Using Two Mode Squeezing to Enhance Quadrature Quantum Sensing
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Research question: How can using two-mode squeezed entangled photons help enhance the quantum detection of quadratures of an arbitrary state?

Background:
Squeezed states enable the reduction of a quantum state quadrature uncertainty below that of the minimal uncertainty state. This project proposes a homodyne detection setup with the intention of using a squeezed state of entangled photons to help improve the sensitivity of quadrature detection of an arbitrary quantum system by enhancing the contrast between the two half modes.

Procedure:
- Generation of two-mode squeezed states:
  \[
  H_I = -\int d\omega \left( \sum_{\lambda=0}^{1} a_{\lambda}^\dagger a_{\lambda} - \frac{\omega}{2} a_{\lambda}^\dagger a_{\lambda} - \frac{\omega}{2} \right) + \frac{1}{2} \sum_{\lambda=0}^{1} \left( \frac{\omega}{2} a_{\lambda}^\dagger a_{\lambda} - \frac{\omega}{2} \right) + \frac{1}{2} \sum_{\lambda=0}^{1} \left( \frac{\omega}{2} a_{\lambda}^\dagger a_{\lambda} - \frac{\omega}{2} \right)
  \]
  Time-independent Interaction Hamiltonian

- Number operators at each detector:
  \[
  n_s = \frac{1}{2} \left( a_{s}^\dagger a_{s} + e^{i\phi_s} a_{s}^\dagger a_{s} - e^{-i\phi_s} a_{s}^\dagger a_{s} + e^{i\phi_s} a_{s}^\dagger a_{s} - e^{-i\phi_s} a_{s}^\dagger a_{s} \right) + \frac{1}{2} \left( a_{i}^\dagger a_{i} + e^{i\phi_i} a_{i}^\dagger a_{i} - e^{-i\phi_i} a_{i}^\dagger a_{i} + e^{i\phi_i} a_{i}^\dagger a_{i} - e^{-i\phi_i} a_{i}^\dagger a_{i} \right)
  \]

Conclusions:
While we can see in the results section that we arrived at the difference operators in terms of quadratures of signal and idler, this setup does not provide a mixing of the local oscillators 1 and 2 and therefore is not ideal for the results intended. We will explore another setup to conduct a joint measurement in which we will mix paths 4 with 7 and 3 with 8.

Results:
- Number operators at each detector:
  \[
  n_s = \frac{1}{2} \left( a_{s}^\dagger a_{s} + e^{i\phi_s} a_{s}^\dagger a_{s} - e^{-i\phi_s} a_{s}^\dagger a_{s} + e^{i\phi_s} a_{s}^\dagger a_{s} - e^{-i\phi_s} a_{s}^\dagger a_{s} \right) + \frac{1}{2} \left( a_{i}^\dagger a_{i} + e^{i\phi_i} a_{i}^\dagger a_{i} - e^{-i\phi_i} a_{i}^\dagger a_{i} + e^{i\phi_i} a_{i}^\dagger a_{i} - e^{-i\phi_i} a_{i}^\dagger a_{i} \right)
  \]

References: