Engineering tunable anharmonic potentials with light-atom interaction

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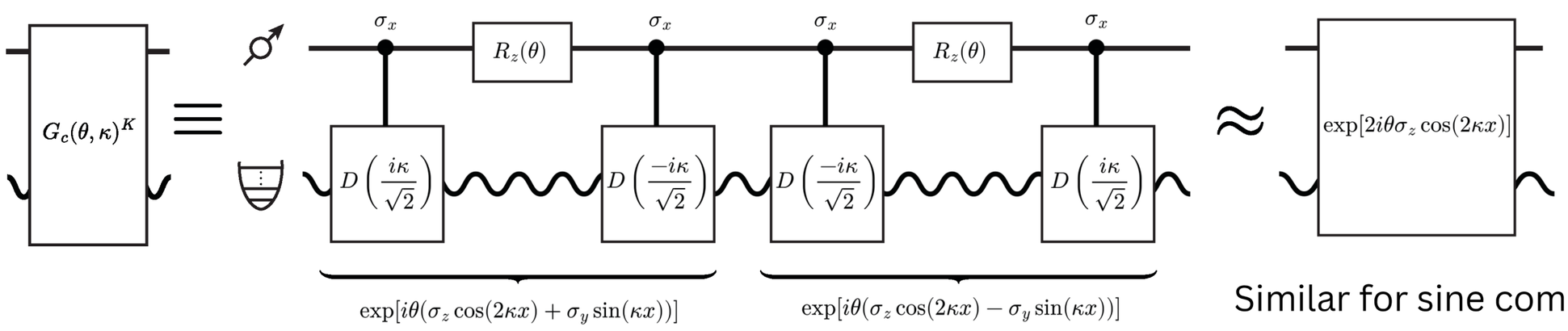
We have developed and implemented a scheme for realising anharmonic motion in a trapped ion system. We use this to investigate quantum tunnelling in a double well.

Theory: Quantum Signal Processing for generation of anharmonic potentials

Target potentials of the form $V(x) \approx \sum_{m=0}^{N_J} \left[A_m \cos\left(\frac{2\pi m}{L} x\right) + B_m \sin\left(\frac{2\pi m}{L} x\right) \right]$

$D(\alpha)$ Displacement operator

$R_z(\theta)$ Single-qubit rotation

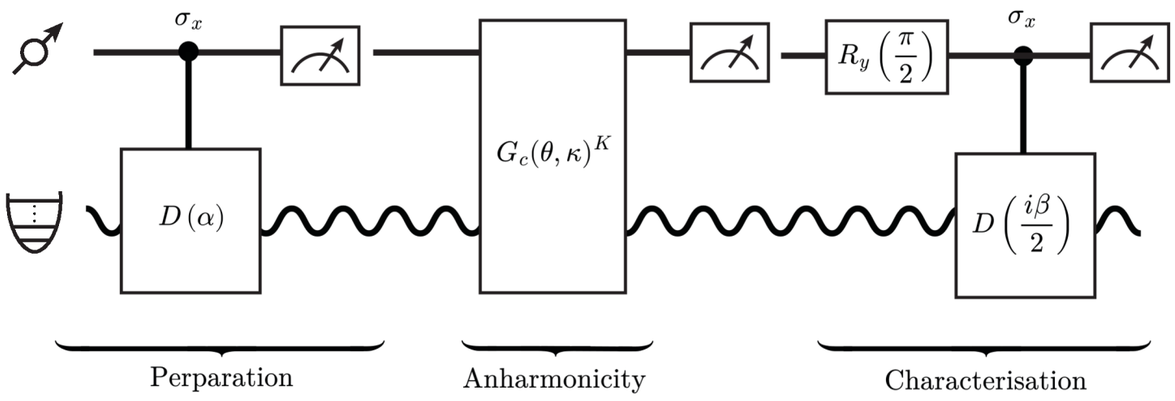


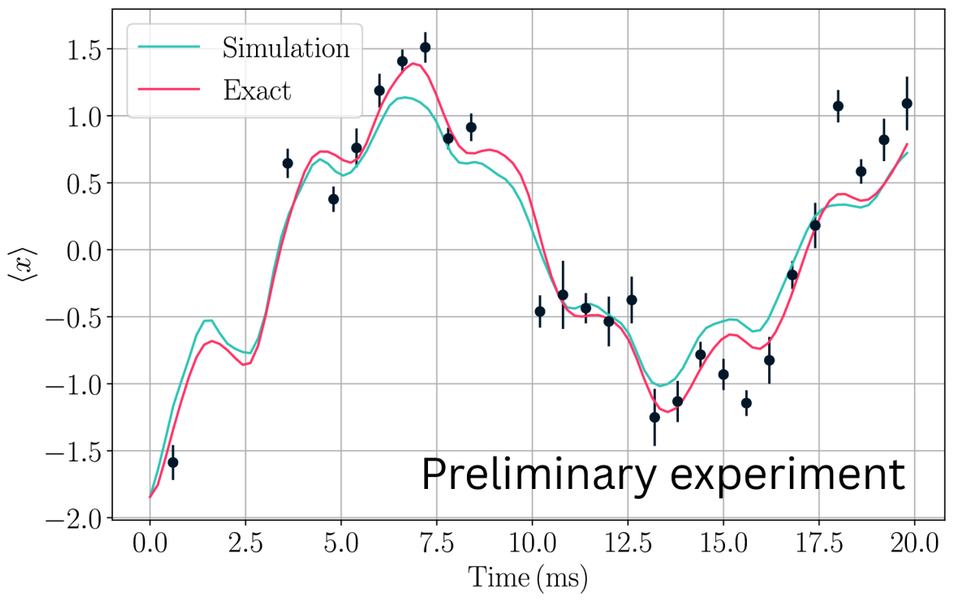
Similar for sine component.

Repeated application of $G_c(\theta,\kappa)$ allows for the realisation of any potential that can be realised by Fourier decomposition. Realising the sine equivalent allows the generation of any arbitrary potential.

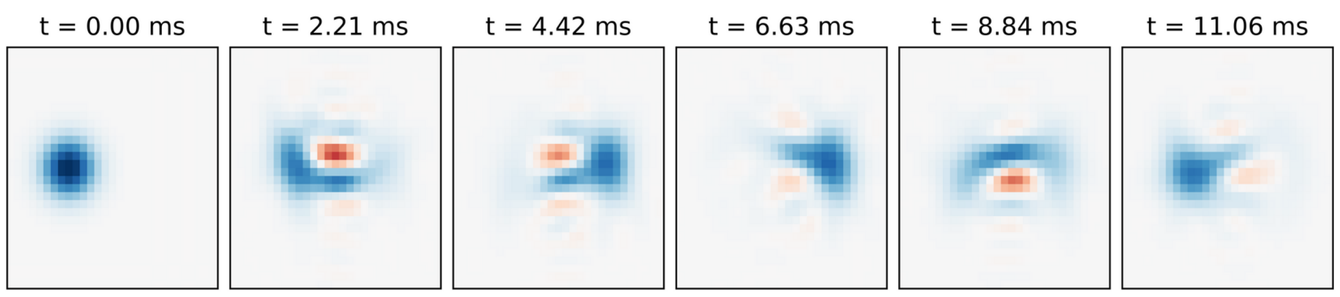
Experiment: simulation of cosine potential

Simulate potential $V(x) \approx \frac{\delta}{2}x^2 + \epsilon\cos(\eta x)$ where the quadradtic term comes from frequency detuning

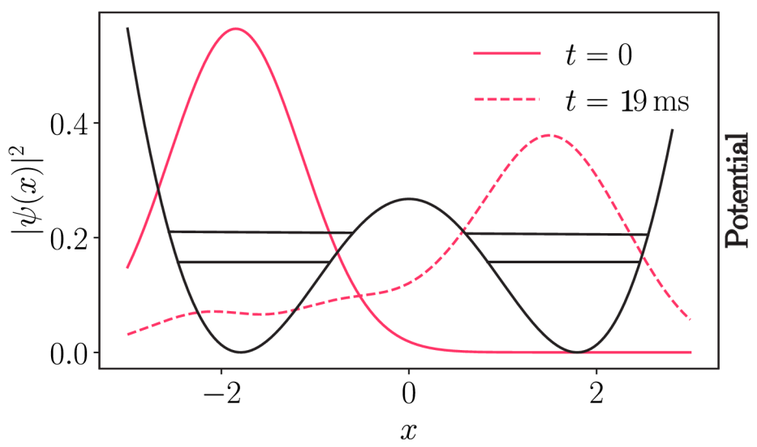




Wigner function during evolution (simulation)



Simulated potential and wavefunction



Application: Chemical dynamics

Target ro-vibrational Hamiltonian and non-linear chemical dynamics simulations. See poster 30 (Frank Scuccimarra)

$H_{\mathrm{VC}} = \sum_j \omega_j a_j^\dagger a_j + \sum_{n,m} C_{n,m} |n\rangle\langle m|$ $\quad C_{n,m} = c_0^{(n,m)} + \sum_j c_j^{(n,m)} x_j + \sum_{j,k} c_{j,k}^{(n,m)} x_j x_k$

Vibrational coupling Hamiltonian — Anharmonicity