## Cost of Single Photon Experiments Kiko Galvez December 2016

Attached are current prices for all the components needed for single-photon experiments. I have divided them in three categories:

- 1. Basic down-conversion: All you need to get photon pairs via parametric down-conversion. This includes a laser, down-conversion crystal, necessary optics, detectors and electronics.
- 2. Single-photon interference: Additional components to do interference and the quantum eraser. It also includes a measurement that photons exists-the Hanbury-Brown-Twiss test. This involves only additional optics components and their mounts.
- 3. Entanglement and Bell: Additional components to obtain polarization entangled photons, measure correlations and violations of Clauser-Horne-Shimony-Hold version of Bell inequalities. This entails an additional crystal and some polarization optics. One expensive item is a good polarizer (Glan Thompson). It is good to have, but it is not absolutely necessary.

Apparatus	Total
Basic	\$10.6k
Single photon int.	\$3.2k
Entanglement	\$3.6k
Totals	\$17.4k

The grand totals are given in the table below:

The details are in the spreadsheets that are enclosed. Implementing the experiments will require some planning. The costs can be reduced, so in the next table we present the costs under a different rubric. What components do we absolutely need to purchase and which components we can get used from in-house or elsewhere? The next table makes this breakdown. (There may be some round-off errors.)

Apparatus	Total	New	Used
Basic	\$10.6k	\$6.9k	\$3.7k
Single photon int.	\$3.2k	\$1.0k	\$2.1k
Entanglement	\$3.6k	\$3.4k	\$0.1
Totals	\$17.2k	\$11.3k	\$5.8k

Notice that the price tag of the "must buy" goes down. Those under "new" are components such as down-conversion crystal, detectors, laser, etc., and those under "used" are mirrors, mounts, the breadboard, laser goggles, etc. Some more sacrifices can be made, but those must be informed decisions. Often being stubborn does not work out (we say this by own experience...). For example, there is no way to compromise on the detectors. Photomultipliers will not work (yet). In the next table we list the type of components, so you get an idea. I have divided them into three categories: "single items" (breadboard, crystals, detectors, etc.), "optics" (mirrors, waveplates) and "mounts" (hardware).

Apparatus	Single items	Optics	Mounts
Basic	\$7.4k	\$1.3k	\$1.6k
Single photon int.	\$0.1k	\$1.4k	\$1.8k
Entanglement		\$2.8k	\$0.8k
Totals	\$7.5k	\$5.5k	\$4.2k

Suppose we have some money this year and some more next year, what are the most expensive items? That is in the next table. Amazingly, the most expensive item is a breadboard. Listed is the range of prices. For example, in optics, the least expensive is a \$70 mirror, and the most expensive is a Glan-Thompson polarizer (\$550). At the high end of mounts we have the beam splitter mounts. I note that one can mount hardware with anything at hand, but for the interferometer I highly recommend the "pedestal mounts" because they are rigid and stable.

Item	Cost
Optical breadboard	\$1.9k
Detectors	\$1.4k (each; need 2-3)
Crystal	\$500-1000
Laser	\$20-500
Optics	\$70-550
Mounts	<\$350

Finally, in a separate spreadsheet I give the individual prices, part numbers and photos of the components..

Price list for									
photon									
experiments KG									
last update: 12/17									
Basic down-									
conversion									totals
		vendor	model		price	#	total		
								It is important to	
								have a mirror that	
								does not absorb the	
								blue laser - Al	
mirror for blue laser	1" dielectric mirror	Thorlabs	BB1-E02		75	1	75	absorbs!	
	mirror mount	Thorlabs	KM100		40	1	40		
	2" pedestal	Newport		9954	26	1	26		
	regular fork clamp	Newport		9909	14	1	14		155
38 4									
Down conversion									
crystal	BBO 5x5x3mm 29deg	Newlight			549	1	549		
		Photonics							
	type-I	Inc.							
a line of the second								NEW- provides most	
								convenient	
and a	Rotational/tilt mount	Thorlabs	KS1RS		232	1	232	adjustments.	
	1.5" pedestal	Newport		9953	26	1	26		
	regular fork clamp	Newport		9909	14				807
Helpful	iris	Thorlabs	ID25SS		56	2	112		
	Magnetic mount	Thorlabs	MB175		48	2	96		
	3" post	Thorlabs	TR3		5	4	20		
	Post holder	Thorlabs	RA90		10	2	20		
La la la la	Thumbscrews	Thorlabs	TS25H		2	4	8		256
· · · ·									
HeNe laser (surplus)									

	•								
Blue laser options		Power						Current and temp	
(NEW)	(1) GaN diode laser	technology			7000	1	7000	control	
		Crystal						Current and temp	
	(2) GaN diode laser	laser	DL-405-50		4000	1	4000	control, 50 mW	
(1)									
		Power						Current control, 50	
	(3) GaN diode laser	technology	GPD405-50		400	1	400	mW	
								Rugged, but with	
- 10 C								current and temp	
	(4) GaN diode laser	Axiz	AIX-405-150T		64	1	64	control, 150 mW	
								· · · · · · · · · · · · · · · · · · ·	
		Laser							
/	(5) GaN laser pointer	pointer pro	HK-E03143		41	1	41	free running	
	1.5" pedestal	Newport		9953	26	2	52	for all but (3)	
(r)	regular fork clamp	Newport		9909	14	2	28	for all but (3)	
(5)	Holder	Thorlabs	KM100V		89	1	89	for (5)	
	Safety goggles	Thorlabs	LG1, LG2 or LG9		196	2	392	as many as needed!	
									872
mirrors for HeNe	20mm mirror mounted	Edmund	M33-502		85	3	255		
1 the	2.5" pedestal	Newport		9955	23	3	69		
	······							These are to connect	
	Thread adapter	Thorlabs	AP8E25E		1.7	3	5.1	mirror	
- 3 <sup>1</sup>	Spacers	Thorlabs	SD1		7	3	21	to pedestal.	
	regular fork clamp	Newport		9909	14	3	42	•	
	<b> </b>	·							
	flipper mirror	Newport		9891	149	1	149		
	1.5" pedestal	Newport		9953	26	1	26		
	dielectric mirror	Thorlabs	BB1-E02		75	1	75		642.1
Band-pass filters	1" 800nm, 40nm	Thorlabs	FB800-40		99	3	297		

1" lens tube   Thorlabs   SM1L05   13   3   39   the fiber collimator   336     Fiber transport (NEW)   Collimator 11mm, FC   Thorlabs   F220FCB   145   3   435   alignment.   336     Mirror mount   Thorlabs   AD11F   28   3   84   -   -   -   -   -   336     Mirror mount   Thorlabs   KM100T   64   1   64   -									
It lens tube   Thorlabs   SMIL05   13   3   39   the iris stratched to reliminator     Fiber transport (NEW)   Collimator 11mm, FC   Thorlabs   F220FCB   145   3   435   alignment.   336     Adapter   Thorlabs   ADITF   28   3   84   - <td< td=""><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>This is mounted on</td><td></td></td<>								This is mounted on	
Instruct     Thorlabs     SM1L05     13     3     39 (the fiber collimator)       Fiber transport     Collimator 11mm, FC     Thorlabs     F220FCB     145     3     435 allgment.     336       Witror mount     Thorlabs     AD11F     28     3     84           Adapter     Thorlabs     SM1D12     56     3     168           Mag mount is best for       Mag mount is best for      Mag mount is best for      Mag mount is best for         Mag mount is best for								the iris attached to	
Fiber transport (NEW) Collimator 11mm, FC Thorlabs F20FCB 145 3 Lambda 435 alignment.   Fiber transport (NEW) Collimator 11mm, FC Thorlabs F20FCB 145 3 435 alignment. 435   Mirror mount Thorlabs AD11F 28 3 84 - <		1" lens tube	Thorlabs	SM1L05	13	3	39	the fiber collimator	
Fiber transport   Collimator 11mm, FC   Thorlabs   F220FCB   145   3   435 allgnment.     Adapter   Thorlabs   AD11F   28   3   84									336
Fiber transport (NEW)   Collimator 11mm, FC   Thorlabs   F220FCB   145   3   435   alignment.     Adapter   Thorlabs   AD11F   28   3   84								This new mount	
	Fiber transport							greatly helps with the	
Adapter   Thorlabs   AD11F   28   3   84   44     Mirror mount   Thorlabs   KM100T   64   1   64   1     Threaded iris   Thorlabs   SM1D12   56   3   168   144   Mag mount is best for   Mag mount is best for   Mag mount is best for   168   144   these   166	(NEW)	Collimator 11mm, FC	Thorlabs	F220FCB	145	3	435	alignment.	
Mirror mountThorlabsKM100T64116411641164116411641164116411641164116411641167167168330167168330 <td></td> <td>Adapter</td> <td>Thorlabs</td> <td>AD11F</td> <td>28</td> <td>3</td> <td>84</td> <td></td> <td></td>		Adapter	Thorlabs	AD11F	28	3	84		
Threaded iris   Thorlabs   SM1D12   56   3   168   mag mount is best for Mag mount is best for     3" post   Thorlabs   MB175   48   3   1444 these   1     Post holder   Thorlabs   RA90   10   3   30   1   1     Post holder   Thorlabs   RA90   10   3   30   1   1     Post holder   Thorlabs   RA90   10   3   30   1   1   1     Post holder   Thorlabs   M31L01   48   3   144   1117   1117     Post holder   Thorlabs   M31L01   48   3   144   1117     plate 3/8" thick, 1-m   reception   Thorlabs   CL5   4   2   8   1   1     radius of curvature   custom   custom   custom   1   1   1   1   1   1     APD detectors   Lable clamps   Thorlabs   CL5   4   2   8   1   1   1   1   1   1   1   1   1   1		Mirror mount	Thorlabs	KM100T	64	1	64		
Magnetic mount Magnetic mountThorlabs ThorlabsMB175483Mag mount is best for 144Mag mount is best for 1443" postThorlabsTR36636	2	Threaded iris	Thorlabs	SM1D12	56	3	168		
Magnetic mountThorlabsMB175483144these3' postThorlabsTR36636								Mag mount is best for	
3" postThorlabsTR366364Post holderThorlabsRA90103304ThumbscrewsThorlabsTS25H26124FC patch fibers 1mThorlabsM31L014831441117plate 3/8" thick, 1-mcustomCustom64288table clampsThorlabsCL54288additional clampsThorlabsCL54288additional clampsThorlabsCL5428420additional clampsThorlabsCL54284290additional clampsThorlabsCL54284290additional clampsThorlabsCL54284290additional clampsThorlabsCL54284290additional clampsThorlabsCL54284290additional clampsThorlabsCL54284290additional clampsThorlabsCL54284290additional clampsThorlabsCL54284290additional clampsFCFCFCFC414303additional clampsFCFCFCFCFCFCadditional clampsFCFCFCFCFCFCadditional clamps <td>And a second sec</td> <td>Magnetic mount</td> <td>Thorlabs</td> <td>MB175</td> <td>48</td> <td>3</td> <td>144</td> <td>these</td> <td></td>	And a second sec	Magnetic mount	Thorlabs	MB175	48	3	144	these	
Post holder   Thorlabs   RA90   10   3   30     Thumbscrews   Thorlabs   TS25H   2   6   12   1117     FC patch fibers 1m   Thorlabs   M31L01   48   3   144   1117     plate 3/8" thick, 1-m   custom   custom   Image: CL5   4   2   8   8     table clamps   Thorlabs   CL5   4   2   8   8   8     fc   table clamps   Thorlabs   CL5   4   2   8   8     fc   intervalue   intervalue   intervalue   intervalue   intervalue   10   <		3" post	Thorlabs	TR3	6	6	36		
Thumbscrews   Thorlabs   TS25H   2   6   12   111     FC patch fibers 1m   Thorlabs   M31L01   48   3   144   1117     plate 3/8" thick, 1-m radius of curvature   custom   CL5   4   2   8   6   1     table clamps   Thorlabs   CL5   4   2   8   8   8     f   and		Post holder	Thorlabs	RA90	10	3	30		
FC patch fibers 1mThorlabsM31L014831441117plate 3/8" thick, 1-m radius of curvaturecustominininininintable clampsThorlabsCL5428inininintable clampsThorlabsCL5428inAPD detectorsin <td></td> <td>Thumbscrews</td> <td>Thorlabs</td> <td>TS25H</td> <td>2</td> <td>6</td> <td>12</td> <td></td> <td></td>		Thumbscrews	Thorlabs	TS25H	2	6	12		
Image: section of the section of th		FC patch fibers 1m	Thorlabs	M31L01	48	3	144		1117
plate 3/8" thick, 1-m radius of curvaturecustom									
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radius of curvaturecustomcustomin<	plate 3/8" thick, 1-m								
table clampsThorlabsCL54288Image: clampsImage: clamps <td>radius of curvature</td> <td></td> <td>custom</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td>	radius of curvature		custom						
Image: second		table clamps	Thorlabs	CL5	4	2	8		8
Image: space of the space of		·							
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Electronics	(1) Coincidence unit	Altera DE2	DE2		250	1	250		250
Contract Constitution of the	software	Labview							
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H <sup>8</sup> A SUR									
Optical breadboard	2'x5'x4"	Thorlabs	B3060G		1900	1	1900		1900
	-								
			Total basic						
			downconversion						10633
Single Photon									
interference setup									
Mach-Zehnder	Non-polarizing beam	Thorlabs	BS017		190	2	380	buy together	
R. Sal-									
	splitters near IR 20mm								
A Ab	Beam splitter mount	Newport		9481	336	2	672		
	1.5" pedestal	Newport		9953	26	3	78		
	mounted mirror	Edmund	M33-502		85	3	255		
	2.5" pedestal	Newport		9955	30	2	60		
	Thread adapter	Thorlabs	AP8E25E		7	2	14		
	short fork holder	Newport		9916	13	4	52		
								6.6x6.5x10mm w/o	
	piezo electric	Thorlabs	AE0505D08F		131	1	131	amplifier	
	linear stage	Thorlabs	MT1		286	1	286		1928
		NewLight							
Eraser additions	Zero-order waveplates	Photonics	WPA03-H-810		249	2	498		
2000	polarizer holder	Optosigma	114-0240		125	2	250		
	holder adapter	Optosigma	114-0420		35	2	70		
	1.5" pedestal	Newport		9953	26	2	52		
	short fork holder	Newport		9916	13	2	26		
0000	polarizing beam splitter	Thorlabs	PBS102		183	1	183		

	Rotary mount	Thorlabs	RSP1x15	128	1	128		
	1" adapter for PBS	custom						
1.12	Magnetic mount	Thorlabs	MB175	48	1	48		
	3" post	Thorlabs	TR3	6	2	12		
	Post holder	Thorlabs	RA90	10	1	10		
	Thumbscrews	Thorlabs	TS25H	2	2	4		1281
	1							
Additional electronics	(1) D/A interface	Arduino	custom	50	1	50		
	(2) Voltage amplifier	Emco	Q02-24	81	1	81		
								131
			Additional					
			interference					3209
(2)								
(2)								
Entanglement/Bell								
setup								
	Half-wave plate	NewLight						
	405nm	Photonics	WPA03-H-405	249	1	249		
	Rotational mount	Thorlabs	RSP1x15	128	1	128		
	Compensating crystal	Newlight	QAR25550-A-AR405	429	1	429		
	Crystal pair	Newlight	PABBO5050-405(I)-HA3	1000	1	1000		
	Rotational/tilt mount	Thorlabs	KS1RS	232	1	232	NEW	
	1.5" pedestal	Newport	9953	20	1	20		
	Glan-Thompson prism	Thorlabs	GTH10M	555	2	1110		
	prism rotary holder	Optosigma	114-0240	125	2	250		
	holder adapter	Optosigma	114-0420	35	2	70		
	1.5" pedestal	Newport	9953	20	2	40		
	regular fork clamp	Newport	9909	14	2	28		
	· · ·							
			Additional					
			Entanglement					3556
			All					17398