Bi-Photon Interference

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1 Introduction

We continue the work done in the single photon interference. We will modify the MZI that we built in the single photon experiment (see Figure 1). Additionally, we will cross-polarize

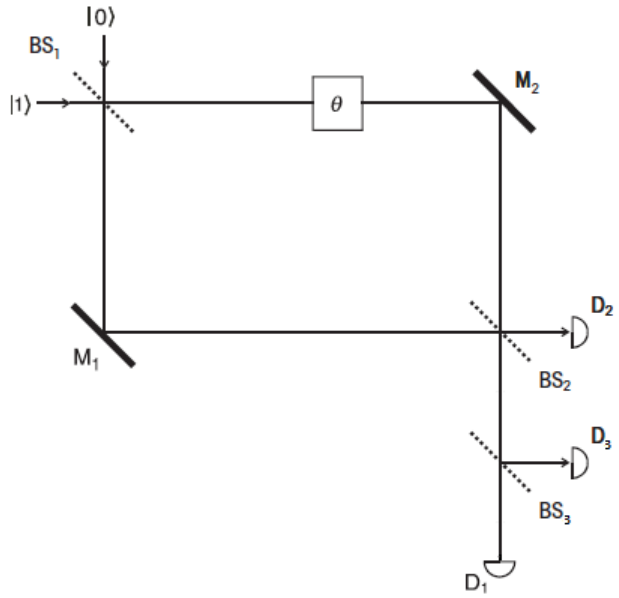


Figure 1: [5] MZI. BS_1, $BS2$, and BS_3 are beam-splitters, θ is the phase difference, M_1 and M_2 are mirrors, and D_1, D_2, and D_3 are detectors.

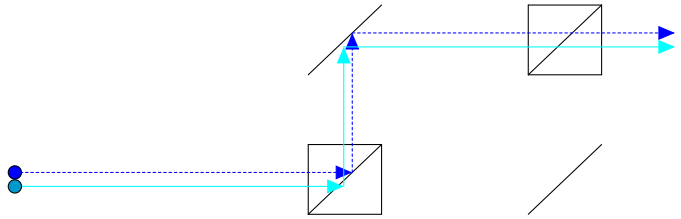
the BBO crystal; this is accomplished by adding a horizontal polarizer to the side of the

BBO crystal and a vertical polarizer to the other side. We must make sure that when aligning that the HeNe (red) laser goes though the interferometer and through the optical fiber of the detectors. Note that in Figure 1 detector D_2 is optional. We do measurements by recording the coincidence between $D1$ and $D2$ and/or $D1$ and $D3$. We choose to do $D1$ and $D2$.

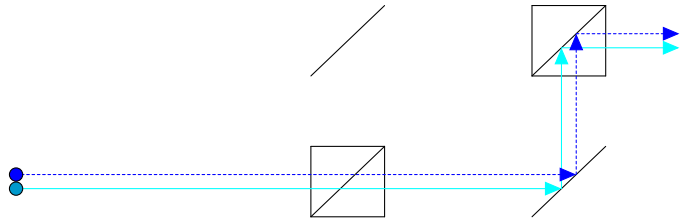
2 Theory

In contrast to the single photon experiment, both of the produced photons will pass through the modified MZI. If we distinguish between photons, we will have four cases to consider.

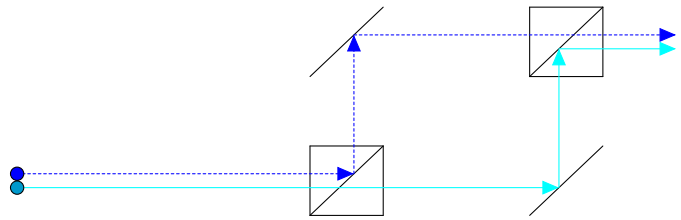
Case 1: Both of the photons will go through one of the arms MZI.



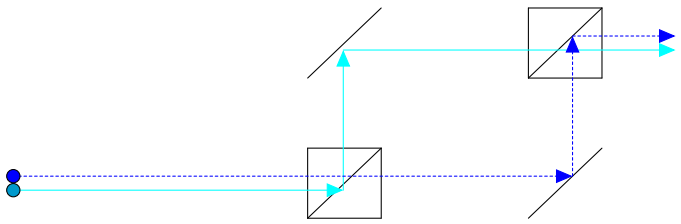
Case 2: Both of the photons will go through the other arm (different from Case 1) of the MZI.



Case 3: One photon will go through one of the hands of the MZI and the other photon through the other hand of the MZI.



Case 4: Same as Case 3, but the photons pass though the other hand of the MZI.



As we showed in the appendix of [1], the probability of a single photon to pass through the MZI is given by

$$P(\text{detecting single photon}) = \frac{1}{2}(1 + \cos\theta)$$

where θ is the phase difference of the arms of the MZI. Observe, in Case 1 and Case 2, the photons are indistinguishable (however independent) of each other. Thus, the probability that we detect these photons is give by

$$\begin{aligned} P(\text{detecting both photons}) &= \frac{1}{2}(1 + \cos\theta) \cdot \frac{1}{2}(1 + \cos\theta) \\ &= \frac{1}{4}(1 + \cos\theta)^2. \end{aligned}$$

This is because the event of detecting the first photon is independent of detecting the second photon.

In Case 3 and Case 4, the photon can be distinguished and so it can be shown that the probability of detecting coincidence[1] is,

$$P(\text{coincidence for Case 3 and 4}) = \frac{1}{4}(1 - \cos 2\theta).$$

3 Experimental Procedure

We assume the reader has followed the procedure laid out in [1]. At the moment our set-up should be as in Figure 2. We will add a third beam-splitter as in Figure 3. Before we continue, replace mirror M4 with a flipper or put it on a translational stage. The alignment is as before. Using the irises make sure all the red beams are align properly. Ultimately, we want to make sure that the red beam is passing through both of the optical fiber of the detectors. Lastly place two irises on either side of the BBO crystal; at this point the red beam should pass through both of these, the BBO crystal and both detectors.

[1] Stated in [2]

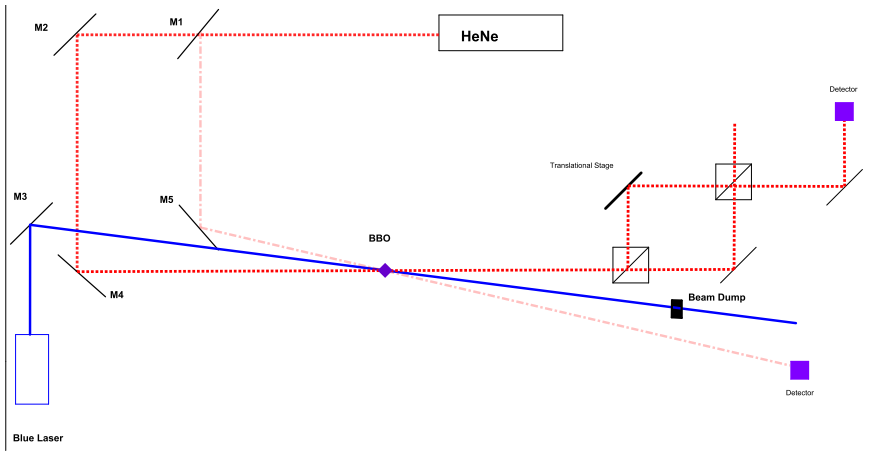


Figure 2: Diagramme of the single photon experiment set-up

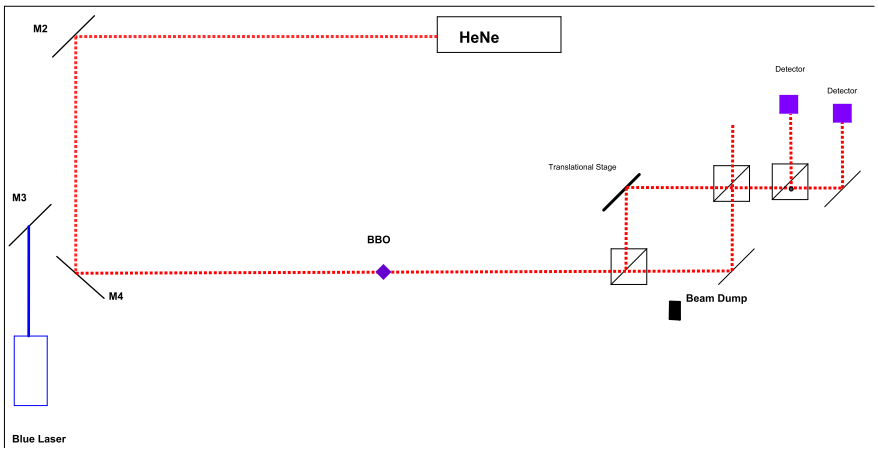


Figure 3: Location of third the 50:50 beam-splitter

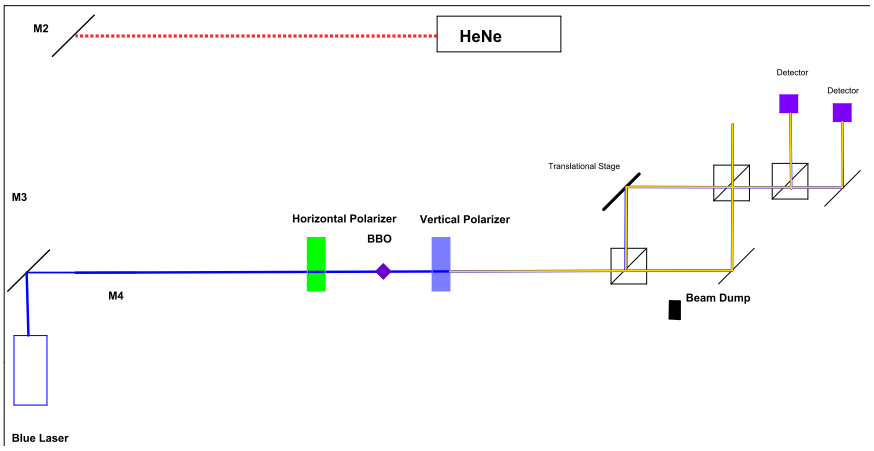


Figure 4: Moving blue beam and adding polarizers to our set-up

Next we will power down the red beam and flip-down (or remove) mirror M4. Make sure the detectors are **not** on. Use protective eyewear. We now will place mirror M3 so that the blue beam passes through both the irises and into the detectors. Now we place two polarizers on either side of the BBO crystal. We first will put a horizontal polarizers followed by a vertical polarizers (see Figure 4). Alternatively, we can use two crossed Glan-Thompson polarizers before and after the BBO crystal. **Make sure the lights are turned off. Turn on the detectors.** The blue beam is being blocked by the polarizers set-up. However, the blue beam can still produce down-conversion photons. Open the file titled *My_Dyn*2013.*vi*. Rotate and tilt the crystal a few degrees so that it will produce down conversion for the new path. Do piezo scans with the desired intervals. We will record the coincide between the two detectors[2]. Export your data and have fun!?!

[2]See appendix A for a modification of this experiment to see the distinguished photon pairs. Note, we do not take data for this; we are going to give the schematic.

References

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Appendix

A. Optional Experiment

We can add a third detector and a mirror so that we can do scans for the case where the photon pair are distinguishable (see Figure 5). We calibrate as we did in this paper for the inclusion of detector D1 (coming from the single photon experiment). Measurements are taken as follows

1. Coincidence between $D1$ and $D2$
2. Coincidence between $D1$ and $D3$
2. Coincidence between $D1$ and $D2$, and $D1$ and $D3$

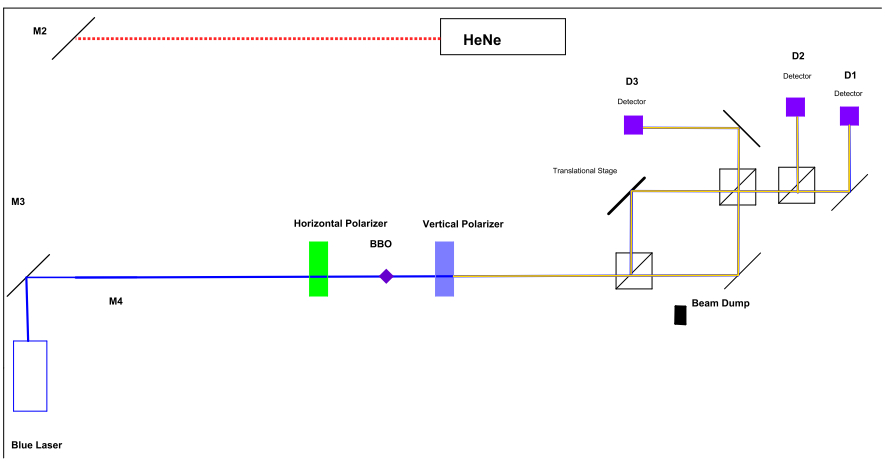

Figure 5: Adding a mirror and a detector

B. Daten

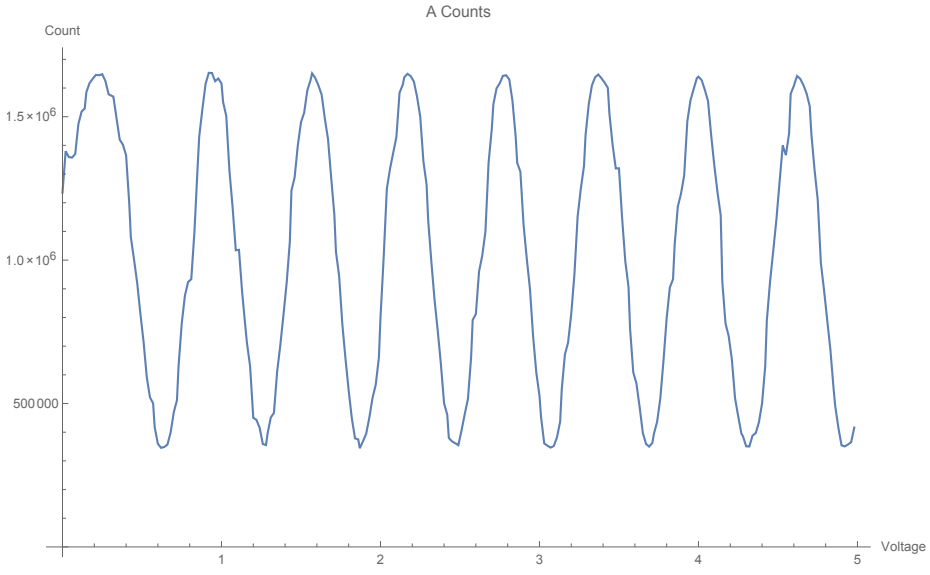

Figure 6: Counts A

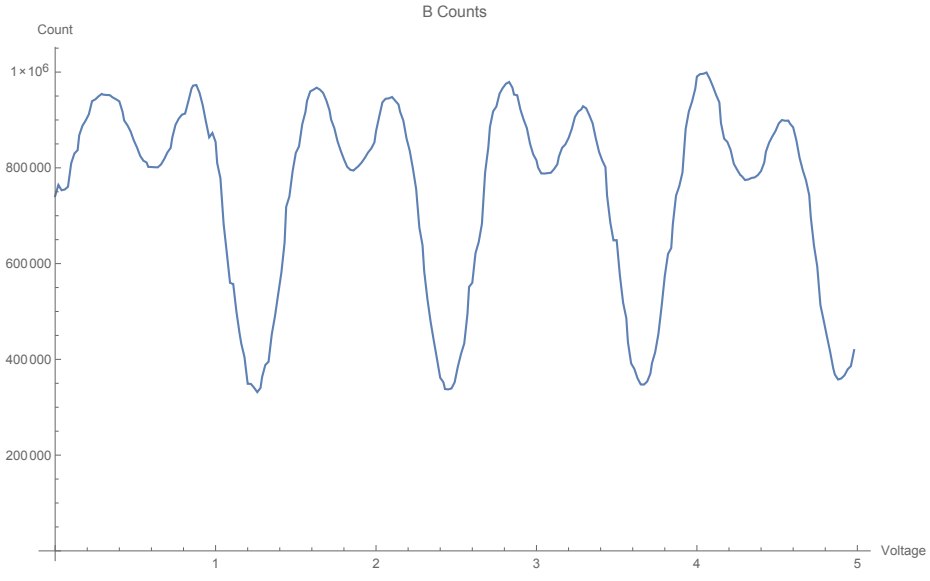

Figure 7: Counts B

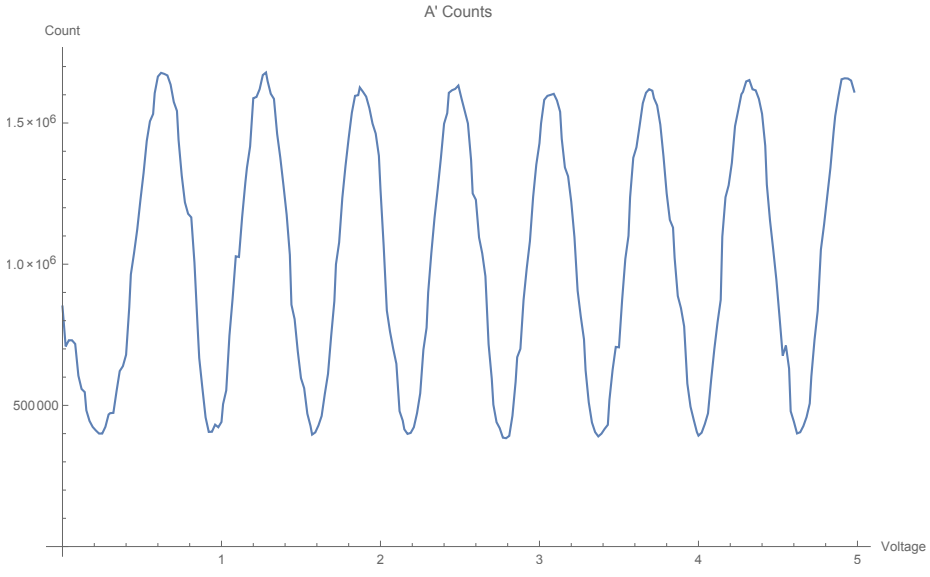

Figure 8: Counts A'

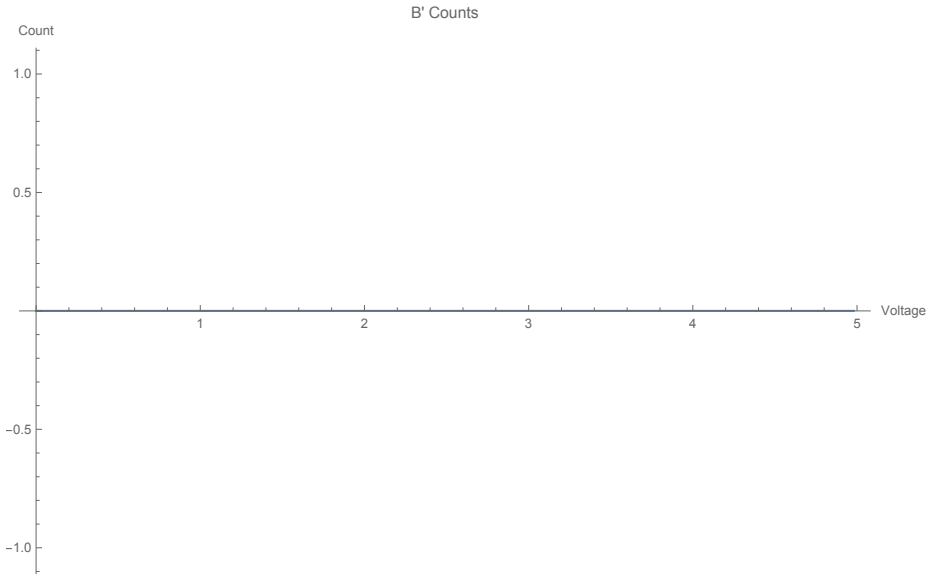

Figure 9: Counts B'

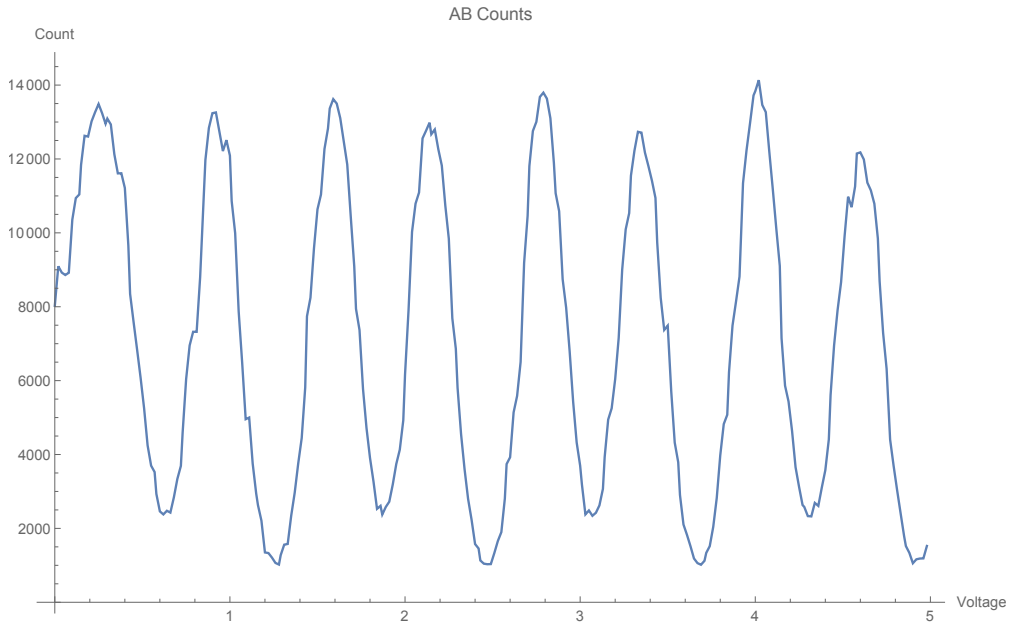

Figure 10: Counts AB

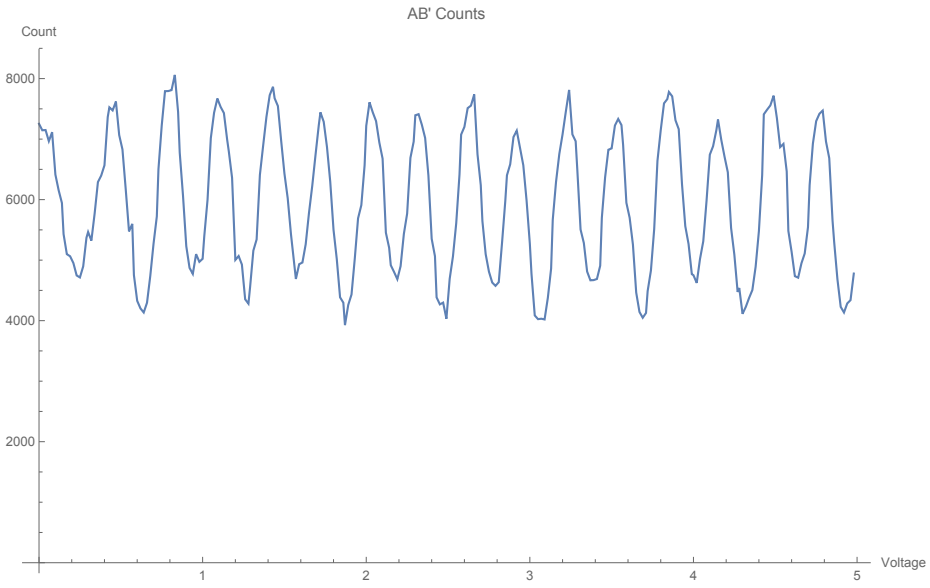

Figure 11: Counts AB'

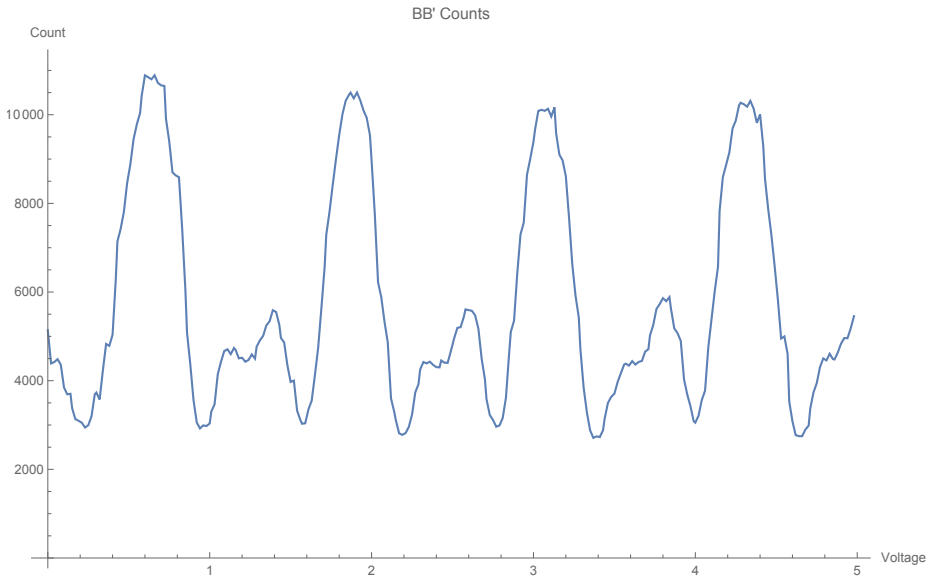

Figure 12: Counts BB'