Mode 0 Photon Statistics

Mean photons: 0.165

Probability vs Photon number

Mode 1 Photon Statistics

Mean photons: 0.404

Probability vs Photon number
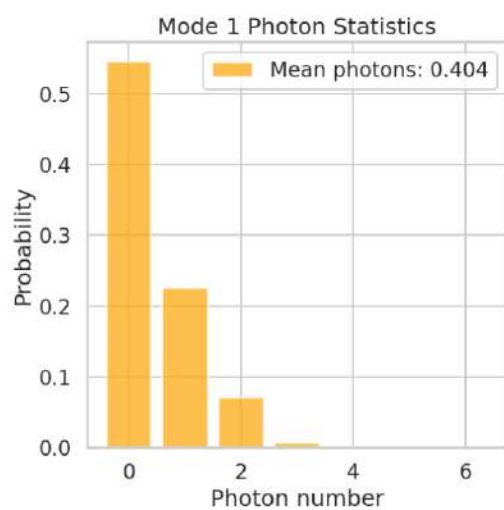
Joint Photon Number Distribution

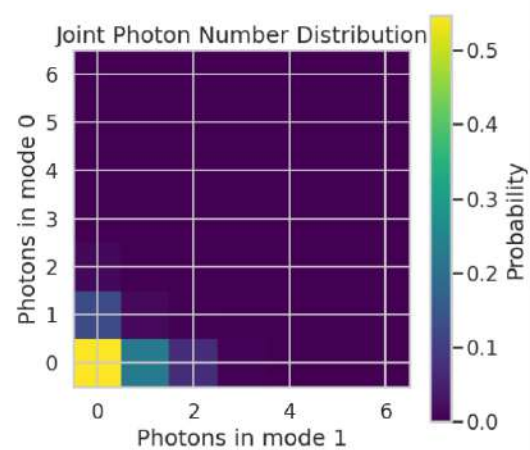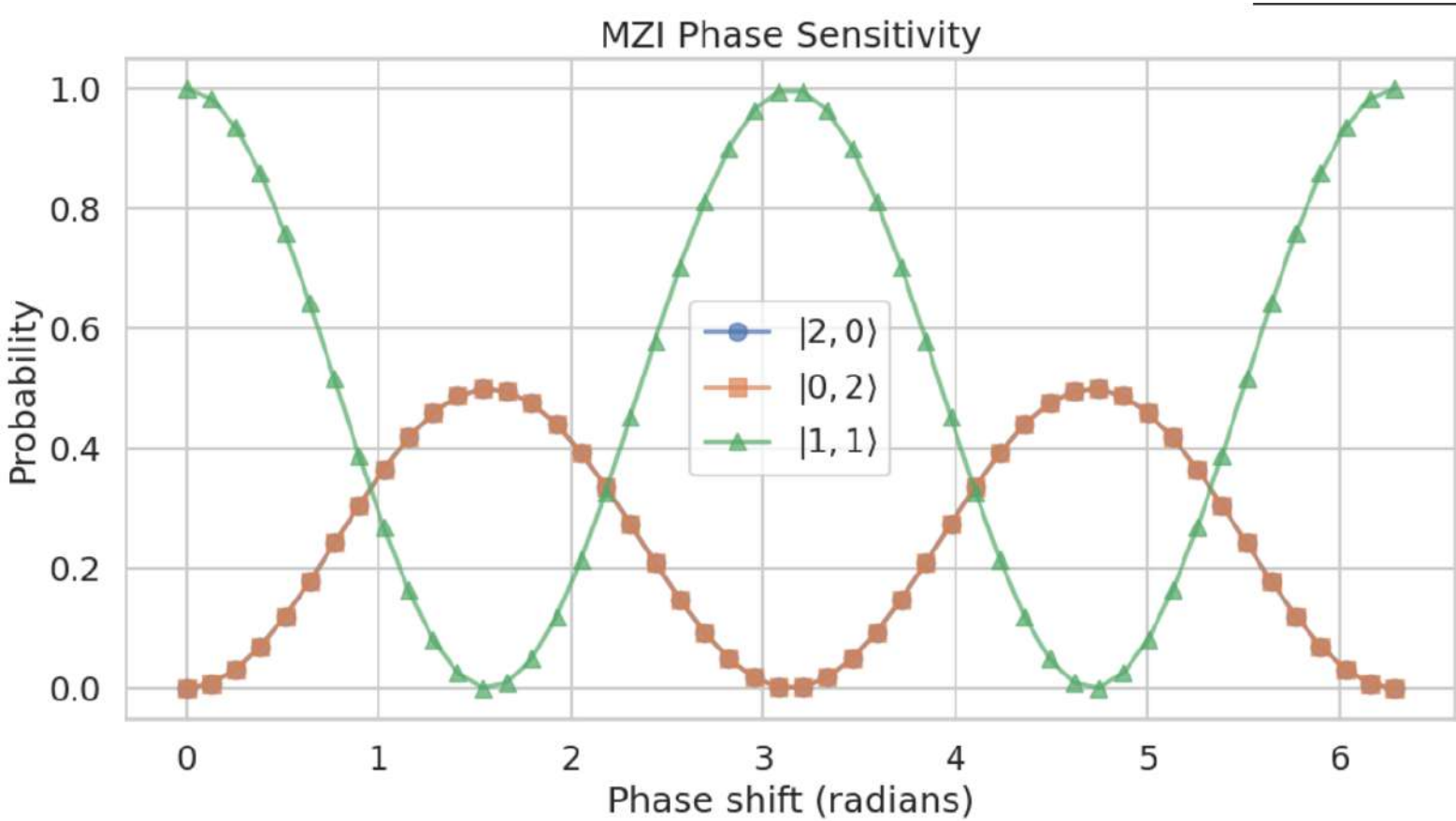Photons in mode 0 vs Photons in mode 1

Probability

Wigner Function - Mode 0 (No Loss)

Wigner Function - Mode 0 (With 10.0% Loss)

MZI Phase Sensitivity

Hong-Ou-Mandel Effect

Effect of Loss on Quantum Interference
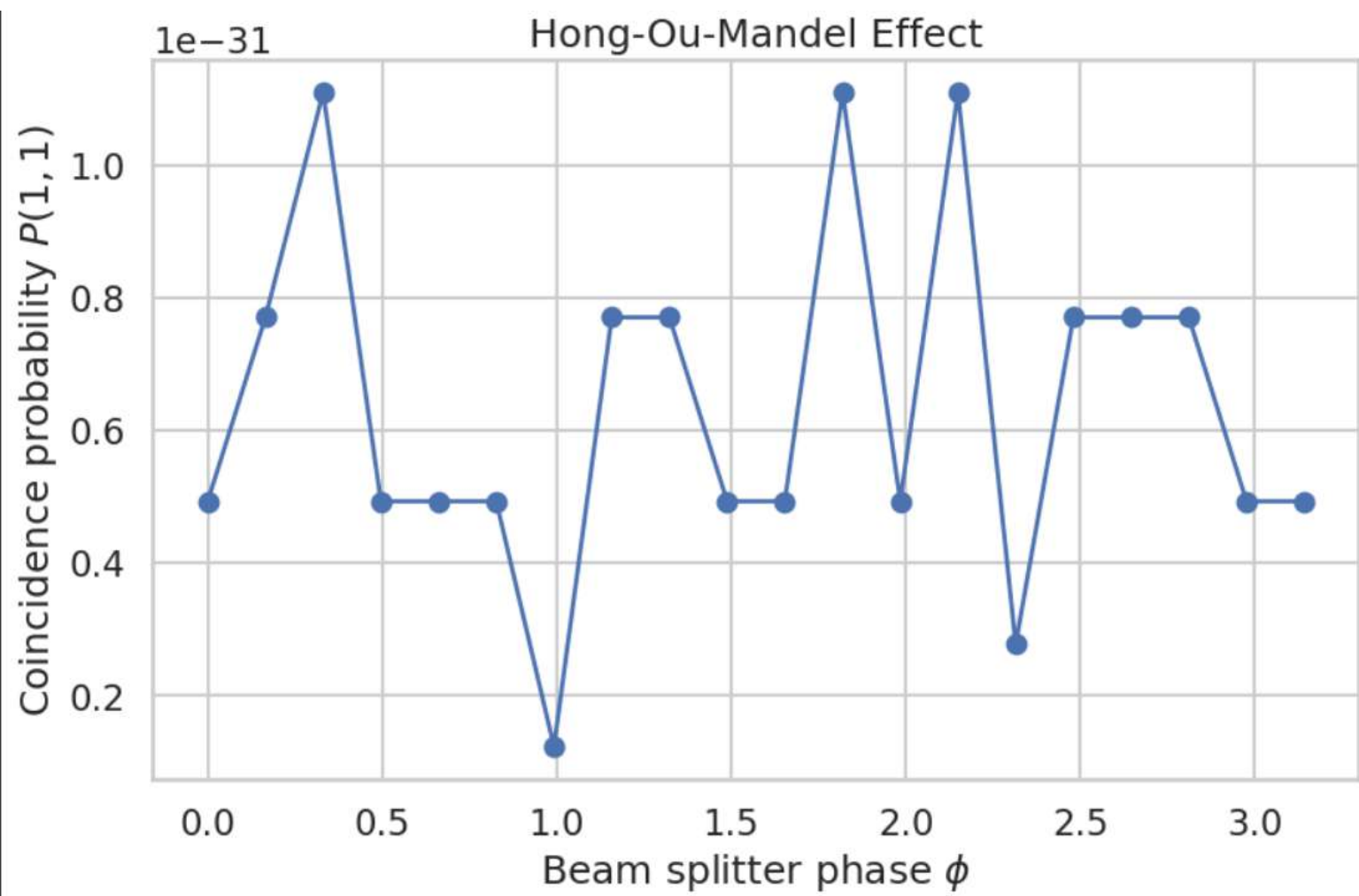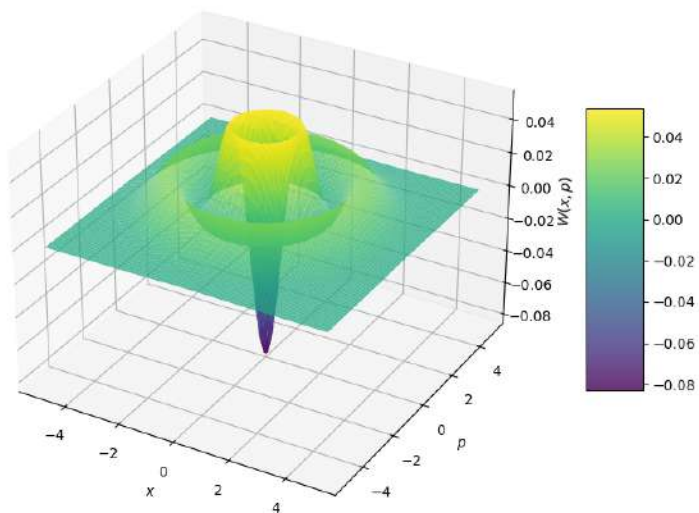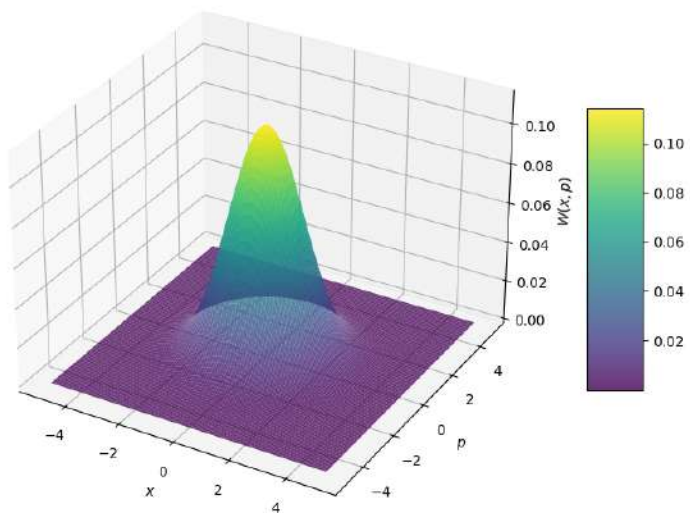
Wigner Function - Mode 0 (No Loss)

Wigner Function - Mode 0 (With 10.0% Loss)

Wigner Function - Mode 1 (No Loss)

Wigner Function - Mode 1 (With 10.0% Loss)

Hong-Ou-Mandel Effect: Coincidence vs. Beam Splitter Phase

Second-Order Coherence vs. Loss Rate

g^(2)

Loss rate

Mode 0
Mode 1

Mean Photon Number vs. Loss Rate

Mean photon number

Loss rate

Mode 0
Mode 1

Wigner Function - Mode 1 (No Loss)

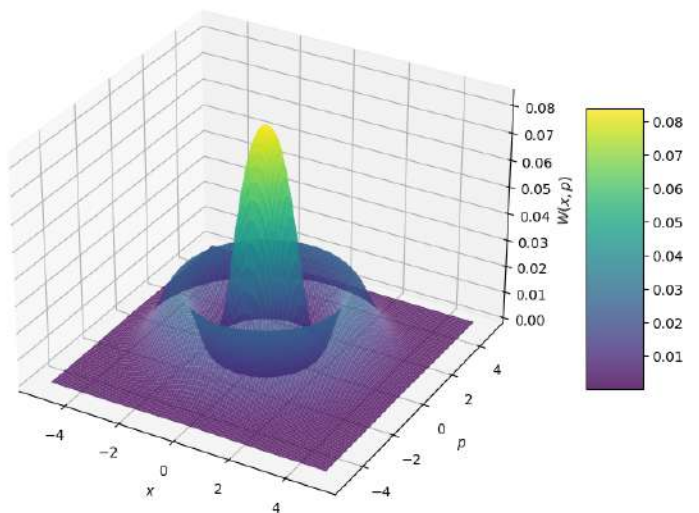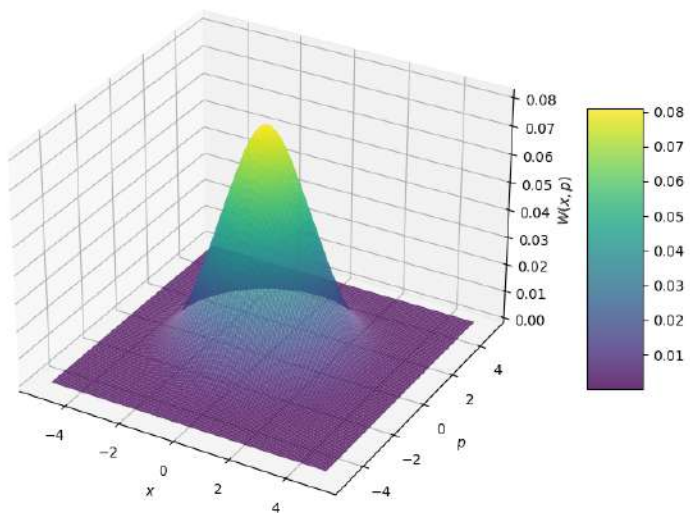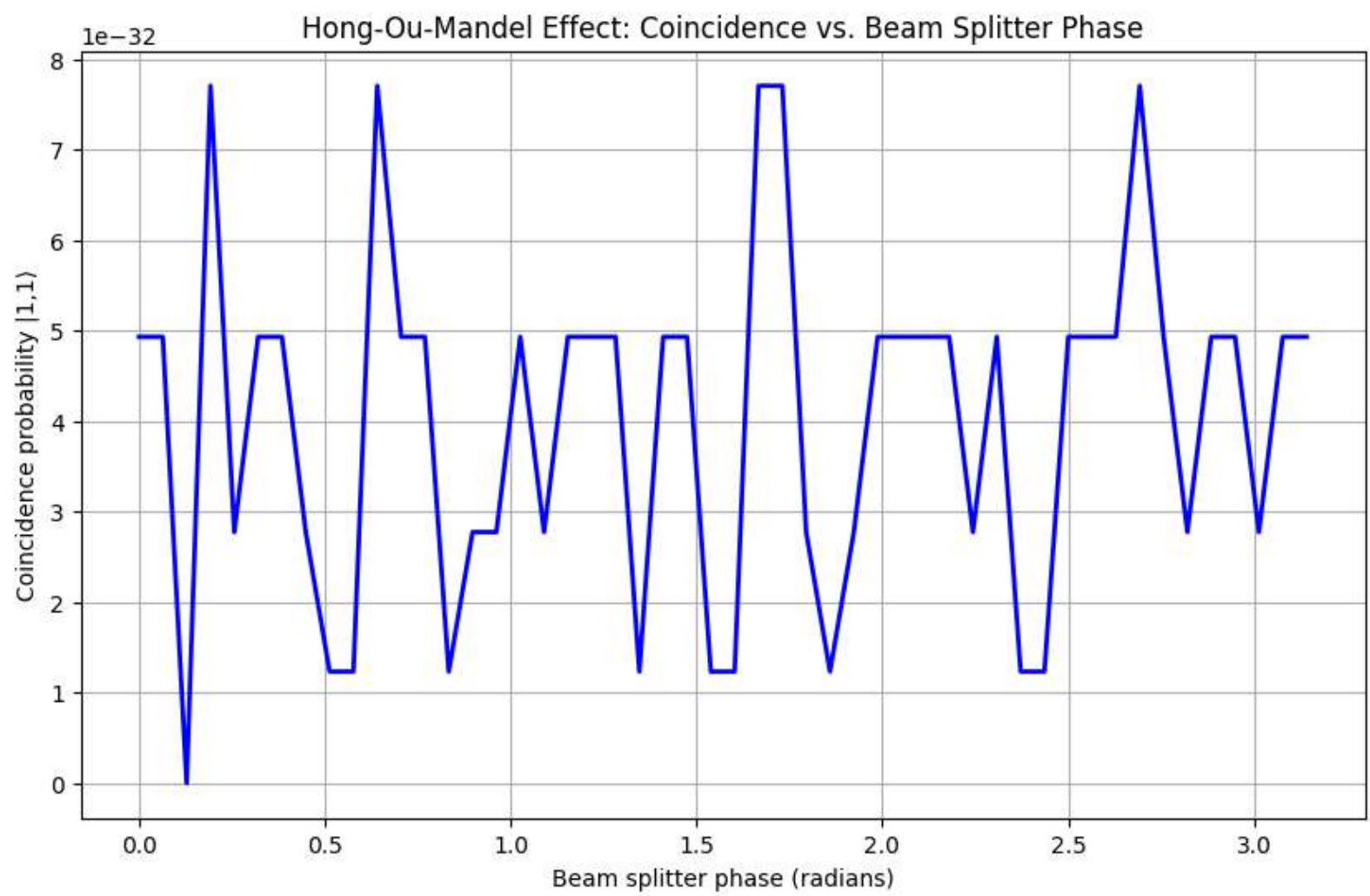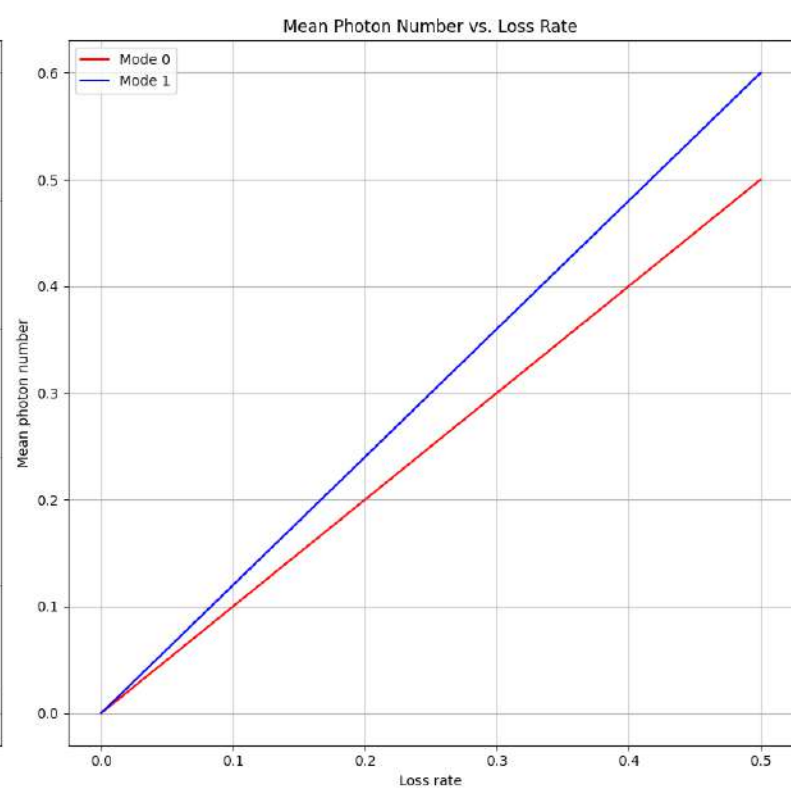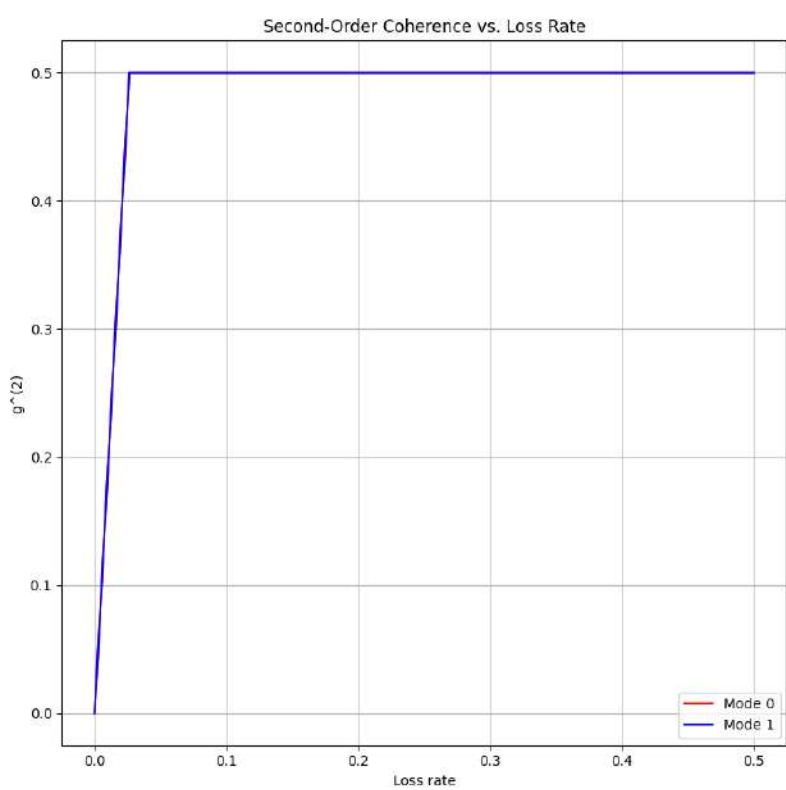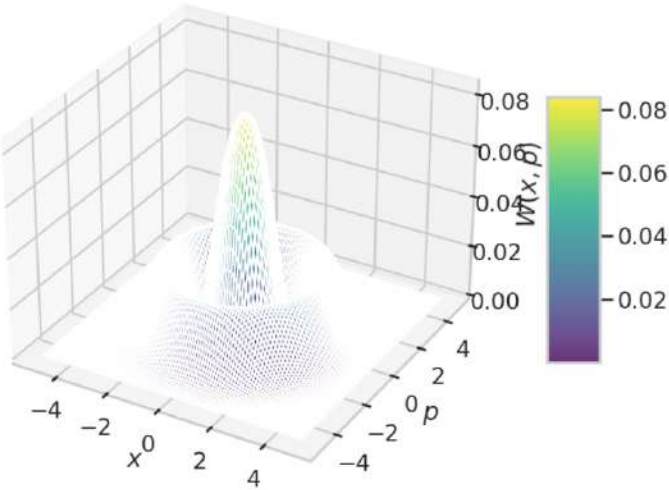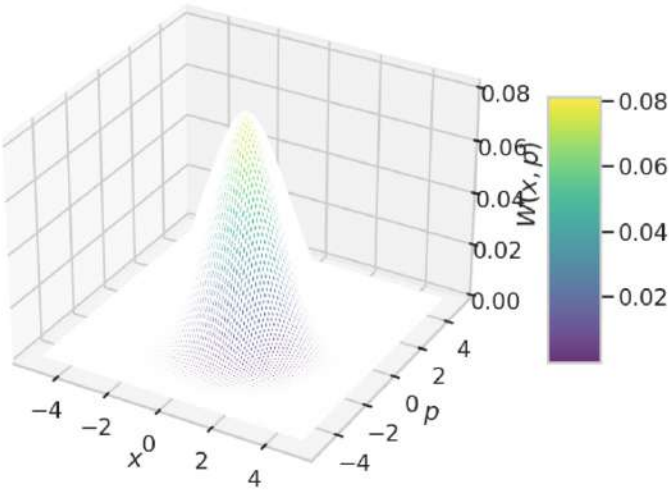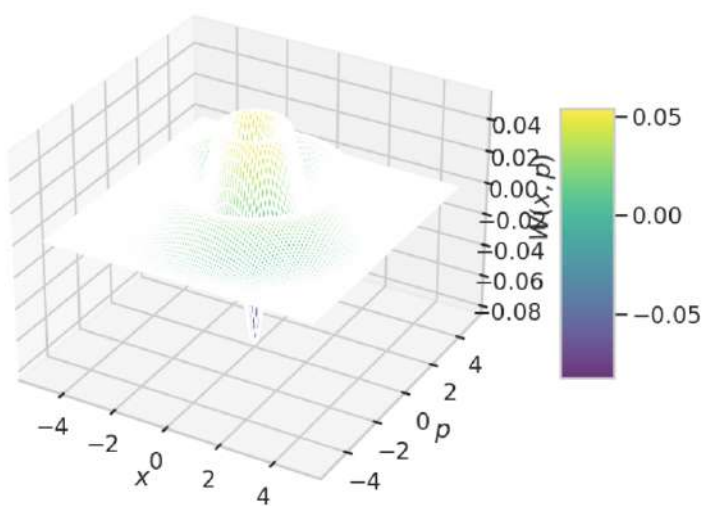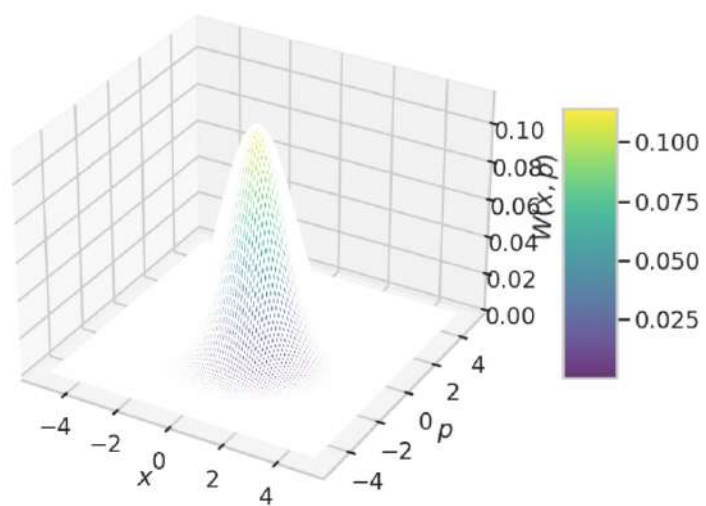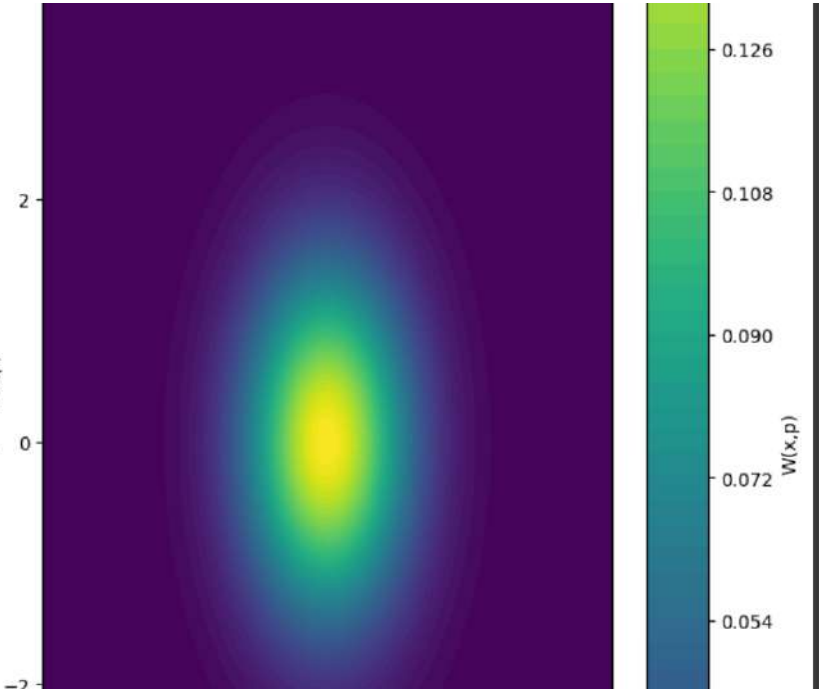Wigner Function - Mode 1 (With 10.0% Loss)

Wigner Function - Mode 1 (No Loss)

Wigner Function - Mode 1 (With 10.0% Loss)

Hamiltonian Simulation - Pump Mode - 3D View
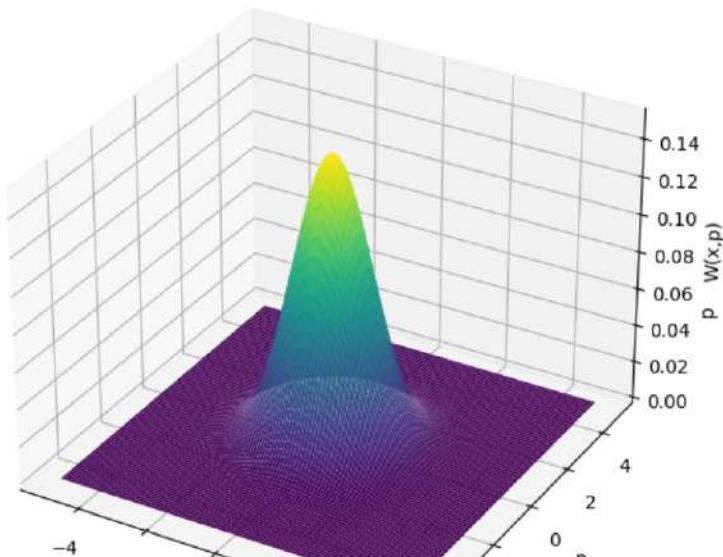
Statistics:

Mode 0: mean = 0.25 ± 0.51

Mode 1: mean = 0.25 ± 0.51

Coincidence counts: 6275

Coincidence rate: 0.209

```
Running Hamiltonian simulation...
Maximum |omega_s - omega_i|: 0.5
HAMILTONIAN RESULTS>>>>>>>
Phase matching: omega_s = 1.25, omega_i = 0.75, omega_p = 2.0
Final state mean values: [-5.69220204e-02  0.00000000e+00 -5.67330363e-03  2.66459772e-06
  0.00000000e+00 -2.65575111e-07]
Final state covariance matrix:
[[ 1.00019738  0.          0.19935566  0.          0.          0.        ]
 [ 0.          1.          0.          0.          0.          0.        ]
 [ 0.19935566  0.          1.01986938  0.          0.          0.        ]
 [ 0.          0.          0.          1.04033485  0.         -0.20335608]
 [ 0.          0.          0.          0.          1.          0.        ]
 [ 0.          0.          0.         -0.20335608  0.          1.02026809]]
Homodyne samples mean: -0.06367821252869874
Homodyne samples std: 1.0749152121323755
First 10 samples: [[ 0.14404179]
 [ 0.18475141]
 [ 0.02330662]
 [ 0.13885395]
 [ 0.01803748]
 [-1.65626326]
 [-0.16756074]
 [ 0.07833346]
 [-4.13199308]
 [-2.83109808]]


==================================================
```

```
4. Quantum State Evolution with 10.0% Loss:
   Loss rate for mode 0: 10.0%
   Loss rate for mode 1: 15.000000000000002%
   State purity after loss: False
   Mean photon number in mode 0: 0.1654
   Mean photon number in mode 1: 0.4037
   Probability of |0,0): 0.5460
   Probability of |0,1): 0.2248
   Probability of |1,0): 0.1237
   Probability of |1,1): 0.0135
   Probability of |2,0): 0.0120
   Probability of |0,2): 0.0703

5. Generating Visualizations...
Maximum difference between mode 0 and mode 1 Wigner functions (no loss): 0.16677180366474592
Maximum difference between mode 0 and mode 1 Wigner functions (with loss): 0.03305919406646812

Analysis complete! All visualizations have been generated.
Summary of files:
1. photon_statistics_no_loss.png - Single and joint photon number distributions (no loss)
2. photon_statistics_with_loss.png - Single and joint photon number distributions (with loss)
3. wigner_functions_comparison.png - Wigner functions comparing both output modes with and without loss
4. hong_ou_mandel_effect.png - HOM interference vs beam splitter phase
5. phase_sensitivity.png - MZI output probabilities vs phase shift
6. loss effects.png - Effect of loss on quantum interference
```

Starting comprehensive quantum optics analysis...

1. Hamiltonian Model Analysis:
   Pump frequency: 2.0 THz
   Signal frequency: 1.2 THz
   Idler frequency: 0.8 THz
   Energy conservation check: True
   Hamiltonian value: 4.0

2. Mach-Zehnder Interferometer Parameters:
   First beam splitter reflectivity: 0.25
   First beam splitter phase: 0.39269908169872414
   Phase shift: 1.5707963267948966 radians (90.0 degrees)
   Second beam splitter reflectivity: 0.75
   Second beam splitter phase: 0.3141592653589793

3. Basic Photon Counting Simulation Results (No Loss):
   State purity: False
   Mean photon number in mode 0: 1.6544
   Mean photon number in mode 1: 1.3456
   Probability of |0,0⟩: 0.0000
   Probability of |0,1⟩: 0.0000
   Probability of |1,0⟩: 0.0000
   Probability of |1,1⟩: 0.0000
   Probability of |2,0⟩: 0.0000
   Probability of |0,2⟩: 0.0000

```
Running MZI simulation...
NOW MZI RESULTS>>>>>>>
Phase matching: omega_s = 1.25, omega_i = 0.75, omega_p = 2.0
Final state mean values: [ 0.03399675  0.          0.00420705 -0.02054644  0.          0.00316015]
Final state covariance matrix:
[[ 1.03357986e+00  0.00000000e+00  2.68059204e-01  4.07494157e-03
   0.00000000e+00  2.65202887e-02]
 [ 0.00000000e+00  1.00000000e+00  0.00000000e+00  0.00000000e+00
   0.00000000e+00  0.00000000e+00]
 [ 2.68059204e-01  0.00000000e+00  1.03569537e+00  2.76515296e-02
   0.00000000e+00 -7.75887912e-05]
 [ 4.07494157e-03  0.00000000e+00  2.76515296e-02  1.03787664e+00
   0.00000000e+00 -2.68517039e-01]
 [ 0.00000000e+00  0.00000000e+00  0.00000000e+00  0.00000000e+00
   1.00000000e+00  0.00000000e+00]
 [ 2.65202887e-02  0.00000000e+00 -7.75887912e-05 -2.68517039e-01
   0.00000000e+00  1.03574065e+00]]
Homodyne samples mean: 0.018010396406285836
Homodyne samples std: 1.0593951232620293
First 10 samples: [[-0.18108381]
 [ 1.18474672]
 [-1.17522465]
 [ 0.35575419]
 [-1.68137271]
 [ 2.49532692]
 [-0.70062399]
 [ 2.01960148]
 [ 0.26360515]
 [ 0.39709501]]

Generating Wigner function visualizations...
```
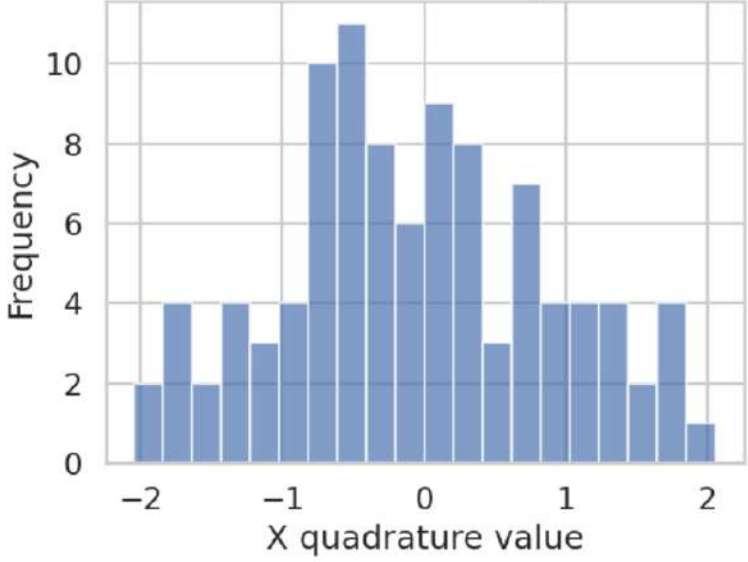
Hamiltonian Simulation - Homodyne Measurements

MZI Simulation - Homodyne Measurements

Loss rate

Mode 0 Photon Statistics

Mean photons: 1.654

Mode 1 Photon Statistics

Mean photons: 1.346

Joint Photon Number Distribution