SPI Supplementary Materials

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1 Multi-Photon Experiment Figures

1.1 Double Slit

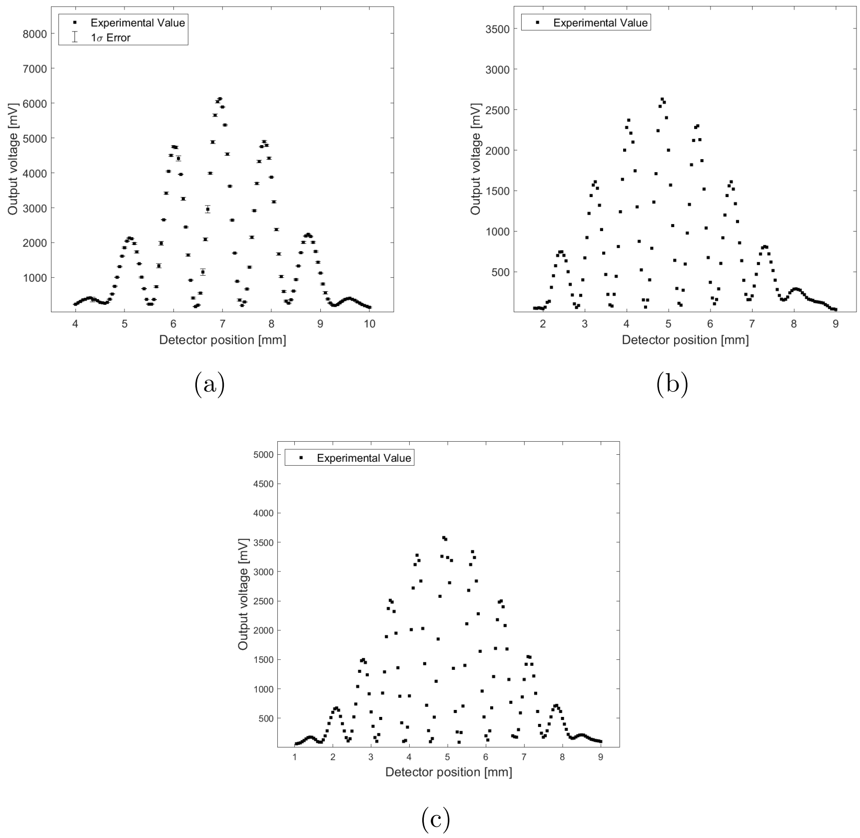
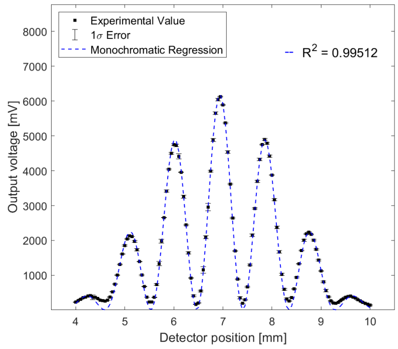
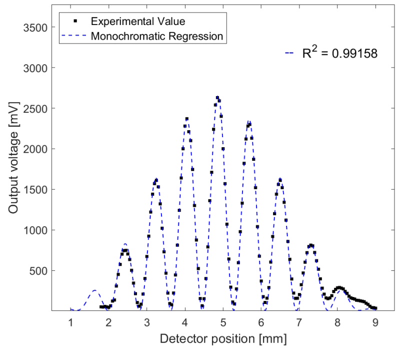


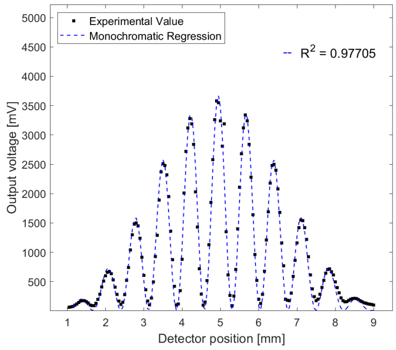
Figure 1: Raw Data - (a) Slit 14, (b) Slit 15, (c) Slit 16



(a)

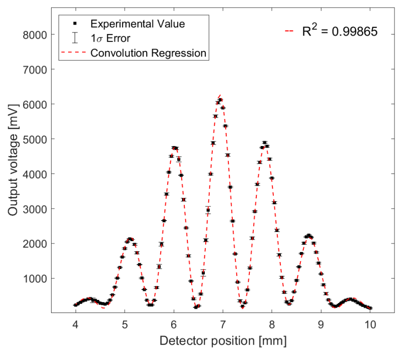


(b)

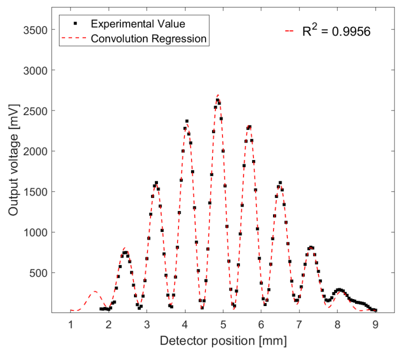


(c)

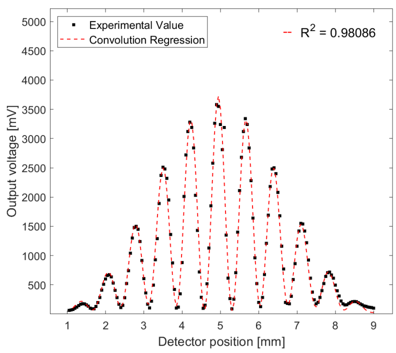
Figure 2: Monochromatic fitting - (a) Slit 14, (b) Slit 15, (c) Slit 16



(a)



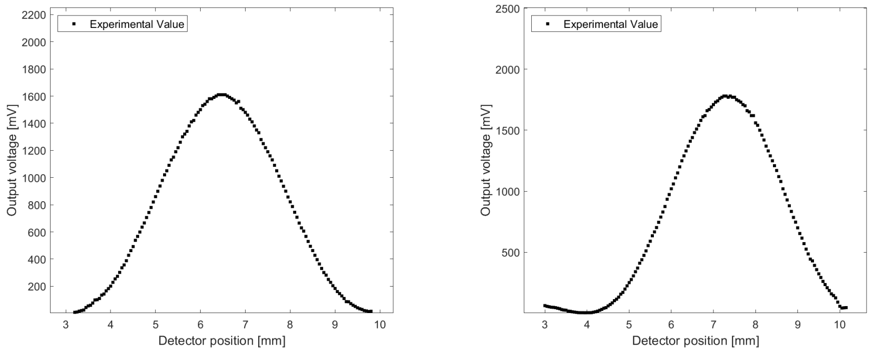
(b)



(c)

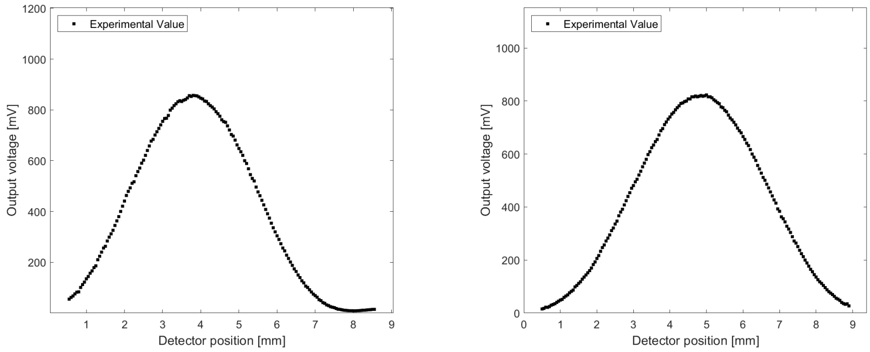
Figure 3: Convolution fitting - (a) Slit 14, (b) Slit 15, (c) Slit 16

1.2 Single Slit



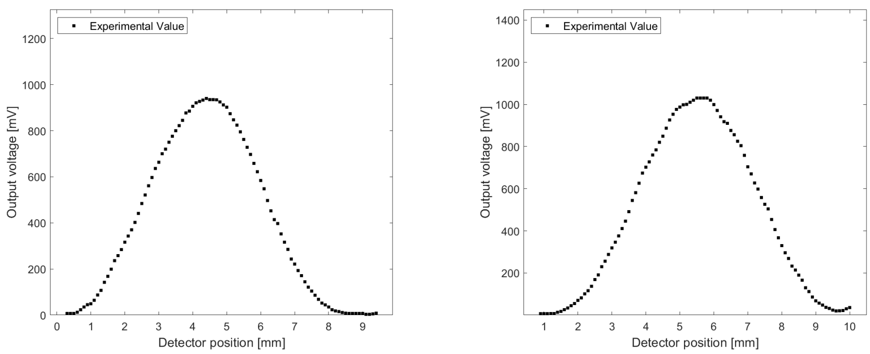
(a) (b)

Figure 4: Raw Data : Slit 14. (a) : left, (b) : right



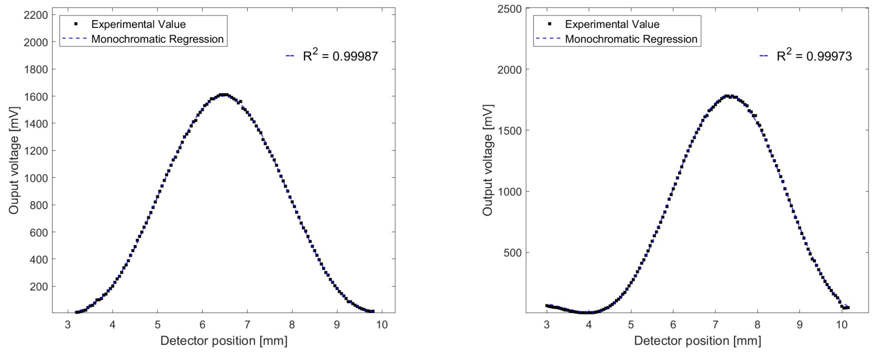
(a) (b)

Figure 5: Raw Data : Slit 15. (a) : left, (b) : right



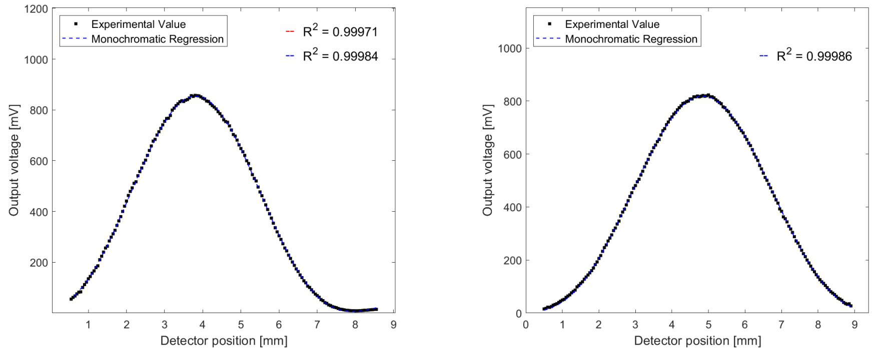
(a) (b)

Figure 6: Raw Data : Slit 16. (a) : left, (b) : right



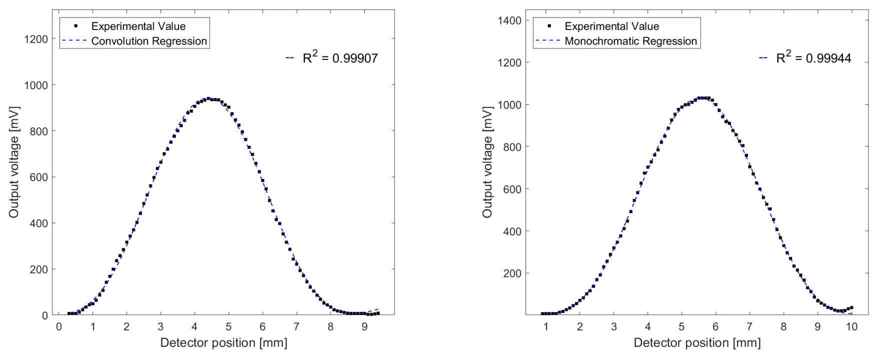
(a) (b)

Figure 7: Monochromatic fitting : Slit 14. (a) : left, (b) : right



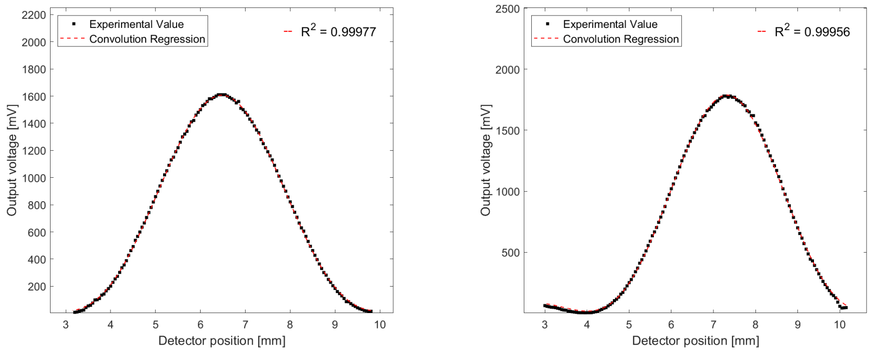
(a) (b)

Figure 8: Monochromatic fitting : Slit 15. (a) : left, (b) : right



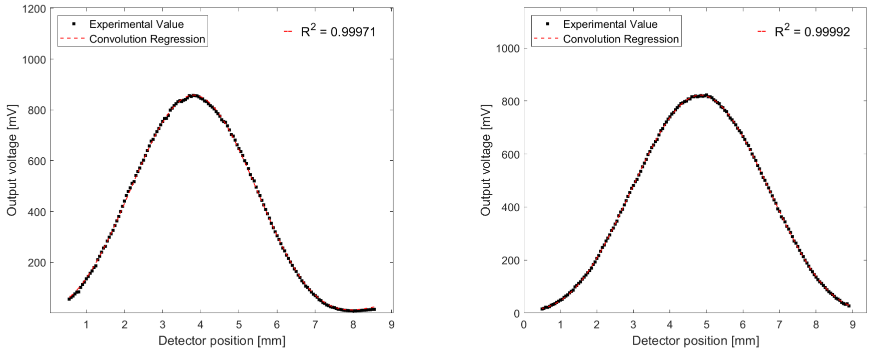
(a) (b)

Figure 9: Monochromatic fitting : Slit 16. (a) : left, (b) : right



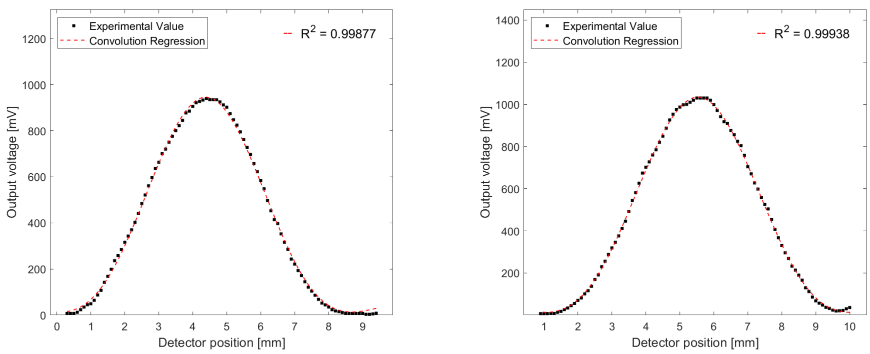
(a) (b)

Figure 10: Convolution fitting : Slit 14. (a) : left, (b) : right



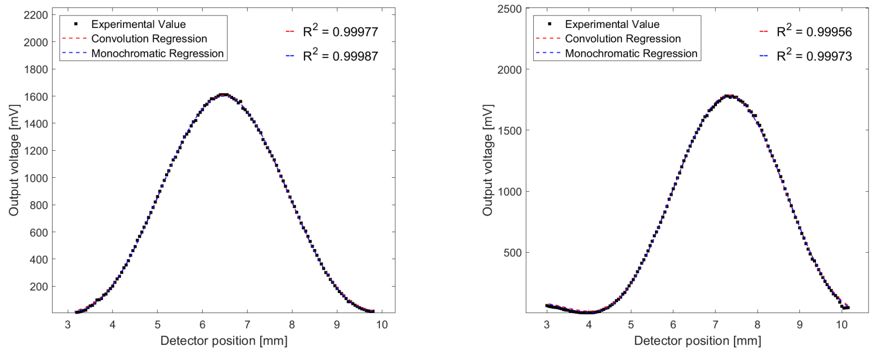
(a) (b)

Figure 11: Convolution fitting : Slit 15. (a) : left, (b) : right



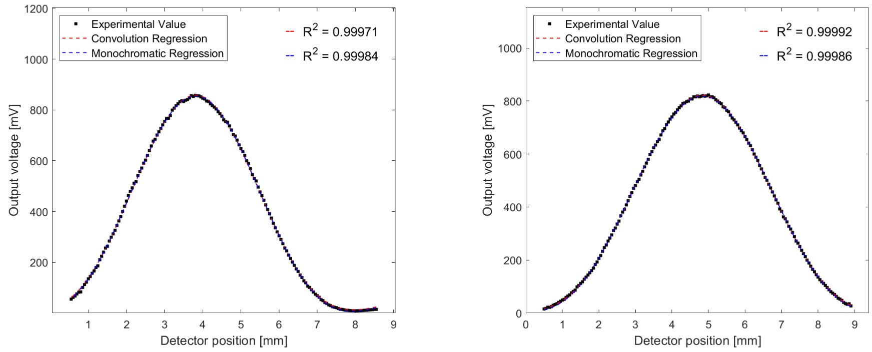
(a) (b)

Figure 12: Convolution fitting : Slit 16. (a) : left, (b) : right



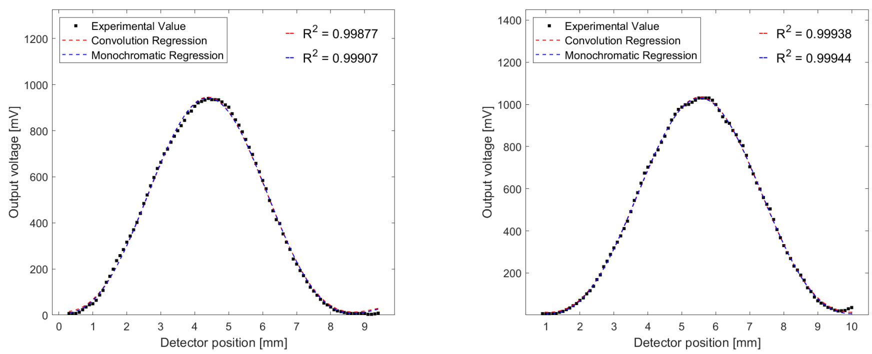
(a) (b)

Figure 13: Convolution and Monochromatic fitting : Slit 14. (a) : left, (b) : right



(a) (b)

Figure 14: Convolution and Monochromatic fitting : Slit 15. (a) : left, (b) : right



(a) (b)

Figure 15: Convolution and Monochromatic fitting : Slit 16. (a) : left, (b) : right

2 Single - Photon Experiment

2.1 Double Slit

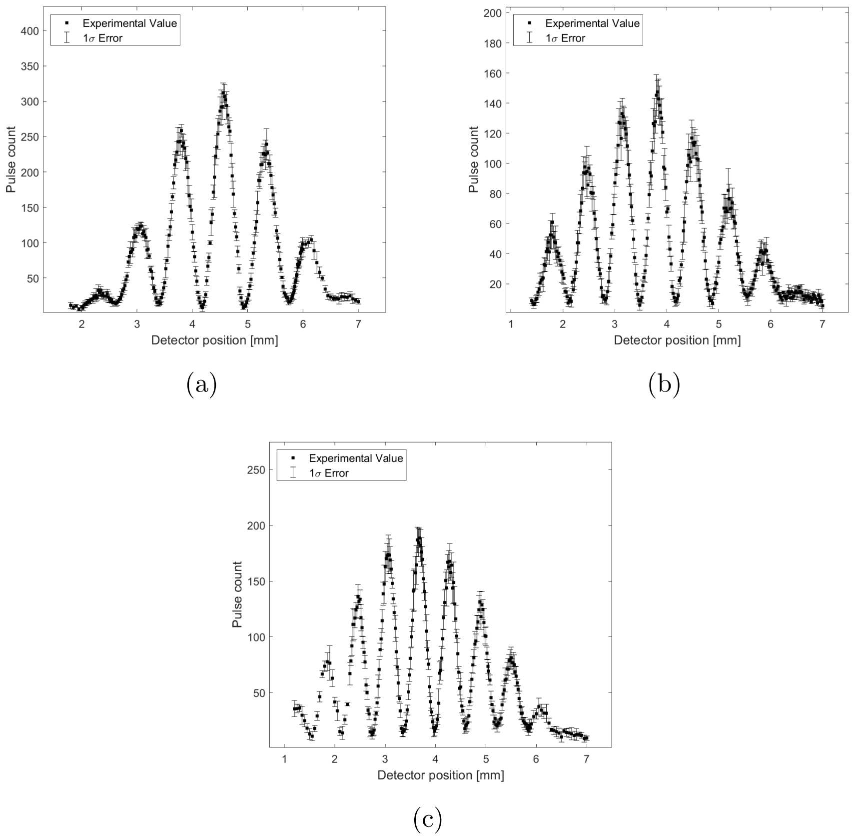
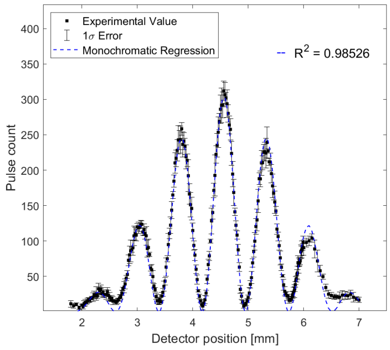
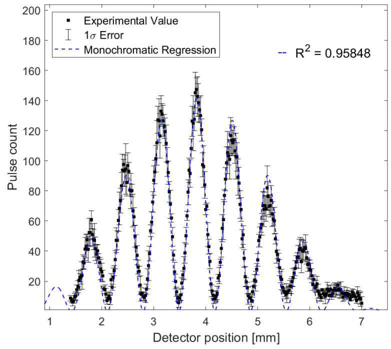


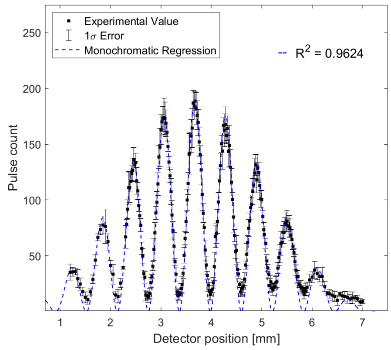
Figure 16: Raw Data - (a) Slit 14, (b) Slit 15, (c) Slit 16



(a)

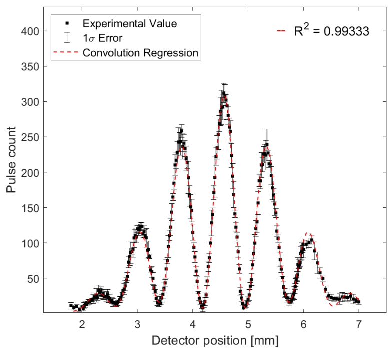


(b)

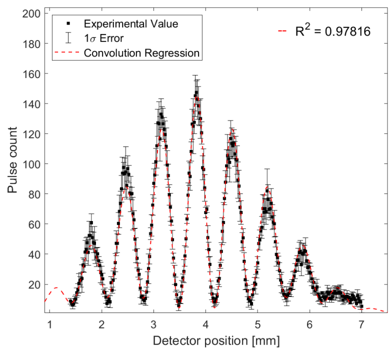


(c)

Figure 17: Monochromatic fitting - (a) Slit 14, (b) Slit 15, (c) Slit 16



(a)



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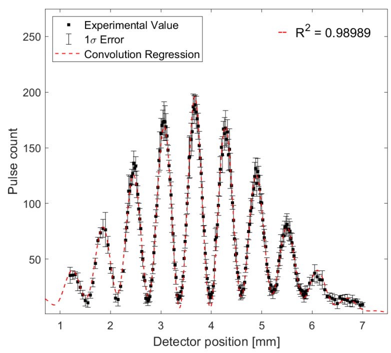
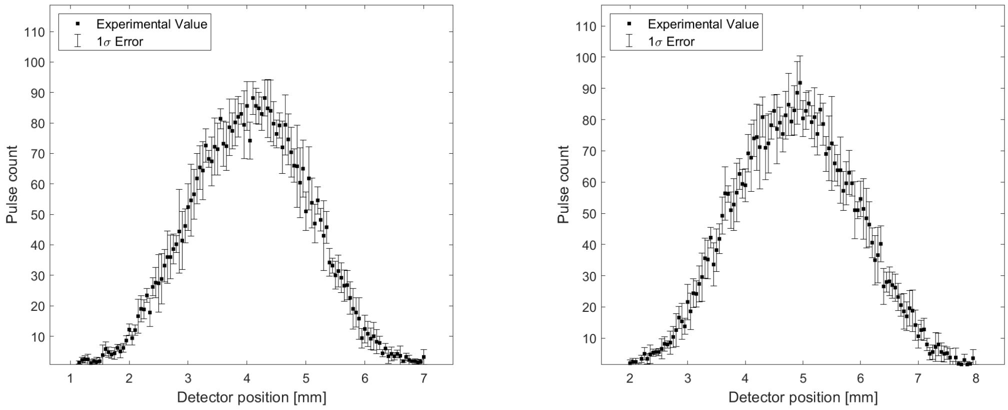


(c)

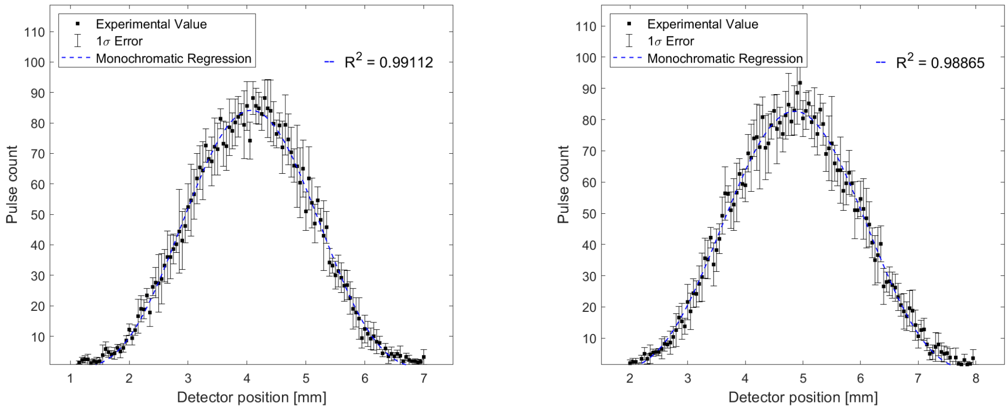
Figure 18: Convolution fitting - (a) Slit 14, (b) Slit 15, (c) Slit 16

2.2 Single Slit



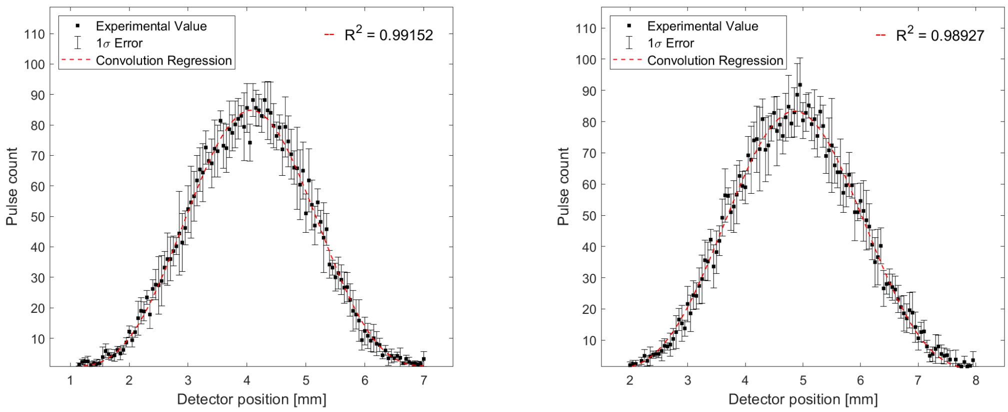
(a) (b)

Figure 19: Raw Data - (a) left, (b) right.



(a) (b)

Figure 20: Monochromatic fitting - (a) left, (b) right.



(a) (b)

Figure 21: Convolution fitting - (a) left, (b) right.

3 Information of Alignment

Slit number	Peak	Left minimum	Right minimum	Left peak	Right peak
14	6135.1 ± 11.652	160.86 ± 12.104	181.12 ± 19.077	4745.6 ± 20.52	4888.6 ± 11.71
15	2657.5 ± 14.338	54.823 ± 19.278	81.142 ± 7.263	2337.1 ± 25.465	2289.8 ± 14.227
16	3613.8 ± 12.419	87.237 ± 11.776	108.56 ± 22.203	3281.9 ± 3.1076	3333.1 ± 14.266

Table 1: The necessary information to estimate the alignment.

4 Result of Regression

4.1 Multi Photon Interference

4.1.1 Double Slit Diffraction

The double slit diffraction coefficients and 1σ error for the fits are listed.

Double Slit No.	14	1σ	15	1σ	16	1σ
wavelength [m]	6.71e-07	8.73e-10	6.72e-07	7.35e-10	6.68e-07	1.01e-09
I_0	6184.32	2.97e-11	2649.29	2.48e-10	3665.24	5.24e-12
slit width[m]	9.50e-05	4.80e-07	7.65e-05	4.79e-07	7.34e-05	7.02e-07
$x0[mm]$	6.94	0.00116	4.87	0.0012	4.95	0.0017

Table 2: Double slit diffraction coefficients and 1σ error for monochromatic fits

Double Slit No.	14 convolution	1σ	15 convolution	1σ	16 convolution	1σ
FWHM/2 [m]	1.02e-08	5.60e-10	7.65e-09	6.54e-10	6.48e-09	1.13e-09
wavelength[m]	6.70e-07	5.11e-10	6.71e-07	5.90e-10	6.67e-07	1.03e-09
I0	2006.62	3.74e-14	858.71	4.22e-10	1188.19	5.14e-11
slit width[m]	9.32e-05	2.96e-07	7.475e-05	4.02e-07	7.25e-05	7.38e-07
x0[mm]	6.94	0.00064	4.87	0.00092	4.94	0.0016

Table 3: Double slit diffraction coefficients and 1σ error for convolution fits

4.1.2 Asymmetrical Double Slit

The asymmetrical double slit diffraction coefficients and 1σ error for the fits are listed.

	left slit [m]	right slit [m]	blocker position [m]	x-scale	x0[mm]	I0
coefficient	8.96e-05	8.96e-05	0.000143	0.628	-7.321	1818.35
1σ	0	9.5e-15	2.8e-15	0.0015	0.0031	4.5

Table 4: Coefficients and 1σ for Blocker position 4.78mm

	left slit [m]	right slit [m]	blocker position [m]	x-scale	x0[mm]	I0
coefficient	0.00011	9.3e-05	0.0001045	0.649	-7.05	2303.64
1σ	0	7.1e-15	1.62e-15	0.0058	0.011	37.07

Table 5: Coefficients and 1σ for Blocker position 4.75mm

	left slit [m]	right slit [m]	blocker position [m]	x-scale	x0[mm]	I0
coefficient	9.5e-05	9.5e-05	4.3e-05	0.71	-6.93	3454.39
1σ	0	7.31e-14	1.25e-14	0.0026	0.0040	43.76

Table 6: Coefficients and 1σ for Blocker position 4.72mm

	left slit [m]	right slit [m]	blocker position [m]	x-scale	x0[mm]	I0
coefficient	0.0001	0.0001	3.0e-05	0.70	-6.89	5078.15
1σ	0	7.97e-15	3.50e-15	0.0010	0.0014	26.07

Table 7: Coefficients and 1σ for Blocker position 4.69mm

4.2 Single Photon Interference

4.2.1 Upper and Lower Bound of Driving Voltage

In this section, the model is $y = a\exp(bx)$.

	a : best estimate	Confidence interval	b : best estimate	Confidence interval
upper	6.754e-10	(-5.356e-09, 6.707e-09)	0.03393	(0.02066, 0.04719)
lower	2.648e-22	(-1.562e-21, 2.091e-21)	0.08636	(0.07522, 0.09749)

Table 8: Driving Voltage Regression with coefficient and 1σ confidence interval.

4.2.2 Detector Transfer Function

In this section, the model is $y = a\exp((-(x-b)/c)^2)$.

a	Confidence Interval	b	Confidence Interval	c	Confidence Interval
1077	(1071, 1084)	3.336	(3.324, 3.348)	2.382	(2.364, 2.401)

Table 9: Regression of Detector Transfer Function with coefficient and 1σ confidence interval

4.2.3 Double Slit Diffraction

The double slit diffraction coefficients and 1σ error for the fits are listed.

Double Slit No.	14	1σ	15	1σ	16	1σ
FWHM/2 [m]	1.20e-08	7.08e-10	1.32e-08	8.45e-10	1.42e-08	5.90e-10
wavelength[m]	5.58e-07	6.23-10	5.59e-07	7.81e-10	5.64e-07	5.44e-10
I0	99.22	3.92e-09	46.71	1.03e-08	62.96	2.62e-09
slit width[m]	8.79e-05	4.57e-07	7.01e-05	5.87e-07	6.82e-05	4.94e-07
x0[mm]	4.56	0.00081	3.83	0.0012	3.67	0.00076

Table 10: Double slit diffraction coefficients and 1σ error for convolution fits

Double Slit No.	14	1σ	15	1σ	16	1σ
wavelength [m]	5.59e-07	8.02e-10	5.61e-07	8.72e-10	5.65e-07	8.34e-10
I0	303.57	7.61e-09	141.51	3.29e-09	189.71	8.04e-09
slit width[m]	9.04e-05	5.91e-07	7.37e-05	6.92e-07	7.30e-05	8.07e-07
x0[mm]	4.56	0.0011	3.83	0.0015	3.67	0.0013

Table 11: Double slit diffraction coefficients and 1σ error for monochromatic fits

4.2.4 Single Slit Diffraction

The single slit diffraction coefficients and 1σ error for the fits are listed. The fits using FWHM and the wavelength produced too small results, thus the wavelength and FWHM were fixed for fitting as the values of $\lambda_0 = 560$nm, FWHM $= 13.1$nm.

Single Slit	14 left	1σ	14 right	1σ
I0	27.22	0.18	26.75	0.19
slit width[m]	9.84e-05	7.09e-07	9.17e-05	7.09e-07
x0[mm]	4.07	0.0079	4.85	0.0091

Table 12: Single slit diffraction coefficients and 1σ error for convolution fits

Single Slit	14 left	1σ	14 right	1σ
I0	84.14	0.55	82.70	0.59
slit width[m]	9.74e-05	6.93e-07	9.07e-05	6.96e-07
x0[mm]	4.07	0.0080	4.85	0.0093

Table 13: Single slit diffraction coefficients and 1σ error for monochromatic fits

4.2.5 Bulb Power Count

In this section, the model is $y = a \exp(bx)$

a	Confidence Interval	b	Confidence Interval
63.77	(28.06, 99.48)	0.9282	0.8125, 1.044)

Table 14: Bulb Power Count regression with coefficient and 1σ confidence interval

4.2.6 The Double Slit Diffraction varying the Bulb Power

Bulb Power	half FWHM	1σ error	λ_0	$1\sigma error$
2	1.4131e-08	9.8682e-10	5.5773e-07	9.6163e-10
3	1.2036e-08	7.0800e-10	5.5824e-07	6.2269e-10
4	1.3311e-08	5.6539e-10	5.5397e-07	2.0323e-09

Table 15: The Regression of double slit diffraction varying the bulb power.

Bulb Power	Amplitude	1σ error	Slit Width	1σ error	Middle	1σ error
2	34.1588	3.29E-08	8.41E-05	6.73E-07	5.101543	0.001257
3	99.2237	3.92E-09	8.79E-05	4.57E-07	4.562961	0.000815
4	478.5107	2.3264e-06	8.90E-05	3.36E-07	4.333682	0.004192

Table 16: The Regression of double slit diffraction varying the bulb power.

4.2.7 Laser single, monochromatic

Single slit	14 left	1σ error	14 right	1σ error
I_0	1592.6491	1.1411	1592.6491	1.1411
slit width [m]	9.5477e-05	7.3855e-08	9.5477e-05	7.3855e-08
x_0 [mm]	6.4748	0.0011	6.4748	0.0011

Table 17: The Regression of single slit with monochromatic fitting : slit 14

Single slit	15 left	1σ error	15 right	1σ error
I_0	847.8248	0.6296	811.9742	0.5039
slit width [m]	8.1100e-05	6.5734e-08	7.1188e-05	4.7856e-08
x_0 [mm]	3.8119	0.0012	4.8327	0.0012

Table 18: The Regression of single slit with monochromatic fitting : slit 15

Single slit	16 left	1σ error	16 right	1σ error
I_0	935.0323	2.3581	1023.0763	1.9361
slit width [m]	7.7883e-05	2.1132e-07	7.4685e-05	1.5254e-07
x_0 [mm]	4.3849	0.0046	5.5311	0.0036

Table 19: The Regression of single slit with monochromatic fitting : slit 16

4.2.8 Laser single, convolution

Single slit	14 left	1σ error	14right	1σ error
I_0	511.1629	0.4854	568.9268	0.7908
slit width [m]	9.5958e-05	9.9696e-08	0.0001	1.5354e-07
x_0 [mm]	6.4749	0.0014	7.3241	0.002

Table 20: The Regression of single slit with convolution fitting : slit 14

Single slit	15 left	1σ error	15 right	1σ error
I_0	271.9935	0.2730	260.5851	0.1212
slit width [m]	8.14362e-05	9.04081e-08	7.1530e-05	3.65329e-08
x_0 [mm]	3.811	0.0018	4.8329	0.0009

Table 21: The Regression of single slit with convolution fitting : slit 15

Single slit	16 left	1σ error	16 right	1σ error
I_0	300.03808	0.87569	300.0381	0.8757
slit width [m]	7.8253e-05	2.4920e-07	7.8253e-05	2.4920e-07
x_0 [mm]	4.3855	0.0053	4.3855	0.0053

Table 22: The Regression of single slit with convolution fitting : slit 16

4.2.9 Asymmetric Fraunhofer

Blocker Position [mm]	469	472
I_0	469.905 ± 5.567	505.892 ± 11.892
slit width [m]	$8.688e-5 \pm 9.553e-7$	$9.570e-05 \pm 1.414e-6$
x_0 [mm]	6.914 ± 0.002	6.941 ± 0.004
p(hidden length) [m]	$1.015e-5 \pm 1.116e-6$	$4.959e-5 \pm 1.996e-6$

Table 23: The Regression of Asymmetric Fraunhofer fitting : 469mm, 472mm

Blocker Position [mm]	475	478
I_0	505.892 ± 11.892	569.915 ± 5.638
slit width [m]	$9.570e-5 \pm 1.414e-6$	$0.0001 \pm 1.093e-6$
x_0 [mm]	6.941 ± 0.004	7.328 ± 0.014
p(hidden length) [m]	$4.959e-05 \pm 1.996e-06$	$0.0001 \pm 1.666e-5$

Table 24: The Regression of Asymmetric Fraunhofer fitting : 475mm, 478mm

5 Code for Fourier Optics

```
function y = FFres(x, xscale, x0, I0, lambda, slitwidthl, slitwidthr, blockerpos)
%blockerpos : blocker position from the edge near the center of the u-tube of the right slit
% slitwidthl : left slit
% slitwidthr : right slit
aperturesize = 0.5;
delta = 1*lambda;
zfresnel = 0.009;
zfraunhofer = 0.489;
blockerwidth = 1.2*10^-3;
slitdistance = 356*10^-6;
blockerpos = -slitdistance/2-slitwidthl/2+blockerpos; %right pos of the blocker aperture end

M = 2^nextpow2(round(aperturesize/lambda));

c = 1:M;

posx = (c-M/2-1)*delta;
OB = zeros(1, M);
for a = 1:M
    if ((-slitdistance/2-slitwidthl/2<posx(a)) && (-slitdistance/2+slitwidthl/2>posx(a))) || ((slitdistance/2-slitwidthr/2<posx(a)) && (slitdistance/2+slitwidthr/2>posx(a)))
        OB(a) = 1;
    end
end
U = fresnel_advance(OB, delta, zfresnel, lambda);
OBlocker = zeros(1, M);
for a = 1:M
    if (posx(a)>blockerpos) && (posx(a)<blockerpos+blockerwidth)
        OBlocker(a) = 1;
    end
```

```
end
% plot(OBlocker.*abs(U))

FD = fftshift(fft(fftshift(OBlocker.*U)));
FD = abs(FD)/max(max(abs(FD)));
I = I0*FD.^2;

xin = c*lambda^2/delta*1000-c(round(length(FD)*0.5))*lambda^2/delta*1000;
xin = xin*(xscale);
xin = xin-x0;
if(min(xin)>min(x))
    xin = [min(x), xin];
    I = [0, I];
end
if(max(xin)<max(x))
    xin = [xin, max(x)];
    I = [I, 0];
end
y = interp1(xin,I,x);

end

function U = fresnel_advance (U0, dx, z, lambda)
% The function receives a field U0 at wavelength lambda
% and returns the field U after distance z, using the Fresnel
% approximation. dx, dy, are spatial resolution.

k=2*pi/lambda;
nx = length(U0);

Lx = dx * nx;

dfx = 1./Lx;

u = ((1:nx)-nx/2)*dfx;

O = fftshift(fft(fftshift(U0)));

H = exp(1i*k*z).*exp(-1i*pi*lambda*z*(u.^2));
U = ifftshift(ifft(ifftshift(O.*H)));
end
```