Quantifying Single Photon Purity in a Commercial Quantum Teaching Apparatus

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INTRODUCTION

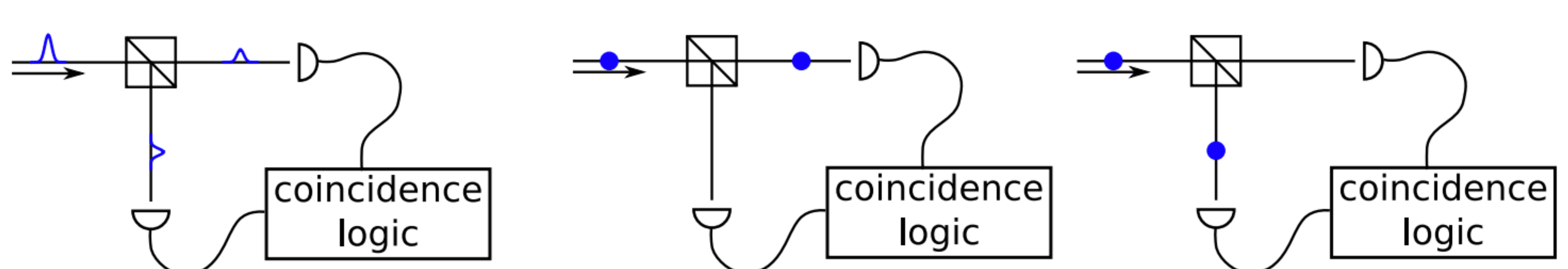
As a part of the shared Quantum Technology Teaching and Testbed (QT3) Laboratory, the quED, a commercial quantum physics science kit developed by quTools, is being used to perform various quantum measurements. A single photon source is required for many of these measurements. So, we will use the g^2 measurement to verify whether the kit's commercial source is a single photon source, and if so, what its single-photon purity is.

BACKGROUND

Quantum Nature of Light

- Light exists in quantized packets of energy
- Smallest, indivisible packet is called a "photon"

Hanbury Brown and Twiss Effect

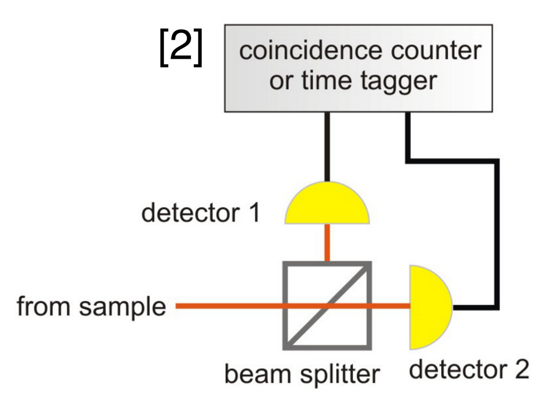


[1]

- Single photon behaves as particle when incident on beam splitter, so can only take one path at a time

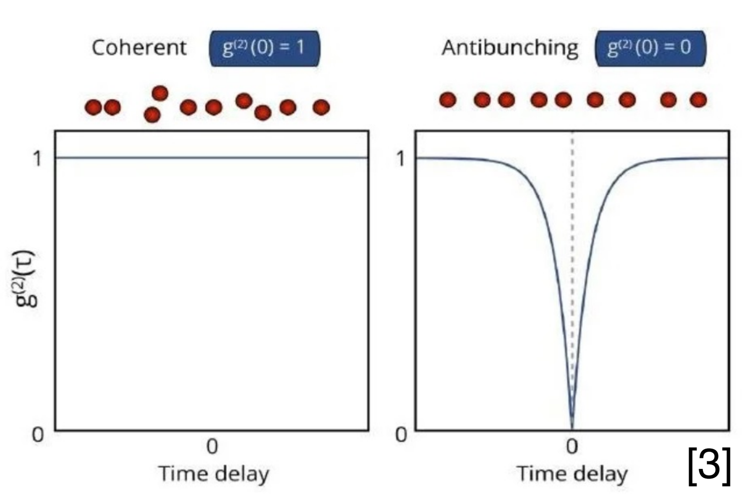
Standard g^2 Measurement

1) Light source incident on beam splitter
2) Detector at either output path
3) Detectors connected to counter
4) Use counts to calculate $g^2(0)$ value

[2]


$g^2(0)$ Value

- Gives correlation between detections on both channels separated by time delay of 0

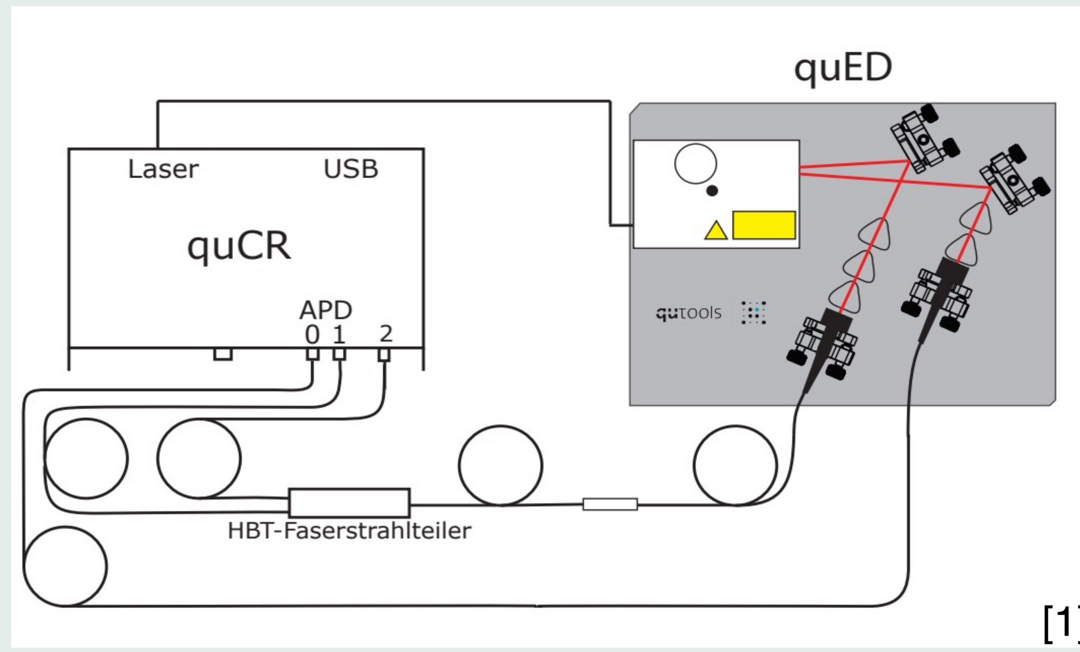


[3]

- Coherent source: $g^2(0) = 1$
- Single-photon source: $g^2(0) = 0$ (we accept $g^2(0) < 0.5$)
- Represents single-photon purity, so a value closer to 0 indicates a better source

METHODS & RESULTS

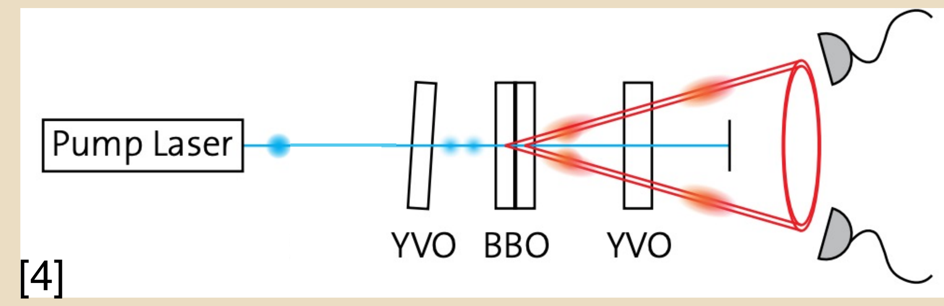
Setup



[1]

What is an SPDC Source?

- Pump photons (405 nm) converted into two lower energy photons (810 nm)
- Creates heralded single-photons
- Low conversion rate



[4]

$g^2(0)$ Measurement on quED

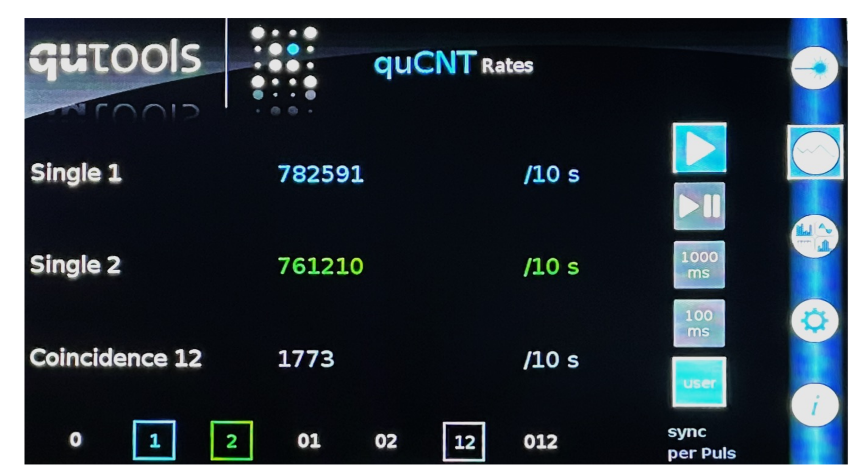
- quED can perform two types of $g^2(0)$ measurements
- Coincidence window: 30 ns

Non-heralded $g^2(0)$

$$g^2(0) = \frac{R_{12}}{R_1 R_2 t_c} = \frac{177.3}{78259.1 * 76121.0 * (30\ ns)}$$

$$= 0.99$$

(R refers to count rates)

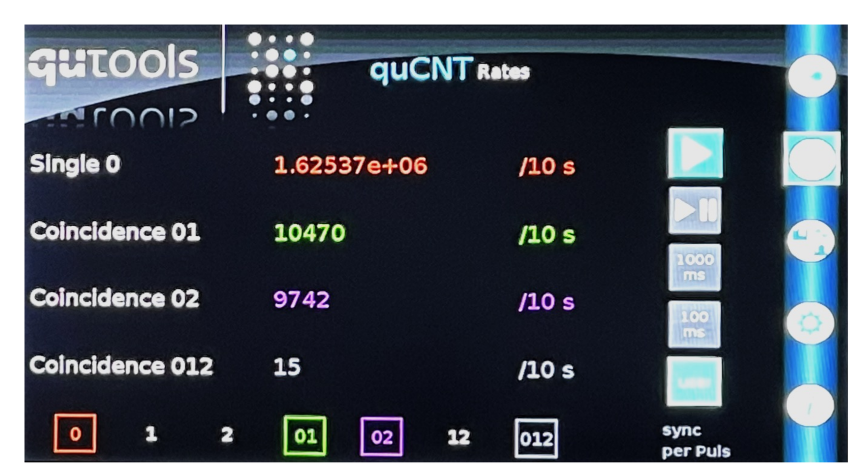


- Suggests it is not a single photon source

Heralded $g^2(0)$

$$g_H^2(0) = \frac{N_{t12} * N_t}{N_{t1} * N_{t2}} = \frac{15 * 1.62537 * 10^6}{10470 * 9742} = 0.24$$

(N refers to the counts)



- Suggests that with heralding, it is a single photon source

ANALYSIS

Why is Heralding Needed?

1. *Eliminates the vacuum (|0>) state*

- Non-heralded: Probability of detecting no photon is much higher than detecting one or more photons, which follows a Poisson distribution and therefore a coherent source.
- Heralded: The vacuum state is never considered because a detection on the trigger arm is required to register as a coincidence, so the |1> state is the most probable. This is what you would expect for a single photon source.

2. *Limits background counts*

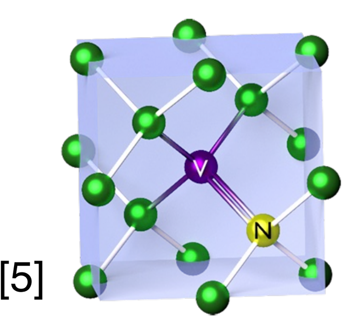
- Addition of trigger arm in heralded g^2 makes it harder for a background count to be registered as a coincidence because it must be detected within the same coincidence window as a heralded photon pair.

Purity of Heralded Single Photon Source

- Many quantum applications require a very high single-photon purity (often a $g^2(0)$ below 0.1)
- Our $g_H^2(0)$ of 0.24 is not very good, which may be a result of the 30 ns time window being a limitation

NEXT STEPS

- A confocal microscope is being developed for the QT3 lab to study single quantum emitters in various solid-state systems
- g^2 measurement can be used to find and verify single nitrogen vacancy centers (NVs)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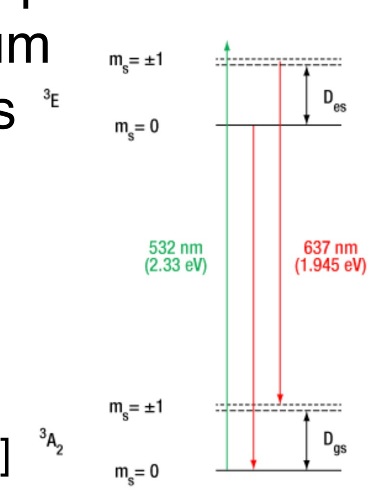

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