Quantum walks on a circle with optomechanical systems

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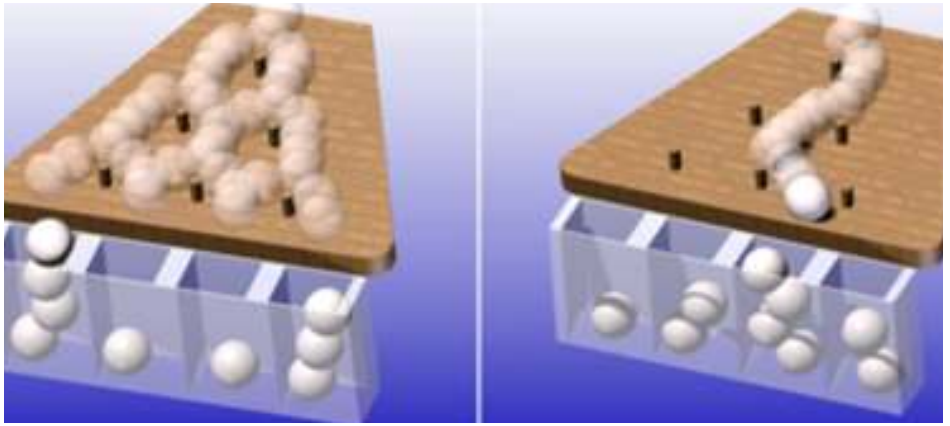
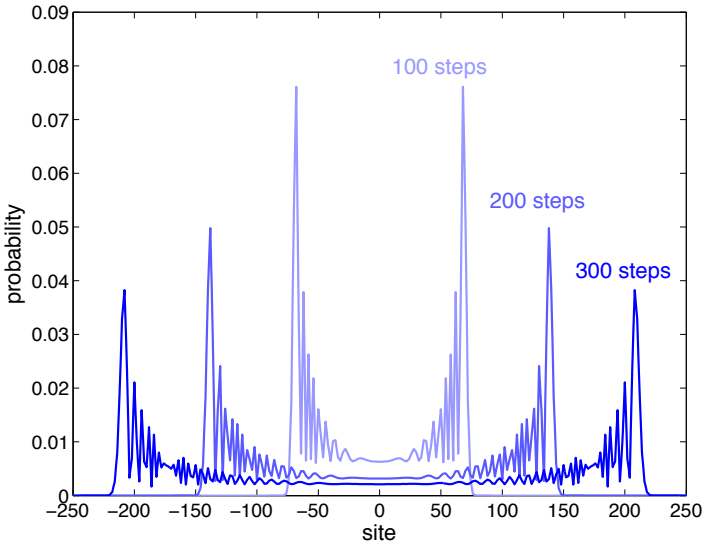
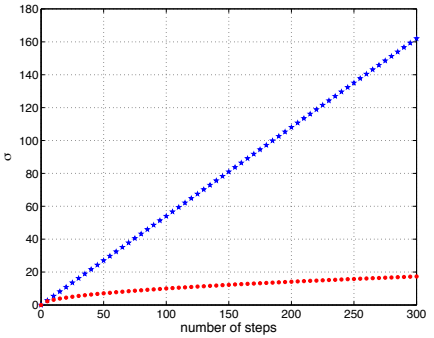
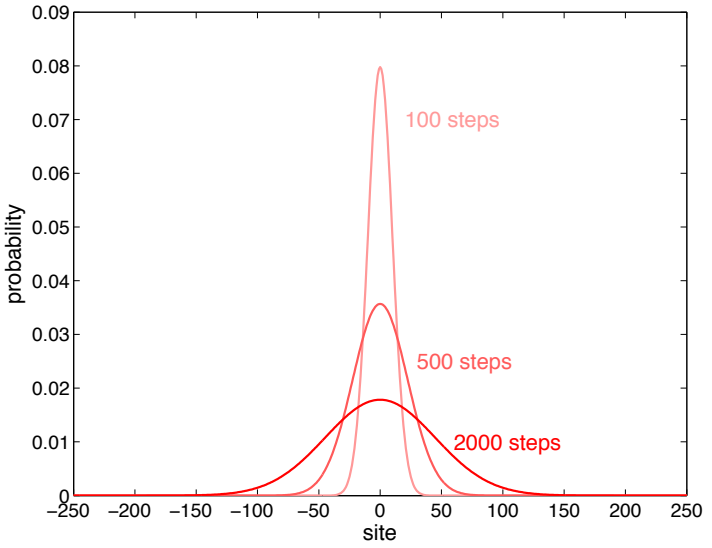


Galton board [MPI for the Science of Light]



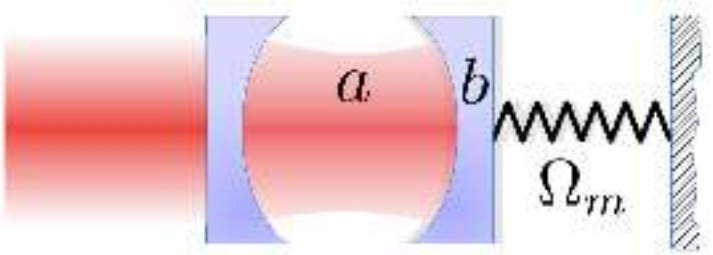




quantum walker

coherent state of the optical resonator

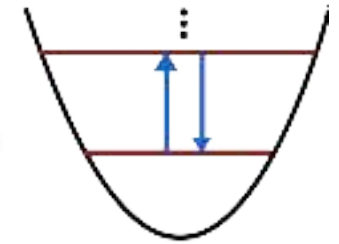
$$|\alpha\rangle = e^{-\frac{1}{2}|\alpha|^2} \sum_{j=0}^{\infty} \frac{\alpha^j}{\sqrt{j!}} |j\rangle$$



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-Troter approximation

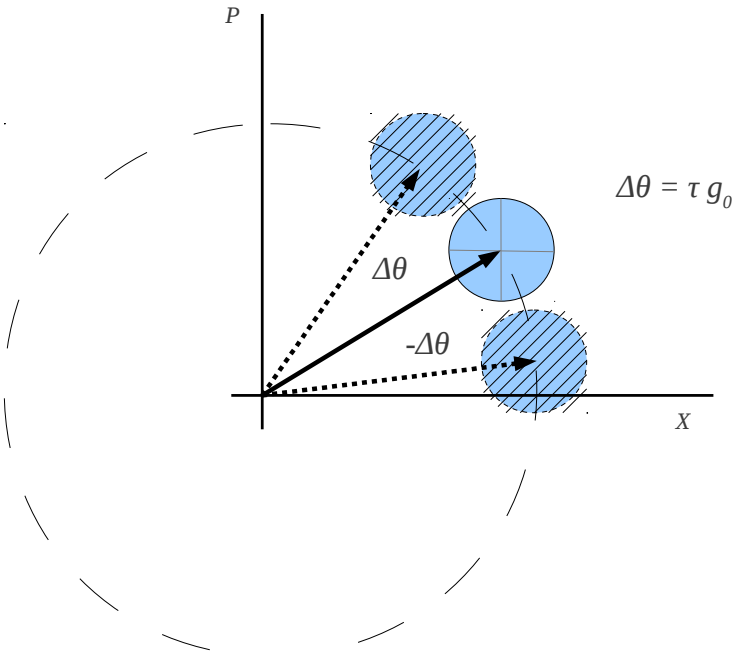
(sufficiently large n)

$$\Downarrow$$

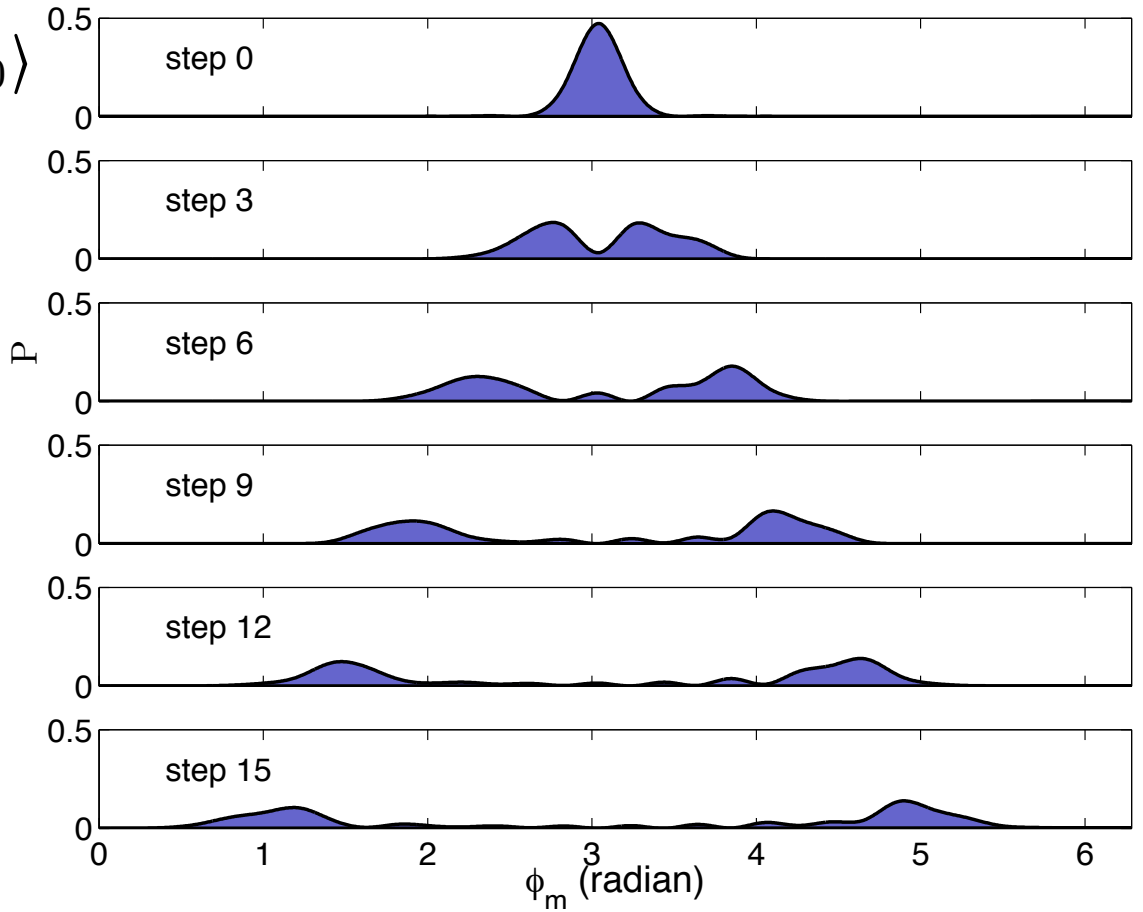
$$\mathcal{U}(T = n\tau) \approx \left[e^{i\tau\Delta a^\dagger a}\ e^{i\tau g_0 a^\dagger a \sigma_z}\ e^{-i\tau\varepsilon(a^\dagger + a)}\ e^{-\frac{i}{2}\tau\omega_m\sigma_x} \right]^n$$

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

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

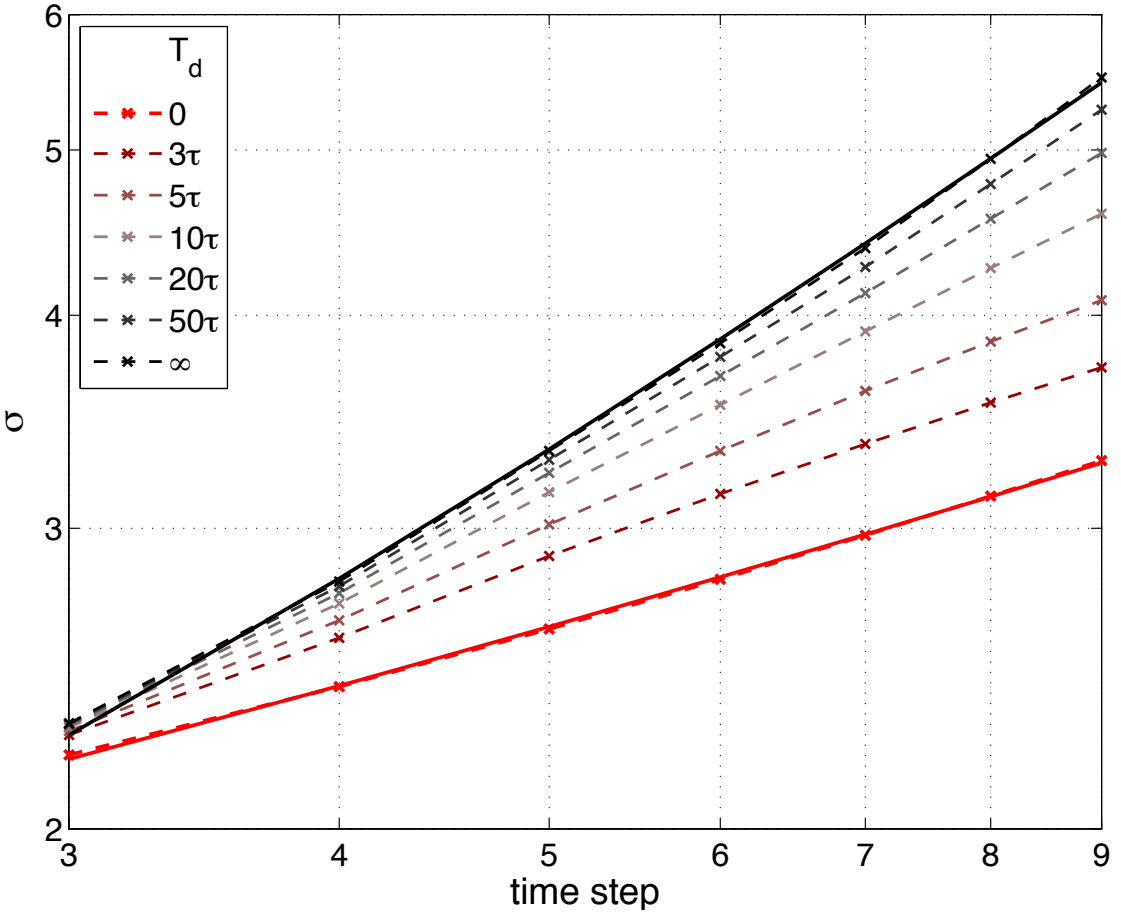
$K = \mathcal{I}_{\text{position}} \otimes \mathcal{E}_{\text{qubit}}$

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

T_d: dephasing time

standard deviation (log-log scale)

quantum-to-classical transition



parameters specification

typically $\begin{cases} \omega_m \approx 10^7 \mathrm{HZ} \\ \tau \sim 1/\omega_m \approx 10^{-7}\mathrm{s} \\ T_d \approx 10^{-1}\mathrm{s} \end{cases} \Rightarrow T_d \approx 10^6 \tau$

$\Downarrow$

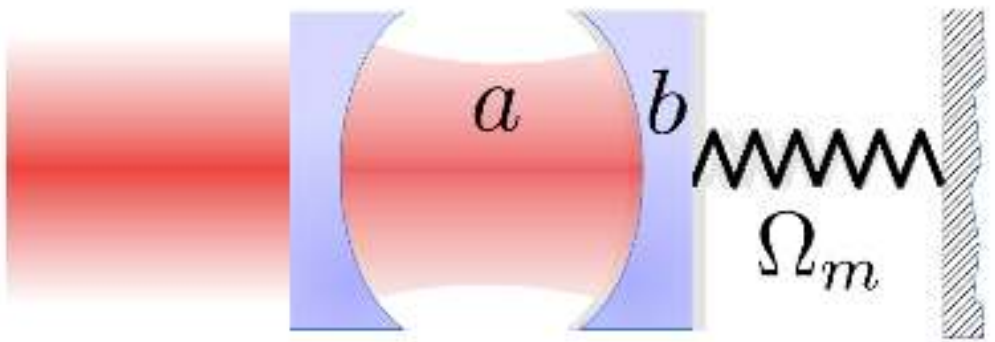
enough time for realizing large number of steps!

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

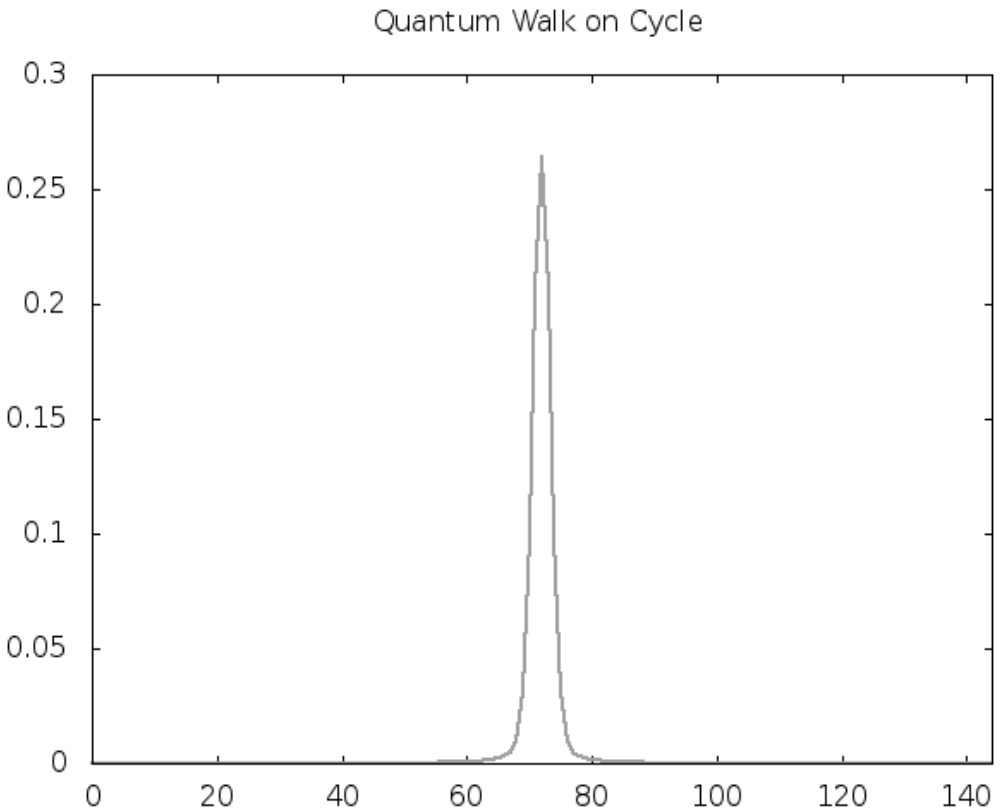
$$d_{max} = 33$$

however it is possible to go to

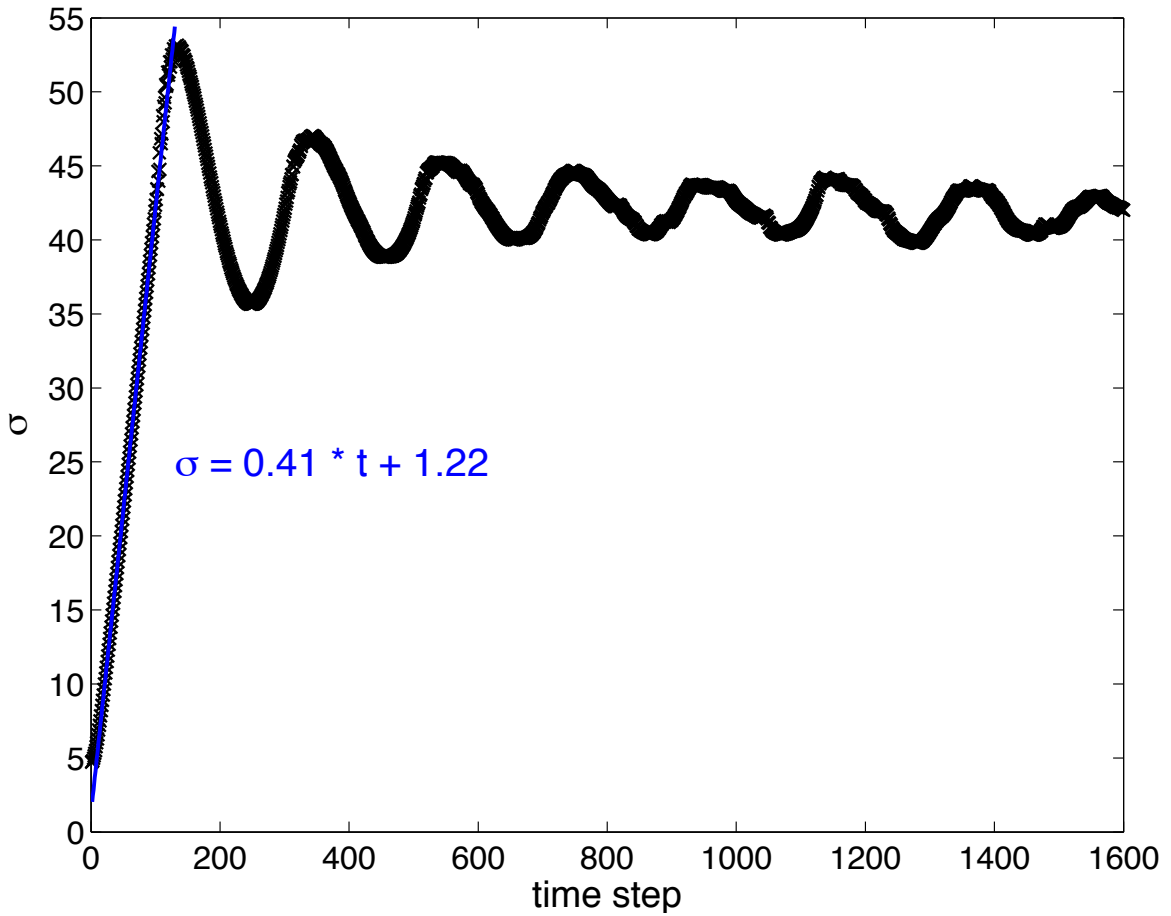
$$d_{max} = 145$$

quantum walk evolution

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



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/`


thanks for your attention!