Application Note

Using an Oscilloscope as a Correlator

SINGLE QUANTUM
Excellence in photon detection

Photon-correlation measurements are the backbone of quantum-optics experiments and are performed with dedicated hardware; a so-called "correlator". Under some circumstances, it would be beneficial to perform correlation measurements with an oscilloscope, because pulses and trigger levels can be visualized and the timing jitter is superior.

Frame rate

Digital oscilloscopes suffer usually from a small acquisition frame rate, often in the 10 kFrames/s. Most of the time the oscilloscope is busy processing the data and, hence, many events are missed. We have tested the *Rhode & Schwartz* RTO2014 oscilloscope which mitigates this issue. We used an SNSPD with a heavily attenuated CW source to generate random trigger events on this oscilloscope. Each pulse trace captured in memory by a successful trigger event of the oscilloscope is called a *Frame*. Figure 1 summarizes this situation. The detector count rate is set by the photon flux, ideally the scope would allow to measure all the detector events (ideal curve). In reality, the scope has a finite processing time which reduces the frame rate. For typical correlation count rates in the order of 40 kCnts/s there is <1% deviation from the ideal acquisition rate. At around 300 kCnts/s the deviation is about 18% and the acquisition frame rate saturates at ~630 kFrames/s.

Time Resolution

We have tested the RTO2014 with 1 GHz bandwidth and achieved a minimum timing jitter between two input channels of 3.6 ps FWHM, and with the RT2044 with 4 GHz bandwidth of 2.2 ps FWHM, see figure 2.

These are excellent numbers and show that an oscilloscope is very suitable for high resolution photon-correlation measurements with *Single Quantum's* SNSPDs reaching jitters <10ps.

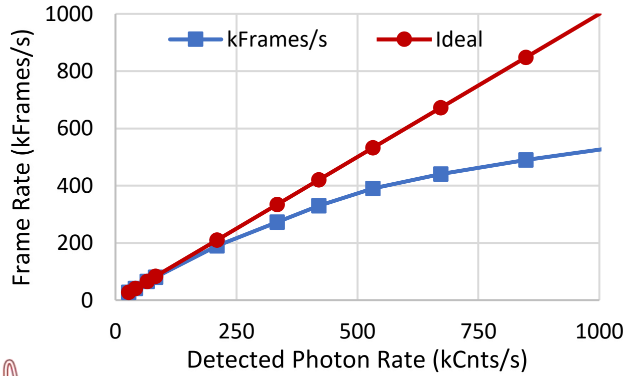

Fig. 1: Detected photon rate on SNSPD versus measured Frame Rate for the RTO2014 oscilloscope.

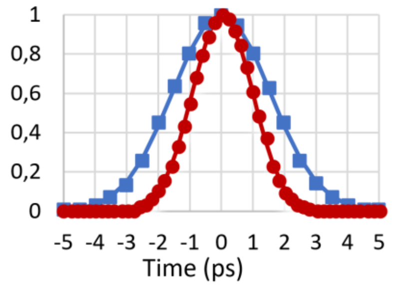

Fig. 2: Minimum timing jitter of the RTO2014 (blue squares) and RTO2044 (red circles). The lines are Gaussian fits.

The difference between a scope and a correlator

The tested oscilloscopes limit the user to 500 time-bins in their fast acquisition mode, and in our tests the largest correlation rate we could measure was 630 kFrames/s. The width of one time-bin is set by the *time scale* and *memory depth* and these settings affect the acquisition speed.

On the other hand, a standard correlator can usually measure correlations much faster, up to several million correlations/second, and provides much more time bins (typical 65k bins) to capture fast and slow process at the same time. On the other hand, the resolution is often worse than the one of an oscilloscope and the instruments are less flexible e.g. they cannot be used to also measure the pulse shape.

Setup and data readout

To perform a correlation measurement, the scope is configured to perform a jitter measurement between the start- and the stop-channel. The histogram of the acquired time differences is the correlation data.

The data can be read-out by an ethernet connection. *Single Quantum* provides sample code in Python.

Conclusion

An oscilloscope from the RTO family provides an excellent effective time resolution on the picosecond level. Typically, photon correlation experiments operate below 100 kCnts/s photons on each correlation channel. In this situation an RTO scope misses only a few percent of the incoming photons. In return a scope allows to perform the experiment in a *What You See Is What You Get* approach, making it easier to use than a traditional correlator.

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