Towards a bright and efficient PPKTP photon pair source

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Motivation

In order to observe the interactions of single photons with single atoms for applications like quantum communication [1], we need a source of photon pairs which must be spectrally bright (with a narrow bandwidth of 10 MHz) and have a high efficiency (pairs to singles ratio).

Experimental setup

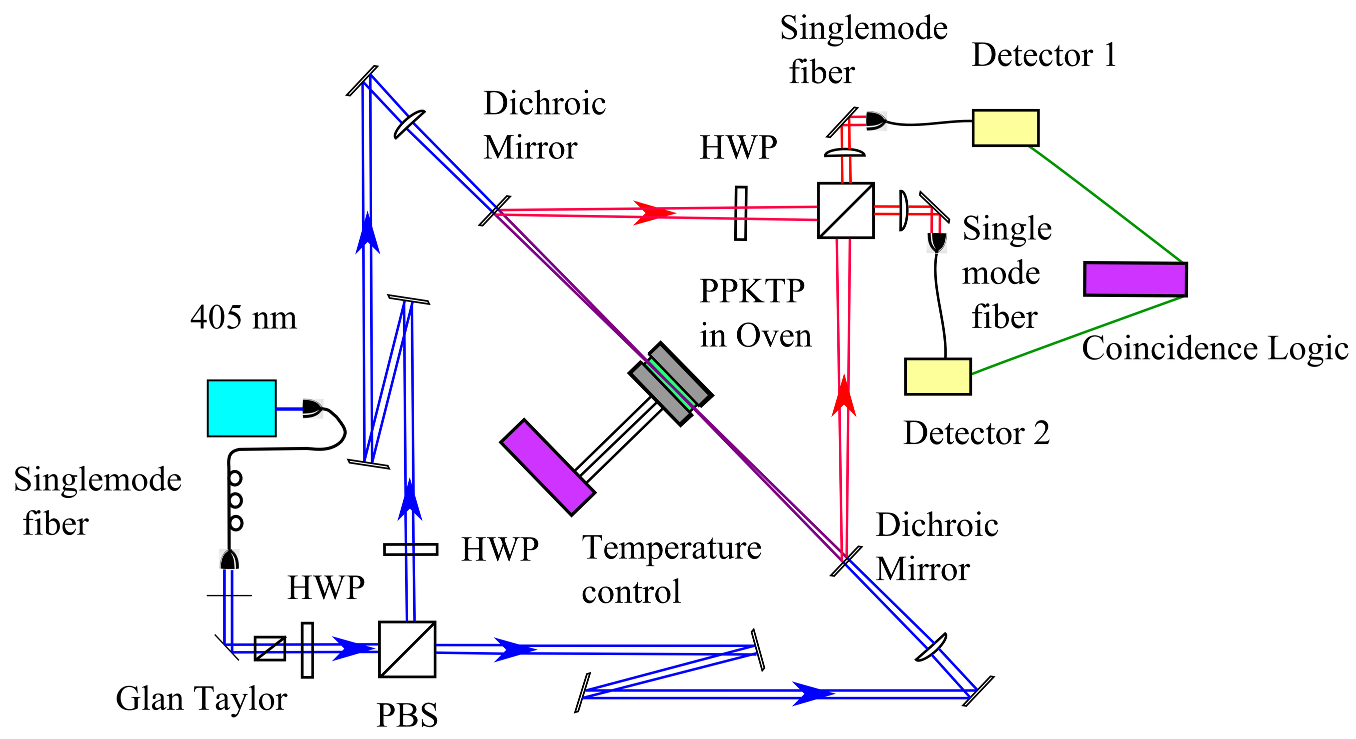

FIGURE 1: The sagnac configuration with independently adjustable red and blue beam paths.

Focus Optimization

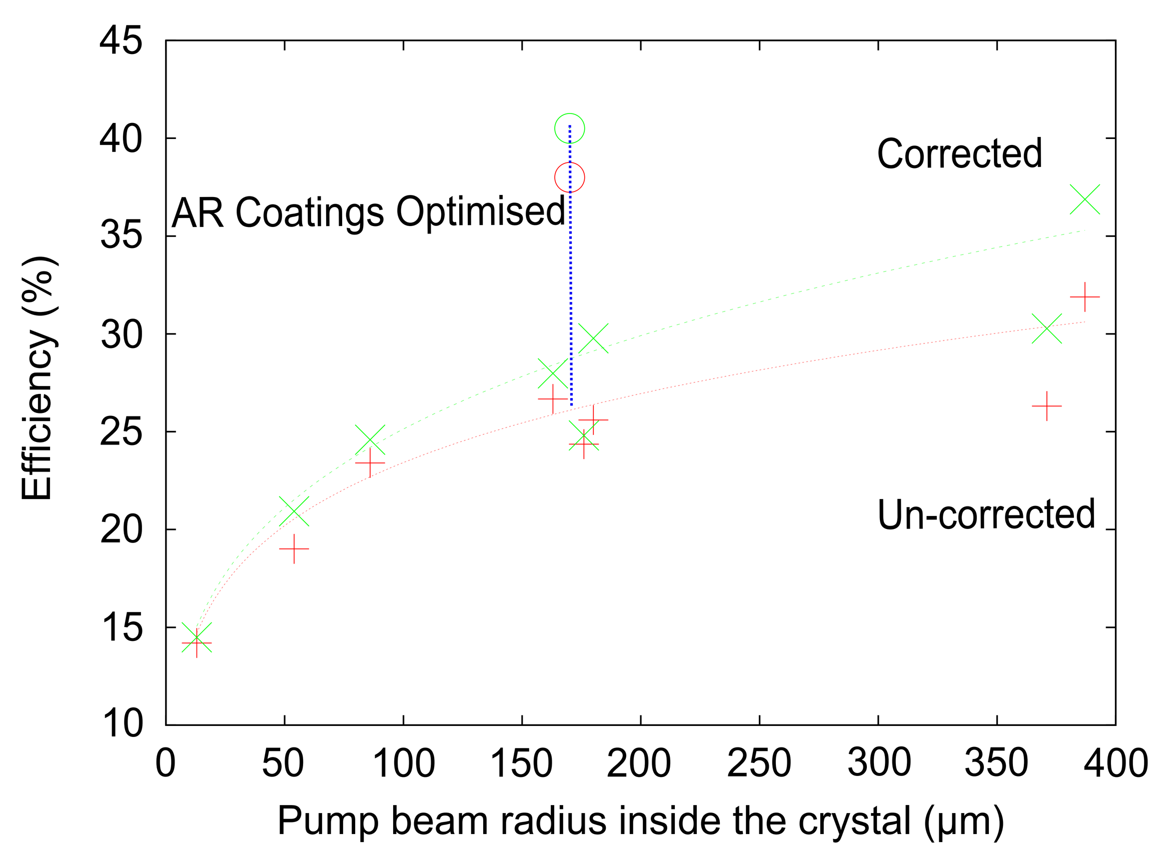

FIGURE 2: A good choice of focus gives high efficiencies.

We find that the ideal focusing for target modes is nearly equal to that of the pump. However, there is a trade off between absolute emission rates and efficiency. We prefer high efficiencies because our source can then be used as an heralded source of photons. We observe uncorrected efficiencies $>37\%$ using silicon Avalanche Photo Diodes (Si APDs) of $\approx 50\%$ detection efficiency. If we use highly efficient transition edge sensors [2] instead of APDs we expect efficiencies $> 70\%$. This will allow us to perform loop hole free Bell tests since we will be well above the 66.7% threshold [3].

Spectral Properties

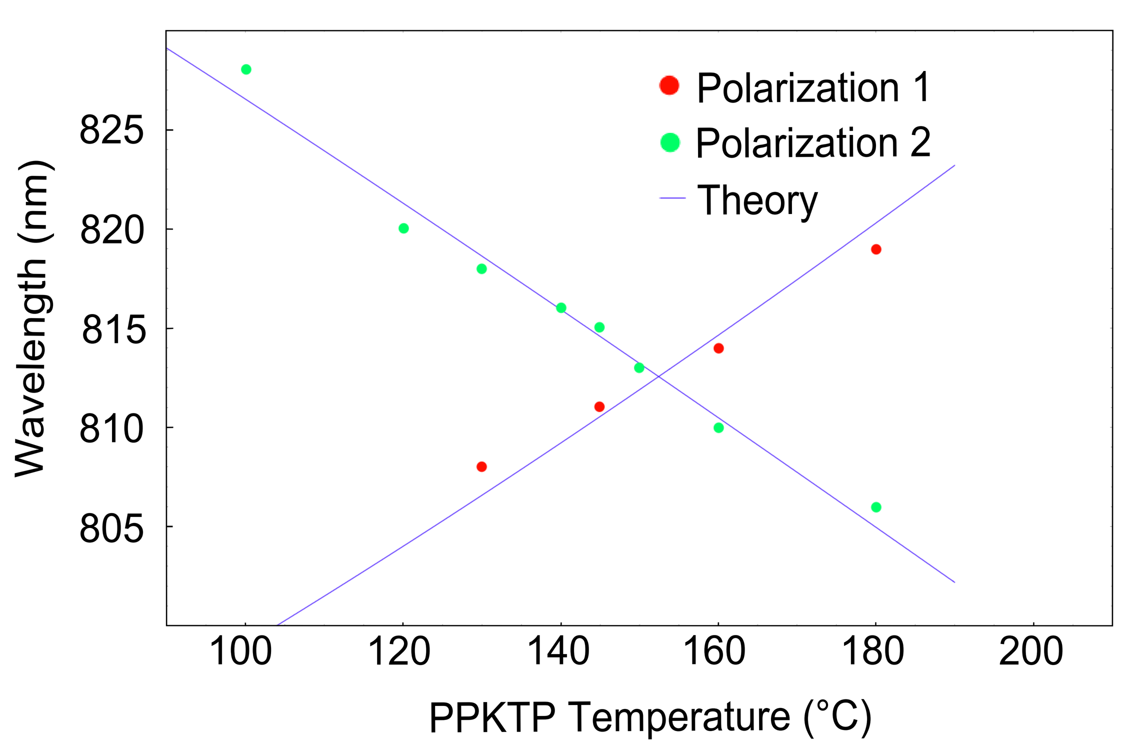

FIGURE 3: Tunability of our source.

Our source can be tuned over a wide range of wavelengths by varying the temperature of the crystal. (0.27 nm/°C or 121 GHz/°C). At 145°C the bandwidth of the downconverted light was 0.18 nm (82 GHz) while at room temperature it was 0.12 nm (55 GHz). We suspect an inhomogeneity in temperature across the crystal.

The theoretical limit [4] on the bandwidth of the downconverted light due to the finite length of the crystal (L) is given by

$$\Delta\lambda = \frac{\lambda^2}{(n_s - n_i) * L} \tag{1}$$

where n_s and n_i represents the refractive indices of the signal and idler light within the crystal. For our crystal, assuming there are no imperfections in the poling period, this is 18 GHz.

Visibility

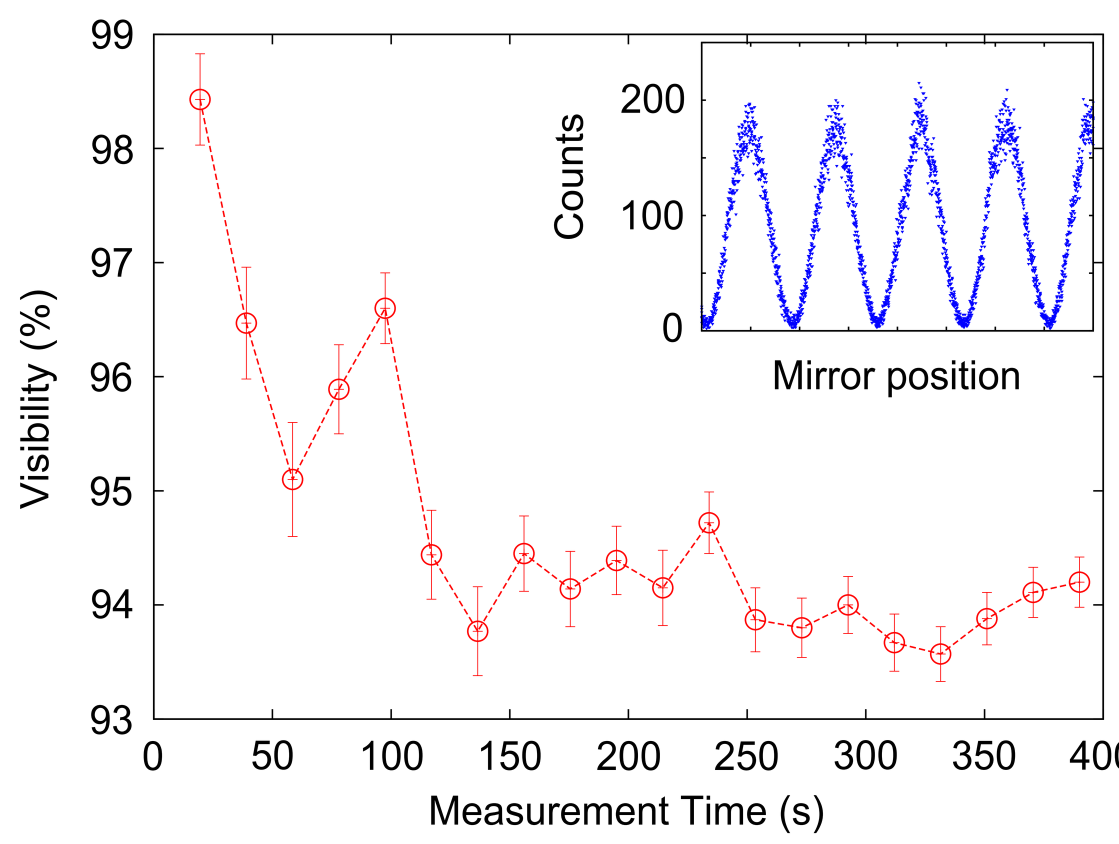

FIGURE 4: Visibility Vs. measurement time. Inset: A sample visibility measurement made by moving a dichroic mirror of the interferometer

We see a high visibility over short intervals, however the visibility is lower when measured over a long period. This is due to slight instabilities in the Sagnac Interferometer which we are trying to fix.

Next steps

Reduce bandwidths (Filter with cavities).
Increase efficiency (Currently 38%).
Increase Visibility (Currently 98.5%).
Perform loop-hole free Bell test.

How do we compare?

Group	Efficiency	Spectral Brightness (pairs/s/mW/GHz)	Absolute Brightness (Pairs/s/mW)	Bandwidth (GHz)	Comments
Fiorentino 2004 [5]	18%	---	12,000	---	150 micron waist
Mitchell 2009 [6]	--	**1,000** 214 (measured)	4.8	0.022	Filtered using a cavity
Koing 2005 [7]	11%	8.6	450	52	PPLN
Trojek 2008 [8]	39%	4.2	27,000	6,435	BBO
U'Ren 2008 [9]	50%	6.2	140,000	22,582	Time Gating
Zeilinger 2007 [10]	~32 %	46	6,500	140	30mm long PPKTP
us	38%	97	8,000	82	25mm long PPKTP

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