Measuring properties of entangled photons using the Hong-Ou-Mandel effect

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Abstract: We model Joint Spectral Intensities of two entangled photons created by spontaneous parametric down conversion using three crystals, β-Barium Borate, Calcium Carbonate and Lithium Iodate. We do so by considering the effect of crystal length and the angle at which the crystal is oriented with respect to the pump laser polarization. We learn that on increasing length of the crystal, peaks of Joint Spectral Intensities get narrower. On increasing the angle of tilt of the crystal, the singular probability peak divides into two peaks and moves out of the visible range. We then model the Hong-Ou-Mandel effect to measure properties of the two photons by modelling the photons passing through a beam splitter after going through two separate paths, with one path having a time delay and getting detected by the detectors at the beam splitter outputs. We model the rate of coincidence, or number of times both photons are detected at different ports simultaneously for different lengths of crystals. We find that on increasing the length of the crystal, the width of the Hong-Ou-Mandel dip increases as well.

Goals:

- Modelling the process of Spontaneous Parametric Down Conversion for various nonlinear crystals
- Modelling two- photon pairs going through a beam splitter and investigating the Hong-Ou-Mandel effect for various crystals

Spontaneous Parametric Down Conversion (SPDC):

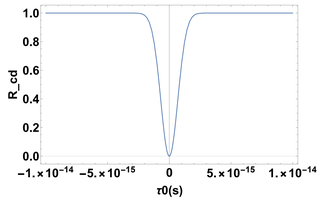
- Process of converting a single photon into two low energy photons on shining a laser through a birefringent crystal.
- Abiding by the law of conservation of energy,

$$\omega_p = \omega_1 + \omega_2$$

- We modelled shining a laser beam of 400 nanometres wavelength through β Barium Borate, Lithium Iodate and Calcium Carbonate crystal.

Hong-Ou-Mandel effect:

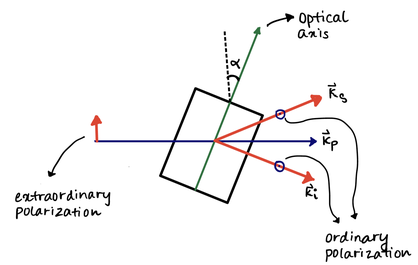
- On passing two entangled photons through a beam splitter, both photons either come out through the same ports or through different ports.
- Depending on the time delay, path length of the crystal changes and it affects whether or not the photons will go through the same or different ports.
- We can calculate the rate of coincidence, the number of times, both photons come out of different ports and on plotting it against the time delay, we get the following graph:



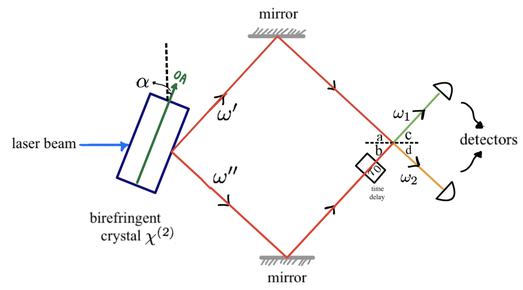
Aknowledgement:

I would like to thank my adviser Dr. Cody Leary for advising me for this project.

Experimental Setup:



Process of spontaneous parametric down conversion, one extraordinarily polarized photon passing through birefringent crystal



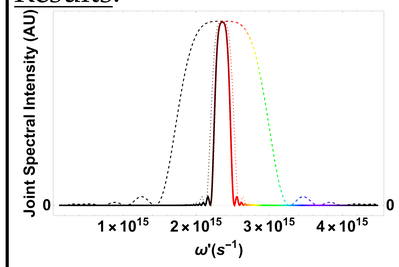
Photons going through a beam splitter and getting detected at the end.

Joint Spectral Intensity:

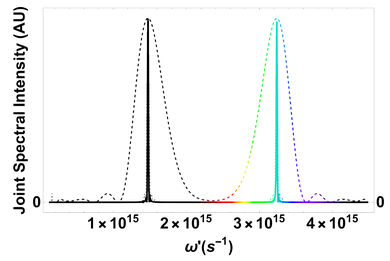
- Joint spectral intensity is a result of squaring the joint spectral amplitude. It gives us the probability of resultant photons ω' and ω''

$$\psi(\omega', \omega'') = \chi^{(2)} \operatorname{sinc}\left(\frac{\Delta k L}{2}\right) \delta(\omega_p - \omega' - \omega'')$$

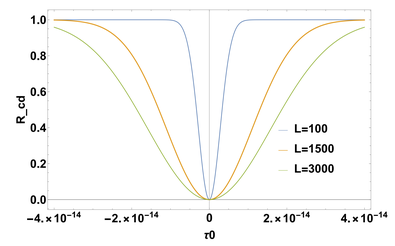
Results:



Joint Spectral Intensity for BBO crystal at $\alpha = 1.0615$



Joint Spectral Intensity for BBO crystal at $\alpha = 1.0945$



Rate of coincidences for BBO crystal at $\alpha = 1.0615$ for 3 different lengths

Conclusions:

- On increasing the length of any of the crystals, Joint Spectral Intensity curves become narrower, making the range of resultant photon colors less.
- On increasing the angle of crystal, there are two curves for Joint Spectral Intensities, meaning both photons will have very different ranges of colors.
- On increasing the length of the crystal, we get wide dips for HOM effect, meaning the rates of coincidence decreases.