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A boson dispensing machine

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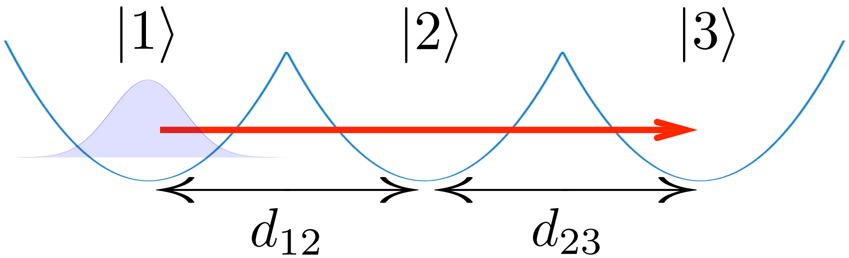
We present a technique to control the spatial state of a small cloud of interacting bosons at low temperatures with almost perfect fidelity using spatial adiabatic passage. To achieve this, the resonant trap energies of the system are engineered in such a way that a single, well-defined eigenstate connects the initial and desired states and is isolated from the rest of the spectrum. We apply this procedure to the task of separating a well-defined number of particles from an initial cloud and show that it can be implemented in radio-frequency traps using experimentally realistic parameters.

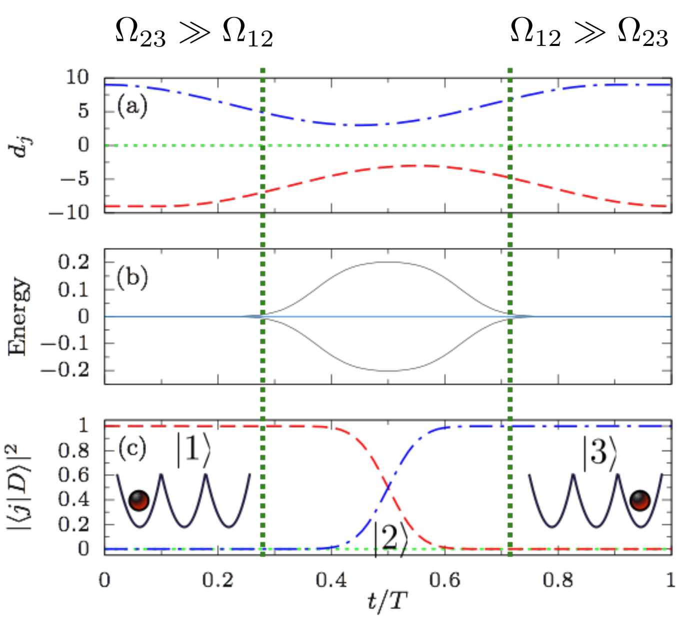
"A robust boson dispenser: Quantum state preparation in interacting many-particle systems", I. Reshodko, A. Benseny, Th. Busch, arXiv:1703.02189

Single particle Spatial Adiabatic Passage



The Hamiltonian:

$$\hat{H}(t) = \hbar \begin{pmatrix} 0 & \Omega_{12}(t) & 0 \\ \Omega_{12}(t) & 0 & \Omega_{23}(t) \\ 0 & \Omega_{23}(t) & 0 \end{pmatrix}$$



Trap movement

Energy spectrum

Dark state

The process must be slow enough to follow the eigenstate (adiabatic).
The initial and the final states must be resonant.

Existence of the "dark state":

$$|D\rangle = \cos\theta |L\rangle - \sin\theta |R\rangle, \quad \tan\theta = \frac{\Omega_{LM}(d_{LM})}{\Omega_{MR}(d_{MR})}$$

$$|L\rangle = |1\rangle, |M\rangle = |2\rangle, |R\rangle = |3\rangle$$

[1] K. Eckert, M. Lewenstein, R. Corbalan, G. Birkl, W. Ertmer, and J. Mompart Phys. Rev. A 70, 023606 (2004)

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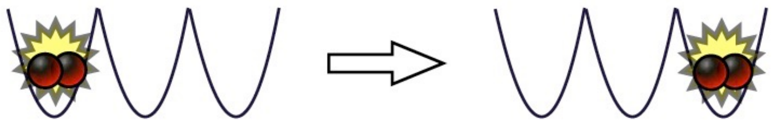
Two-boson Spatial Adiabatic Passage



Transfer fidelity depends on the interaction strength *g* [2]

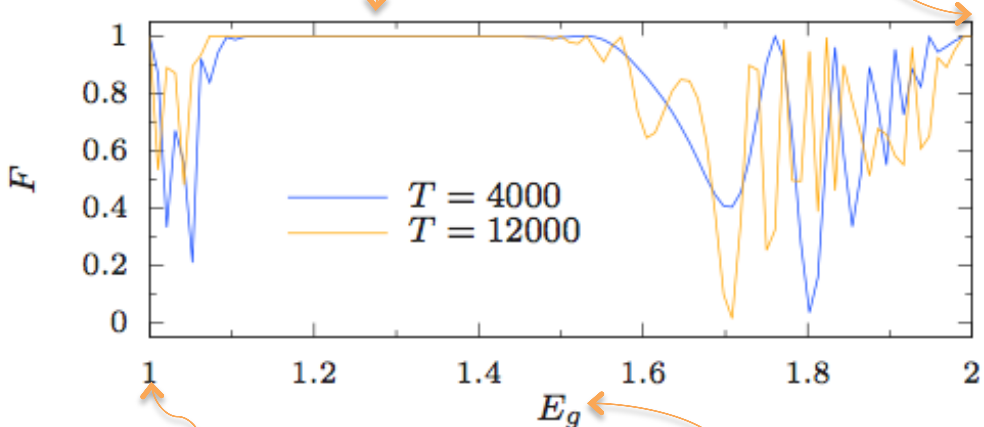
The Hamiltonian:

$$H = H_{01} + H_{02} + g\delta(x_1 - x_2)$$

Resonance is no longer guaranteed due to interaction term

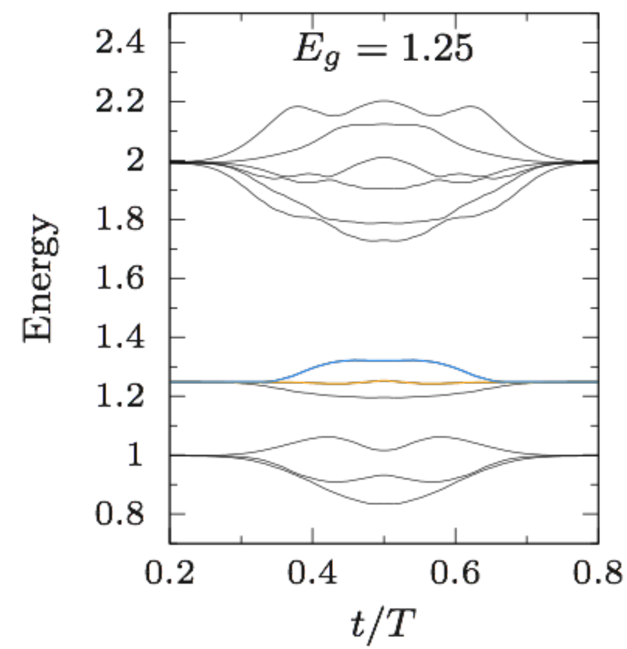
plateau for intermediate values

g=∞ corresponds to Fermion-like behavior



g=0 is equivalent to single particle case

as *g* spans from *0* to ∞ the energy goes from 1 to 2



[2] A. Benseny, J. Gillet, and Th. Busch Phys. Rev. A 93, 033629 (2016)

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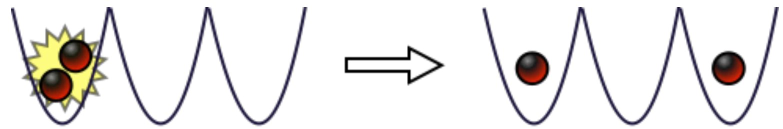
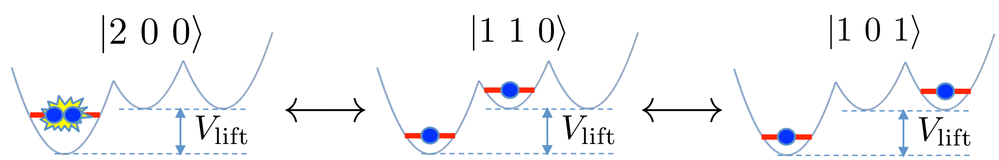
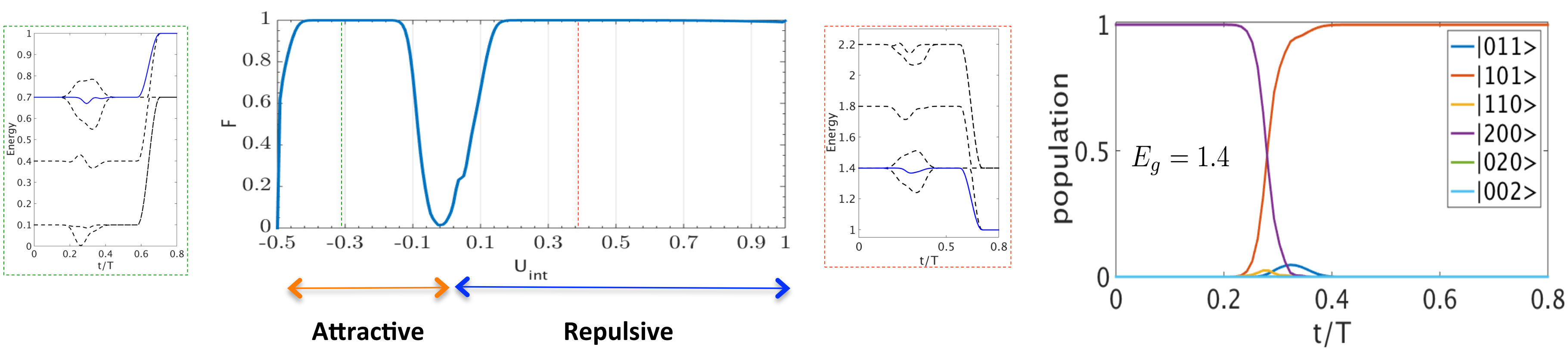
Beyond transport: particle separation

$$|2\ 0\ 0\rangle \rightarrow |1\ 0\ 1\rangle$$



Lift the traps while moving them to compensate for the interaction energy





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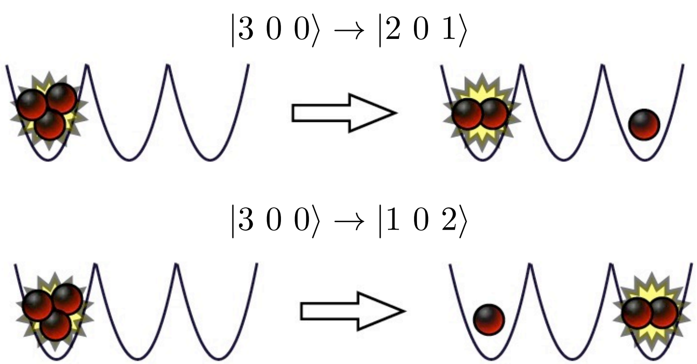
Separating more particles

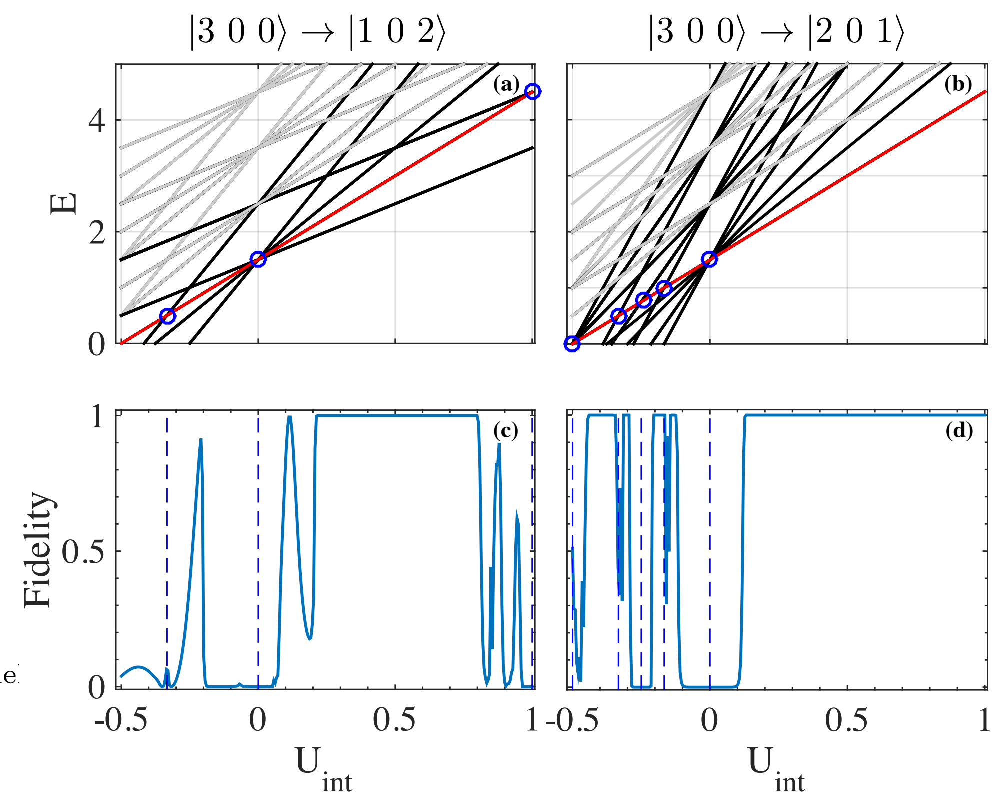
$$|\psi_{\text{init}}\rangle = |N\ 0\ 0\rangle \rightarrow |\psi_{\text{target}}\rangle = |M\ 0\ (N-M)\rangle$$

$$V_{\text{lift}} = MU_{\text{int}}$$

Does not depend on the total number of particles!



$$\hat{H}_{\text{BH}} = \hbar\omega \sum_{j=0}^{m_{\text{L}}-1} \left(j + \frac{1}{2}\right) \hat{N}_j^{\text{level}} + \sum_{i=1}^{3} V_i \hat{N}_i^{\text{trap}} + \frac{U_{\text{int}}}{2} \sum_{i=1}^{3} \hat{N}_i^{\text{trap}} \left(\hat{N}_i^{\text{trap}} - 1\right) + H_{\text{tunnel}}$$



Experimental realization proposal and more details: "A robust boson dispenser: Quantum state preparation in interacting many-particle systems", I. Reshodko, A. Benseny, Th. Busch, arXiv:1703.02189