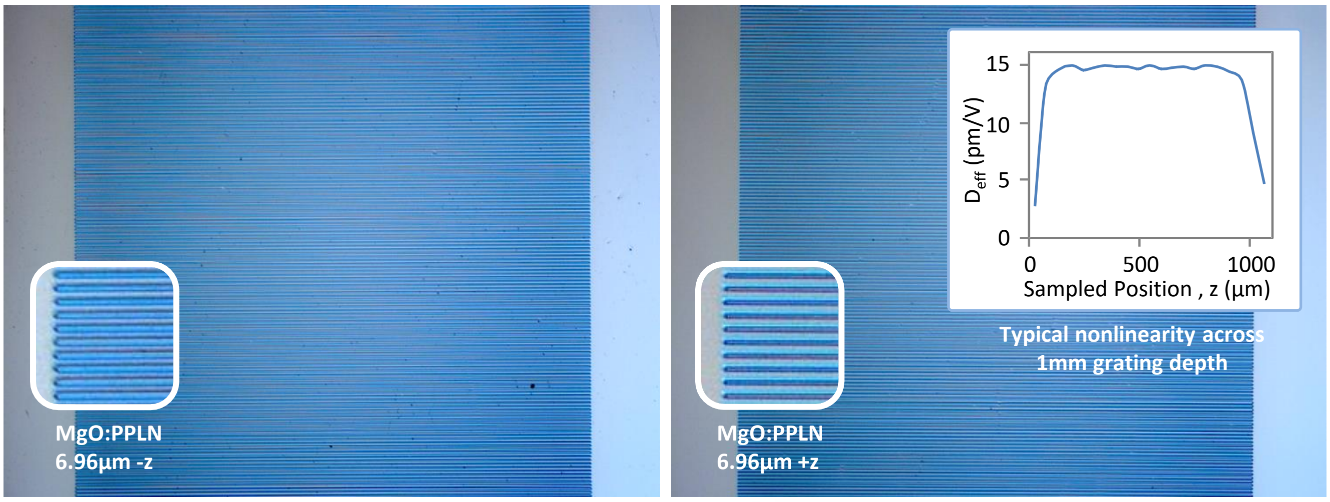
After acquisition of Electron Dynamics, Covesion also offers a range of **technical services**, from feasibility studies, circuit design and prototype development through to full manufacture. With many years of experience specializing in thermal management, we also manufacture a range of bespoke temperature controllers.



MgO:PPLN for Efficient Wavelength Conversion

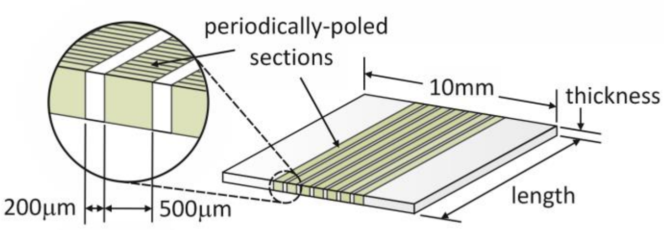
Adding 5% magnesium-oxide to lithium niobate significantly increases the optical and photorefractive resistance of the crystal while preserving its high nonlinear coefficient [1]. This allows more stable operation at visible wavelengths and lower temperature operation than a similar undoped crystal. MgO:PPLN can be operated at temperatures as low as room temperature and in some cases, without temperature stabilisation. With temperatures from ambient up to 200°C, MgO:PPLN offers significantly wider wavelength operation than undoped PPLN.

Specially developed for **red**-**green**-**blue** generation and high-power mid-IR operation, our proprietary MgO:PPLN poling process offers high fidelity periods from 4.5µm to 33µm+ and is ideal for volume manufacture. As shown below, our MgO:PPLN domains are poled through the entire thickness of the sample, providing maximum optical aperture.



Our MgO:PPLN crystals are designed to work with a wide range of common laser wavelengths. Each off-the-shelf device includes multiple gratings for flexible temperature and wavelength operation. MgO:PPLN has a wide operating temperature range from 30-200°C.

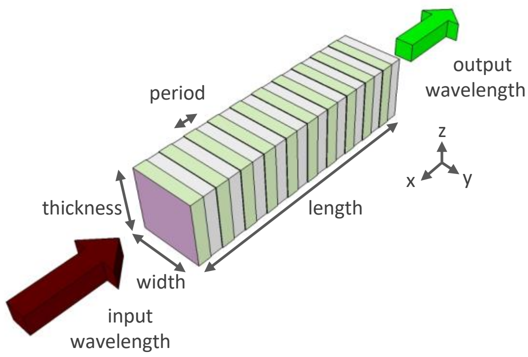
Crystal lengths are 0.3mm to 1mm for short-pulse femtosecond lasers and 10mm to 40mm for ns to CW systems. Our standard crystals are supplied clip-mounted and off-the-shelf. Custom crystal lengths, thicknesses, AR coatings, and grating designs are also available upon request.



Standard MgO:PPLN crystal layout

- Multi-band AR coated
- Flatness <λ/4@633nm
- Parallel to ±5minutes
- Better than 70:30 mark-to-space ratio
- Polished to 20-10 scratch dig
- Fewer than two 100µm edge chips per facet

1, 10, 20 & 40mm clip-mounted MgO:PPLN



Pictorial representation of a PPLN grating where laser light focused into the grating is converted to another wavelength. This can be achieved with the correct poling period, crystal temperature, and z-axis polarization.

[1] *"High-Beam-Quality Continuous Wave 3W Green-Light Generation in Bulk Periodically Poled MgO:LiNbO3"*
H.Furuya, A.Morikawa, K.Mizuuchi, K.Yamamoto, Japanese Journal of Applied Physics, Vol.45 No.8B pp.6704-6707 (2006)

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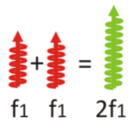
MgO:PPLN for SHG: Visible and Near-IR Wavelengths

Second Harmonic Generation

- High efficiency frequency doubling of IR lasers to visible and shorter near-IR wavelengths
- Available in 0.5mm and 1.0mm apertures
- Mounted and double-band AR coated



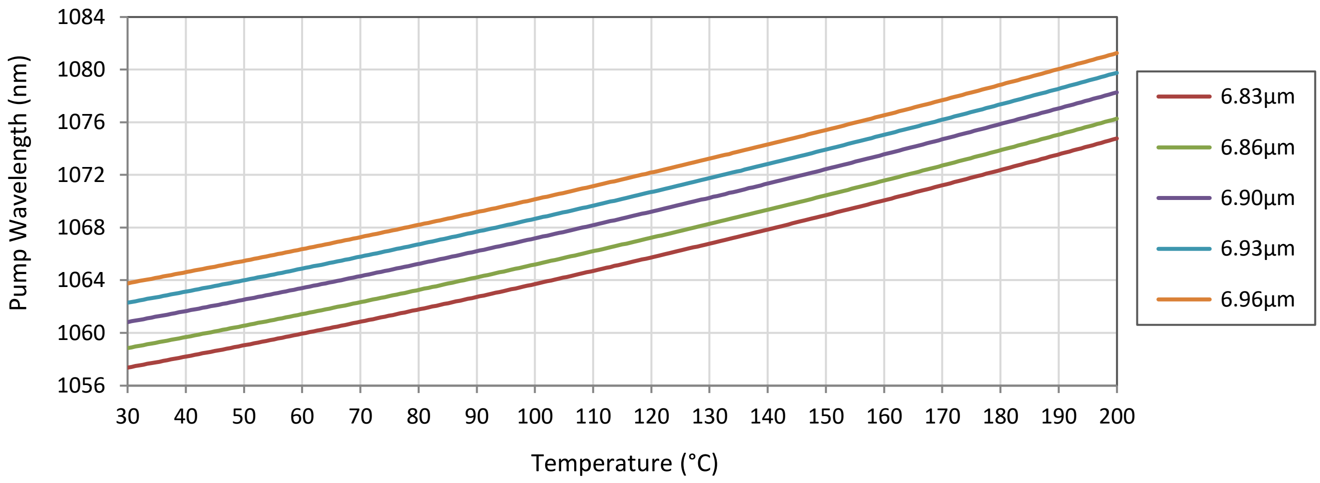
Applications

- Green and blue generation
- Scientific & medical
- Frequency comb stabilization
- Fluorescence microscopy

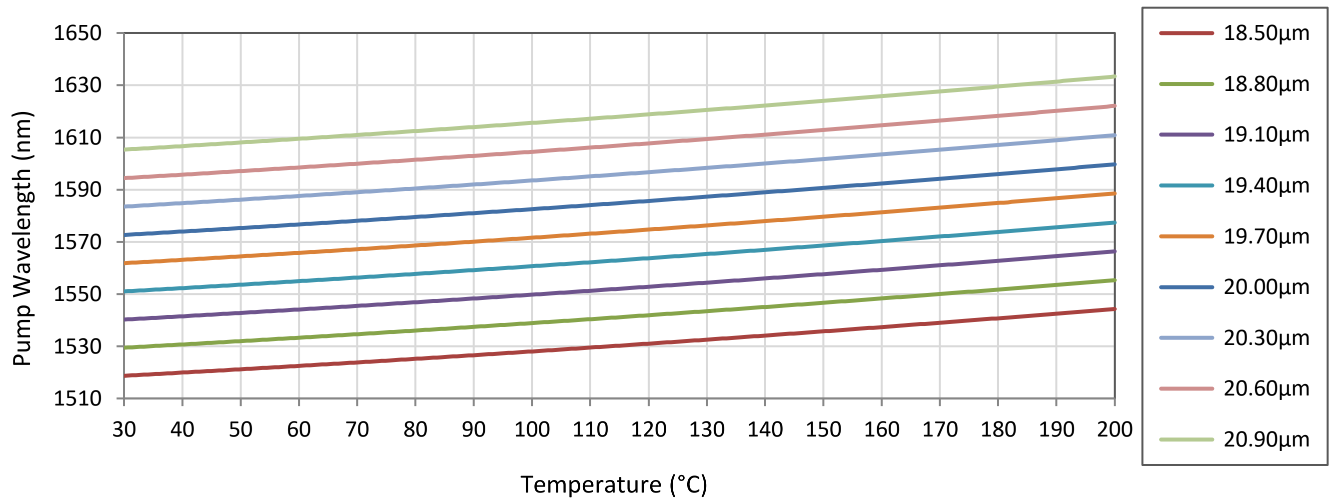
Our **SHG MgO:PPLN crystals** are designed to work with a wide range of common laser wavelengths. Each device has several gratings to allow phase matching at different temperatures. The visible wavelength devices contain multiple gratings designed for phase matching of the nominal pump wavelength typically between 30-200°C. Tuning to temperatures up to 200°C allows phase matching to longer wavelengths.

All our products undergo rigorous quality inspection and are supplied clip-mounted and off-the-shelf. Custom crystal lengths, thicknesses, AR coatings, and grating designs are also available upon request.

Calculated temperature vs. phase matching wavelength tuning curve of MSHG1064



Calculated temperature vs. phase matching wavelength tuning curve of MSHG1550-0.5



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MgO:PPLN for SHG: Visible and Near-IR Wavelengths

part #	pump (nm)	output (nm)	grating periods (µm)	temperature tuning range (°C)	thickness (mm)	standard* lengths (mm)
MSHG960-0.5	945 – 966	473-483	4.76, 4.80, 4.84	30 – 200	0.5	1, 3, 5, 10, 20, 40
MSHG976-0.5	970 – 992	485 – 496	5.17, 5.20, 5.23, 5.26, 5.29	30 – 200	0.5	1, 3, 5, 10, 20, 40
MSHG1020-1.0	1006-1036	503-518	5.84, 5.98, 6.08	30 – 200	1.0	1, 3, 5, 10, 20, 40
MSHG1030-0.5	1024 – 1047	512 – 524	6.16, 6.19, 6.23, 6.26, 6.29	30 – 200	0.5	1, 3, 5, 10, 20, 40
MSHG1047-0.5	1040 – 1064	520 – 532	6.48, 6.52, 6.55, 6.59, 6.62	30 – 200	0.5	1, 3, 5, 10, 20, 40
MSHG1064-1.0	1058 – 1080	529 – 540	6.83, 6.86, 6.90, 6.93, 6.96	30 – 200	1.0	1, 3, 5, 10, 20, 40
MSHG1080-0.5	1060-1116	530-558	6.90, 7.10, 7.30, 7.50, 7.70	30 – 200	0.5	1, 3, 5, 10, 20, 40
MSHG1120-1.0	1106-1158	553-579	7.87, 7.99, 8.11, 8.23, 8.35, 8.47, 8.59	30 – 200	1.0	1, 3, 5, 10, 20, 40
MSHG1180-0.5	1166-1220	583-610	9.20, 9.40, 9.60, 9.80, 10.00	30 – 200	0.5	1, 3, 5, 10, 20, 40
MSHG1230-0.5	1216-1262	608-631	10.40, 10.55, 10.70, 10.85, 11.00	30 – 200	0.5	1, 3, 5, 10, 20, 40
MSHG1320-0.5	1284-1336	642-668	12.10, 12.30, 12.50, 12.70, 12.90	30 – 200	0.5	1, 3, 5, 10, 20, 40
MSHG1350-0.5	1296-1422	648-711	12.40, 12.80, 13.20, 13.60, 14.00, 14.40, 14.80, 15.20	30 – 200	0.5	1, 3, 5, 10, 20, 40
MSHG1420-0.5	1350-1490	675-745	13.83, 13.96,14.08, 14.55, 15.10, 15.60, 16.10, 16.60, 17.10	30 – 200	0.5	1, 3, 5, 10, 20, 40
MSHG1550-0.5	1520 – 1632	760 – 816	18.50, 18.80, 19.10, 19.40, 19.70, 20.00, 20.30, 20.60, 20.90	30 – 200	0.5	0.3, 0.5, 1, 3, 5, 10, 20, 40
MSHG1550-1.0	1545 – 1610	773 – 805	19.20, 19.50, 19.80, 20.10, 20.40	30 – 200	1.0	1, 3, 5, 10, 20, 40
MSHG1650-0.5	1605 – 1720	803 – 860	20.90, 21.20, 21.50, 21.80, 22.10, 22.40, 22.70, 23.00, 23.30	30 – 200	0.5	1, 3, 5, 10, 20, 40
MSHG1820-0.5	1720 – 1928	860 – 964	23.95, 24.45, 24.95, 25.45, 25.95, 26.45, 26.95, 27.45, 27.95	30 – 200	0.5	1, 3, 5, 10, 20, 40
MSHG2100-0.5	1925-2250	963-1125	28.40, 29.00, 29.60, 30.20, 30.80, 31.40, 32.00, 32.60, 33.20	30 – 200	0.5	1, 3, 5, 10, 20, 40
MSHG2100-1.0	1968-2250	984-1125	29.60, 30.20, 30.80, 31.40, 32.00, 32.60, 33.20	30 – 200	1.0	1, 3, 5, 10, 20, 40
MSHG2600-1.0	2260-3300	1130-1650	34.00, 34.80, 35.50, 35.80, 35.97	30 – 200	1.0	1, 3, 5, 10, 20, 40

**custom crystal lengths from 0.3mm to 50mm available upon request*

MgO:PPLN for OPO, DFG and SFG

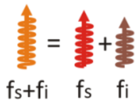
The wide transmission range and non-critical walk-off angle of MgO:PPLN make this material ideal for generating wavelengths throughout the mid-IR.

Based on our standard design layout, our **MgO:PPLN OPO, DFG and SFG crystals** are designed to work with common pump wavelengths at 1064nm, tunable 775nm and 1550nm. Our OPO and DFG crystals cover a broad continous tuning range from the near-IR to beyond 4.5µm in the mid-IR, whilst our SFG crystals are designed for tunable green generation.

Our crystals undergo quality inspection and are supplied off-the-shelf. Our crystals are AR coated and clip-mounted, ready for use with our ovens and controller.

Optical Parametric Oscillation / Generation

- Widely tunable mid-IR from a 1064nm pump source †
- Also suitable for DFG
- Temperature tuning 30-200 °C
- Available in 0.5mm and 1.0mm apertures
- Mounted and triple-band AR coated



Applications

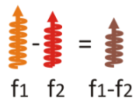
- Mid-IR spectroscopy
- Environmental monitoring
- LIDAR & laser counter measures

part #	pump (nm)	signal (nm)	idler (nm)	grating periods (µm)	thickness (mm)	standard* lengths (mm)
MOPO515-0.5	515	640 – 1030	1030 – 2530	6.00, 6.26, 6.53, 6.81, 7.10, 7.40, 7.71, 8.03, 8.36	0.5	1, 3, 5, 10, 20, 40
MOPA532-1.0	532	690 – 1064	1064 – 2310	6.85, 7.15, 7.45, 7.75, 8.05, 8.35, 8.65	1.0	1, 3, 5, 10, 20, 40
MOPO1-0.5	1064	1410 – 2128	2128 – 4340	27.91, 28.28, 28.67, 29.08, 29.52, 29.98, 30.49, 31.02, 31.59	0.5	1, 3, 5, 10, 20, 40
MOPO1-1.0	1064	1480 – 2128	2128 – 3785	29.52, 29.98, 30.49, 31.02, 31.59	1.0	1, 3, 5, 10, 20, 40
MOPO2-1.0	1064	1342 – 1460	3945 – 5135	25.5, 26.0, 26.5, 27.0, 27.5, 28.0, 28.5	1.0	1, 3, 5, 10, 20, 50
MOPO3-1.0	1064	1430 – 2085	2085 – 4185	28.5, 29.0, 29.5, 30.0, 30.5, 31.0, 31.7	1.0	1, 3, 5, 10, 20, 50

**custom crystal lengths from 0.3mm to 50mm available upon request*

Difference Frequency Generation

- Temperature tuning 30-200 °C
- Available in 0.5mm and 1.0mm apertures
- Mounted and triple-band AR coated



Applications

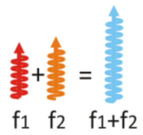
- Mid-IR spectroscopy
- Environmental monitoring
- LIDAR & laser counter measures

part #	pumps (nm)	output (nm)	grating periods (µm)	thickness (mm)	standard* lengths (mm)
MDFG1-0.5	737 – 786 & 1064	2398 – 3008	18.50, 18.80, 19.10, 19.40, 19.70, 20.00, 20.30, 20.60, 20.90	0.5	1, 3, 5, 10, 20, 40
MDFG2-0.5	775 – 869 & 1064	2853 – 4741	20.90, 21.20, 21.50, 21.80, 22.10, 22.40, 22.70, 23.00, 23.30	0.5	1, 3, 5, 10, 20, 40
MDFG3-1.0	1480 – 2128 & 1064	2128 – 3785	29.52, 29.98, 30.49, 31.02, 31.59	1.0	1, 3, 5, 10, 20, 40
MDFG4-0.5	885 – 1210 & 1550	2063 – 5516	24.06, 24.63, 25.23, 25.86, 26.53, 27.22, 27.96, 28.74, 29.56, 30.43, 31.35, 32.33, 33.37, 34.48, 35.67, 36.95	0.5	1, 3, 5, 10, 20, 40

**custom crystal lengths from 0.3mm to 50mm available upon request*

Sum Frequency Generation

- Combines fixed 1550nm and tunable 780nm or 810nm pump sources to provide tunable green wavelengths
- Mounted and triple-band AR coated



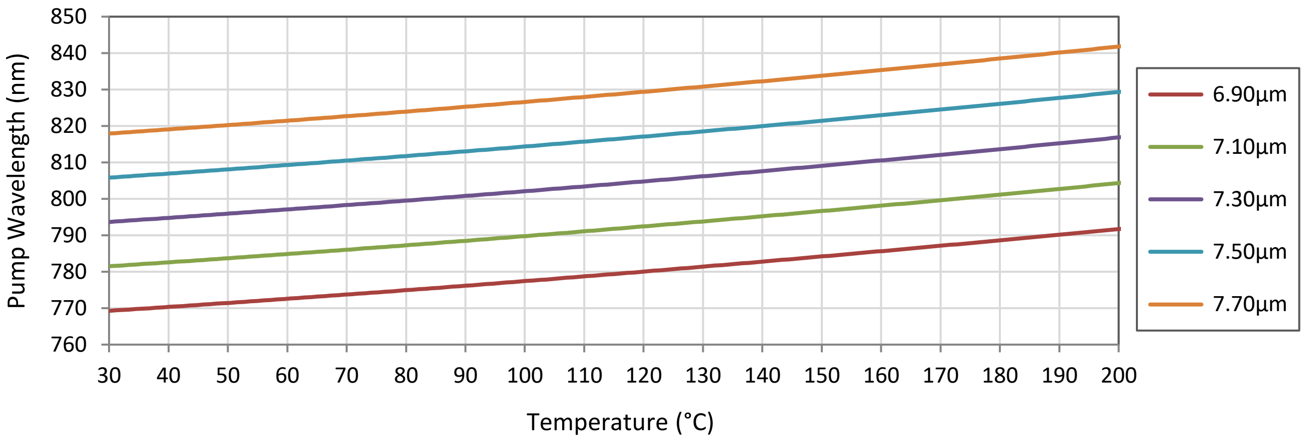
Applications

- Cascaded THG from 1550nm
- Quantum optics

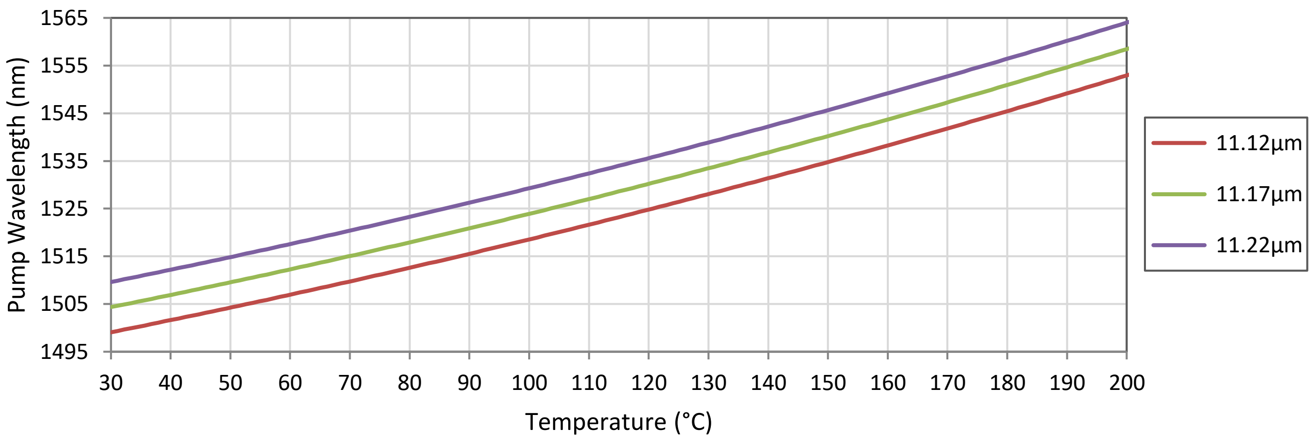
part #	pump (nm)	output (nm)	grating periods (µm)	thickness (mm)	standard lengths* (mm)
MSFG1-0.5	775 – 840 & 1550	516 – 544	6.90, 7.10, 7.30, 7.50, 7.70	0.5	1, 3, 5, 10, 20, 40
MSFG578-0.5	1280 – 1365 & 1030	570 – 587	8.70, 8.80, 8.90, 9.00, 9.10	0.5	1, 3, 5, 10, 20, 40
MSFG612-0.5	1000 – 1025 & 1550	608 – 617	10.40, 10.55, 10.70, 10.85, 11.00	0.5	1, 3, 5, 10, 20, 40
MSFG626-0.5	1550 –1560 & 1051	618 – 628	11.12, 11.17, 11.22	0.5	1, 3, 5, 10, 20, 40
MSFG637-0.5	1520 – 1590 & 1070	628 – 640	11.60, 11.65, 11.70, 11.75, 11.80	0.5	1, 3, 5, 10, 20, 40
MSFG647-0.5	1085 – 1160 & 1550	638 – 663	12.10, 12.30, 12.50, 12.70, 12.90	0.5	1, 3, 5, 10, 20, 40

**custom crystal lengths from 0.3mm to 50mm available upon request*

Calculated temperature vs. phase matching wavelength tuning curve of MSFG1 with 1550nm pump



Calculated temperature vs. phase matching wavelength tuning curve of MSFG626 with 1051nm pump



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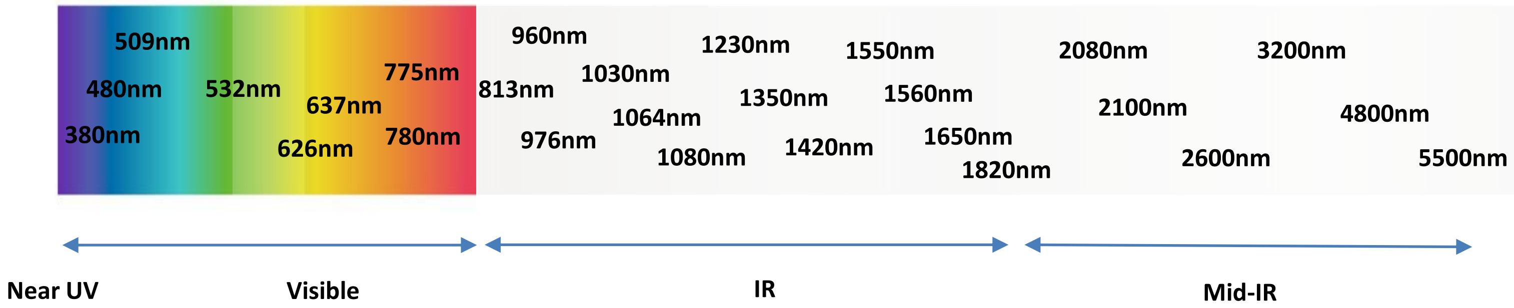
MgO:PPLN Fiber Coupled Bulk Module

Fiber-coupled bulk module for non-linear wavelength conversion

Utilising our extensive range of bulk MgO:PPLN crystals we can provide customisable solutions with fiber coupling (input and output) for non-linear wavelength conversion; designed for OEMs and researchers who need maximum ouput power with high efficiency.



Key Features

- Fully customisable compact solution
- Simple to use
- High efficiency design
- Robust with long lifetime
- Compatible with Covesion temperature controllers
- Design for OEM integration through to R&D use
- Solution available for 1x0, 1x1, 2x1, 1x2
- Options for power monitoring, control and output filtering
- Integrated TEC and resistive heater options

Fiber-coupled bulk module FBM

FBM with temperature controller OC3

FCBM Example Specification*

Non-linear interaction	Type 0 (ee-e)
Input wavelength for SHG [nm]	1064
Output wavelength [nm]	532
Phase match temperature between [^{o}C]	30 to 70
CW pump power [W]	2
SHG output power [mW]	125
Fiber connector	PM-FC-APC
Input/ Output fiber	PM1064/PM488
Connector keyway alignment	Slow Axis

*Specifications are representative of typical product performance

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MgO:PPLN Waveguide Package

Fibre-coupled ruggedised waveguide package for SHG and SPDC

Our current range of MgO:PPLN waveguides, have been available in different packaged formats, which has allowed you to use our great conversion efficiency to produce a range of power levels at second harmonic generation (SHG) wavelengths 767.5-785nm using affordable, readily available pump sources. This can also be used for spontaneous parametric down-conversion (SPDC) to generate photons at C-band. Our products have become synonymous with simple, reliable, frequency conversion for researchers and OEMs working in many different fields.

The package waveguide is fully compatible with our OC3 temperature controllers. We also offer waveguide accessory package. Each Waveguide Accessory Pack will contain a 1m 1550nm PM patch cord and a 1m 850nm PM patch cord which are exactly matched to our fibres, ensuring that the loss of output power is significantly reduced when compared to other commercially available patch cords. The pack also contains two PM fibre mating sleeves.

WGP

WGP with OC3

WGP Key Features

- Simple to use
- Flexible over a range of Input powers up to 3W
- Robust with long lifetime
- Compatible with OC3 Temperature controllers

Applications

- Atomic clock
- Quantum computing
- Quantum communication

Fibre-coupled component waveguide for SHG and SPDC

These products are designed for researchers and OEM's who require reliable output power from a few mW to over 2W. The new range is also fully compatible with our OC3 temperature controllers. The Component Waveguides are available in fibre in/fibre out and fibre in/free space out formats.

WGCO

WGCF

WGCO/ WGCF Key Features

- Simple to use
- Robust with long lifetime
- Flexible over a range of Input powers up to 3W
- Compatible with OC3 Temperature controllers
- Compact size to integrate into your own system

Applications

- Atomic clock
- Quantum computing
- Quantum communication

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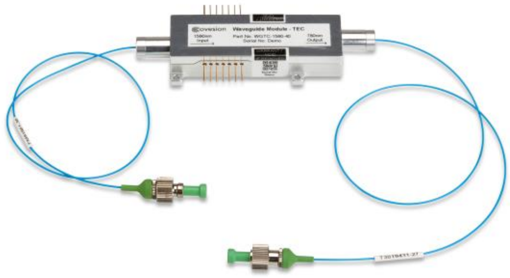
MgO:PPLN Waveguide Package

TEC based, fiber-coupled waveguide package for SHG and SPDC

These products are designed for researchers and OEM's who require reliable output power from a few mW to over 2W. The new range is also fully compatible with our MC1 temperature controllers. The Component Waveguides are available in fibre in/fibre out and fibre in/free space out formats.

WGTC Key Features

- Simple to use
- Robust with long lifetime
- Flexible over a range of Input powers up to 4.5W
- Compatible with MC1 Temperature controllers
- Compact size to integrate into your own system



C-band Waveguide Specification

Packaging type	WGP	WGCO	WGCF	WGTC
Non-linear interaction	Type 0 (ee-e)	Type 0 (ee-e)	Type 0 (ee-e)	Type 0 (ee-e)
Input wavelength range for SHG* [nm]	1535 – 1570	1535 – 1570	1535 – 1570	1535 – 1570
Output wavelength range [nm]	767.5 – 785	767.5 – 785	767.5 – 785	767.5 – 785
Phase match temperature between [^{o}C]	30 to 110	30 to 110	30 to 110	10 to 75
Recommended max. CW pump launch [W]	3	3	4.5	4.5
Input/Output fiber	PM1550/PM850	PM1550/PM850	PM1550/ free space output	PM1550/PM850
Fiber connector	PM-FC-APC	PM-FC-APC	PM-FC-APC	PM-FC-APC
Connector keyway alignment	Slow Axis	Slow Axis	Slow Axis	Slow Axis
Heater/ Temperature sensor	Resistive/PT1000	Resistive/PT1000	Resistive/PT1000	TEC/NTC Thermistor

**custom wavelength available upon request*

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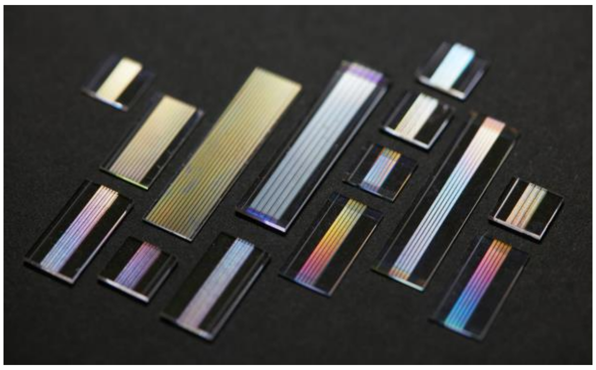
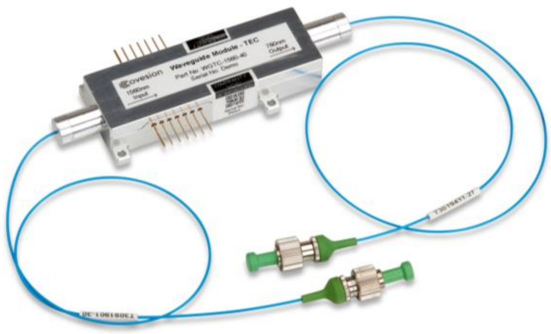
Custom Solutions for R&D to High-Volume OEM

Covesion's wavelength conversion technology provides a versatile basis for the design and manufacture of unique solutions. Our custom design and fabrication service provides application-specific technical consultation with specialist design and contract manufacture, resulting in a wavelength conversion solution tailored to your target laser system. We offer a range of custom design services including:

- One-off chips
- Bespoke packaging
- OEM prototyping
- Large-volume manufacture
- OEM temperature controllers





Our custom fabrication service involves consultation with the customer for design of the non-linear optical chip through to fiber coupled packaging requirements.

Your custom non-linear optical chip can be designed to be a bulk crystal or waveguide to provide optimal optical performance. Bespoke packaging solutions are available to provide ease of use through fiber coupled input and output.

OEM temperature control options are available to support full system integration.

We can manufacture single crystals as small as <1mm^3 for compact intra-cavity designs, or several millimetres wide aperture gratings with a long crystal length for high power applications.

Custom Designs for Non-standard Interactions

PPLN crystals and waveguides can be designed with aperiodic grating patterns to enable tailored spectral or thermal performance.

Periodic Custom designs:
- Specific poling periods with custom AR coating
- Specific poling periods with wider aperture
- Non-standard length and custom aperture angles

Aperiodic Custom designs:
- Linear period chirped gratings
- Non-linear period chirped gratings

Please contact our technical experts to discuss your custom requirements.

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MgO:PPLN Applications

Our MgO:PPLN has a wide range of applications:

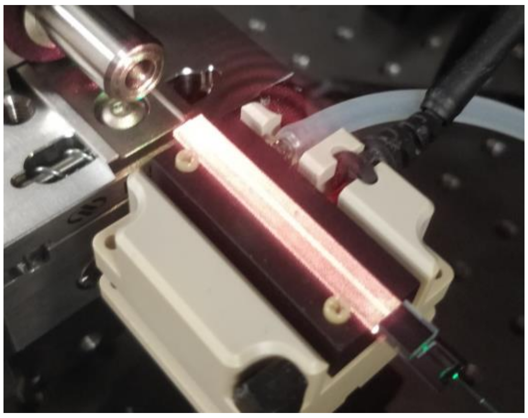
Quantum Technology
- Quantum Sensing
- Quantum Communication
- Quantum Computing
- Quantum Navigation & Timing

Lasers & Scientific Instrumentation
- Harmonic generation
- Tunable OPO
- Super-resolution imaging
- Metrology

Aerospace & Defence
- Laser Countermeasures
- LIDAR
- Stand-off sensing
- Upconversion detection

Environmental, Medical & Life Science
- Gas Sensing
- CARS microscopy
- Flow cytometry

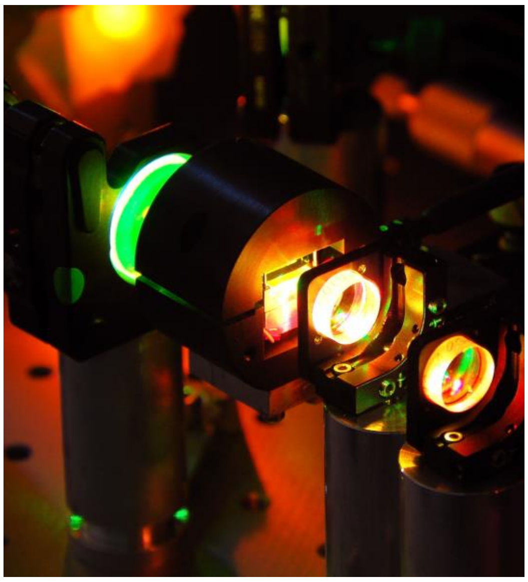
Research
- Frequency comb stabilization
- THz generation
- Nonlinear interferometry



High efficiency generation of visible light via SHG using Covesion PPLN waveguide

Covesion PPLN solutions are designed for efficient frequency conversion allowing you to reach wavelengths that cannot be achieved with conventional lasers.

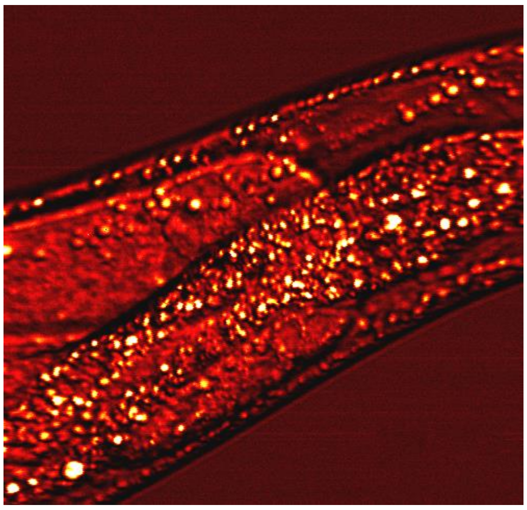
PPLN crystals, waveguides and modules can be used to generate narrow linewidth, low noise laser light targeting specific atomic and ionic transitions. Examples include generation of 780nm light by frequency doubling telecoms lasers for Rb atom cooling, trapping and interferometry for use in quantum timing, sensing and computing applications.



Nanosecond optical parametric oscillator for mid-IR generation
Image courtesy of Elforlight

Due to its high, optical non-linearity PPLN is an efficient solution for photon pair generation via the spontaneous parametric down conversion (SPDC) process. The generation and subsequent entanglement of photon pairs is a key requirement in quantum communication and cryptography applications including quantum key distribution (QKD).

PPLN devices are commonly used for high power mid-IR generation in an optical parametric oscillator. Tuneable mid-IR systems are used in a wide range of microscopy imaging techniques as well as spectroscopy applications for environmental imaging. With pulse energies in excess of 1mJ, these mid-IR sources are also used in the defence industry for laser countermeasures and LIDAR systems.



CARS microscopy image of *C. elegans* worm
G. Krauss et al. *Opt. Lett. 34, 18, 2847 (2009)*

The upconversion of light from the MIR to the NIR/visible in highly efficient PPLN waveguides enables the use of state-of-the-art, low cost, Si photodetectors rather than expensive, cooled MIR detectors. Thereby increasing the utility of applications such as stand-off gas detection.

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PPLN Accessories

Covesion's team of optical engineers have designed a range of PPLN crystal clips, ovens, temperature controllers and mounting accessories, providing a **complete PPLN solutions** for easy integration into your optical arrangement.

PPLN clip kits

The **Covesion PPLN Clip Kits** provide secure mounting of our PPLN crystals.

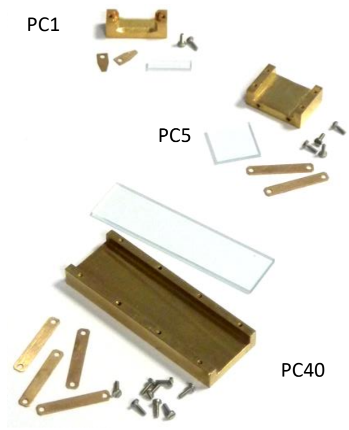
part #	crystal length
PC1-PC5	1-5 mm
PC10	10mm
PC20	20mm
PC40	40mm
PC50	50mm

Key Features

- Simple pin-aligned mounting in PPLN ovens
- Uniform temperature distribution
- Spring clips secure the crystal with minimal stress
- ITO coated glass for electrostatic charge dissipation

Each clip kit contains:

- a clip body
- an ITO coated cover glass
- a number of springs and screws



PV oven series

The **Covesion PV Oven Series** is specially designed to provide secure mounting and robust thermal stability for our PPLN crystals.

Key Features

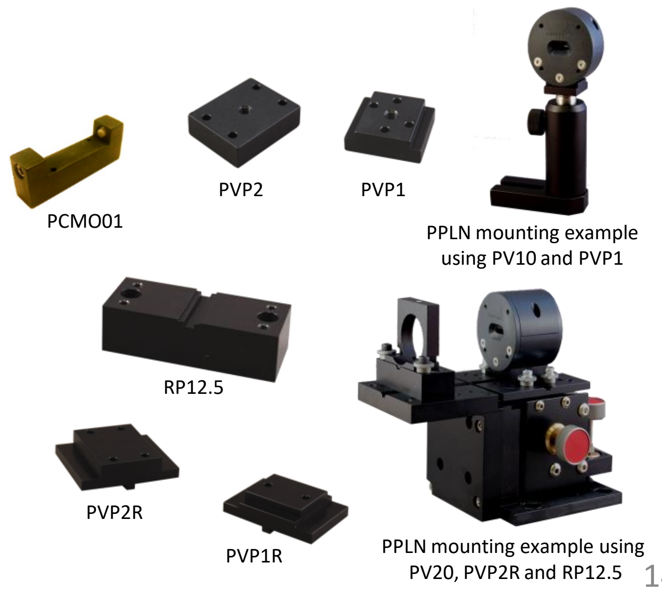
- Auto-locating dowel pins for alignment-free insertion
- Temperature stability of ±0.01°C with OC3 controller
- Various mounting options available

part #	crystal length	oven length	PPLN clip
PV10	1mm, 10mm	22mm	PC1, PC10
PV20	20mm	32mm	PC20
PV40	40mm	52mm	PC40
PV50	50mm	62mm	PC50

Free space mounting solutions

The **Covesion free space mounting solutions** contain post mount adaptors, flexure stage adapters and oven free mouting solutions.

part #	description	optical height
PCMO01	Oven free PC01 clip mount adapter	8mm
PVP1	PV10 post mount adapter	25mm
PVP2	PV20, PV40 and PV50 post mount adapter	25mm
PVP1R	PV10 adapter mount for flexure stages	25mm
PVP2R	PV20, PV40 and PV50 adapter mount for flexure stages	25mm
RP12.5	12.5mm riser plate for flexure stage mounts	25mm



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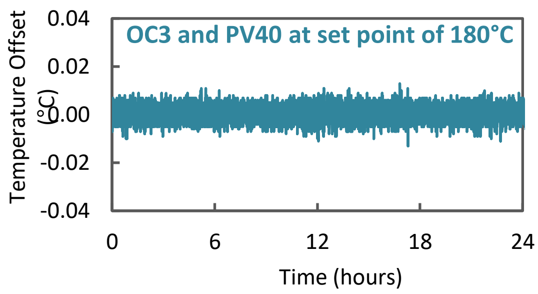
Temperature controller

The **Covesion OC3/ MC1** temperature controller is a compact stand-alone benchtop unit for use with our PPLN oven range. The auto-detect feature provides hassle-free, plug-and-play functionality. The user can simply dial in the required temperature and allow the oven to reach optimum stability.



OC3/ MC1 Key Features

- Simple push button interface
- Set point stability ±0.01°C
- Set point resolution 0.01°C
- Standard USB type B connector
- LabVIEW / Python drivers
- OC3 Maximum temperature 200°C
- MC1 Maximum temperature 80°C
- PC control interface via USB
- Auto-detect feature for Covesion ovens and components

part #	control range	set point resolution	stability	for ovens	for components	input
OC3	near-ambient to 200°C	0.01°C	±0.01°C	PV10, PV20, PV40, PV50	WGP, WGCO, WGCF, FCBM	90 – 240VAC
MC1	5 - 80°C	0.01°C	±0.01°C	NA	WGTC, FCBM	100 – 250VAC

OC3-PCB & MC1-PCB

Covesion temperuatre controller PCB is specially designed for use with our PPLN ovens and components. It's ideal to integrate into your own system.

OC3-PCB Key Features

- Set point stability ±0.01°C
- Set point resolution 0.01°C
- Maximum temperature 200°C
- PC control interface via USB
- Oven connector
- Molex KK254 2 pin power connector

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Electronic Control Products

Covesion design, develop and manufacture solution orientated, electronic control products for customers operating in the healthcare, energy, defence and scientific instrumentation markets. Specialising in thermal management and sensor control systems, Covesion offers a range of products from off-the-shelf to custom solutions. Covesion have the expertise to provide bespoke temperature control solutions providing thermal stability within 0.001°C, product compactness and reliability, low operating noise, and simplicity in use.

Covesion supply a range of off-the-shelf electronic control solutions for temperature control and thermal management. Through our bespoke design and OEM manufacturing service, we can also cater for specific product application requirements.

Our wide range of standard temperature controllers provide high precision control of TEC's and resistive heating elements:

- **Temperature control from –200ºC to 350ºC with up to 0.001ºC stability**
- **0 – 24V TEC drivers, rated at 5 – 15A output current**
- **Wide range of sensor options; RTD PT100, PT1000, Thermistor, LM35, AD590, LM335 etc**
- **Wide range of interface options; USB, RS232, RS485, Ethernet etc**
- **PCB and encased versions available**
- **GUI temperature control interface**
- **User configuration of output limits, PID terms, temperature alarms and operating modes**
- **Designed for standalone operation and OEM integration**

Standard Temperature Controller Options

Model	TC Lite	TC LV	TC M
Supply	5V to 24V DC	12V or 15V	5V to 28V DC
Output	5V to 24V, up to 10A	0 to 5V, up to 5A	5V to 24V, up to 15A
Sensor options	Various	Various	Various
Temperature control range	–200ºC to 350ºC	–100ºC to 100ºC	–100ºC to 200ºC
Temperature resolution	0.05ºC	0.001ºC	0.001ºC
Temperature stability	0.05ºC	0.001ºC	0.001ºC
Control interface	Various	Various	Various
PCB version	Yes	Yes	Yes
Encased version	Yes	No	Yes

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Covesion specialises in the manufacture of **periodically poled lithium niobate (PPLN)** devices, such as, **MgO-doped periodically poled lithium niobate (MgO:PPLN or PPMgO:LN) bulk crystal** and **waveguide**. These PPLN devices are highly efficient mediums for nonlinear wavelength conversion processes, such as: second harmonic generation; difference frequency generation; sum frequency generation; optical parametric oscillation; and other second order nonlinear processes.

Principles

Second order nonlinear processes (Fig. 1) involve the mixing of three electromagnetic waves, where the magnitude of the nonlinear response of the crystal is characterized by the $\chi^{(2)}$ coefficient. Second harmonic generation (SHG), or frequency doubling, is the most common application that utilizes the $\chi^{(2)}$ properties of a nonlinear crystal. In SHG, two input pump photons with the same wavelength λ_p are combined through a nonlinear process to generate a third photon at $\lambda_{SHG} = \lambda_p/2$. Similar to SHG, sum frequency generation (SFG) combines two input photons at λ_p and λ_s to generate an output photon at λ_{SFG} with $\lambda_{SFG} = (1/\lambda_p + 1/\lambda_s)^{-1}$. Alternatively, in difference frequency generation (DFG) when two input photons at λ_p and λ_s are incident on the crystal, the presence of the lower frequency *signal* photon, λ_s, stimulates the *pump* photon, λ_p, to emit a signal photon λ_s and *idler* photon at λ_i with $\lambda_i = (1/\lambda_p - 1/\lambda_s)^{-1}$. In this process, two signal photons and one idler photon exit the crystal resulting in an amplified signal field. This is known as optical parametric amplification. Furthermore, by placing the nonlinear crystal within an optical resonator, also known as an optical parametric oscillator (OPO), the efficiency can be significantly enhanced.

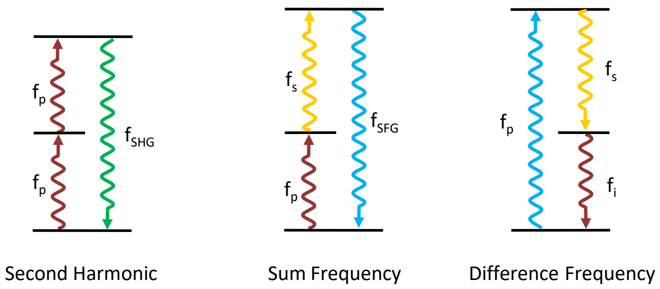

Fig. 1 Second-Order Nonlinear Interactions

Phase matching refers to fixing the relative phase between two or more frequencies of light as they propagate through the crystal. The refractive index is dependent on the frequency of light. Thus, the phase relation between two photons of different frequencies will vary as the photons propagate through the material, unless the crystal is phase matched for those frequencies. It is necessary for the phase relation between the input and generated photons to be maintained throughout the crystal for efficient nonlinear conversion of input photons. If this is not the case, the generated photons will move in and out put phase with each other in a sinusoidal manner, limiting the number of generated photons that exit the crystal. This is shown in Fig. 2. Traditional phase matching requires that the light is propagated through the crystal in a direction where the natural birefringence of the crystal matches the refractive index of the generated light. Despite providing perfect phase matching, this technique is limited to a small range of wavelengths in those materials that can be phase matched.

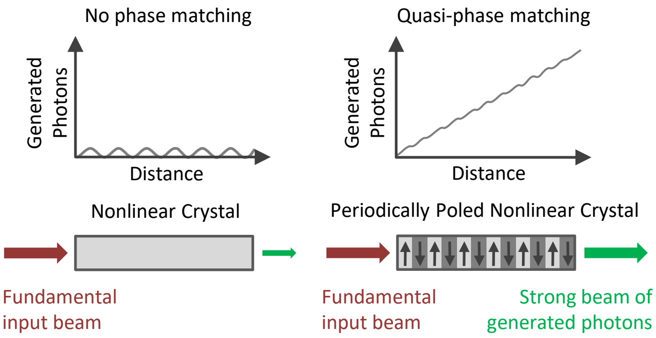

Fig. 2 Quasi-Phase Matching

PPLN is an engineered, quasi-phase-matched material. The term engineered refers to the fact that the orientation of the lithium niobate crystal is periodically inverted (poled). By inverting the crystal orientation at every peak of the sinusoidal generation, one can avoid the photons slipping out of phase with each other. As a result, the number of generated photons will grow as the light propagates through the PPLN, yielding a high conversion efficiency of input to generated photons (Fig. 2).

The period with which the crystal needs to be inverted (the poling period) depends on the interacting wavelengths and the temperature of the PPLN. For example, a PPLN crystal with a poling period of 6.6µm will efficiently generate frequency doubled photons from 1060nm photons when the crystal temperature is held at 100°C. By increasing the temperature of the crystal to 200°C the same PPLN crystal will efficiently generate frequency doubled photons from 1068.6nm wavelength photons. Thus, changing the temperature of the crystal therefore varies the phase matching conditions, allowing some tuning of the wavelength interaction.

Example uses of PPLN

Optical Parametric Oscillator:

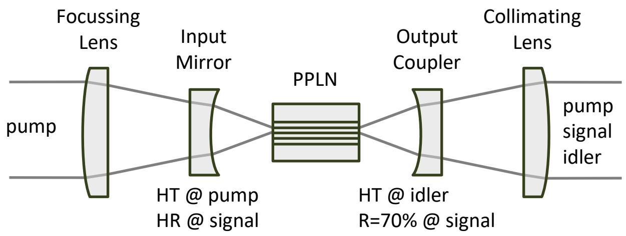

Fig. 3 Typical schematic of an OPO

One of the most common uses of PPLN is in an Optical Parametric Oscillator (OPO). A schematic of an OPO is shown in Fig. 3. The common arrangement uses a 1064nm pump laser and can produce signal and idler beams at any wavelength longer than the pump laser wavelength. The exact wavelengths are determined by two factors: energy conservation and phase matching. Energy conservation dictates that the sum of the energy of a signal photon and an idler photon must equal the energy of a pump photon. Therefore an infinite number of generated photon combinations are possible. However, the combination that will be efficiently produced is the one for which the periodicity of the

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poling in the lithium niobate creates a quasi-phase matched condition. The combination of wavelengths that is quasi-phase matched, and hence referred to as the operation wavelength, is altered by changing the PPLN temperature or by using PPLN with a different poling period. Nd:YAG pumped OPOs based on PPLN can efficiently produce tunable light at wavelengths between 1.3 and 5µm and can even produce light at longer wavelengths but with lower efficiency. The PPLN OPO can produce output powers of several watts and can be pumped with pulsed or CW pump lasers.

Second Harmonic Generation:

PPLN is one of the most efficient crystals for frequency doubling and is well known for highly efficient green and red generation. It has been used to frequency double 1064nm beams with up to 80% conversion efficiency in a single pass pulsed system[1]. In CW systems, conversion efficiencies in excess of 50% have been demonstrated in an intracavity arrangement[2].

How to use PPLN

Crystal length:

The crystal length is an important factor when choosing a crystal. For narrowband CW sources our longer crystal lengths, at 20 to 40mm, should give best efficiency. However, for pulsed sources, a long crystal can have a negative effect due to increased sensitivity to laser bandwidth and pulse duration. For nanosecond pulses, we typically recommend 10mm lengths and our shortest lengths at 0.5 to 1mm are ideal for femtosecond pulse systems.

Polarization:

In order to access the highest nonlinear coefficient of lithium niobate, the input light must e-polarized, i.e. the polarization must be aligned with the dipole moment of the crystal. This is accomplished by aligning the polarization axis of the light parallel to the thickness of the crystal. This applies to all nonlinear interactions.

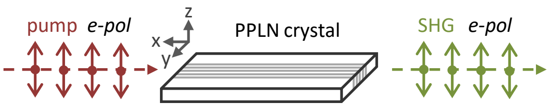

Fig. 4 SHG requires polarization parallel to the z-axis

Focusing and the Optical Arrangement:

Since PPLN is a nonlinear material, the highest conversion efficiency from input photons to generated photons will occur when the intensity of photons in the crystal is the greatest. This is normally accomplished by coupling focused light into the center of the PPLN crystal through the end face of the crystal at normal incidence. For a particular laser beam and crystal, there is an optimum spot size to achieve optimum conversion efficiency. If the spot size is too small, the intensity at the waist is high, but the Rayleigh range is much shorter than the crystal. Therefore, the size of the beam at the input face of the crystal is large, resulting in a lower average intensity over the whole crystal length, which reduces the conversion efficiency. ***A good rule of thumb is that for a CW laser beam with a Gaussian beam profile, the spot size should be chosen such that the Rayleigh range is half the length of the crystal.*** The spot size can then be reduced in small increments until the maximum efficiency is obtained. PPLN has a high index of refraction that results in a 14% Fresnel loss per uncoated surface. To increase transmission through our crystals, the crystal input and output facets are AR coated, thus reducing the reflections at each surface to less than 1%.

Temperature and Period:

The poling period of a PPLN crystal is determined by the wavelengths of light being used. The quasi-phase-matched wavelength can be tuned slightly by varying the temperature of the crystal.

Covesion's range of off-the-shelf PPLN crystals each include multiple different poling periods, which allow different wavelengths to be used at a given crystal temperature. Our calculated tuning curves give a good indication of the required temperature for phase-matching. The temperature dependence of conversion efficiency follows a sinc^2 function, describing a crystal *temperature acceptance bandwidth* (Fig. 5). The longer the crystal, the narrower and more sensitive the acceptance bandwidth. In many cases the efficiency of the nonlinear interaction is very sensitive to within a few degrees Celsius.

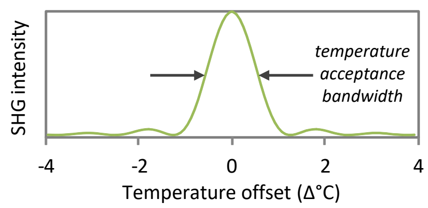

Fig. 5 SHG intensity temperature dependence for 1064nm pump in a 20mm long MgO:PPLN crystal

The optimum temperature can be determined by heating the crystal to e.g. 10°C higher than the calculated temperature and then allowing the crystal to cool whilst monitoring the output power at the generated wavelength.

The Covesion PPLN oven is easy to incorporate into an optical setup. It can be paired with Covesion's OC3 temperature controller to maintain the crystal temperature to within ±0.01°C, providing highly stable output power.

MgO:PPLN vs undoped PPLN

Undoped PPLN is usually operated at temperatures between 100°C and 200°C, to minimize the photorefractive effect that can damage the crystal and cause the output beam to become distorted. Since the photorefractive effect is more severe in PPLN when higher energy photons in the visible part of the spectrum are present, it is especially important to use the crystal only in the recommended temperature range.

The addition of 5% MgO to lithium niobate significantly increases the optical and photorefractive resistance of the crystal while preserving its high nonlinear coefficient. With a higher damage threshold, MgO:PPLN is suitable for high power applications. It can also be operated from room temperature up to 200°C, significantly increasing the wavelength tunability of the device. Moreover, in some special cases, the MgO:PPLN can be operated at room temperature and without the need for temperature control.

[1] *Opt. Lett. 23 (3) pp. 162-164 (1998)* [2] *Laser Phys. 20 (7) pp. 1568-1571 (2010)*

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