Oregon Center for Optical, Molecular & Quantum Science

A Single Photon Detector Design based on a First Order Dissipative Phase Transition

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Model

A driven dissipative first order phase transition: Nonlinear Kerr Model

$$\hat{H} = -\Delta\hat{a}^\dagger\hat{a} + \frac{U}{2}\hat{a}^\dagger\hat{a}^\dagger\hat{a}\hat{a} + F(\hat{a}^\dagger + \hat{a})$$

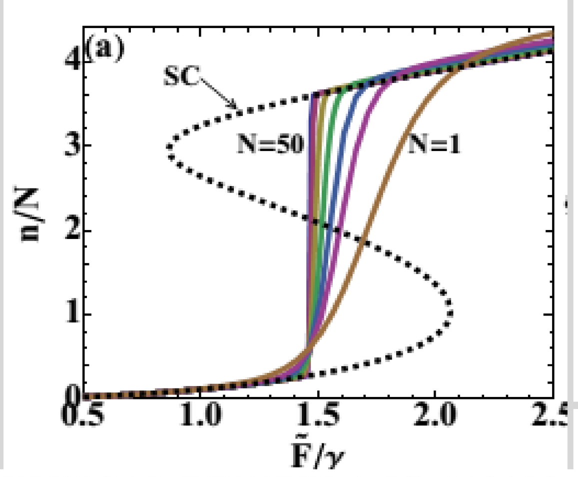
1. Single-site critical phenomena: dynamical optical hysteresis in the Kerr model.

Storme, F. (2017). *Dissipative phase transitions in open quantum lattice systems* (Doctoral dissertation, Université Paris Diderot (Paris 7), Sorbonne Paris Cité).

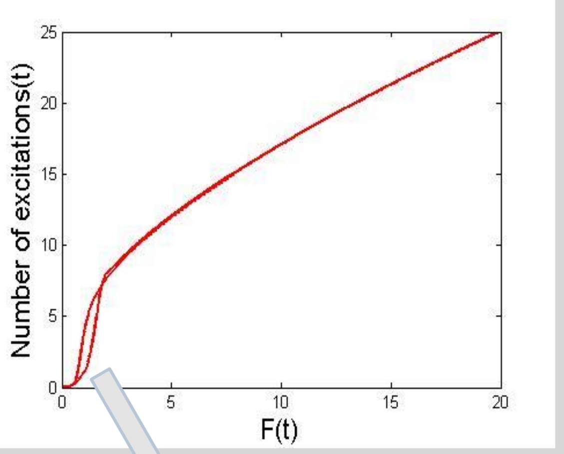
2. A superconducting, ladder-type artificial atom, a transmon, strongly coupled to a waveguide

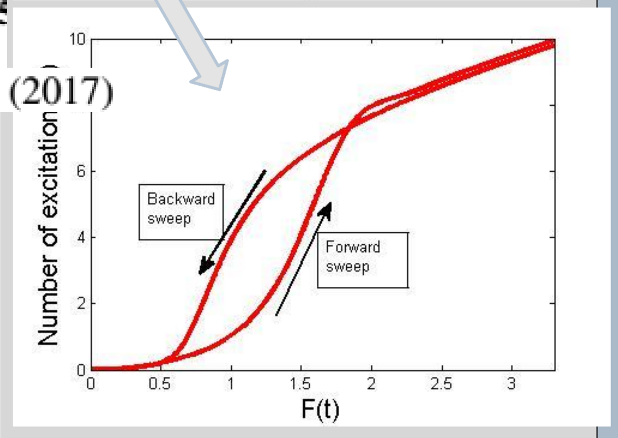
Gasparinetti et al.(2019). Two-Photon Resonance Fluorescence of a Ladder-Type Atomic System. *arXiv preprint arXiv:1901.00414*.

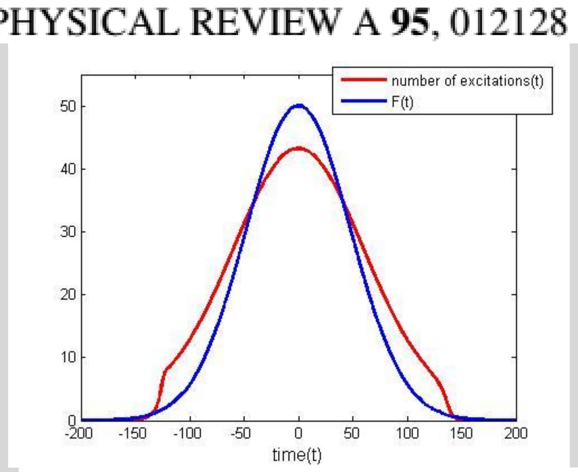
$$\partial_t\hat{\rho} = -\mathrm{i}[\hat{H}, \hat{\rho}] + \frac{\gamma}{2}\left(2\hat{a}\hat{\rho}\hat{a}^\dagger - \hat{a}^\dagger\hat{a}\hat{\rho} - \hat{\rho}\hat{a}^\dagger\hat{a}\right)$$



PHYSICAL REVIEW A 95, 012128 (2017)







QuTiP
Quantum Toolbox in Python

$$H = -\Delta b^\dagger b + \frac{U}{2}b^\dagger b^\dagger bb + \hat{F}(b^\dagger + b) + H_{ph-F}$$

$$H_{ph-F} = \sqrt{\kappa}\phi(t)|F_1\rangle\langle F_0| + H.C.$$

$$\hat{F} = F_0|F_0\rangle\langle F_0| + F_1|F_1\rangle\langle F_1| + +F_2|F_2\rangle\langle F_2|,$$

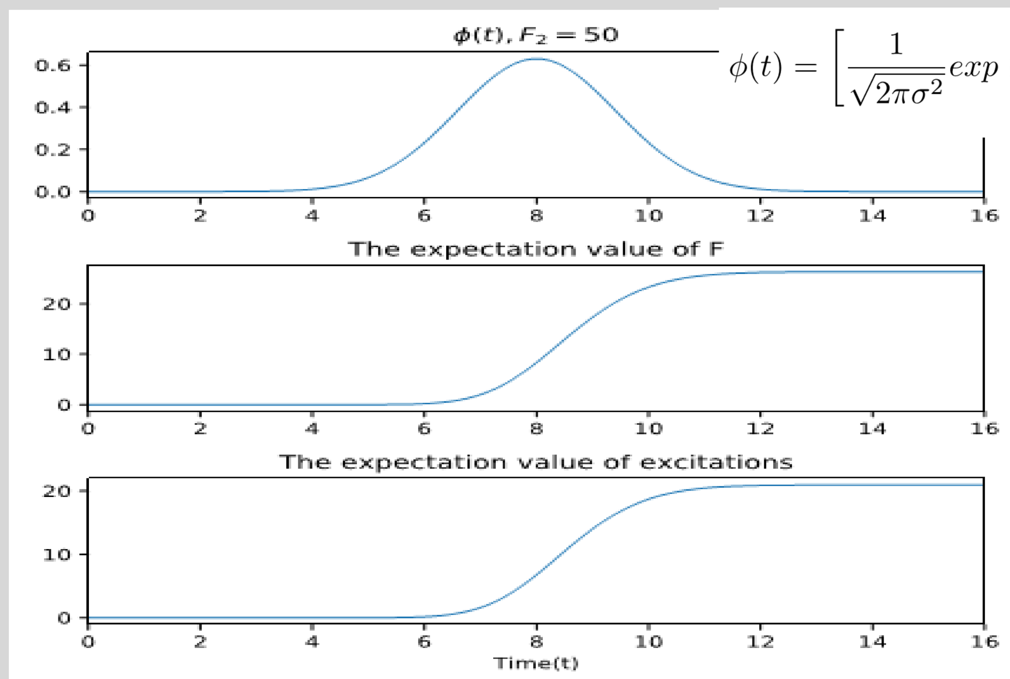
$$\dot{\rho} = -\frac{i}{\hbar}[H,\rho] + \mathcal{L}_A + \mathcal{L}_B + \mathcal{L}_C + \mathcal{L}_D + \mathcal{L}_E$$

$$\mathcal{L}_X = X\rho X^\dagger - \frac{1}{2}X^\dagger X\rho - \frac{1}{2}\rho X^\dagger X$$

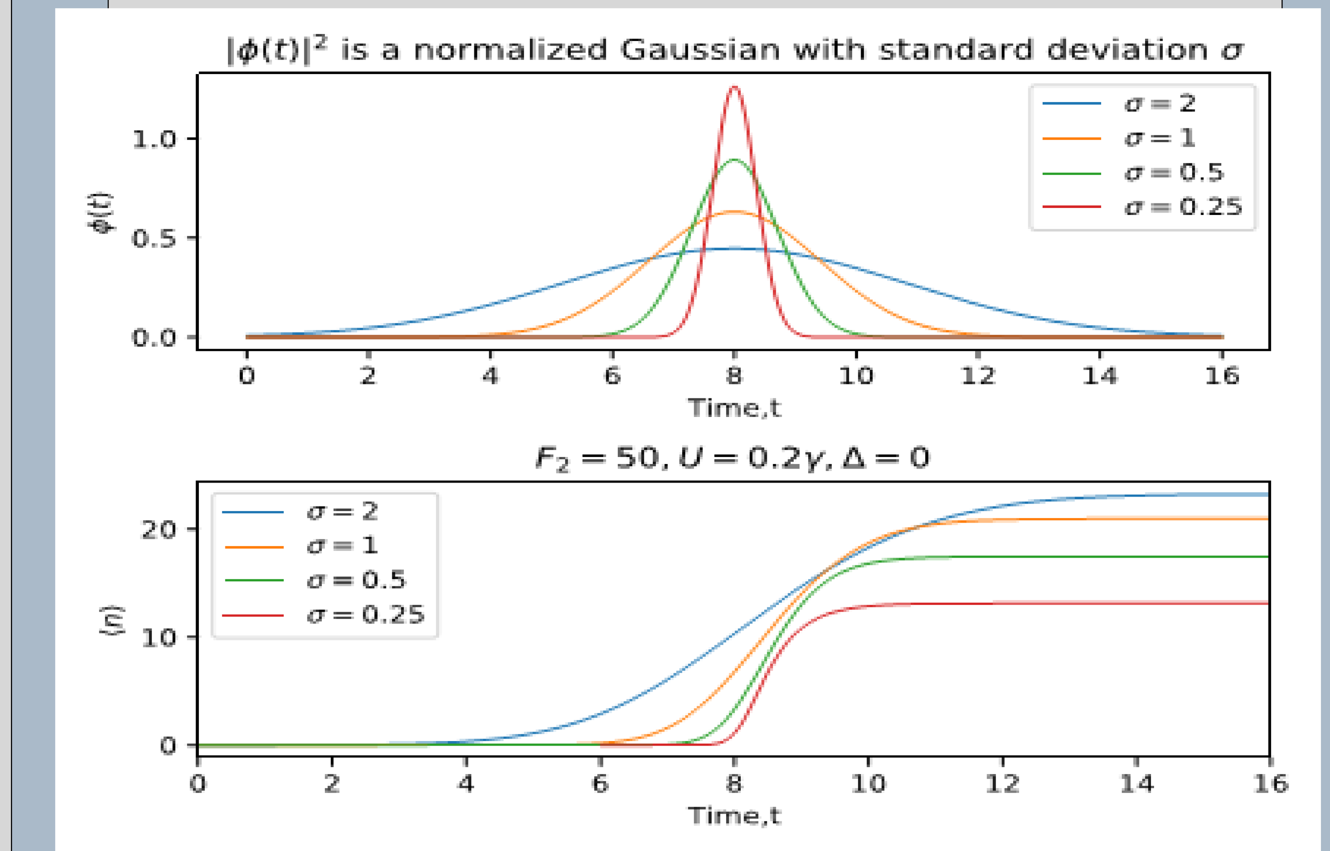
$$A = \sqrt{\gamma b}, B = \sqrt{\kappa p_{1,0}}|F_0\rangle\langle F_1|, C = \sqrt{\kappa(1-p_{1,0})}|F_1\rangle\langle F_0|,$$

$$D = \sqrt{\lambda p_{1,2}}|F_1\rangle\langle F_2|, E = \sqrt{\lambda(1-p_{1,2})}|F_2\rangle\langle F_1|$$

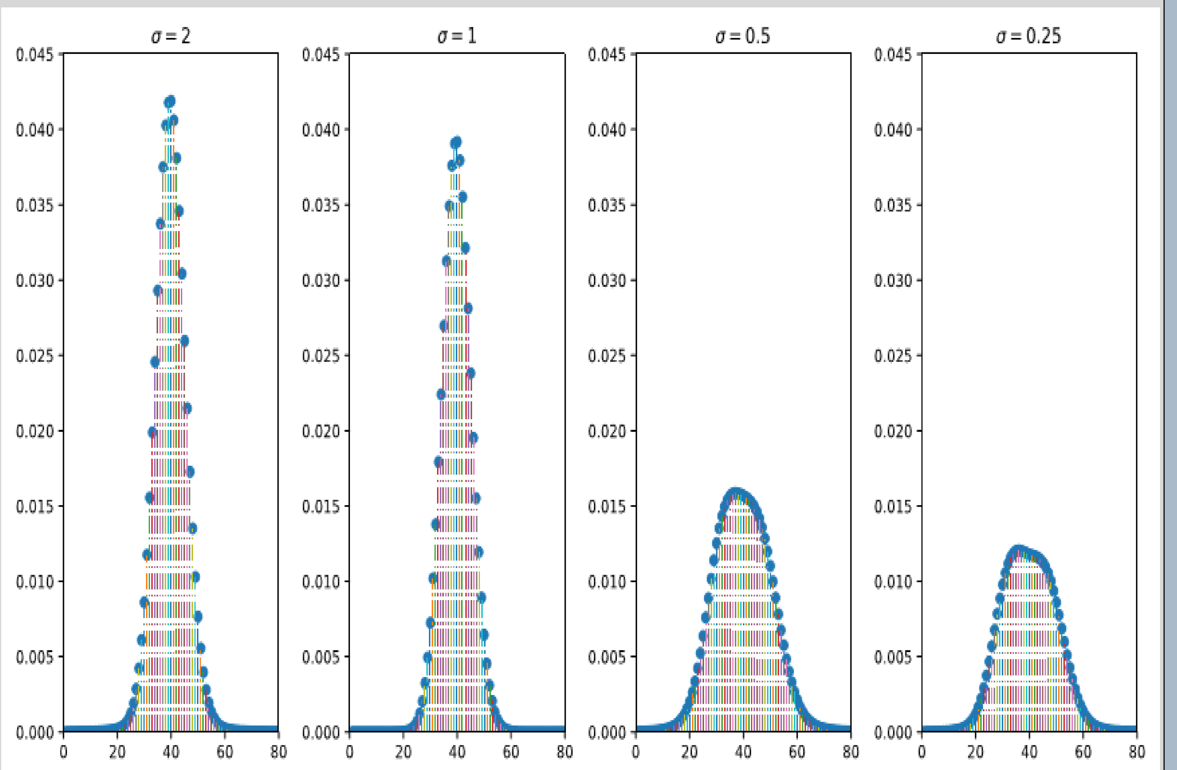
$$\phi(t) = \left[\frac{1}{\sqrt{2\pi\sigma^2}}exp\left(-\frac{(t-t_0)^2}{2\sigma^2}\right)\right]^{1/2}$$



Effect of Photon Wave-function width on the average dynamics

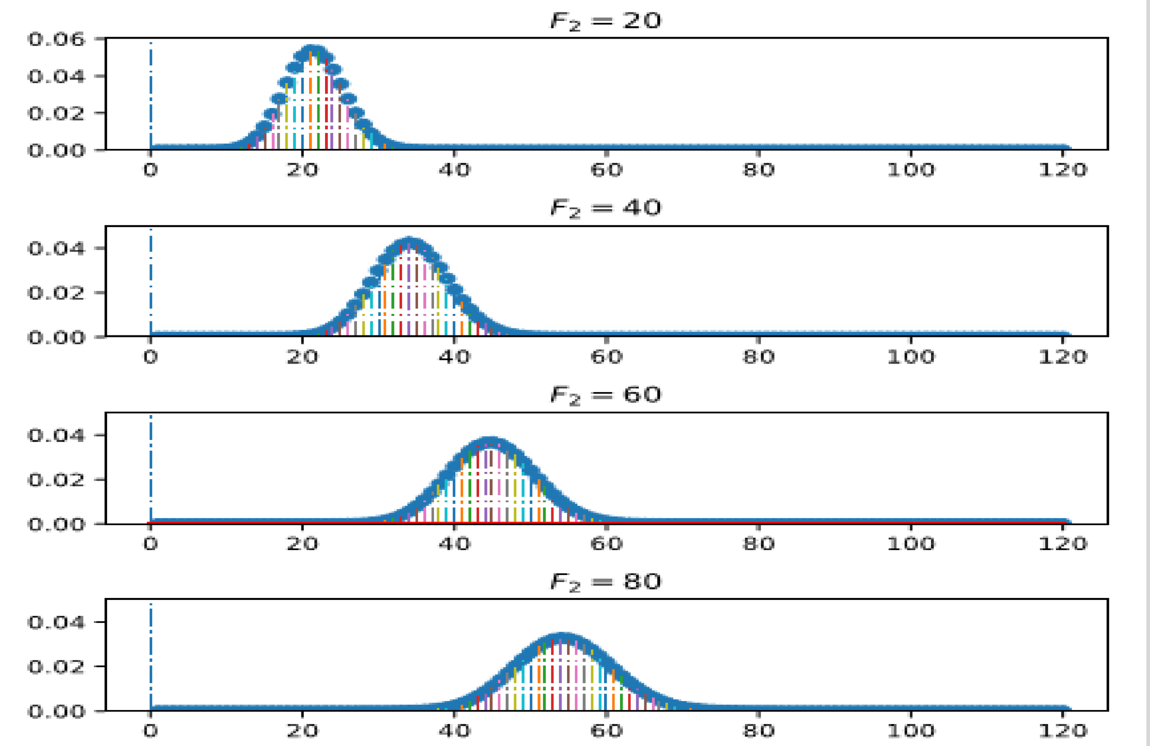


Comparison of probability distribution of excitation numbers in the steady state for different widths of the photon wave-function

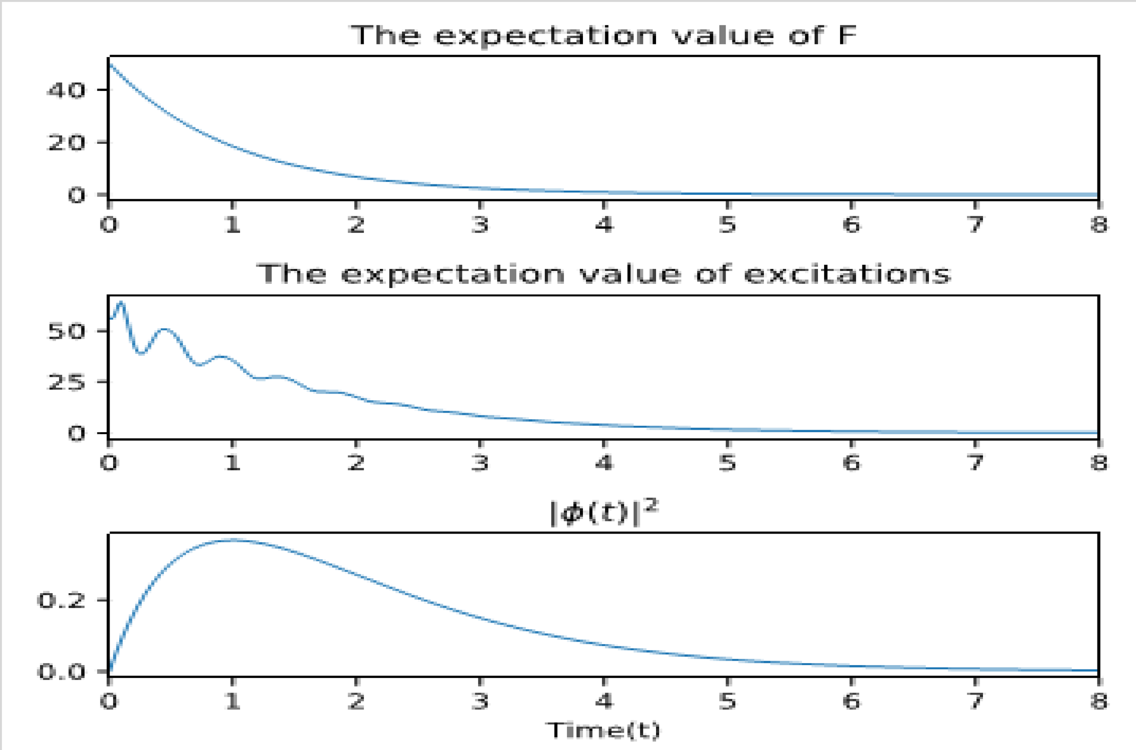


Effect of the values of F2

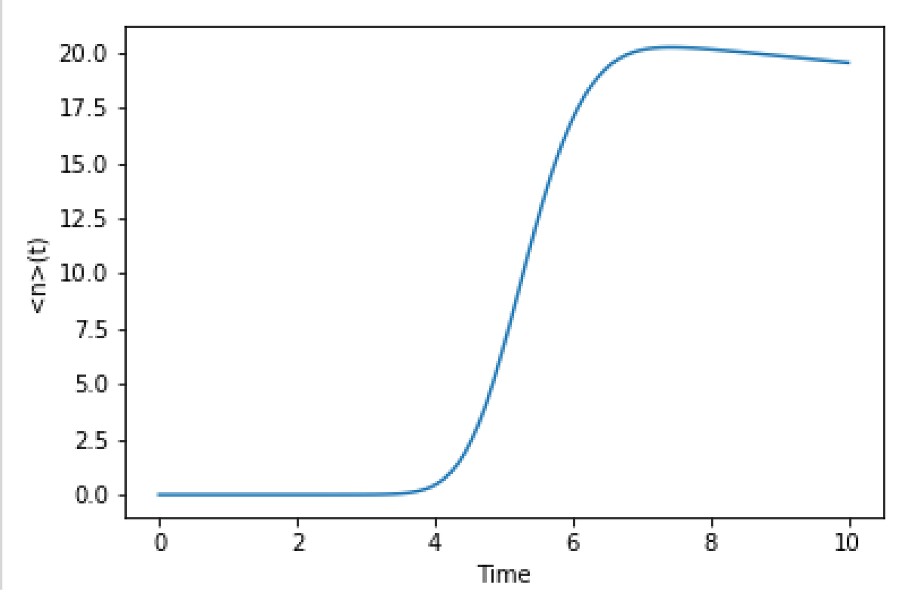
Comparison of probability distribution of excitation numbers in the steady state for different values of F2



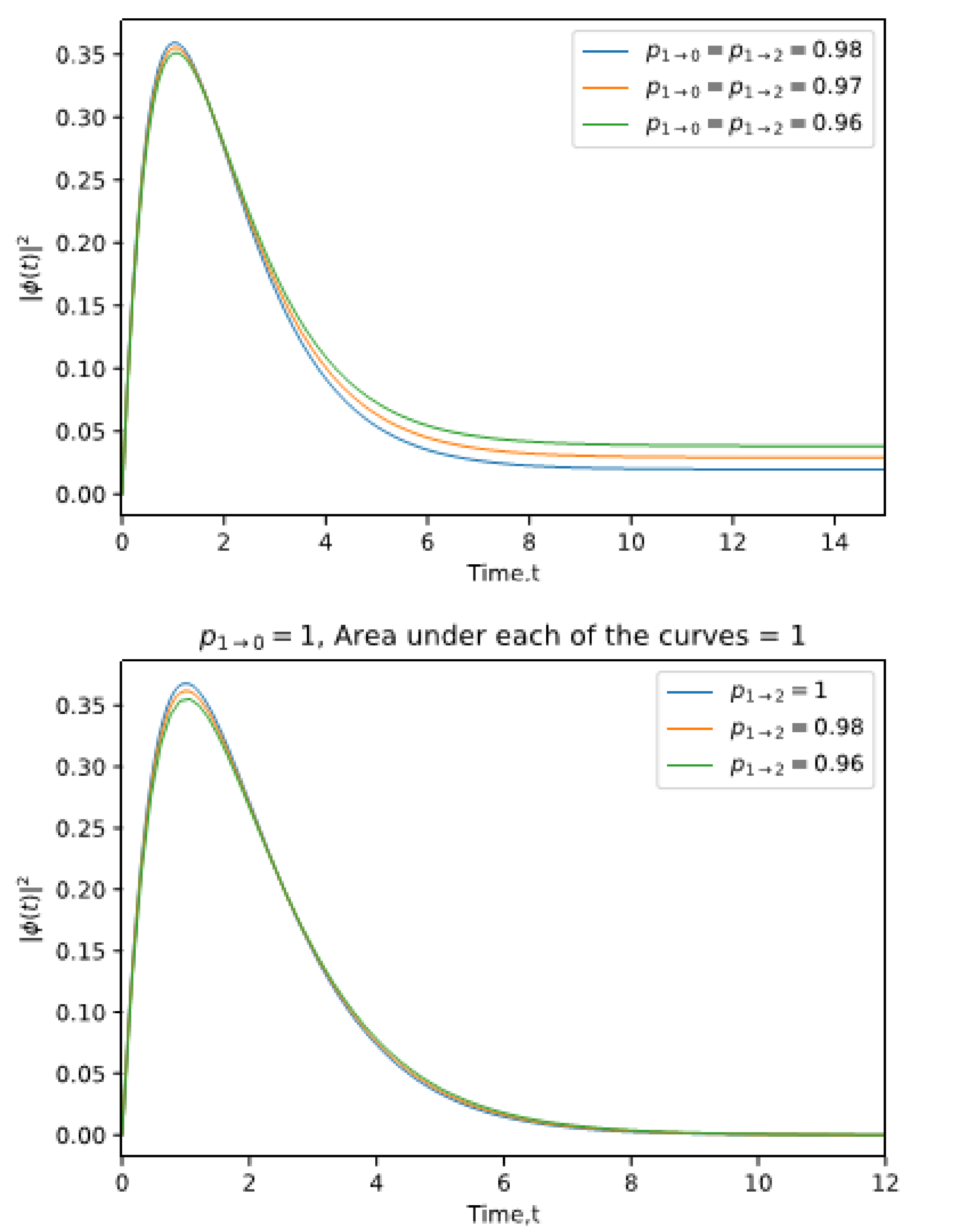
Calculation of the modulus squared Photon Wave function



The wigner function develops a bimodality close to the onset of the steady state in the average dynamics



Effects of thermal fluctuations



The calculated photon wave-function reveals the nature of the final equilibrium.

Properties of the steady state of the average dynamics