

Quantum walks on a circle with optomechanical systems

Jalil Khatibi Moqadam

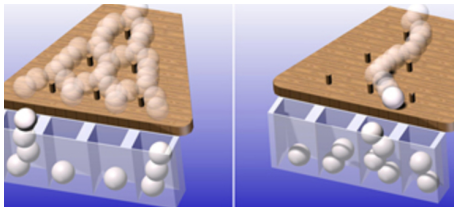
Laboratório Nacional de Computação Científica

Petrópolis - RJ - Brasil

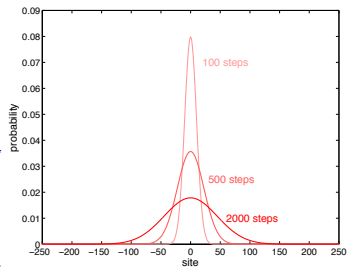
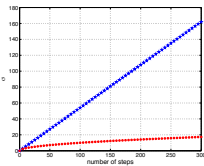
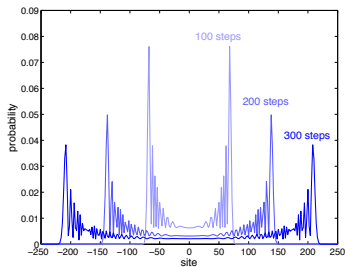
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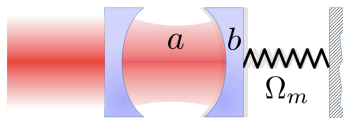
Galton board [MPI for the Science of Light]



quantum walker

coherent state of
the optical resonator

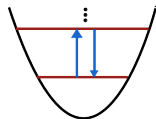
$$|\alpha\rangle = e^{-\frac{1}{2}|\alpha|^2} \sum_{j=0}^{\infty} \frac{\alpha^j}{\sqrt{j!}} |j\rangle$$



quantum coin

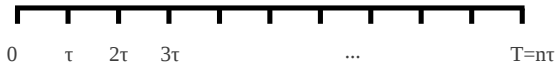
two lowest level of the
mechanical resonator

$$|q\rangle = |\uparrow\rangle, |\downarrow\rangle$$



$$\mathcal{H} = -\hbar\Delta a^\dagger a - \hbar g_0 a^\dagger a \sigma_z + \hbar\varepsilon(a^\dagger + a) + \frac{1}{2}\hbar\omega_m \sigma_x$$

$$\mathcal{U}(T) = e^{-\frac{i}{\hbar}HT}$$



Suzuki-Trotter approximation

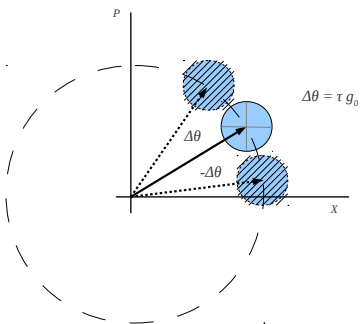
(sufficiently large n)



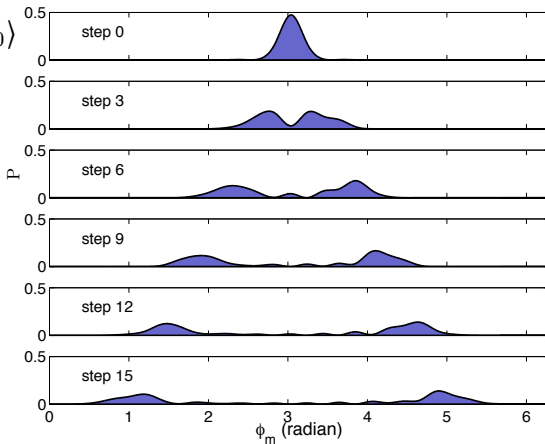
$$\mathcal{U}(T = n\tau) \approx \left[e^{i\tau\Delta a^\dagger a} e^{i\tau g_0 a^\dagger a \sigma_z} e^{-i\tau\varepsilon(a^\dagger + a)} e^{-\frac{i}{2}\tau\omega_m \sigma_x} \right]^n$$

quantum walk dynamics

$$\mathcal{U}(\tau) \approx e^{i\tau\Delta a^\dagger a} \underbrace{e^{i\tau g_0 a^\dagger a \sigma_z}}_{\text{shift operator}} e^{-i\tau\varepsilon(a^\dagger + a)} \underbrace{e^{-\frac{i}{2}\tau\omega_m \sigma_x}}_{\text{coin operator}}$$



$$|\psi_0\rangle = \frac{|\uparrow\rangle + |\downarrow\rangle}{\sqrt{2}} |\alpha_0\rangle$$



decoherence

dephasing channel on the **two-level mechanical resonator**

$$\rho_l = \sum_j K_j U \rho_{l-1} U^\dagger K_j^\dagger$$

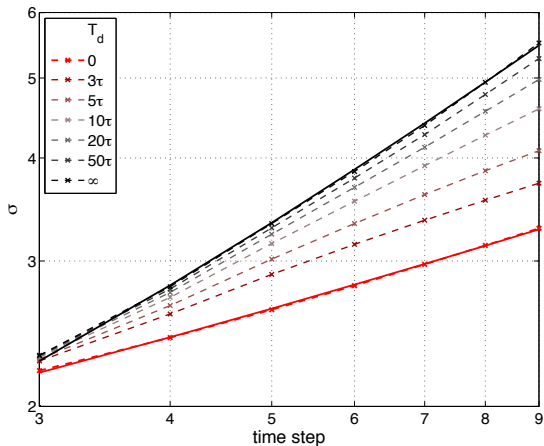
$$K = \mathcal{I}_{\text{position}} \otimes \mathcal{E}_{\text{qubit}}$$

$$\mathcal{E}_{\text{qubit}} = \mathcal{E}_{\text{qubit}}(\lambda = 1 - e^{-l\tau/T_d})$$

T_d : dephasing time

standard deviation (log-log scale)

quantum-to-classical transition



parameters specification

typically
$$\left\{ \begin{array}{l} \omega_m \approx 10^7 \text{HZ} \\ \tau \sim 1/\omega_m \approx 10^{-7} \text{s} \\ T_d \approx 10^{-1} \text{s} \end{array} \right. \Rightarrow T_d \approx 10^6 \tau$$



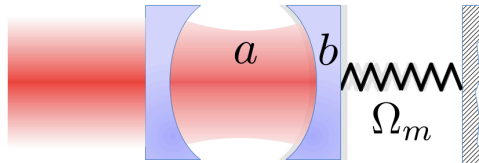
enough time for realizing large number of steps!

Implementation with less decoherence!

coin operator \Rightarrow interaction with the system

HOWEVER

in our proposal no deriving is required!



quantum walks in phase space is not just a toy model!

maximum number of sites was firstly suggested

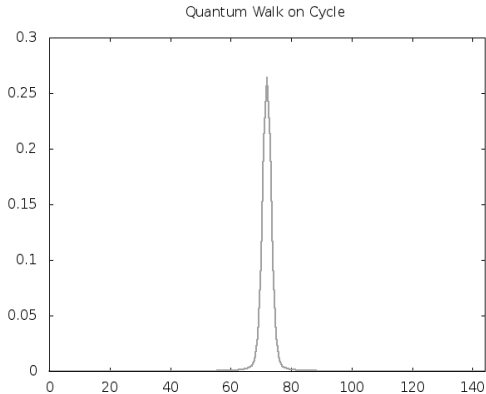
$$d_{max} = 33$$

however it is possible to go to

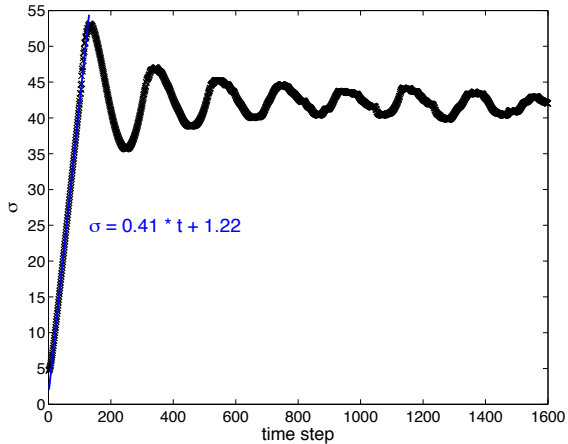
$$d_{max} = 145$$

quantum walk evolution

$$|\psi_0\rangle = \frac{|\uparrow\rangle + |\downarrow\rangle}{\sqrt{2}} |\alpha_0\rangle, \quad |\alpha_0| \approx 11.5, \quad d = 145, \quad n = 1000$$



standard deviation



collaborators

Professor Renato Portugal

*Quantum Computing Group
Laboratório Nacional de Computação Científica*

Professor Marcos Cesar de Oliveira

*Instituto de Física “Gleb Wataghin”
Universidade Estadual de Campinas*

**free quantum walk simulator code developed by
Pedro Lara and Aaron Leão at**

<http://qubit.lncc.br/>

An aerial photograph of a large resort or hotel complex. The main building is a long, multi-story structure with a light-colored facade and a prominent central tower. It is surrounded by lush green trees and a well-maintained lawn. A swimming pool is visible near the center of the complex. In the foreground, there is a large green field, possibly a sports field. The background shows a road and more greenery. The text "thanks for your attention!" is overlaid in the center of the image.

thanks for your attention!