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Exciting the Bound State through Multiphoton Scattering

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Background

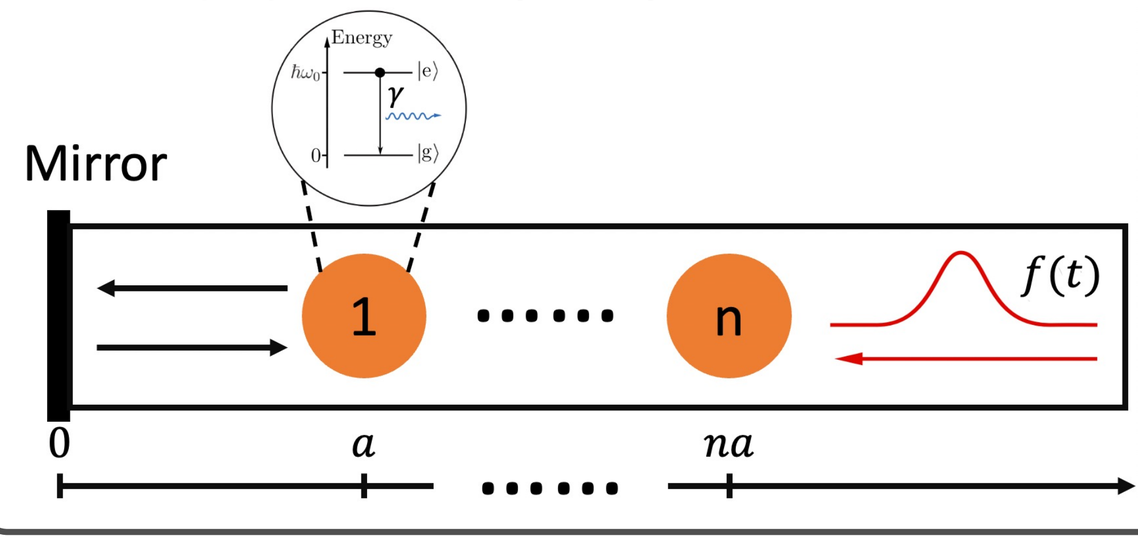
Waveguide Quantum ElectroDynamics (QED) is a growing area of quantum optics investigating the interaction between atoms and photons. The formation of the atom-photon bound state is one of its main features. According to recent research, we can also excite the bound states inside the continuum by taking the delayed feedback. It is one of the potential approaches for future quantum memory devices.

Project Aims

1. Find the bound-state trapping probability in the non-Markovian regime of the systems.
2. Find the effect of the mirror's property on the dynamics.
3. Find the property of the trapping probability.

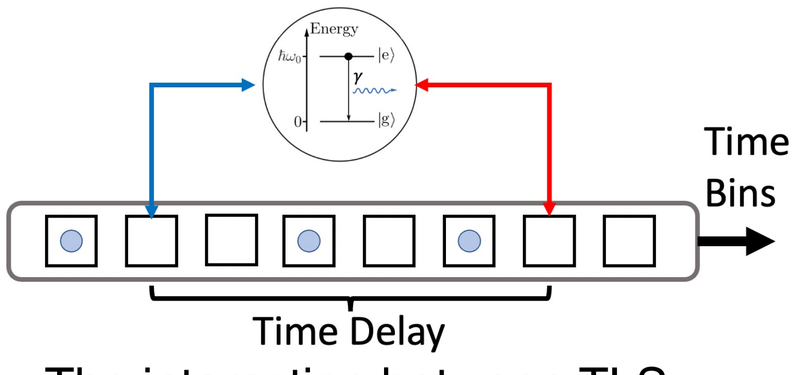
Model

- Identical two-level systems (TLS) with separation sufficient to break down the Markovian approximation are coupled to a semi-infinite one-dimensional waveguide.
- A mirror is placed at one end of the waveguide.
- The TLSs are excited via a quantum pulse $f(t)$.
- In our project, we only study the case $n = 1, 2$.



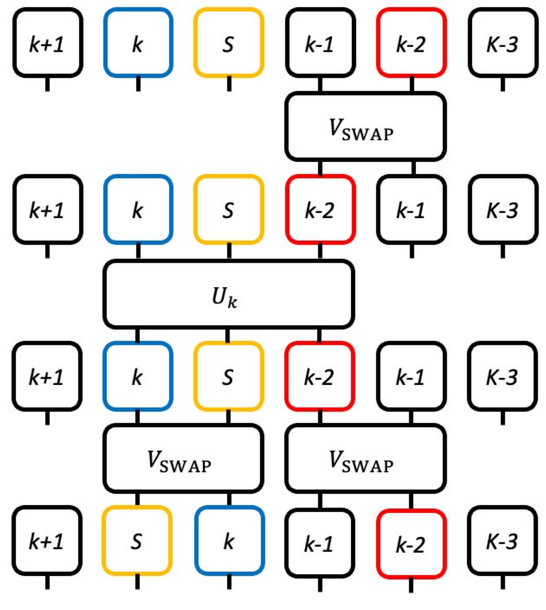
Methods

1. Find the Hamiltonian of the system
2. Discretize time in steps (time bins)
3. Find the coarse-grained evolution operator U_k, where $|\Psi(t_{k+1})\rangle = U_k|\Psi(t_k)\rangle$
4. Represent the initial state in matrix products states (MPS) representation
4. Use MPS, evolution operator and swap operator to simulate the dynamics

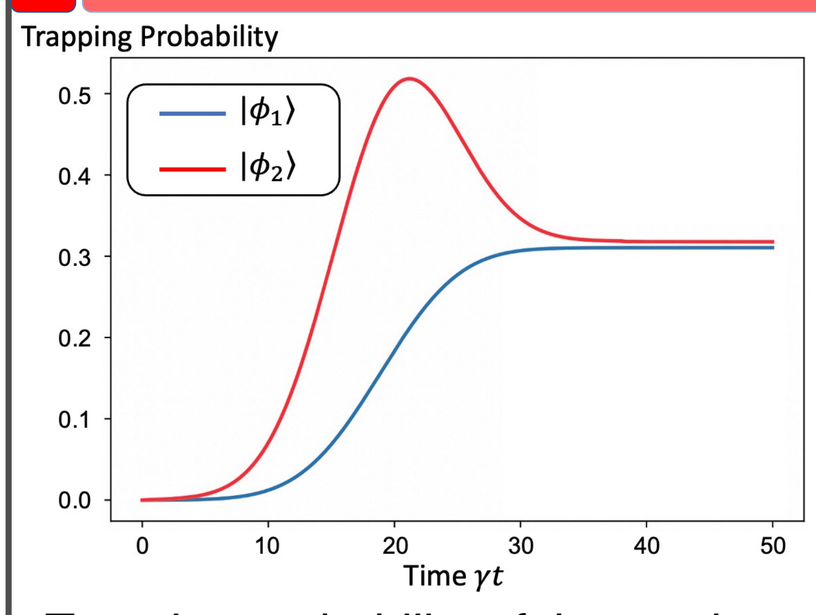


The interaction between TLS and the time bins, for $n = 1$.x

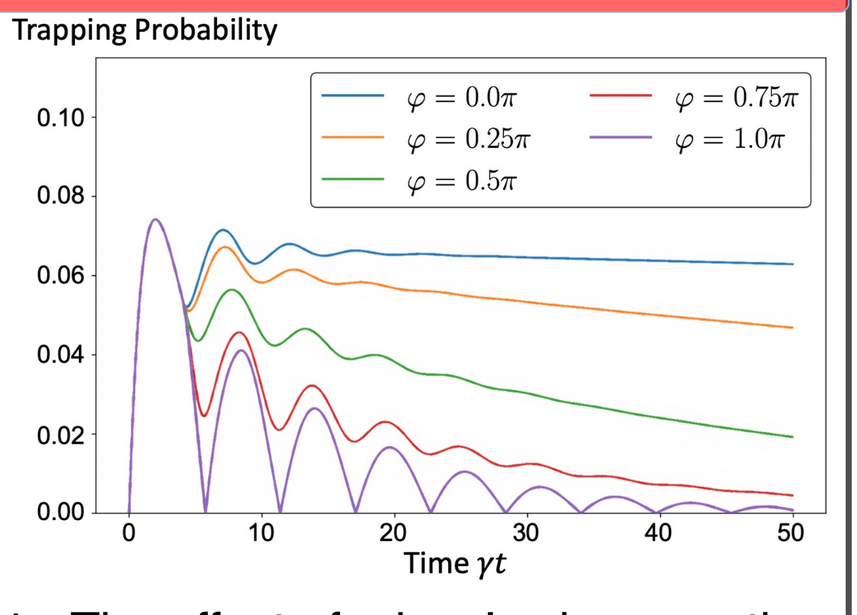
MPS representation allows us to write any state $|\Psi\rangle = \sum_{i,j\ldots k}\psi_{i,j\ldots k}|ij\ldots k\rangle$ as $|\Psi\rangle = \sum_{i,j\ldots k}Tr[A^iA^j\ldots A^k]|ij\ldots k\rangle$ through singular value (Schmidt) decomposition.
MPS representation deals with quantum mechanics in the Hilbert space with fewer dimensions.



Main Results



Trapping probability of the two bound states which are corresponded to the two TLSs respectively. $t_d = 1/2\gamma$



The effect of mirror's phase on the trapping probability. $t_d = 2/\gamma$

Future

Our finding suggests that exciting superpositions of the different bound states with different probabilities are possible. And we show the effects of the mirror's property. This can be an important step on the path towards implementing effective quantum memory.
Extending our model to the systems with more photons in the incoming quantum pulse will be interesting.