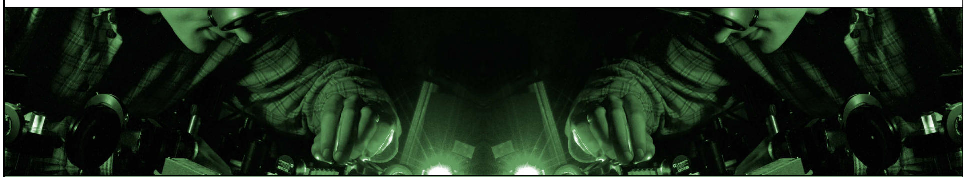

December 1, 2016

6.453 *Quantum Optical Communication* Lecture 22

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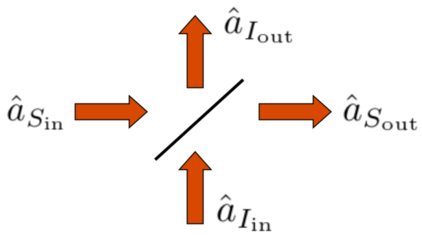
Optical and Quantum Communications Group

6.453 *Quantum Optical Communication* - Lecture 22

- Announcements
  - Pick up lecture notes, slides
  - Last lecture will be Tuesday, December 13th
  - Term papers are due Tuesday, December 13th
- Quantum Signatures from Parametric Interactions
  - Hong-Ou-Mandel dip produced by parametric downconversion
  - Polarization entanglement produced by parametric downconversion
  - Photon twins from parametric amplifiers

Quantum Interference Between Single Photons

- Input State to 50/50 Beam Splitter: $|1\rangle_{S_{\rm in}}|1\rangle_{I_{\rm in}}$



$$\hat{a}_{S_{\rm out}} = \frac{j\hat{a}_{S_{\rm in}} - \hat{a}_{I_{\rm in}}}{\sqrt{2}}$$

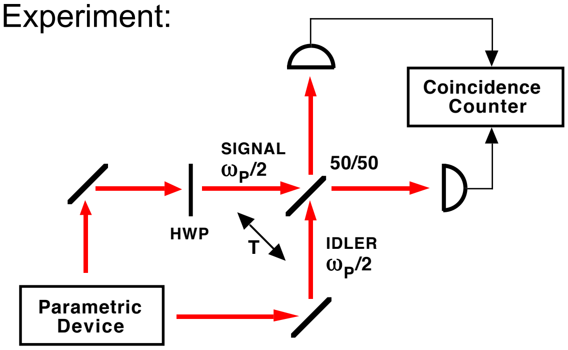
$$\hat{a}_{I_{\rm out}} = \frac{j\hat{a}_{I_{\rm in}} - \hat{a}_{S_{\rm in}}}{\sqrt{2}}$$

- Output State from 50/50 Beam Splitter:

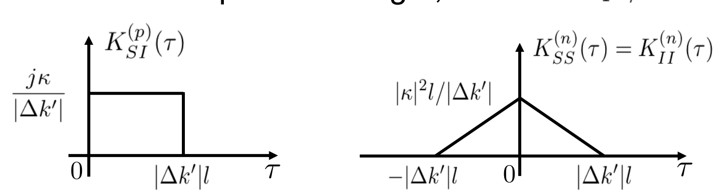
$$\frac{|2\rangle_{S_{\rm out}}|0\rangle_{I_{\rm out}} + |0\rangle_{S_{\rm out}}|2\rangle_{I_{\rm out}}}{\sqrt{2}}$$

Hong-Ou-Mandel Interferometer

- Type-II Experiment:



- PPKTP: 795 nm output wavelength, $\Delta k' = -3.3\,{\rm ps/cm}$



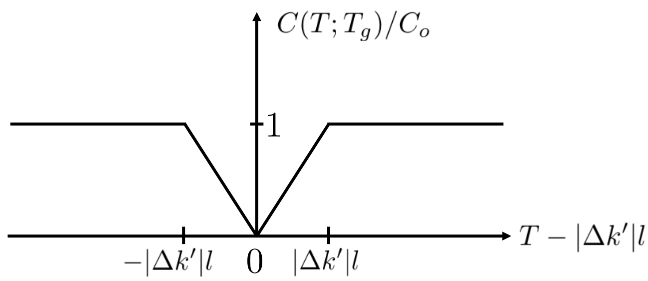
Hong-Ou-Mandel Coincidence Dip

- Average Low-Flux Coincidence Count in T_g-Sec-Long Gate:

$$C(T;T_g) = \left\langle \int_0^{T_g} \mathrm{d}t\, \hat{E}'^{\dagger}_{S_{\text{out}}}(t)\hat{E}'_{S_{\text{out}}}(t) \int_0^{T_g} \mathrm{d}u\, \hat{E}'^{\dagger}_{I_{\text{out}}}(u)\hat{E}'_{I_{\text{out}}}(u) \right\rangle$$

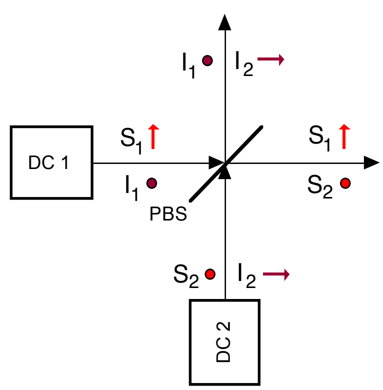
- Low-Flux Gaussian-State Coincidence Counting Theory:

$$C(T;T_g) = \frac{\eta^2 T_g}{4} \int \mathrm{d}\tau\, |K^{(p)}_{SI}(\tau) - K^{(p)}_{SI}(-\tau + T)|^2$$



Polarization-Entanglement From Downconversion

- Anti-Phased Coherently-Pumped Type-II Downconverters:



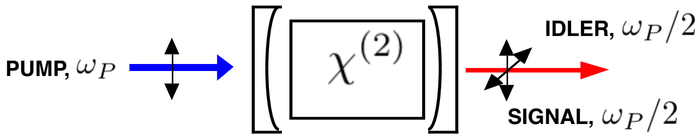
$$C_{\vec{\mathbf{i}}\vec{\mathbf{i}}'}(T_g) = \eta^2 T_g \frac{|\kappa|^2 l}{|\Delta k'|}$$

$$C_{\vec{\mathbf{i}}\vec{\mathbf{i}}}(T_g) = 0$$

$\vec{\mathbf{i}}$ and $\vec{\mathbf{i}}'$ conjugate polarziations

Type-II Optical Parametric Amplifier

- Doubly-Resonant Operation at Frequency Degeneracy



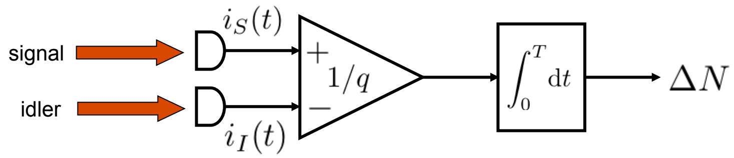
- Normally-Ordered and Phase-Sensitive Covariances:

$$K^{(n)}(\tau) = \frac{G\Gamma}{2}\left[\frac{e^{-(1-G)\Gamma|\tau|}}{1-G} - \frac{e^{-(1+G)|\tau|}}{1+G}\right]$$

$$K_{SI}^{(p)}(\tau) = \frac{G\Gamma}{2}\left[\frac{e^{-(1-G)\Gamma|\tau|}}{1-G} + \frac{e^{-(1+G)|\tau|}}{1+G}\right]$$

Photon Twins from a Parametric Amplifier

- Signal-Minus-Idler Photon Count Difference



- Unity-Quantum-Efficiency Detection

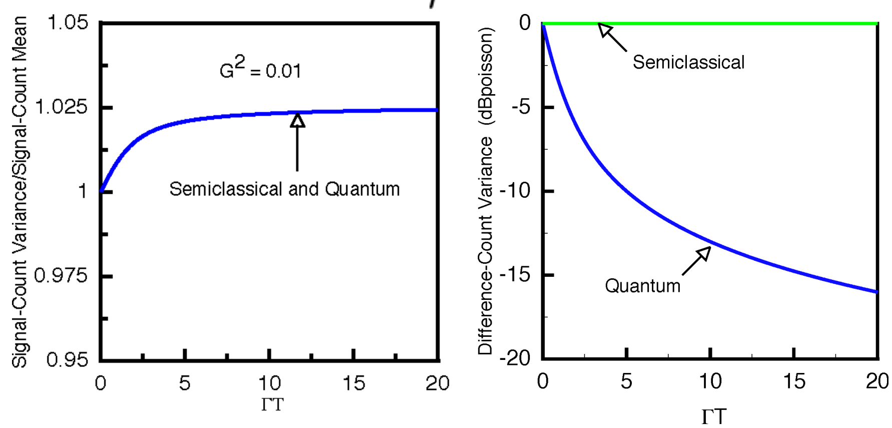
$$\Delta N \leftrightarrow \widehat{\Delta N} = \int_0^T \mathrm{dt}\left[\hat{E}_S^\dagger(t)\hat{E}_S(t) - \hat{E}_I^\dagger(t)\hat{E}_I(t)\right]$$

$$\frac{\langle \Delta N^2 \rangle}{\langle N_S \rangle + \langle N_I \rangle} = \frac{1-e^{-2\Gamma T}}{2\Gamma T}$$

Photon Twins from a Parametric Amplifier

- Signal-Count and Signal-Minus-Idler Count Variances

$$\eta = 1$$



Coming Attractions: Lecture 23

- Lecture 23:
  More Quantum Optical Applications
  - Binary optical communication with squeezed states
  - Phase-sensing interferometry with squeezed states
  - Super-dense coding with entangled states
  - Quantum lithography with “N00N” states

6.453 Quantum Optical Communication
Fall 2016