Spontaneous Parametric Down Conversion and Evidence of Photon Anticorrelation on a Beam Splitter

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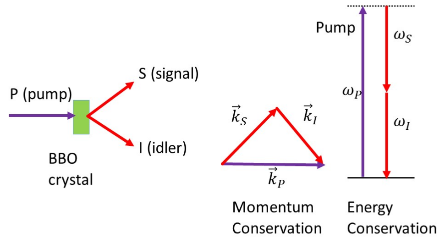
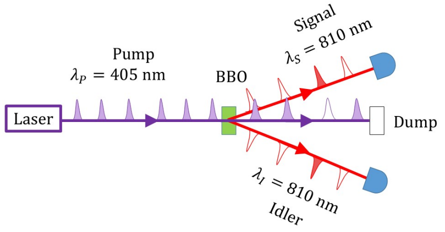
This project investigate the quantum nature of single photon, a quantum a light.

Photons are produced by a process known as spontaneous parametric down conversion (SPDC). Starting with a powerful blue laser (405 nm), this process divides the initial beam (or pump) into two light cones (the signal and the idler).

This process is different from the use of a beam splitter because it involves dividing a photon into two through a Beta-Barium Borate (BBO) crystal, and must obey the conservation of energy and momentum. Consequently, the two light cones must each have twice the wavelength of the pump (810nm) and they must be separated by an angle of 3.0° in both directions from the direction of propagation of the pump. Only in a billion blue photon will undergo such SPDC.

Spontaneous Parametric Down Conversion

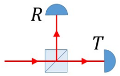




Single Photon

In a coincidence correlation setup, the photons emitted by the systems are split using a 50/50 beamsplitter and send onto two single photon sensitive detectors.

Coincidence Rate is $g_2 = \frac{\langle I_T I_R \rangle}{\langle I_T \rangle \langle I_R \rangle}$



Classical	Quantum
Waves	Particle-Waves
$g_2 \geq 1$	$g_2 < 1$

If a single photon is incident on a beamsplitter, only one detector will fire. Perfect single photons have $g_2 = 0$.

"...a single photon can only be detected once!"
- *Grangier et al.*

A field with g_2 cannot be described classically, and is inherently quantum mechanical.

Detection and Coincidence

The detection is done through a fix-focused collimation lens coupled to an optical fiber attached to an avalanche photodiode detector, operated in "Geiger-mode". A single photon triggers an avalanche of electrons.

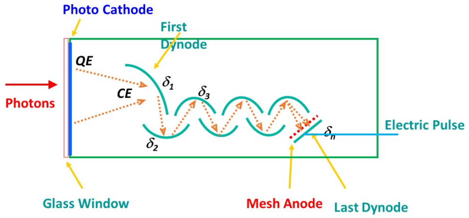
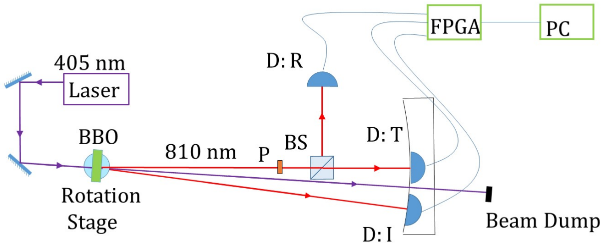


Photo detection efficiency of 60% at 800 nm. Photons are converted to an electric pulse (TTL) . The dark counts is below 4000 counts/s.

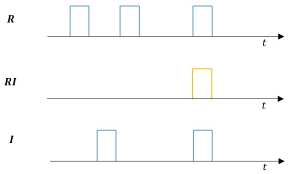
Experimental Setup

FPGA	Field Programmable Gate Array
BBO	Barium Borate Crystal: $Ba(BO_2)_2$
P	Polarizer at 45°
BS	Beam Splitter
D	Single-Photon Counting Module



Coincidence

The output of the single photon detector is fed into a field programmable gate array that allows to detect coincidences with a 10-nanosecond resolution.



We measure a total of seven photocounts in each data acquisition interval: singles counts from each of the three detectors, double coincidence N_{RI}, N_{TI} , and N_{RT} , as well as the triple coincidence count N_{TRI}.

Result

Counts	Double Coincidence	Triple Coincidence
$N_R = 4.9 \times 10^6/s$ $N_T = 1.9 \times 10^5/s$ $N_I = 7.9 \times 10^5/s$	$N_{RI} = 1.8 \times 10^3/s$ $N_{TI} = 7.0 \times 10^3/s$	$N_{TRI} = 20\ /s$

In terms of counts, $g_2 = \frac{N_{TRI} N_I}{N_{TI} N_{RI}}$ and we find that $g_2 = 0.689 \pm 0.162$ after integrating over 250 s.
A truly single-photon state incident on the beam splitter would yield $g_2 = 0$.
Why don't we see $g_2 = 0$? A consequence of defining a ''coincidence'' with a finite time window. There is the possibility that uncorrelated photons from different down conversion events may hit the T and R detectors within our finite coincidence window; these are ''accidental'' coincidences.

Conclusion

A photon coincidence experiment using SPDC was performed. We demonstrated that spontaneous parametrical down-conversion delivers sufficient power for both single photons and coincidence counting. The SPDC contained biphoton states that cannot be attributed to coincidences of the classical field. We have performed an experiment that is in agreement with a quantum description involving single-photon states.

Acknowledgments:
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References:

P. Grangier, G. Roger, and A. Aspect, Europhys. Lett. 1, 173-179 (1986).