Redefining Measurement

QUANTUM SENSING APPLICATION NOTE

Photon correlation using state of the art equipment for precision, speed and performance

February 2020

ID QUANTIQUE SA
Chemin de la Marbrerie 3
1227 Carouge/Geneva
Switzerland
T +41 22 301 83 71
F +41 22 301 89 79
info@idquantique.com
www.idquantique.com

Introduction

You might be creating powerful technology in a commercial environment – or pushing boundaries in quantum communication, computing or optics through your research. If you are using photon correlation in your work, to check particle sizing, quantum key distribution or signal to noise ratio enhancement, ID Quantique (IDQ) can provide the efficient equipment you need.

As a leading manufacturer of photon counting modules, timing electronics and photonic sensing solutions for industrial and research applications, our equipment offers you state-of-the-art precision, speed and performance. Our products are designed for accurate measurement, excellent timing resolution, fast detection, lower noise and adjustable parameters to make sure everything is aligned properly.

It is ideal if you are creating a new laboratory, or preparing to undertake new experiments that include a single photon source, or more complex one such as swapping entanglement to benefit from the best equipment that enables you to demonstrate the results as effectively as possible with real peace of mind.

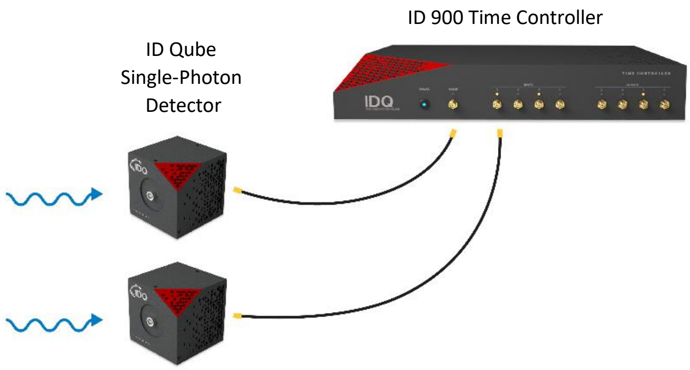
Photon correlation at-a-glance

In general, we say that 2 or more photons are correlated if the results of a given measurement on each individual photon exhibit a relationship. For instance, 2 photons that are time-correlated (which is the usual case with photon correlation) will show a relationship on their arrival time measurement. Often, the relationship is simple – the 2 photons are more likely to be detected at the same time or be detected with the same time difference.

Nevertheless, the correlation nature could be very different from one application to another. To some extent, correlation between photons is so strong that it cannot even be described by classical physics. In that case, we talk about quantum correlation.

Three ways to apply photon correlation

The basis of a correlation setup will consist of 2 single-photon detectors and a TCSPC (time-correlated single photon counting) device. In our example, using IDQ's ID Qube series and ID900 Time Controller.



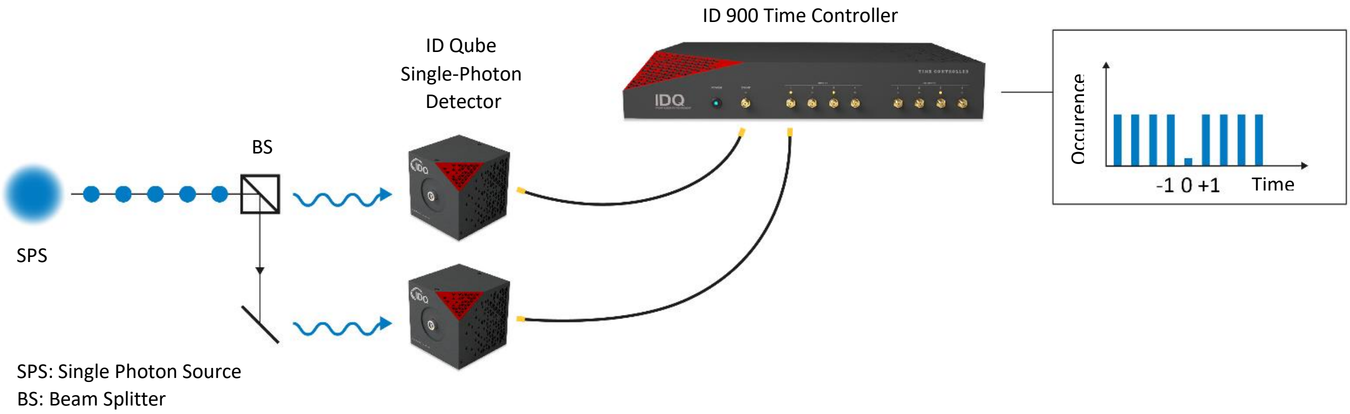
1. Single-photon source characterization

Purity measurement: A perfect single-photon source generates pure single photons, in other terms, a quantum state of light that only contains the single-photon Fock state component $|1\rangle$. In the real world, none of the single-photon sources are perfect and there is always a small fraction of 2 photon Fock state $|2\rangle$ and more in the quantum state.

For this reason, it is important to characterize the photon-source by measuring its purity, in other words how much 2 photons (or more) component is contained in the state.

Hanbury Brown and Twiss (HBT)[1] measurement is exactly measuring this: The output of the single-photon source is sent into a beam splitter. The outputs of the beam splitter are then sent to the basic correlation setup as described below.

Making the histogram of the detectors time difference leads to the histogram shown below:



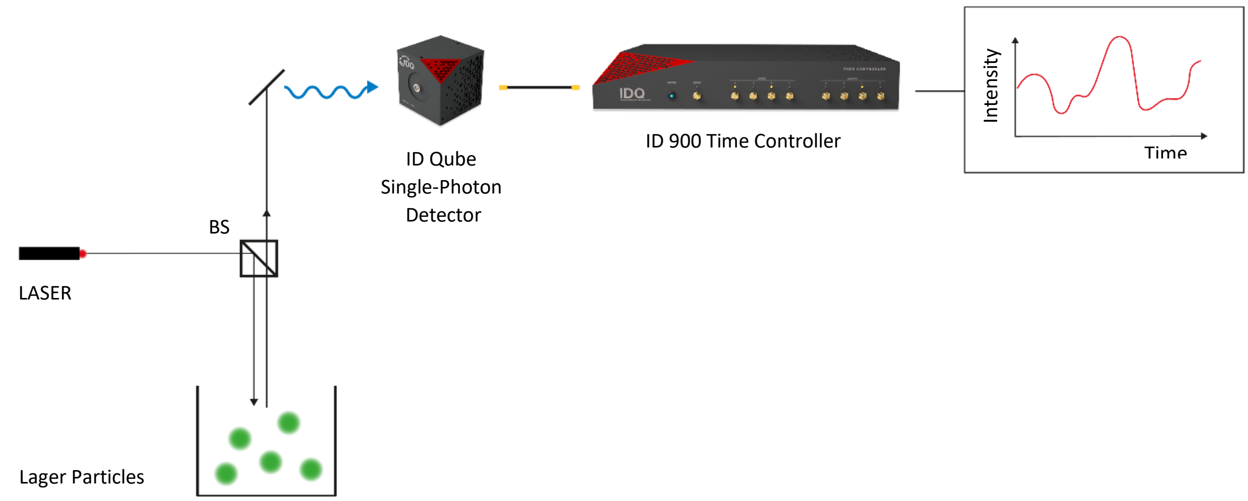
1. HBT: Nature, Volume 178, Issue 4541, pp. 1046-1048 (1956)

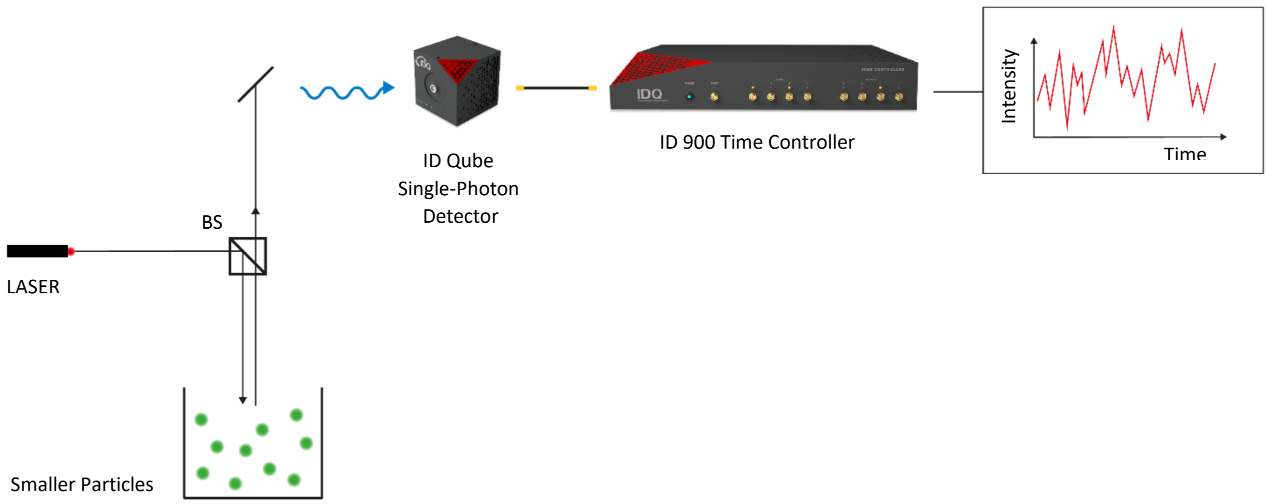
The fact that there is almost no double detection for zero-time difference makes sense because the single-photon source is sending one photon, and not more, at once. In that case, we talk about anti-correlation. The remaining counts at zero are attributed to the SPS imperfection and thus decrease the purity of the source.

One can use almost the same setup to characterize the distinguishability of the SPS by doing an Hong-Ou-Mandel (HOM)[2] experiment.

2. Photon correlation spectroscopy (PCS)

In this application, we are looking at the scattered photons light from a sample (solution or gas) that contains particles from nanometer to micrometer size. Because of the Brownian motion of those particles, we observe fluctuations in time on the arrival of the photons scattered by the sample. Small particles produce fast fluctuations while larger particles produce slow fluctuations as shown below:





2. HOM: Phys. Rev. Lett. 59, 2044

ID QUANTIQUE SA
Chemin de la Marbrerie 3
1227 Carouge/Geneva
Switzerland
T +41 22 301 83 71
F +41 22 301 89 79
info@idquantique.com
www.idquantique.com

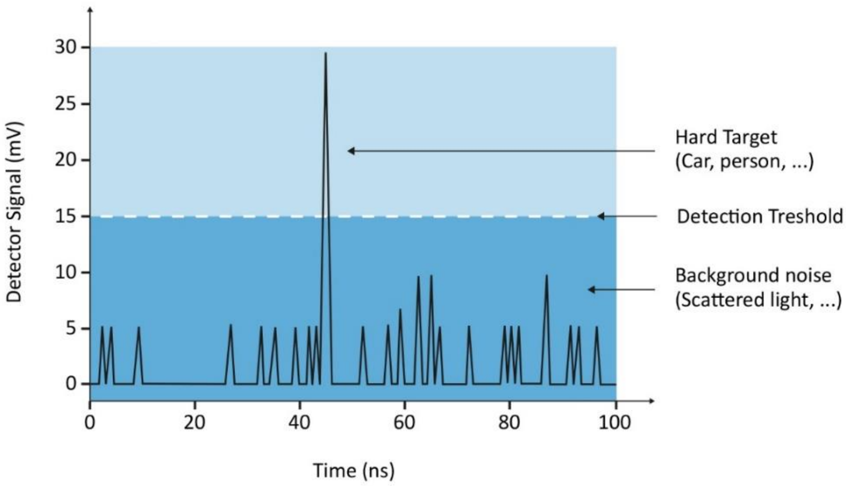
From this data, one can reconstruct the autocorrelation function and determine the size of the particles from the dominant fluctuation frequencies. It is essential for this application to have a very good high timing resolution to be able to measure fast fluctuations of small particles. Using any IDQ single photon detector and ID900 Time Controller will lead to state-of-the-art picosecond precision photon correlation spectroscopy.

3. Photon correlation for metrology – LiDAR

Photon correlation is also used in LiDAR applications to improve signal to noise ratio. In principle, this allows LiDAR to detect obstacles even in very bad visibility conditions. Indeed, because the LiDAR is sending short and bright pulses, we receive a lot of scattered photons from a hard target in a very short time window.

Scattering from fog, rain or snow lead to photons spreading out in time because those soft targets are spread out in space. Long distance LiDAR requires ability to detect few photons and distinction between scattered photons from fog and diffuse objects and hard targets (people, animals, trees, etc). Correlation helps to achieve this.

Considering only detections of 2 or more photons (this threshold could also be 3 or more photons), one can almost annihilate contribution from the soft target, as described below:



Products

Our single-photon counters are available in free-space or fibre-coupled (SMF/MMF) versions. They offer the possibility to receive external pulses for fast and slow gating operations depending on the model.

A first module is optimised for fast-gated (up to 100 MHz) operations at telecom wavelengths, specially suited for quantum communication protocol while a second module offers ultra-low noise free-running operation mainly required for photon correlation and Time of Flight measurement.

ID Qube NIR Free-Running
(900-1700 nm)

- Free-running & Gated
- Low Afterpulsing Rate
- Low Dark Count Rate (800

ID Qube Gated
(900-1700 nm)

- Fast Gated (up to 100 MHz) & Free-running
- 150 ps Timing Resolution
- Low Dark Count Rate (800 Hz)

Be even more efficient in the lab. ID Quantique's products are specially designed to be combined together. We recommend to operate the ID Qube detectors together with the ID900 Time Controller, IDQ's central platform which combines the functionalities of a Time-tagger, delay and pattern generator.

it aims to efficiently and reliably solve a large number of problems encountered in the modern laboratory.

ID900 Time Controller

- 3 Series available : TCSPC, Master, Dleay Generator
- Conditional programmable outputs
- Picosecond Timing