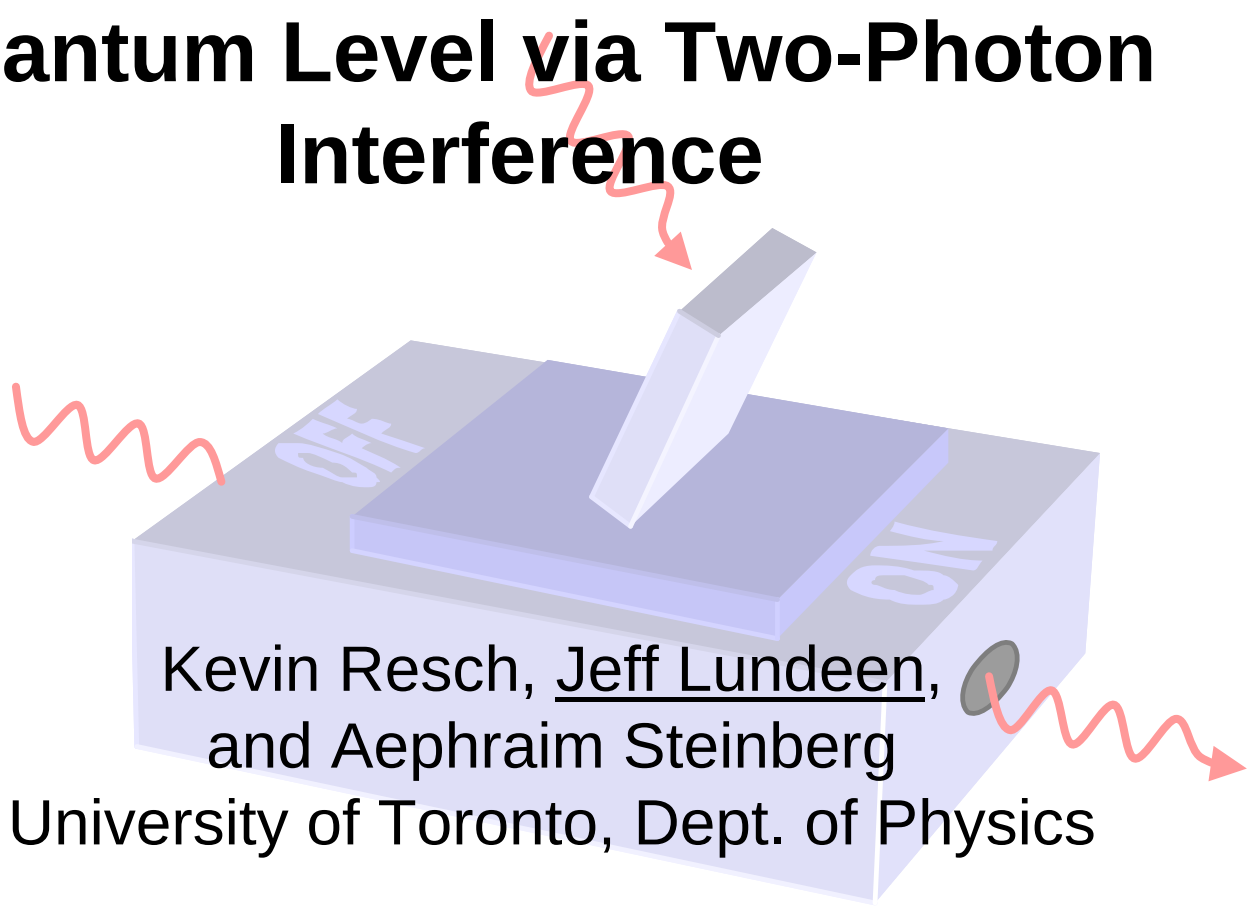
Nonlinear Optics at the Quantum Level via Two-Photon Interference



Kevin Resch, Jeff Lundeen,
and Aephraim Steinberg
University of Toronto, Dept. of Physics

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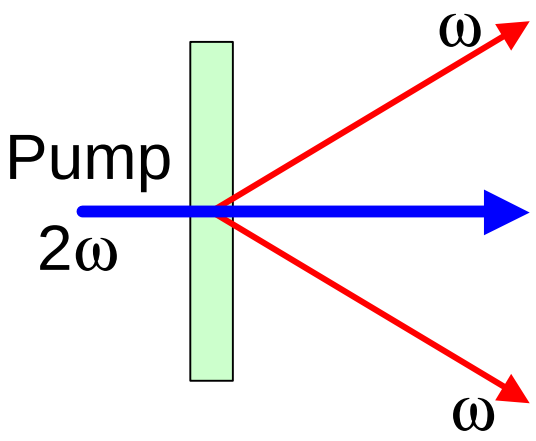
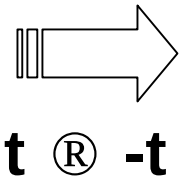
Outline

- Can we see strong conditional dynamics between free photons?
- Is 100% efficient upconversion possible at the quantum level?
- Experimental Realization and Results.
- What aspects of this effective nonlinearity need a quantum description?

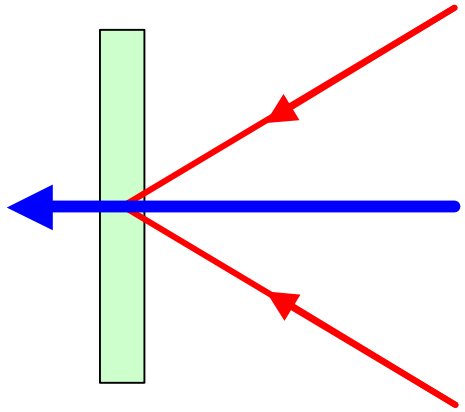
Consider…

Spontaneous Parametric Down-conversion





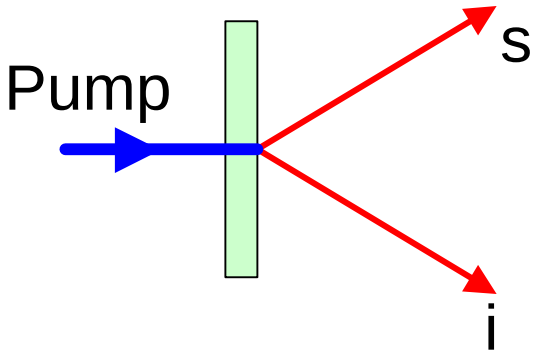
Time-Reversed



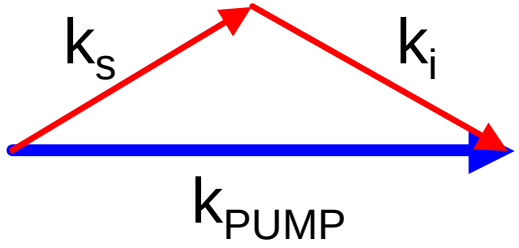
- 100% efficient upconversion

Spontaneous Parametric Downconversion

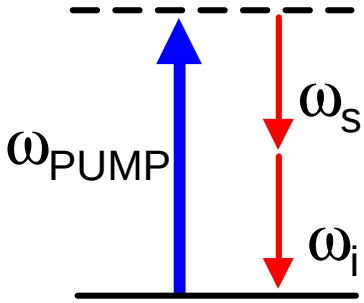
Downconversion



Momentum is conserved..



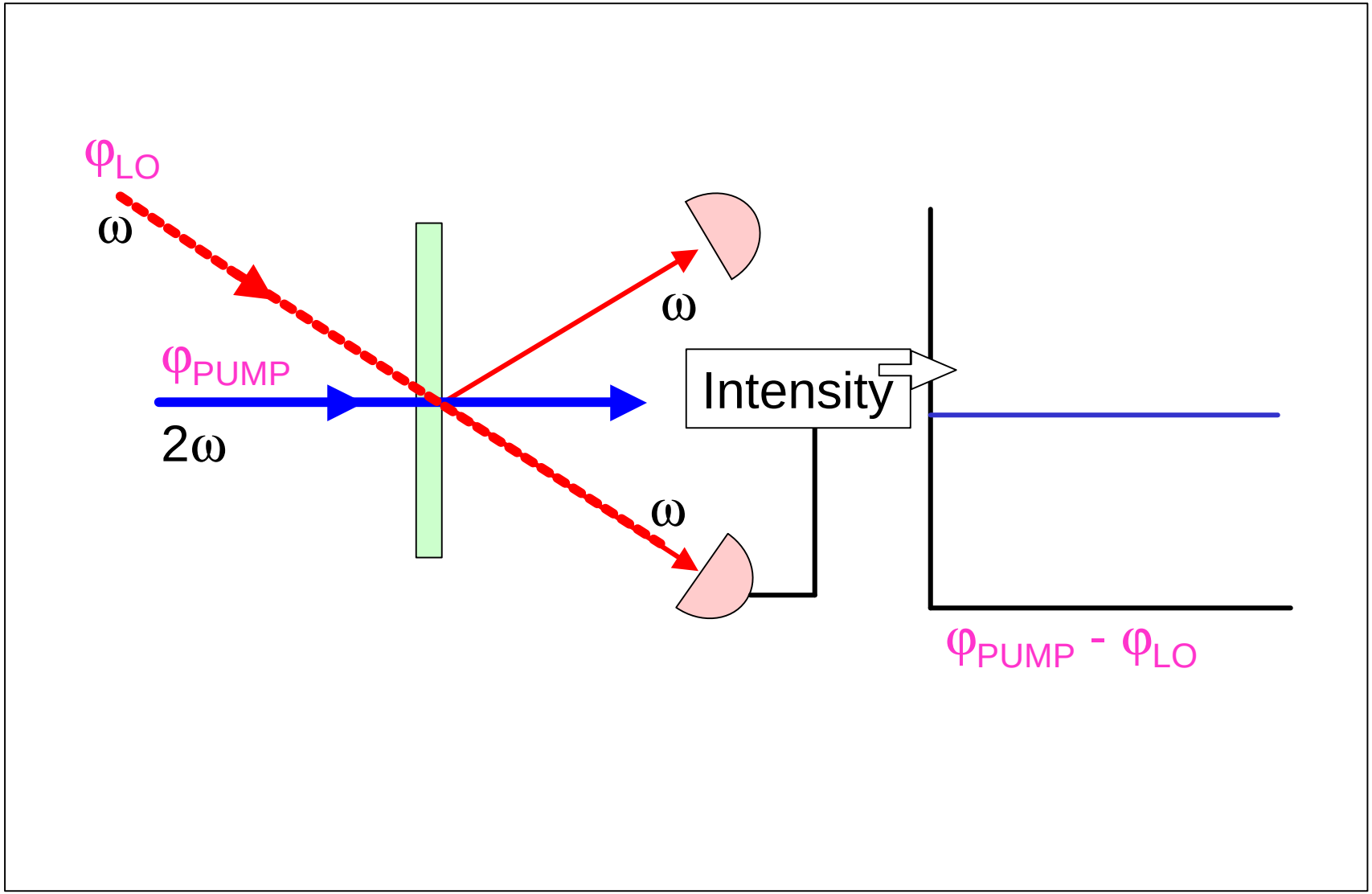
..as well as energy



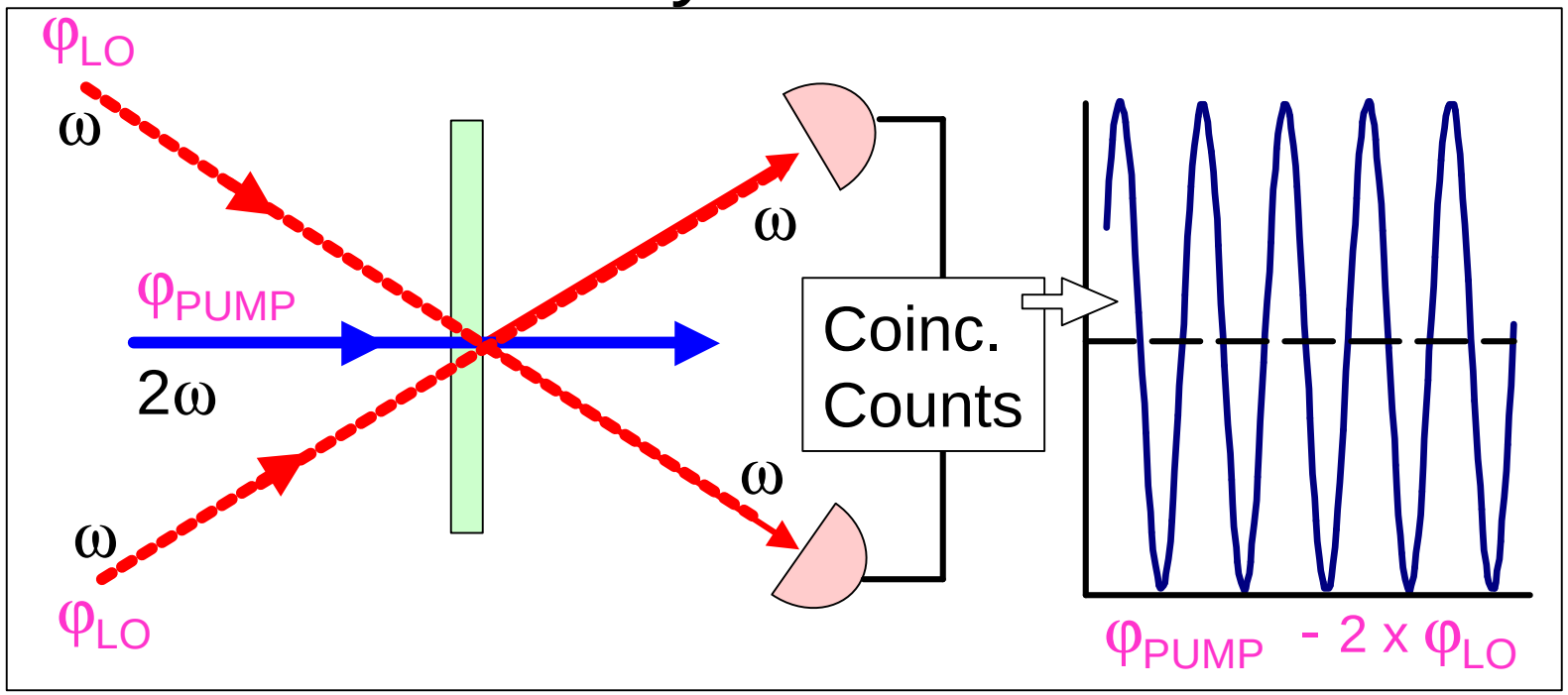
$\varphi_{PUMP} = \varphi_s + \varphi_i$

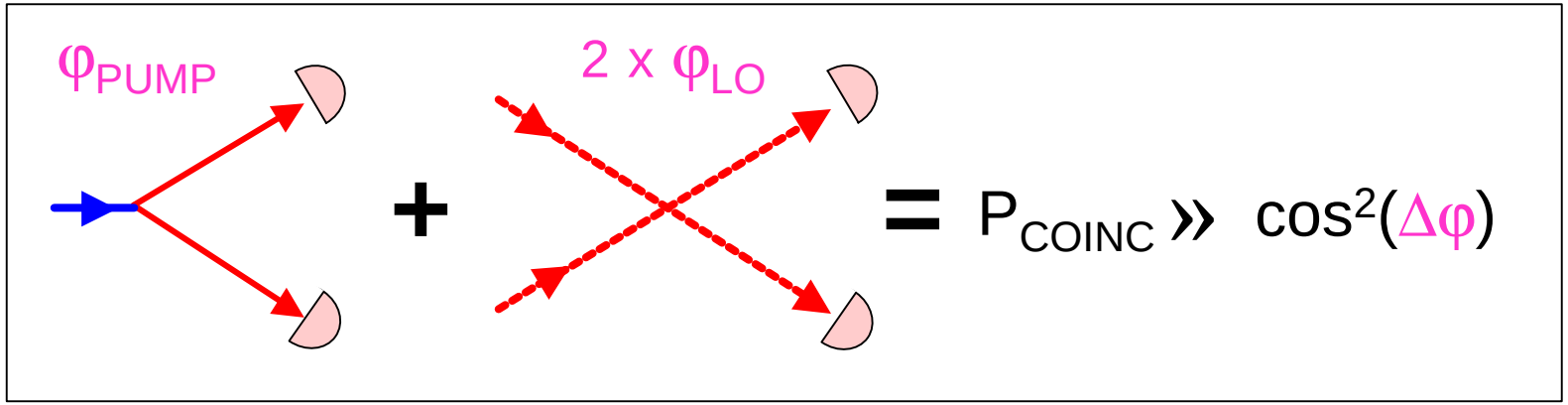
- A pump photon is spontaneously converted into two lower frequency photons in a material with a nonzero $\chi^{(2)}$

Which-Path Information



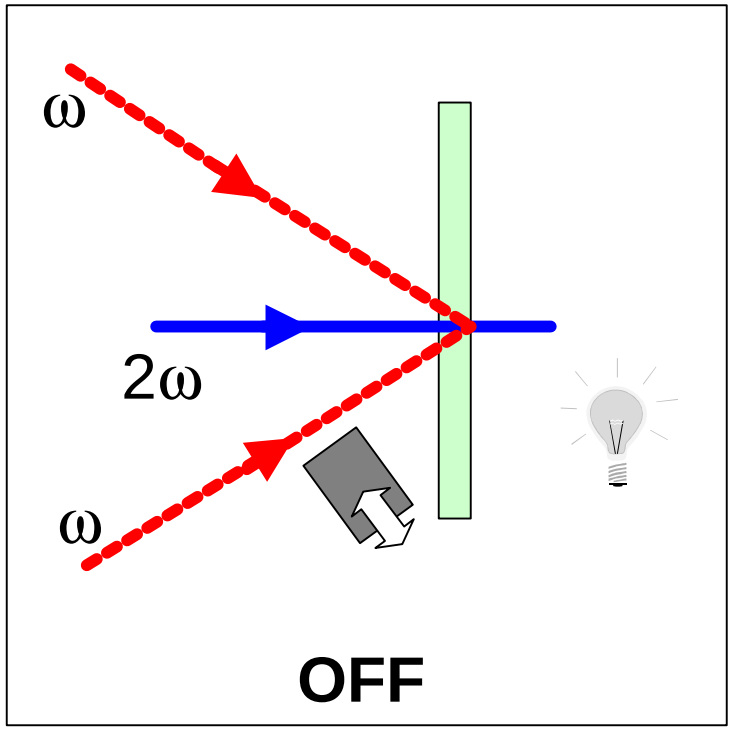
The Feynman Paths

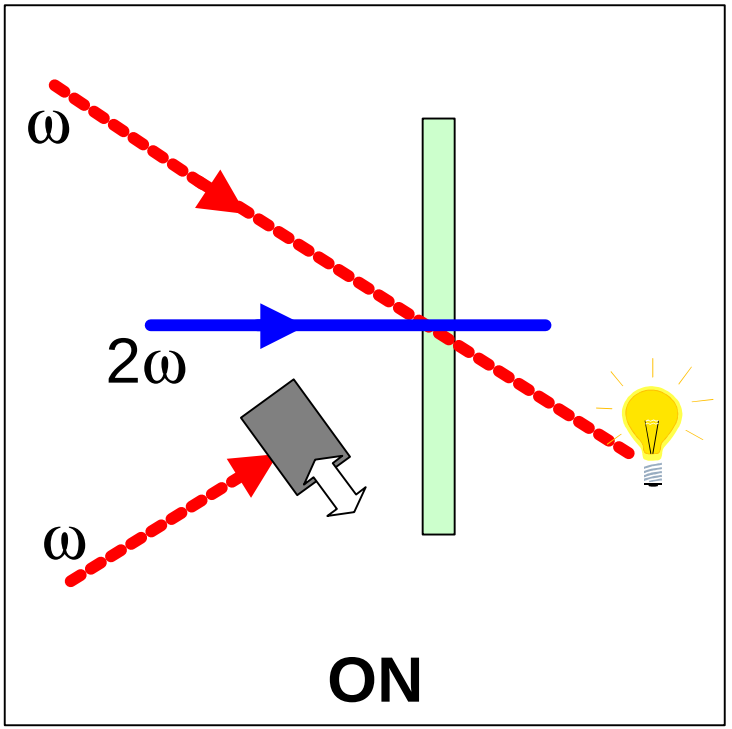




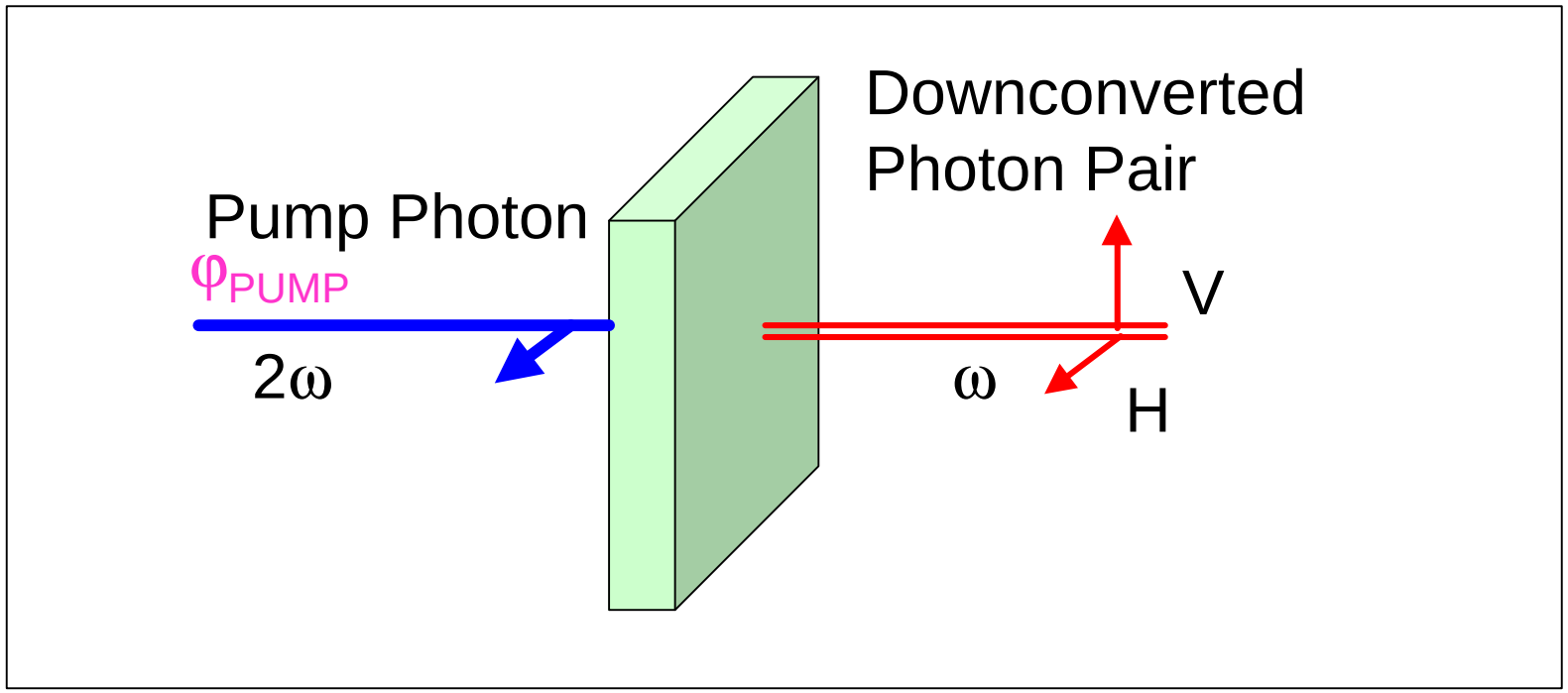
The Switch

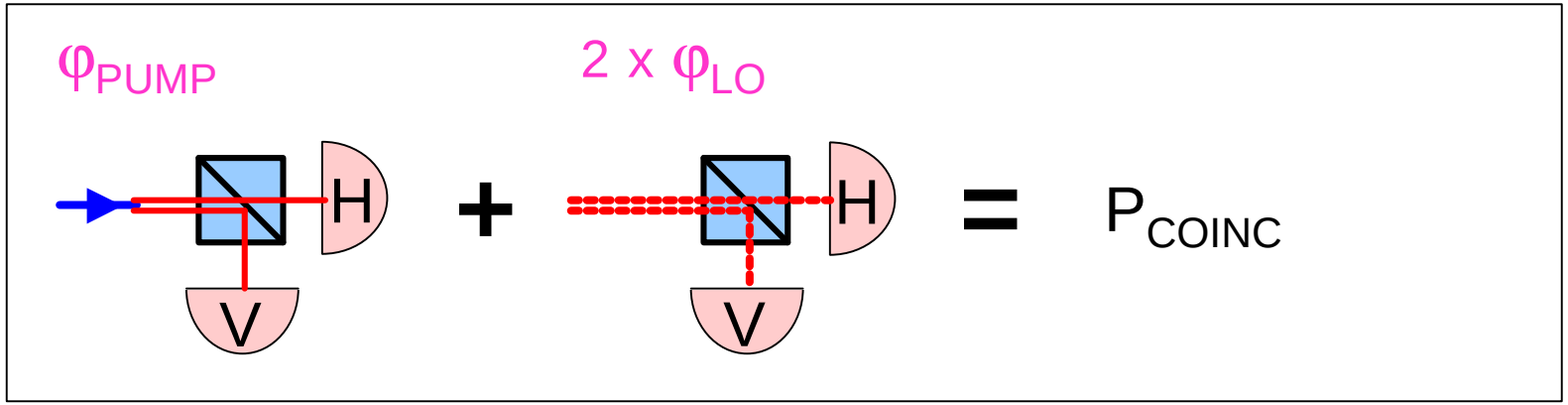
- Phase chosen so that coincidences are eliminated



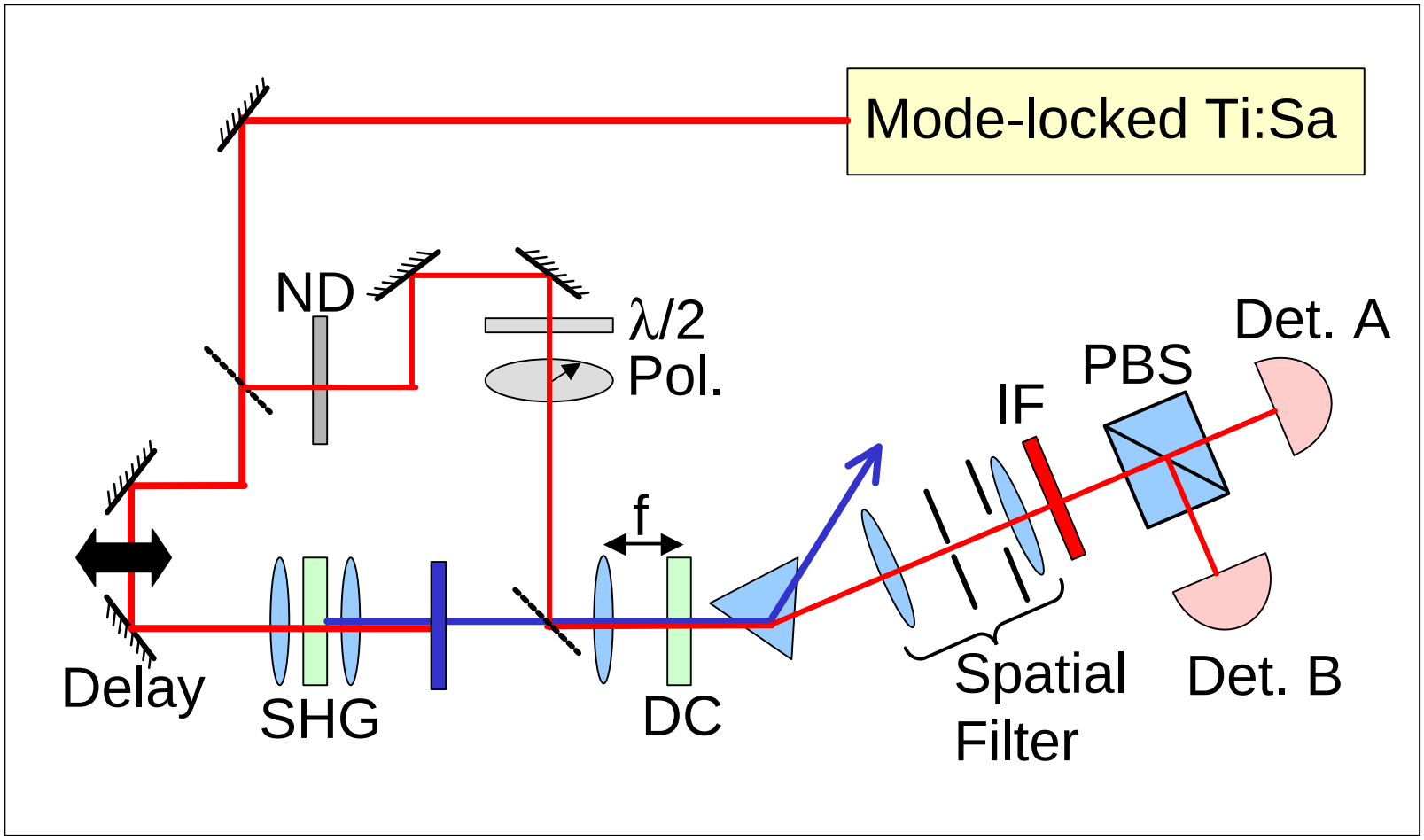


Type II Downconversion

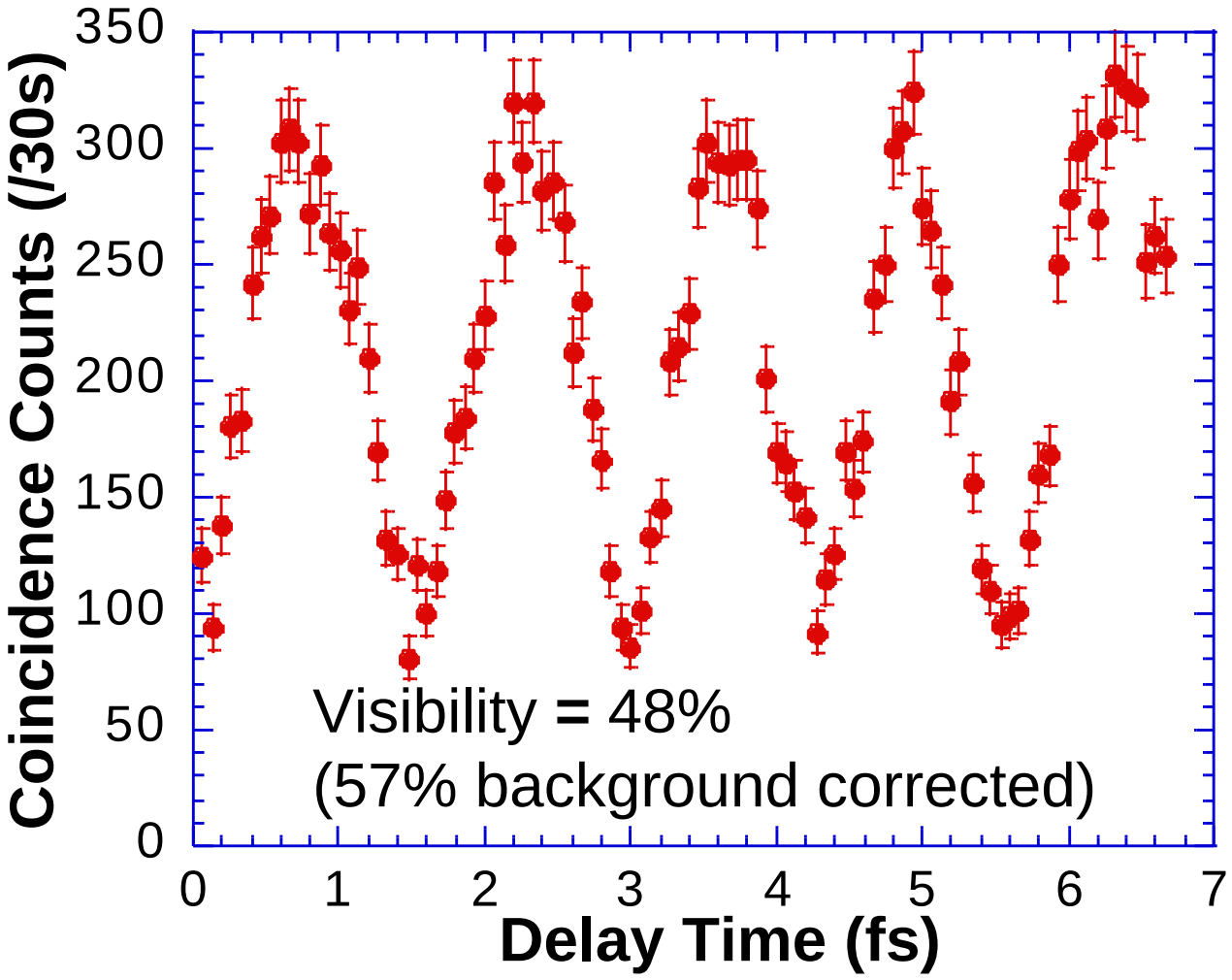




Experimental Setup

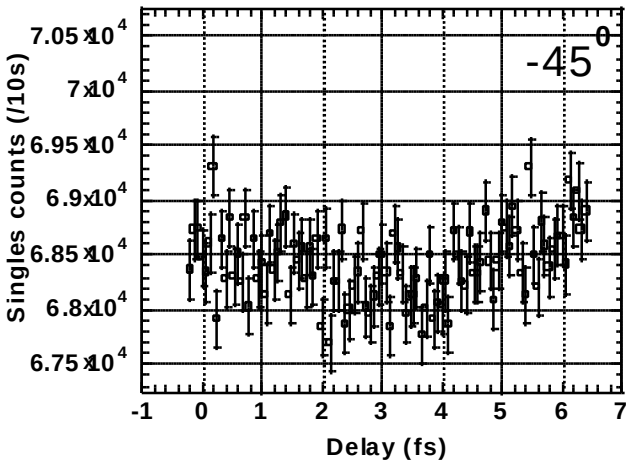


Suppression and Enhancement of Coincidence Counts

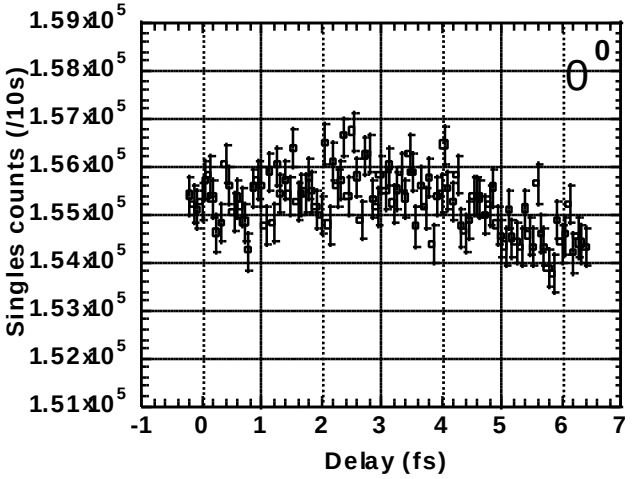


Intensity Modulations: The Switch

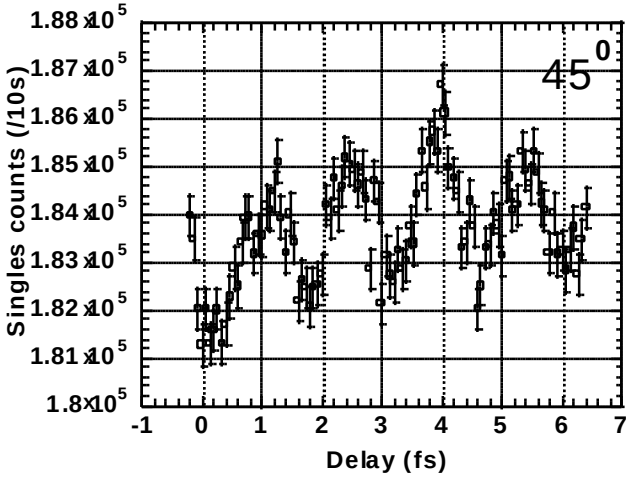
Both LO's blocked



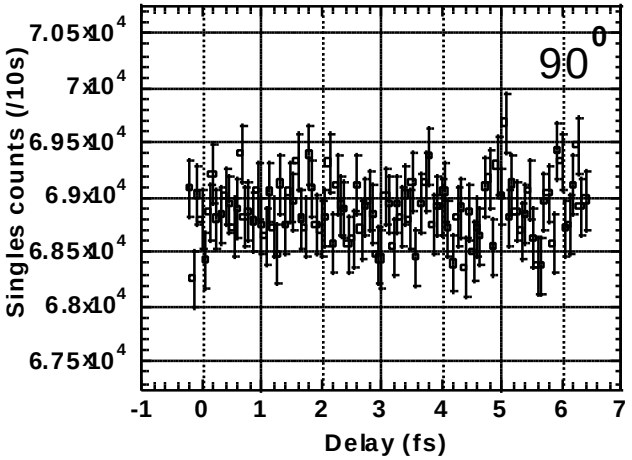
Vertical LO blocked



Both LO's unblocked

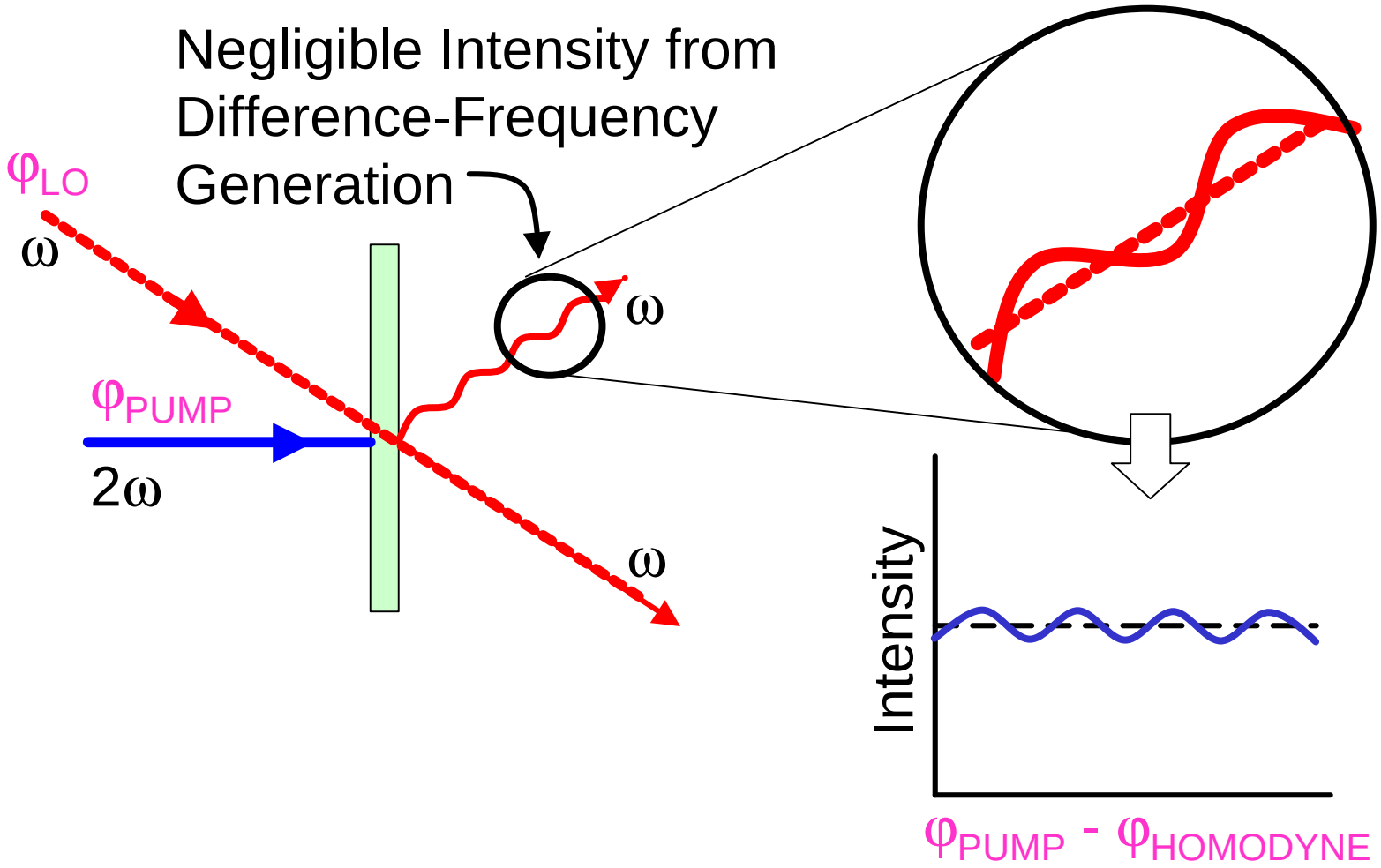


Horizontal LO blocked

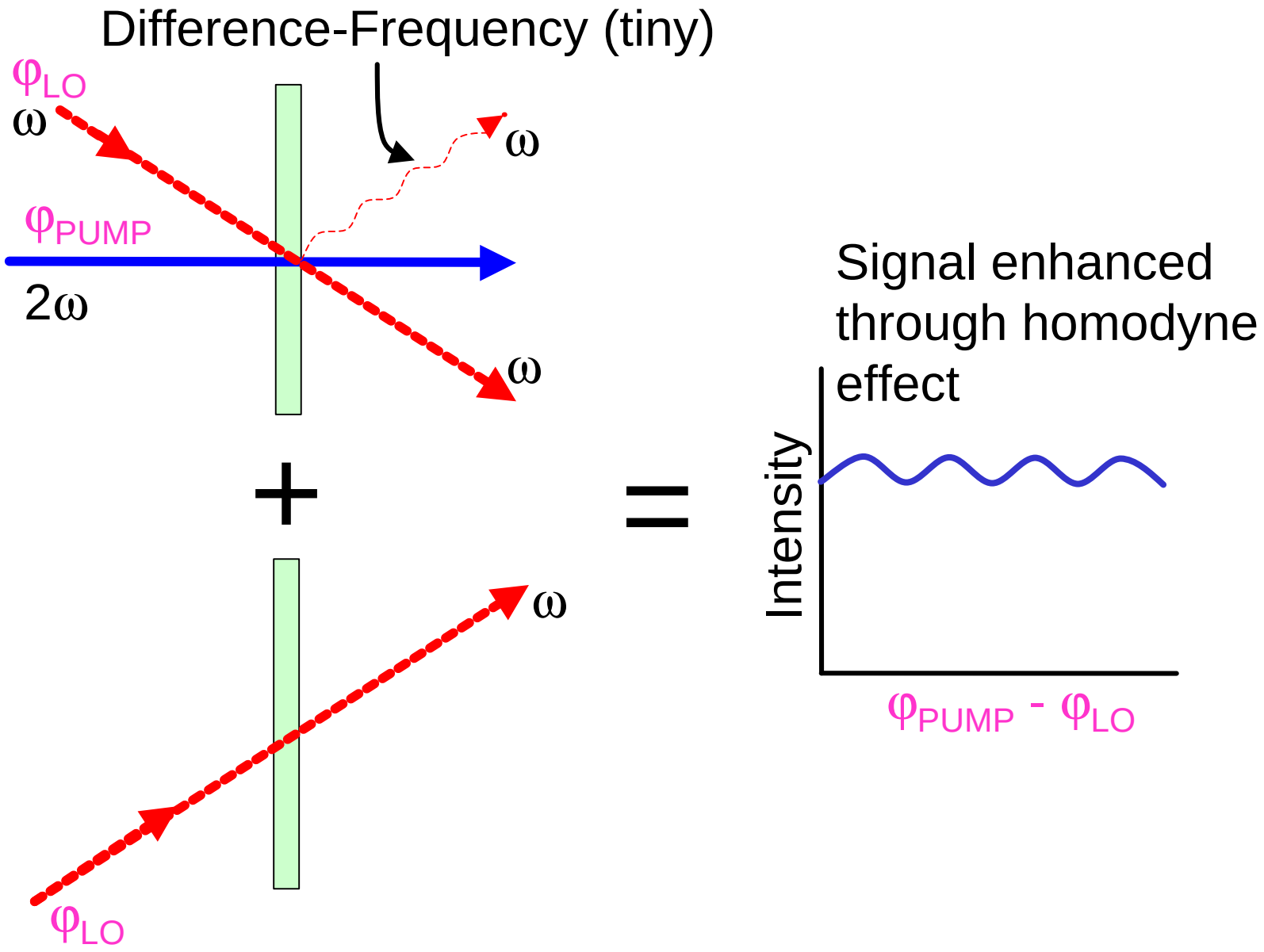


Intensity Modulations: Classical or Quantum?

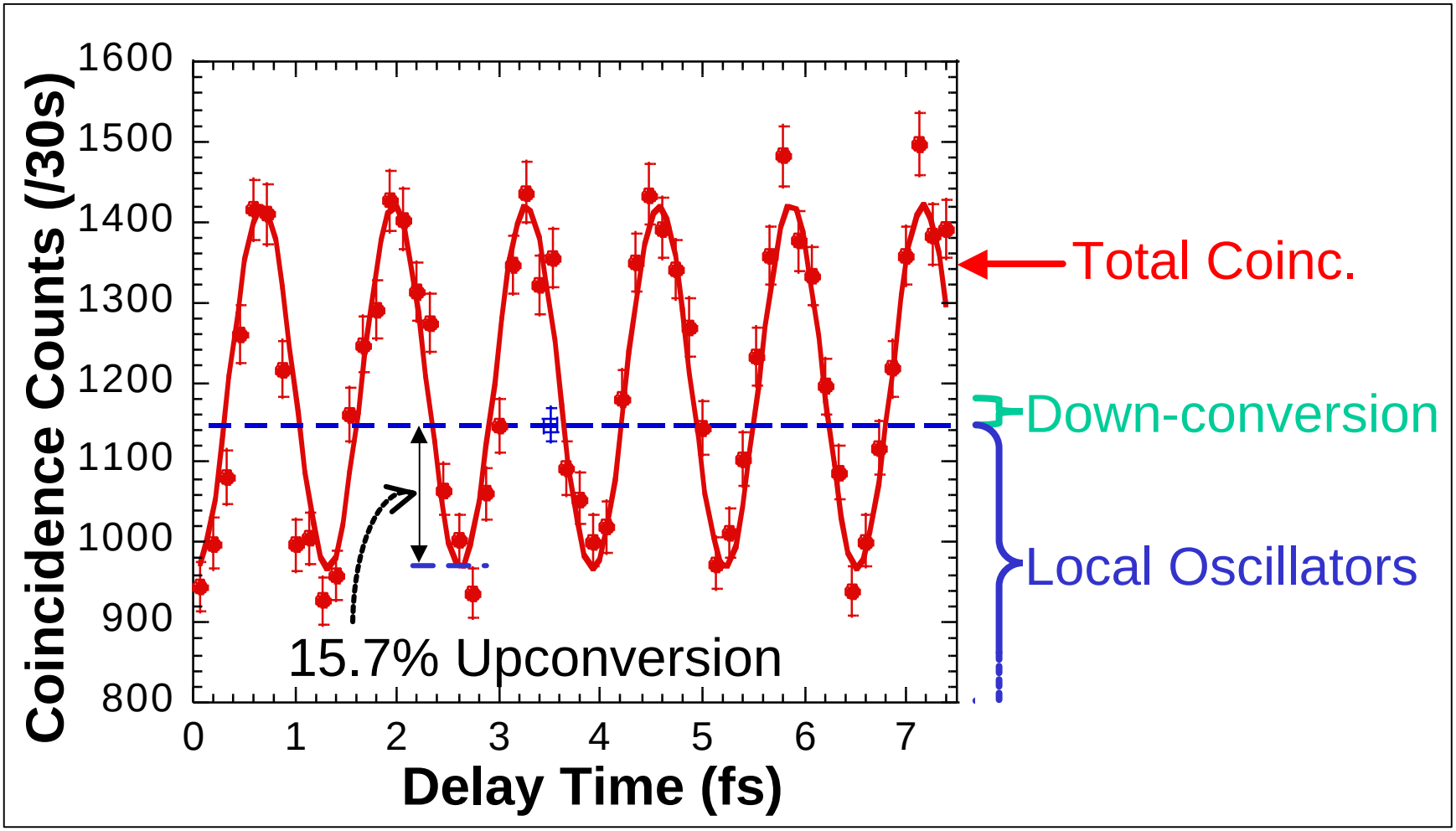
∴ Observed by Homodyne



Intensity Modulations: Classical or Quantum?



Upconversion of Photon-Pairs



Summary

- **We have demonstrated a quantum interference effect which is an effective nonlinearity at the single-photon level.**
- **Pairs of photons can be removed from independent laser beams.**
- **These conditional dynamics might be useful for quantum gates.**
- **A conditional phase-shift may be possible: Controlled phase gate?**