Nonlinear Optics With Less Than One Photon

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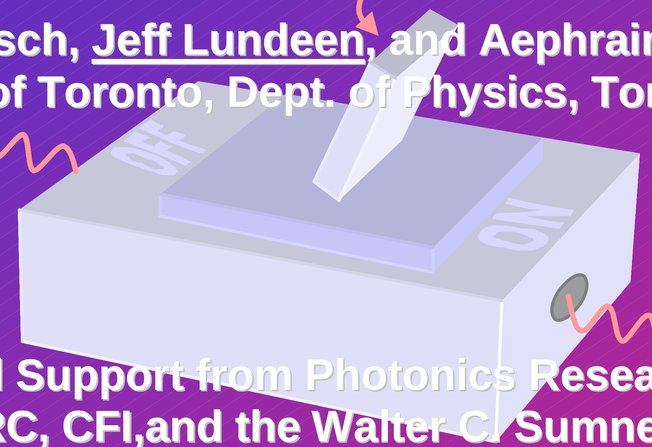
Motivation

- A nonlinear response between two photons is required for quantum information processing with light (a controlled-not gate).
- To build an all-optical switch for single photons.
- Develop understanding of *quantum* nonlinear optics.



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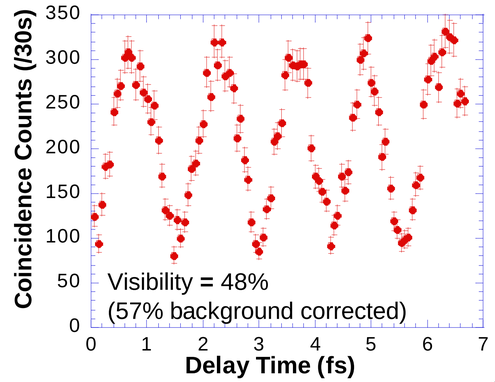
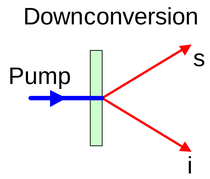
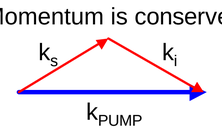
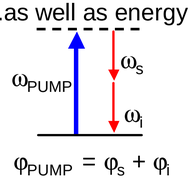
Suppression and Enhancement of Photon Pairs



Spontaneous Parametric Down-conversion



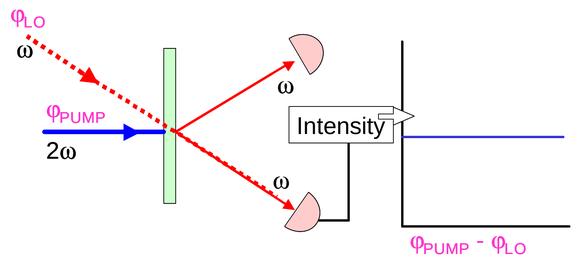




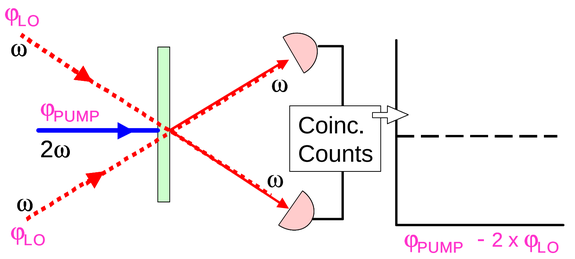
- A pump photon is spontaneously converted into ***two*** lower frequency photons (signal and idler) in a material with a nonzero $\chi^{(2)}$

The Concept

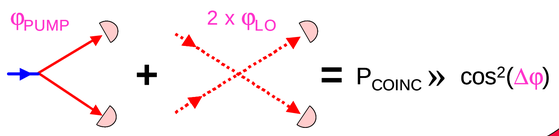
- **Can we see interference if we pass a laser through the back of a down-conversion crystal?**



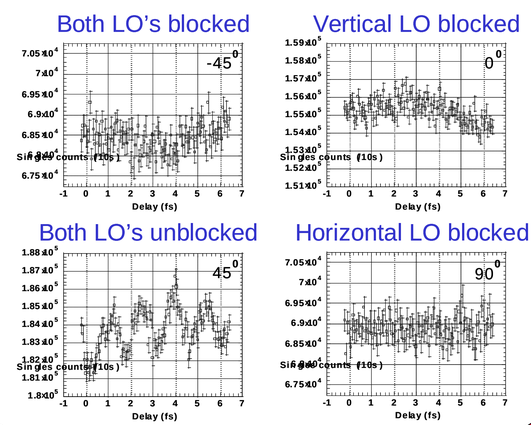
- **No, interference is impossible because the other down-converted photon gives which-path information.**



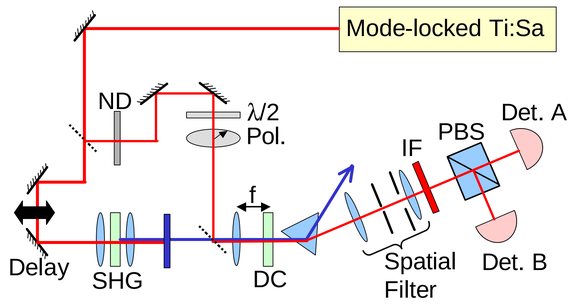
- **Yes, interference is possible. There are two indistinguishable Feynman paths that lead to a pair of photons. Either the pair comes from down-conversion or from the pair of lasers.**



Intensity Modulations: A photon switch



Experimental Setup



Summary

- **We have demonstrated a quantum interference effect which is an effective nonlinearity at the single-photon level.**
- **The effect is approximately 10 billion times stronger than conventional SHG.**
- **Pairs of photons can be removed from independent laser beams.**
- **A single-photon switch was demonstrated by observing a change in the intensity of the beams.**