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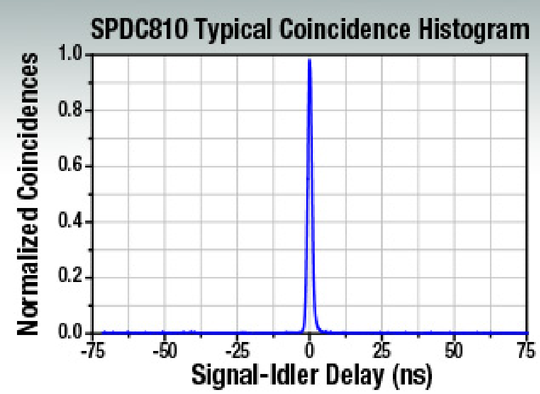
CORRELATED PHOTON-PAIR SOURCE

- Heralded Single-Photon Source with $g^{(2)}(\tau = 0) < 0.1$
- Photon-Pair Generation at 810 nm
- Integrated 405 nm Pump Laser

SPDC810
Correlated Photon-Pair Source



A second-order correlation measurement [$g^{(2)}(\tau)$] between signal and idler photons. The peak at τ = 0 confirms the generation of photon pairs. Data is taken at 35 mW.

OVERVIEW

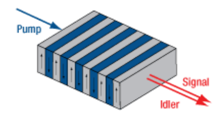
Features

- Spontaneous Parametric Down-Conversion (SPDC) Source (Collinear Type-II)
- >0.45 High-Efficiency Heralding Ratio
- >450 kHz Pair Generation Rate
- ±2.5 nm Wavelength Stability for Emitted Photons
- Pump Laser Power Adjustable from 10 mW to 150 mW
- Room Temperature Operation
- Remote Operation of 405 nm Pump Laser (Serial RS232)

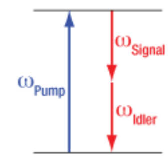
Typical Applications

- Heralded $g^{(2)}$ Measurements
- Absorption Spectroscopy
- Quantum Metrology
- Sub-Shot-Noise Imaging
- 2-Photon Interference

Thorlabs' Correlated Photon-Pair Source uses spontaneous parametric down-conversion (SPDC) to create a pair of energy-time entangled photons at 810 nm. With an integrated 405 nm pump laser, this self-contained source results in >450 kHz photon pairs per second and a high-efficiency heralding ratio of >0.45. A zero-time delay second-order correlation function [$g^{(2)}$ (τ = 0)] value of <0.1 can be achieved with this source, making it a high-brightness heralded single-photon source ideal for quantum optics applications. For complete performance specifications, please see the *Specs* tab; note that the heralding ratio, pair rate, and $g^{(2)}(0)$ values are given for the pump laser operating at 35 mW and the observed statistics will vary with the pump power and detector specifications.



Click to Enlarge
Collinear Type-II SPDC of one 405 nm pump photon entering a PPKTP crystal and exiting as two 810 nm output photons.



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The SPDC conversion process obeys energy and momentum conservation.

In this SPDC source, a nonlinear crystal [periodically poled potassium titanyl phosphate (PPKTP)] converts one 405 nm pump photon into two 810 nm photons (the signal and idler) in a single event. The resulting signal and idler photons have type-II phase matching, which means they propagate with orthogonal polarizations (extraordinary and ordinary); see the schematics to the right. As a source that emits photon-pairs in a simultaneous event, it can be used as a heralded single-photon source. This is when the detection of one photon (idler) heralds the presence of the second photon (signal). More information about single-photon verification can be found in the *Single-Photon Output* tab.

Click to Enlarge
Photon-Pair Source shown with P1-780PM-FC-1 patch cables (not included) connected to the signal and idler outputs.

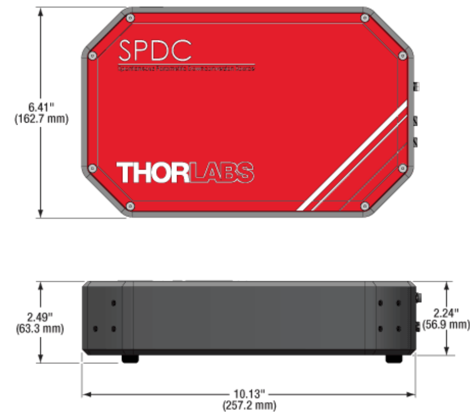
To efficiently collect the down-converted light, the signal and idler channel outputs are FC/PC coupled. We recommend using PM780-HP FC/PC patch cables to maintain polarization, such as P1-780PM-FC-1. If polarization information does not need to be retained, 780HP FC/PC patch cables can also be used.

The photon-pair source contains an oven to maintain the temperature of the nonlinear crystal and the wavelength of the down-converted photons, resulting in a wavelength stability of ±2.5 nm. For adequate cooling, the unit requires 1" of clearance on all sides.

This SPDC source is factory-aligned and ready to use. If misalignment occurs but signal is still detected, x- and y-axes adjustments to the internal mirrors can be made through the access holes in the side of the housing; see the manual for details. The internal adjusters accept a 5/64" or 2 mm ball driver (not included). Please contact Applications@thorlabs.com if no signal is detected.

The unit is shipped with a 12 V power supply with an M8 connector and an RS232 cable for operating the pump laser. For more information about these connectors, please see the *Pin Diagrams* tab.

SPECS



Click to Enlarge
Correlated Photon-Pair Source Housing Dimensions

Specifications	
Optical Specifications	
Operating Wavelength	810 ± 2 nm
η_{si} (Detector Excluded)[a,b]	>0.45
Max Pairs/Second	>450 kHz
Wavelength Stability[a]	±2.5 nm
Temperature Control	No
$g^{(2)}(\tau = 0)$[a,c]	<0.1
Extinction Ratio[a]	>17 dB
Lifetime	>2500 Hours of Pump Emission
Pump Laser Power[d]	10 mW to 150 mW
User Servicable	No
Electrical Specifications	
Input Voltage	100 - 240 V
Frequency	50 - 60 Hz
Power Consumption	25 W (Max)
Interface	RS232 Serial
Environmental Requirements	
Room Temperature	18 °C to 25 °C
Storage Temperature	-10 °C to 60 °C
Humidity	Non-Condensing
Physical Dimensions	
Dimensions (L x W x H)	10.13" x 6.41" x 2.24" (257.2 mm x 162.7 mm x 56.9 mm)
Weight	2.6 kg

- For a Pump Laser Power of 35 mW
- η_{si} is the heralding ratio and can be determined using C/sqrt($P_s P_i$), where C respresents the coincidence counts and P_s and P_i are the raw counts on the signal and idler channels, respectively.
- Second-order correlation measurement at zero time delay. See the *Single-Photon Output* tab for more details.
- The SPDC810 source can be used at lower pump powers, but specifications will not be met.

SIDE PANEL

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Correlated Photon-Pair Source Electrical Connections

Correlated Photon-Pair Source Side Panel	
Callout	**Description**
1	Signal Channel Output, 2.0 mm Narrow Key FC/PC Fiber Connector
2	Idler Channel Output, 2.0 mm Narrow Key FC/PC Fiber Connector
3	Serial RS232 Connector for Pump Laser
4	M8 Power Connector, 12 VDC Supply

SINGLE-PHOTON OUTPUT

Verification of Single-Photon Output

One of the most important characteristics of any single-photon source is the degree to which its output consists of only single photons. It is not enough to be able to detect a signal using single photon detectors, which can be easily achieved by attenuating a classical light source. Also, the output of a true single photon source may be contaminated with additional light due to leakage or multiphoton events. Therefore, while a coincidence peak can confirm the presence of single photons, it provides little information about the present noise. Please note that throughout this discussion, singles refers to a single detection event on one channel, ideally half of the photon pair.

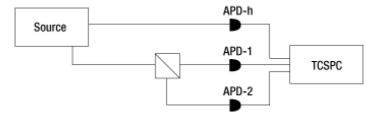

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Figure 1: Experimental setup for testing single-photon generation. APD-h is the avalanche photodiodes for the heralded photons, while APD-1 and APD-2 are the ones for the signal photons. TCSPC is the time-correlated single-photon counter.

Thorlabs' SPDC810 Photon-Pair Source is based on spontaneous parametric down-conversion (SPDC) and, thus, generates a pair of photons at any moment in time. An experimental setup to verify its single-photon operation is shown in Figure 1. One of the outputs is connected directly to a single-photon detector, which in this case is a single-photon avalanche photodiode (APD). This channel is often referred to as a heralding or trigger channel, as it confirms the existence of a photon in the other arm. The signal channel is split on a 50:50 beamsplitter in a Hanbury-Brown-Twiss configuration and is connected to detectors 1 and 2. All 3 detectors are then connected to a coincidence counter, which is a time-correlated single-photon counter (TCSPC). If the output of the source truly consists only of photon pairs, there will only be two-fold coincidences between the heralding detector and detector 1 or 2, which are $C_{h,1}$ and $C_{h,2}$ respectively. This is demonstrated in Figure 2. Three-fold coincidences between all three detectors $C_{h,1,2}$ should not occur, as there are only two photons present.

Example data obtained using the SPDC810 photon-pair source is presented in Table 1. As expected, the singles are split according to the beamsplitter reflectance. In this case, the additional loss was due to fiber-to-fiber coupling. The same is true for coincidences $C_{h,1}$ and $C_{h,2}$, which are similarly distributed between the two detectors. However, three-fold coincidences $C_{h,1,2}$ are very close to 0. The results confirm the true single-photon output of the source. In addition, the experiment also confirms the particle nature of light, i.e., a photon cannot be split.

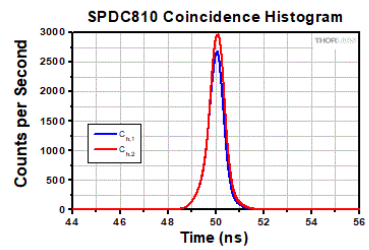

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Figure 2: Coincidence Histogram for $C_{h,1}$ and $C_{h,2}$, which are the coincidences between APD-h and APD-1 or -2, respectively. The peak at 50 ns confirms pair emission; a heralding photon reaches APD-h and 50 ns later (an added time delay) a signal photon reaches APD-1 or APD-2. Data acquired using Thorlabs' SPDC810 Photon-Pair Source.

Table 1			
Average Coincidences per Second		Singles per Second	
$C_{h,1}$	15229	S_h	130796
$C_{h,2}$	17435	S_1	45376
$C_{h,1,2}$	8	S_2	55128

The measurement described above is often referred to as a heralded second-order intensity correlation $g_h^{(2)}(\tau)$, where τ is the time difference between the arrival times t_1 and t_2. At τ = 0, which is our point of interest, it can be quantified using the following formula:

$$g_h^{(2)}(0) = \frac{S_h \times C_{h,1,2}}{C_{h,1} \times C_{h,2}} \qquad (1)$$

For an ideal photon pair source, the conditional probability of detecting photons at both detectors 1 and 2 at the same time (τ=0), given that a photon is detected at the heralding detector, is 0. Based on the data shown in Table 1 and using equation 1, we obtain $g_h^{(2)}(0)$ = 0.004, which is very close to ideal performance. In addition, the second order intensity correlation has a more fundamental importance. It is used to prove the non-classical nature of light, as the value of $g^{(2)}(0)$ depends on the type of light being investigated:

$$g_h^{(2)}(0) = 1 \quad \textit{Coherent Light}$$

$$g_h^{(2)}(0) > 1 \quad \textit{Bunched Light}$$

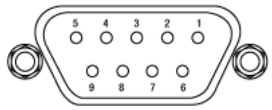
$$g_h^{(2)}(0) < 1 \quad \textit{Antibunched Light}$$

Depending on the experimental configuration, photon pair sources can exhibit both bunched and antibunched light statistics. Thermal light is a typical example of bunched light, where the probability of photons being detected across the outputs of a beamsplitter increases for τ ≈ 0, peaking at τ = 0. In contrast, an ideal single photon source exhibits antibunching, as discussed earlier. However, if a $g^{(2)}(\tau)$ measurement is performed only on one of the channels, with the other one ignored, then such a source will produce thermal statistics.

PIN DIAGRAMS

SPDC810 Correlated Photon-Pair Source Electrical Connections

RS232 Female Connector (On Housing)



The RS232 connector provides connection to the pump laser.

Pin	Description	Pin	
1	Data Carrier Detect (DCD)	6	Data Set Ready (DSR)
2	Receive Data (RXD)	7	Request to Send (RTS)
3	Transmit Data (TXD)	8	Clear to Send (CTS)
4	Data Terminal Ready (DTR)	9	Ring Indicator (RI)
5	Signal Ground (GND)	-	-

M8 Male Connector (On Housing)

Pin	Description
1	Not Connected
2	Not Connected
3	+12 V
4	Ground

For Connection to DS12 12 VDC Power Supply

Correlated Photon-Pair Source

Part Number	Description	Price	Availability
SPDC810	810 nm Correlated Photon-Pair Source with Integrated Pump Laser	$22,000.00	Lead Time

Visit the *Correlated Photon-Pair Source* page for pricing and availability information:
https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=13675