Towards an 8 Photon Graph

Expected Rates From Sagnac Sources

In the case of most previous results obtained via the above method we always had the photon source configured such that a separable state was produced. Although this is fine to use for the analysis in the Gaussian crystal paper–where we only consider that the source is set up in such a way–when it comes to approximating the rates we would see for an 8 photon GHZ state, the sources will be producing Bell states. In this configuration one cannot assume that we can achieve the same brightness and efficiencies that we achieved with the pair source due to the greater complexity in optical alignment. Therefore, a better understanding of source performance is to align the sources in a way that produces Bell pairs, and run a power dependence, performing tomography at these powers and then gathering the singles and coincidences from these measurements.

Crude Calculation of Rates

Rather than relying on the model, we can use the following function to quickly work out what rate we would expect with known brightness, pump power, repetition rate and interference visibility:

$$\left(\frac{\text{Brightness} \times \text{Power}}{\text{Repetition Rate}}\right)^4 \times \text{Repetition Rate} \times \left(\text{Visibility} \times \frac{1}{2}\right)^3. \tag{1}$$

Now, we can use this function to estimate the expected maximum 8-fold rate for a GHZ state involving three fusions. For the "Experimental Ten Photon Entanglement" JWP paper they quoted an 8 photon GHZ state rate of 0.2Hz. Using the crude calculation with 85% visibility and an overall throughput of 90%, the function outputs 0.1908Hz, roughly the quoted rate. For our sources, assuming 89.8% and 83.3% interference visibility for aKTP (with semrocks) and ppKTP respectively (calculated from the interference experiments pre-lockdown, where the results are in the gaussian paper and extrapolating the linear fit), and the brightnesses we could achieve with a 40cm focus lens of 3.6kHz (only seen in a non-collinear operation) and 4kHz, the rates for our crystals are 0.39Hz and 0.48Hz. Thats around double the rates of JWP. We could then potentially afford to use one pass of the interlever for gains in state purity and fidelity. These rates would then need to be scaled by a factor of 8 to 0.07 and 0.08 respectively for aKTP and ppKTP.

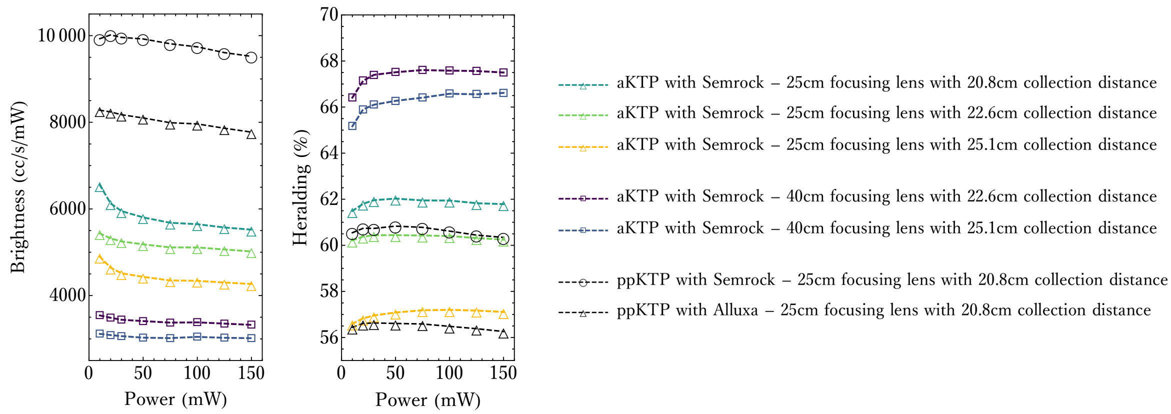
Moving Towards 400mW of Pump Power

Some things to consider are; whether the linear extrapolation is an okay treatment, we would need to run this test when we can achieve at least 400mW in each Sagnac. We should also investigate how accurately we can overlap any arms of a "smaller" interlever. The plan discussed so far is to not have a "long" arm to put the successive pulses symmetrically between each other, but to use a shorter arm that is designed to up the repetition rate whilst enabling an easier and more stable overlap.

Lens Configurations

From the the detector model results it is clear to see that we need shorter focal length lenses (I would say that 40cm is a minimum) to achieve the rates we desire. At the moment we have 40cm lens and 50cm lens available for S3, S4 and S1, S2 respectively. We however need to prioritise getting the highest brightness we can. This means that we should be using 40cm lenses or shorter. There is a limit to how short a lens we can use and this limit is bound by two things: the placement of the BS's that separate the pump into two sources and the distance from the crystal to the coupling lenses. However, from a previous scan of distance from crystal to couplers using a Sagnac we can get to 20cm collection distances.

Interestingly, we could get up to 8kHz with ppKTP and 6kHz brightness with aKTP (with semrocks) within the limits of allowable collection distances. But placing a 25cm focusing lens in front of the Sagnacs is something that may not be achievable. Seeing as we are going to be altering the interlever, maybe being able to focus with 25cm, or somewhere between 25cm and 40cm lenses into the Sagnacs is something we should consider.



Novelty

We should be more than capable of achieving better rates than JWP, given the brightnesses we have seen and according to the crude model, but something that adds a large degree of novelty to this work would be to remove all spectral filtering (other than silicon windows to block the pump). This is convenient as it also means we will not have to order another 4 semrock filters whilst we exploit the new aKTP's ability to allow these multi-photon experiments without filtering. The actual coincident count rate should differ by (some percentage I will work out) with the caveat of a drop in interference visibility of 3.7% (at 400mW of pump power).

So far, without filtering, we have seen 3600cc/mW (with good colineararity in the sagnac) which, using the crude model, gives an 8-fold rate of ∼0.35 Hz. This rate represents an upper bound based on 10% loss (same as JWP quoted) and the relevant losses applied to fusions that depend on the interference visibility of aKTP without filters at 400mW of pump power. With shorter lenses we could gain significantly more rates. A shorter lens with aKTP could potentially produce a brightness of ∼5000cc/mW. Then the eightfold rate is 1.3Hz. If we deployed the interlever with this brightness, we could achieve a rate of 0.16Hz, comparable to JWP rates but with, in theory, a higher quality state.

The next steps will be to build the new interlever, decide on a lens configuration, and run independent HOM between two sources,. This will let us obtain the 4 fold rates that can be mapped to the detector model outputs. That then should further help us predict a more realistic 8 photon rate.