Loschmidt echos in the delta-kicked rotor

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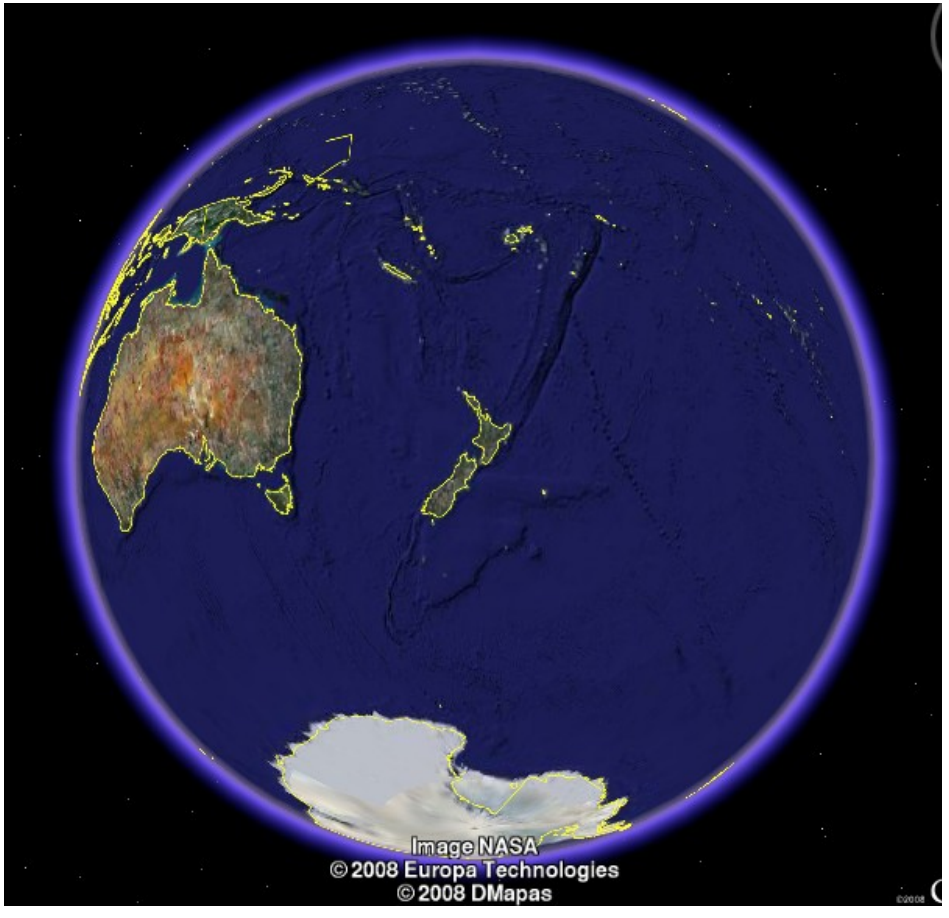

(Simon Whalen)
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Arif Ullah

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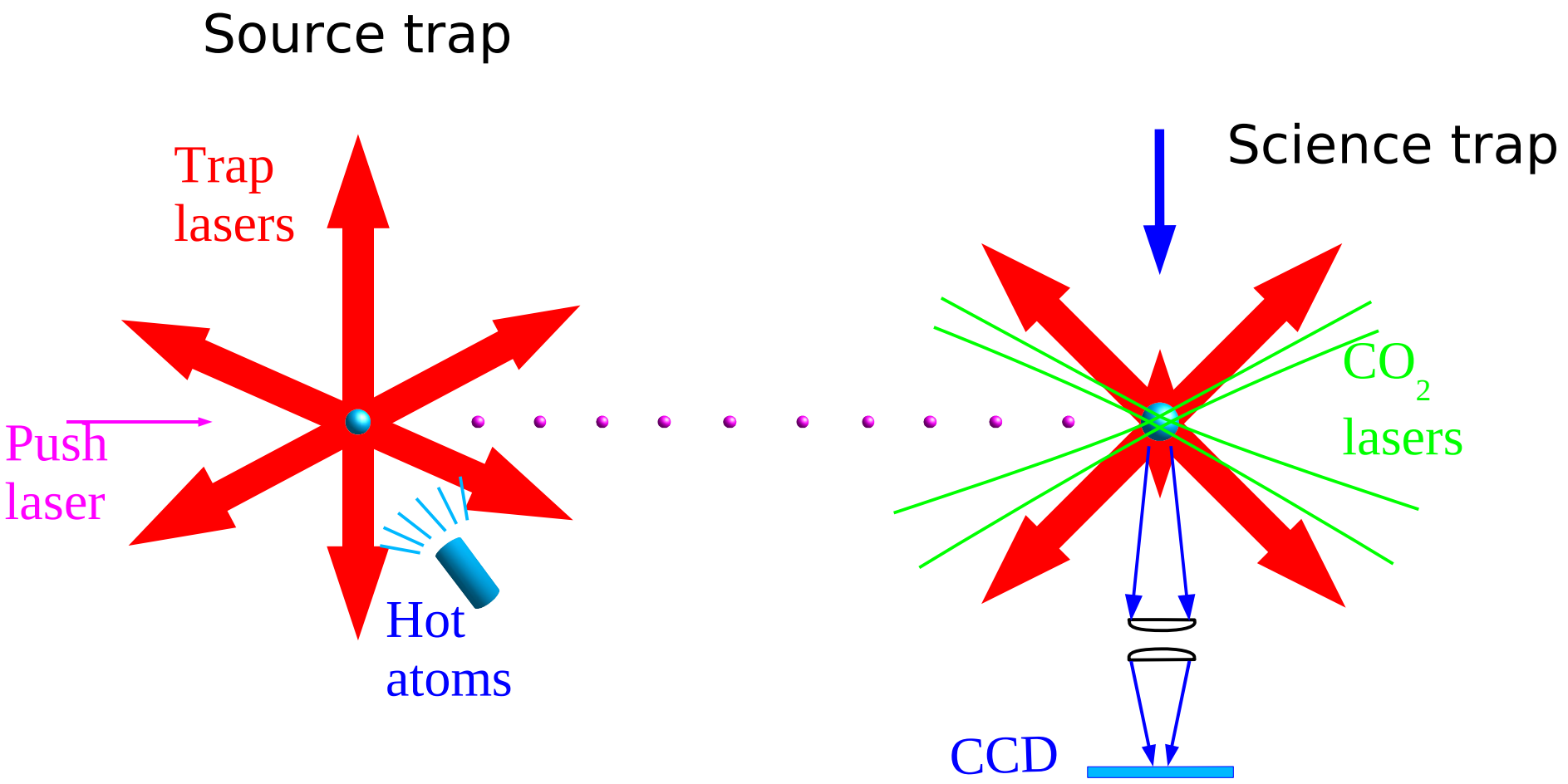
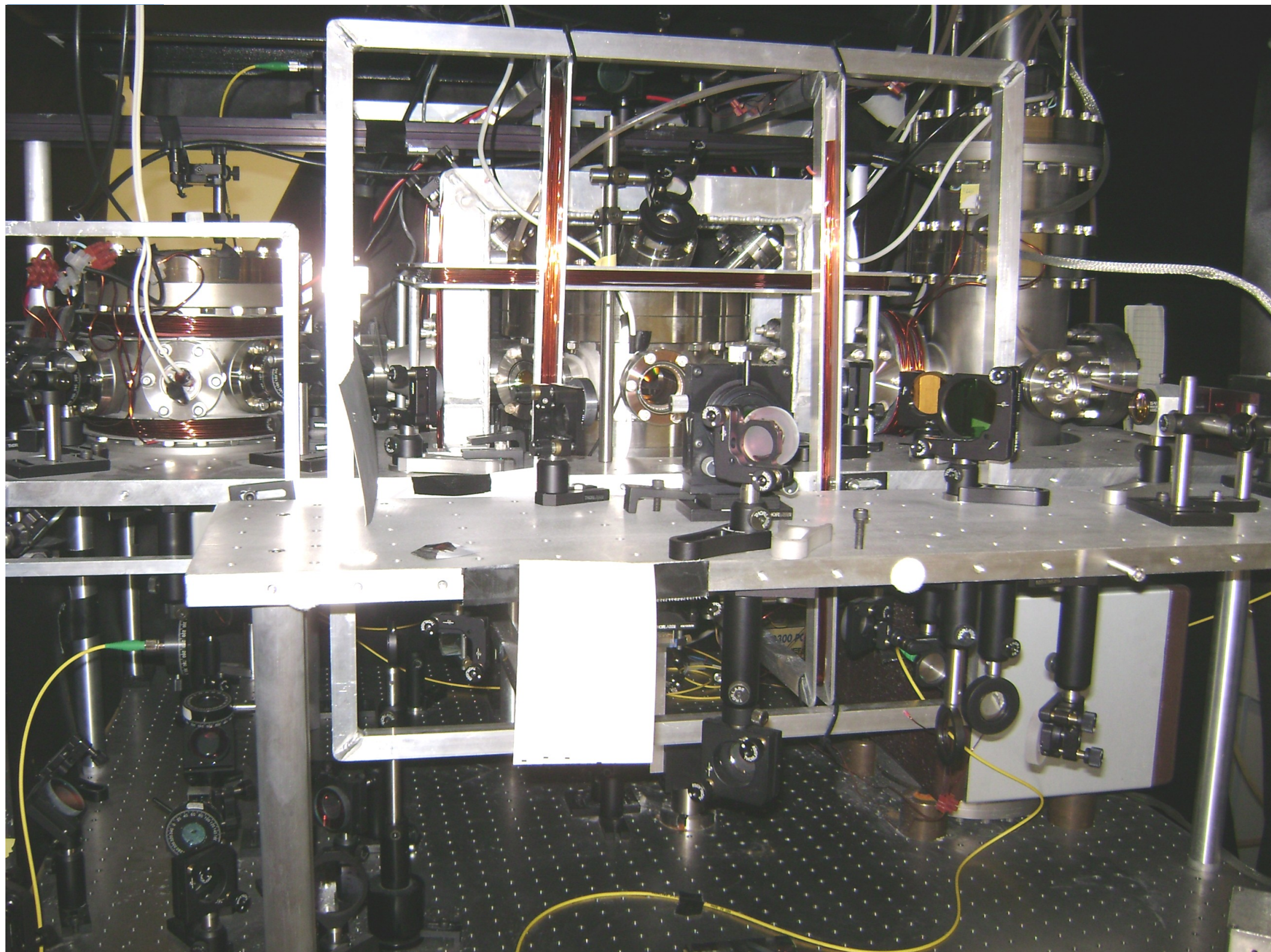
Outline

- All-Optical BEC
- Delta-kicked rotors
- Loschmidt echos

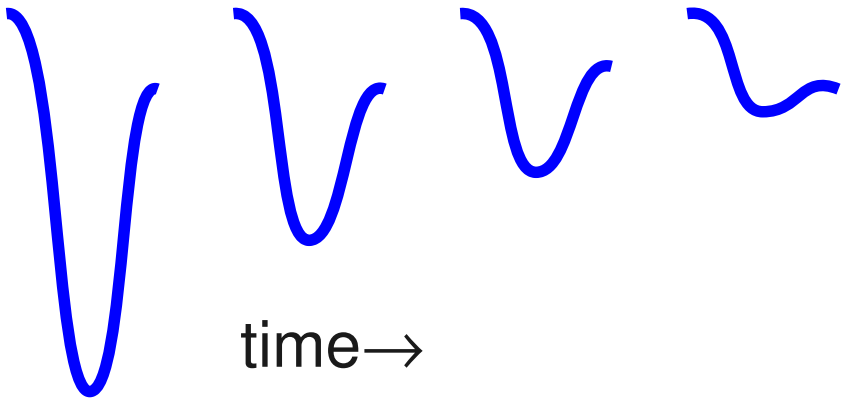
All Optical BEC Setup

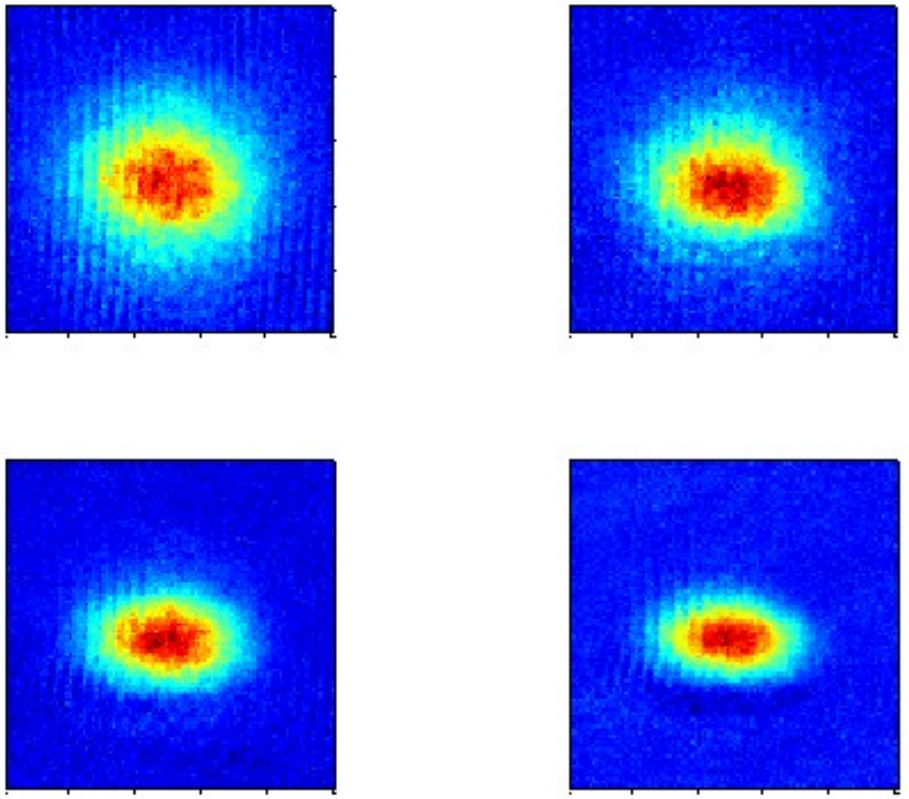




BEC result

- Reduce power to reduce trap depth
- 5 10^4 atoms
- 60 nK

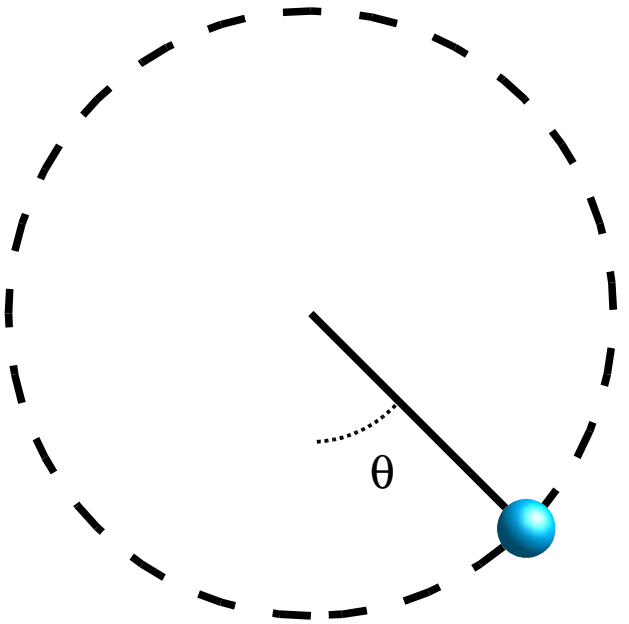




Delta-kicked rotor

- Force switched on periodically
- Classically chaotic system
- Quantum correlations lead to reduced energy growth

$$V = -V_0 \cos\theta \sum_n$$



$$U = (U_{kick} U_{free})^N$$

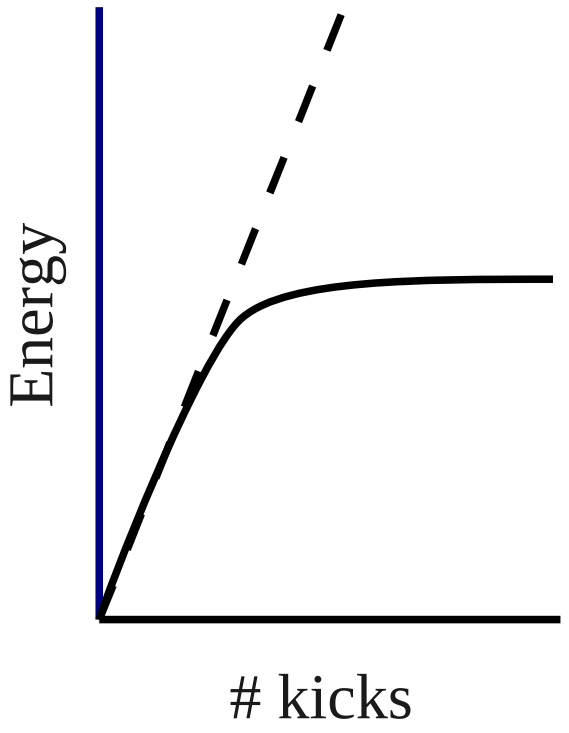
$$U_{free} = \exp\left(-i \frac{p^2}{2m}\right.$$

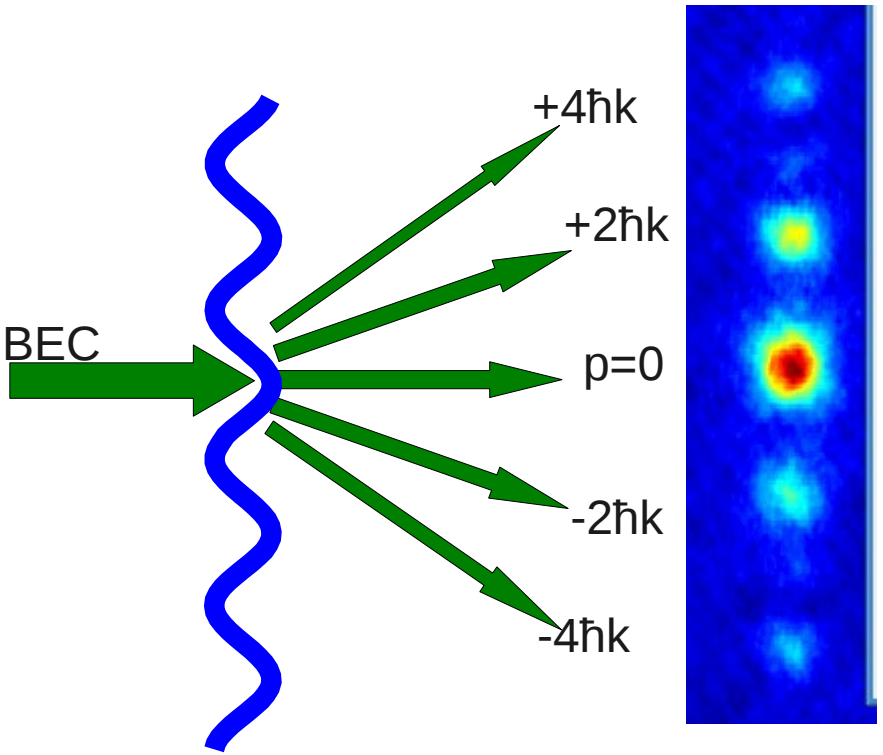
$$U_{kick} = \exp(-i V_0$$

Atom optics kicked rotor

- Atoms moving in a pulsed detuned standing wave laser field.

- Optical standing waves from a 780 *nm* diode laser.





Talbot effect

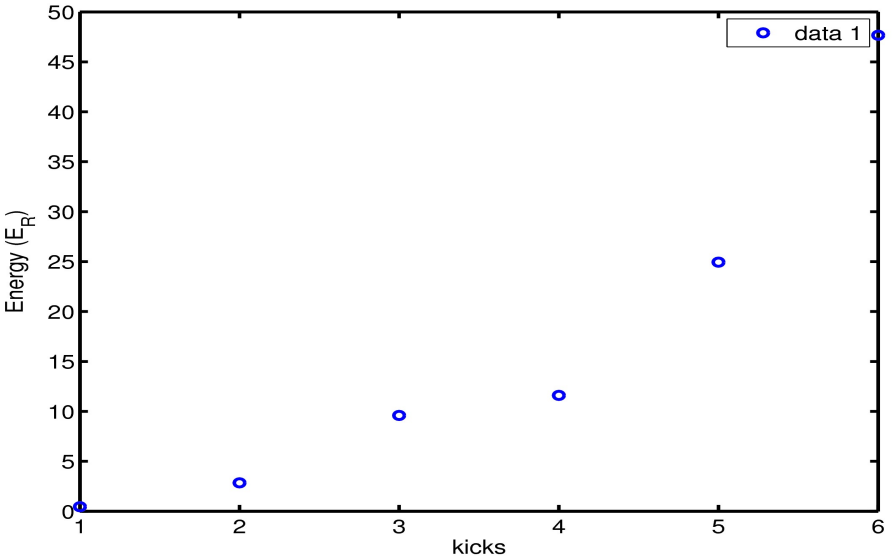
- Well known optical gratings are reformed after Talbot distance
- For atoms: temporal
- Free evolution between kicks:

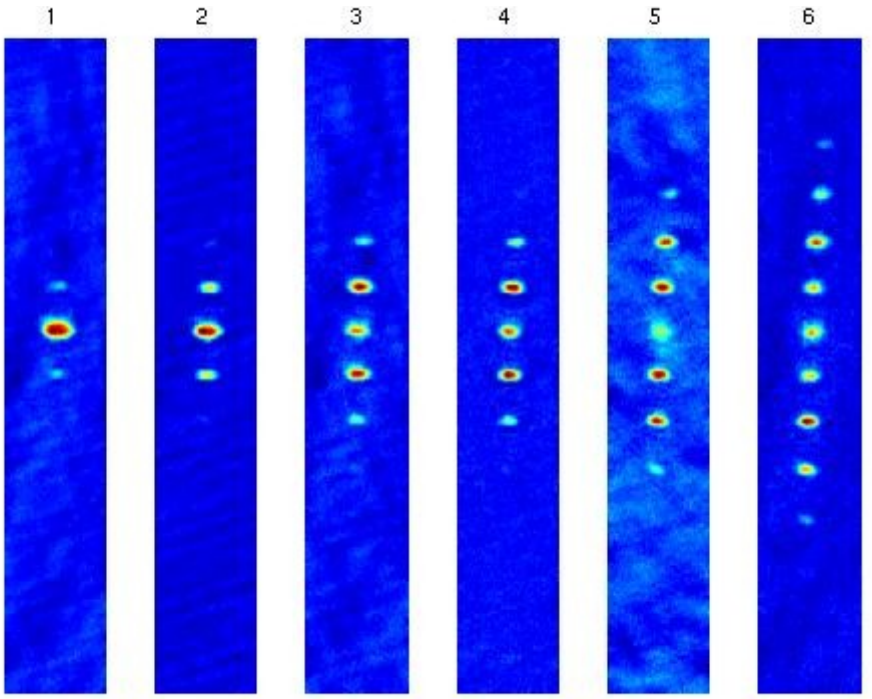
$$U_{free} = \exp(-$$

- $U_{free} = 1$ for $T = \frac{\pi}{2\omega_r}$

Talbot effect

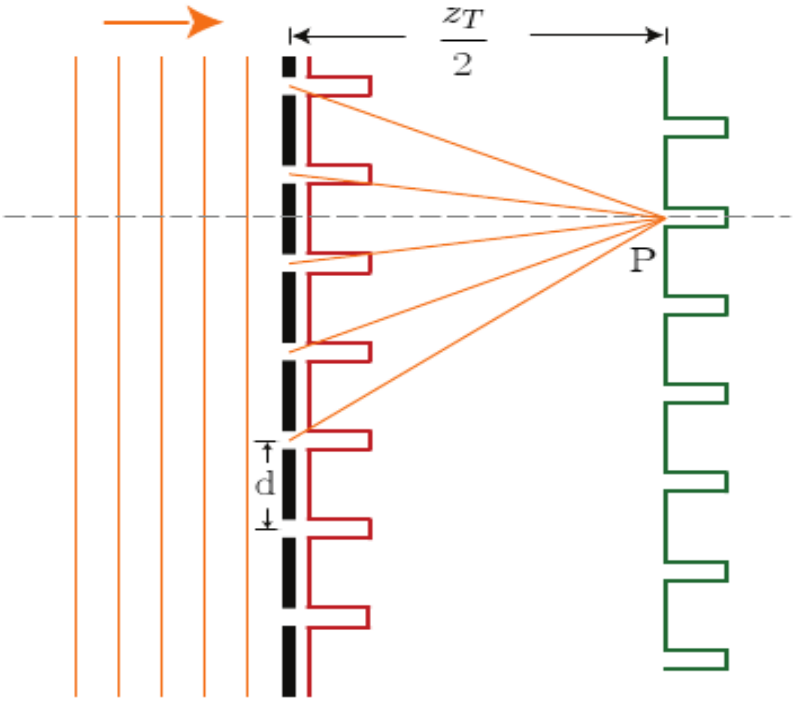
- Kick period 66.3 μs
- Phase shift is 2π for atoms with $2\hbar k$ momentum
- Quadratic growth of the energy with the number of kicks

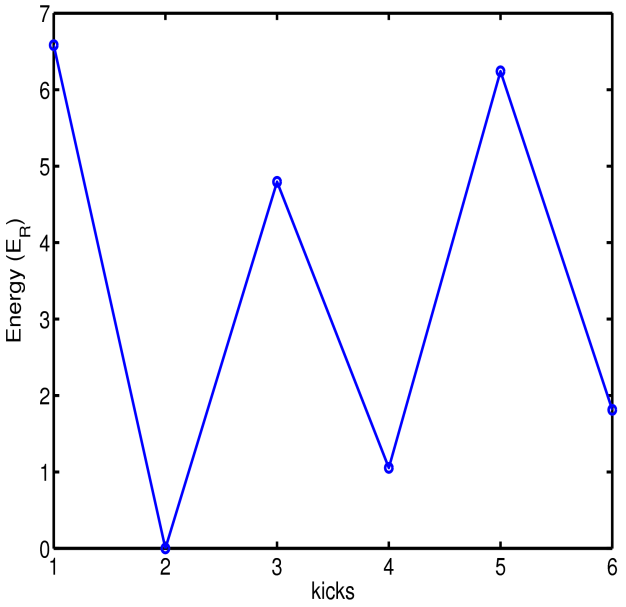


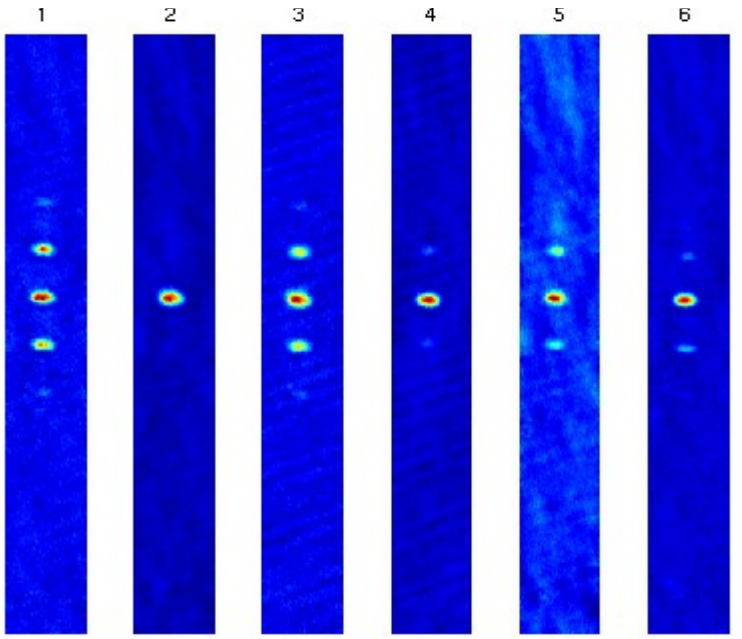


Fractional Talbot effect

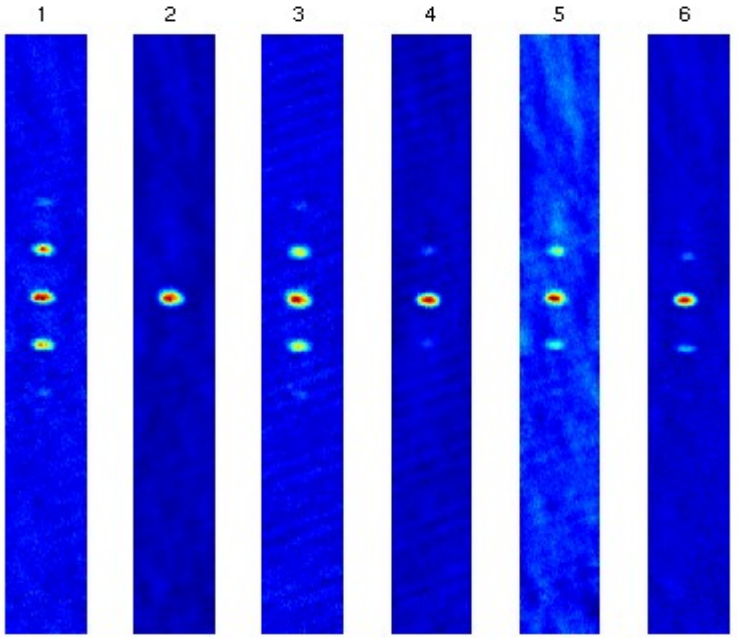
- Restored wave with negative sign
- Second kick undoes first kick

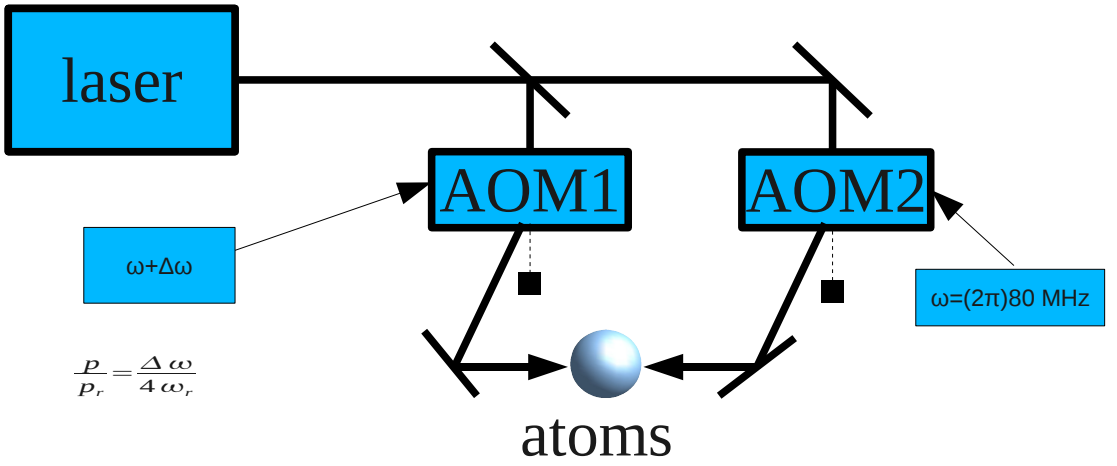




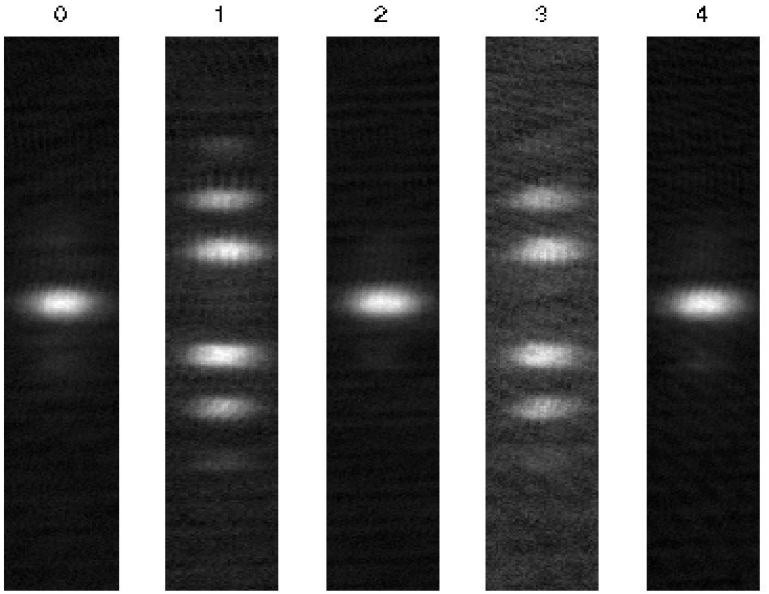


Initial momentum



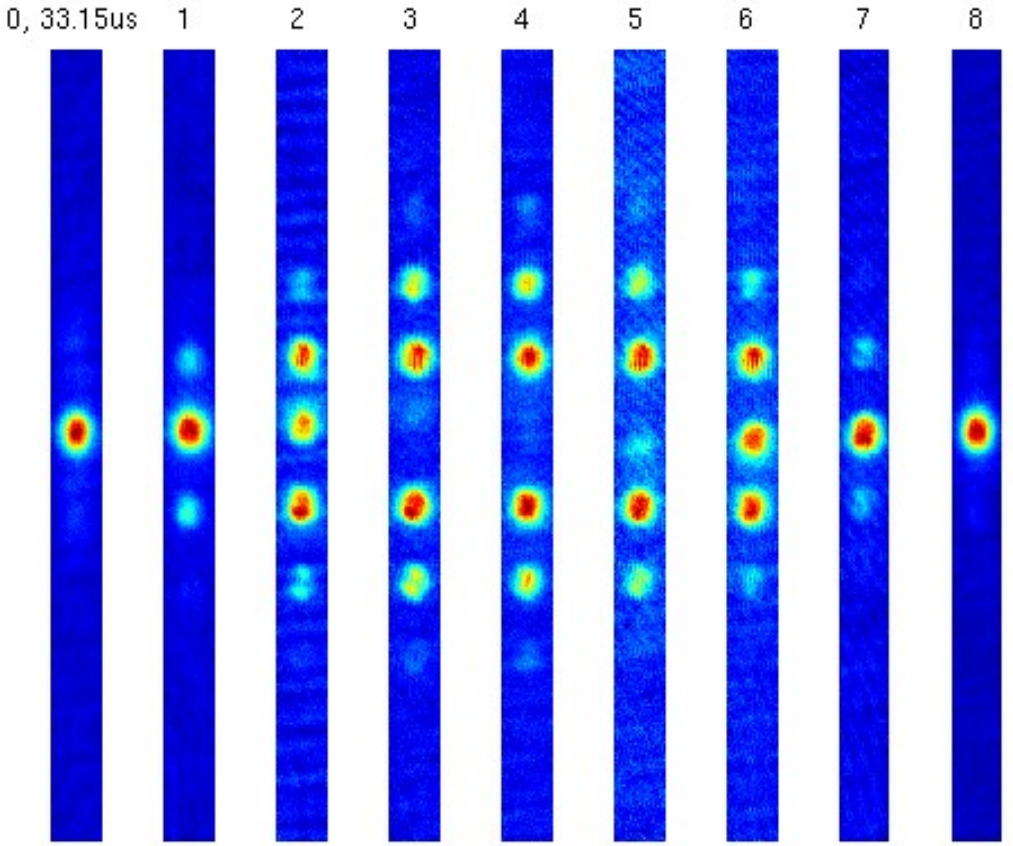


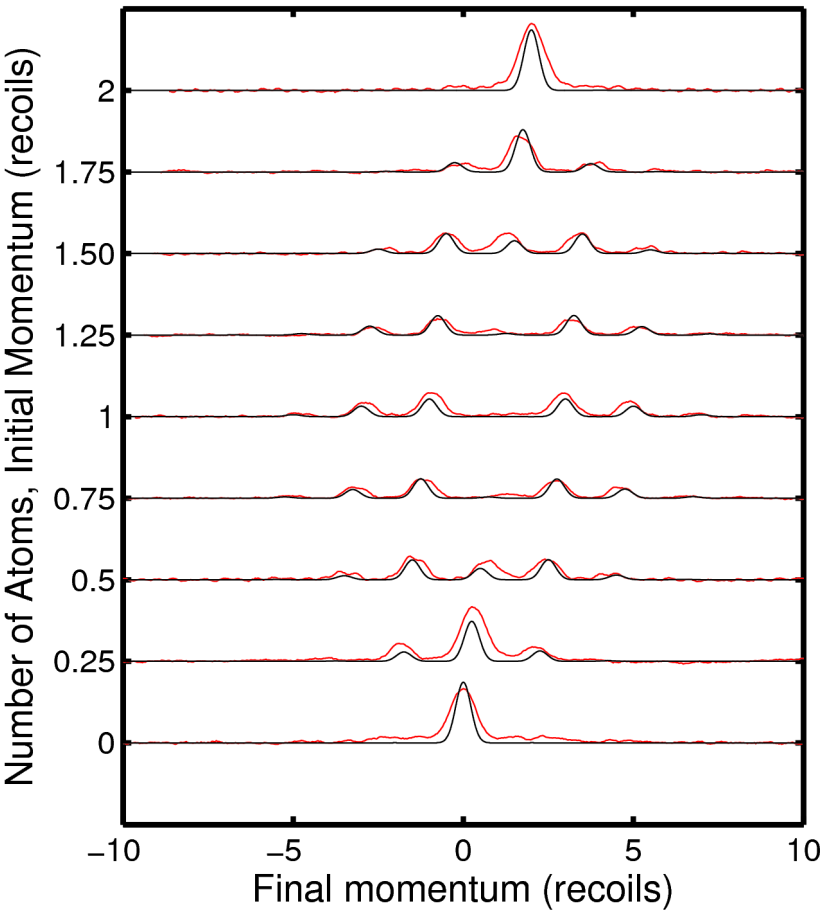
- Two kicks
- T=2π
- anti-resonance



Two kicks

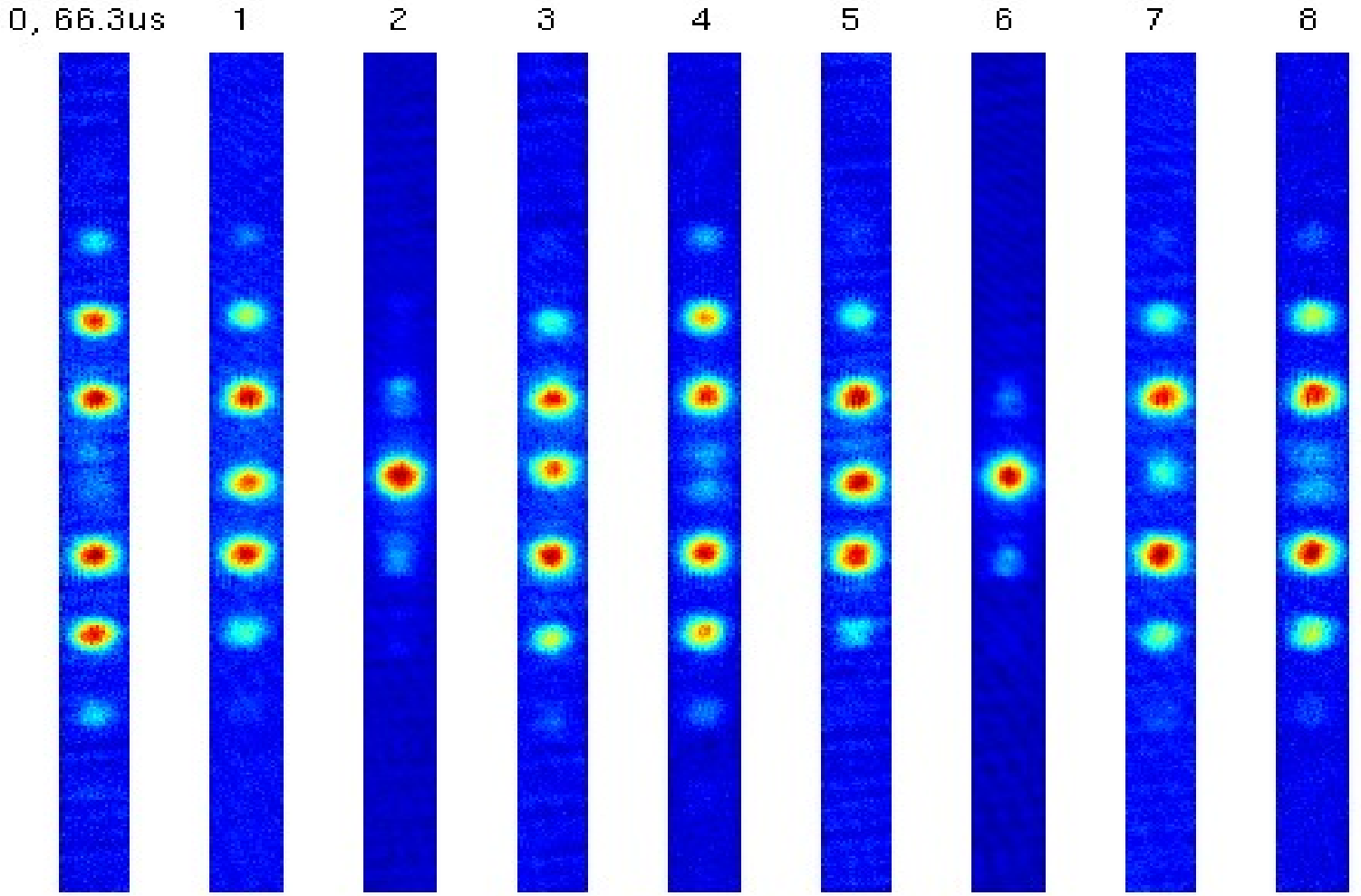
$k=2\pi$





Two kicks

$k=4\pi$



Energies

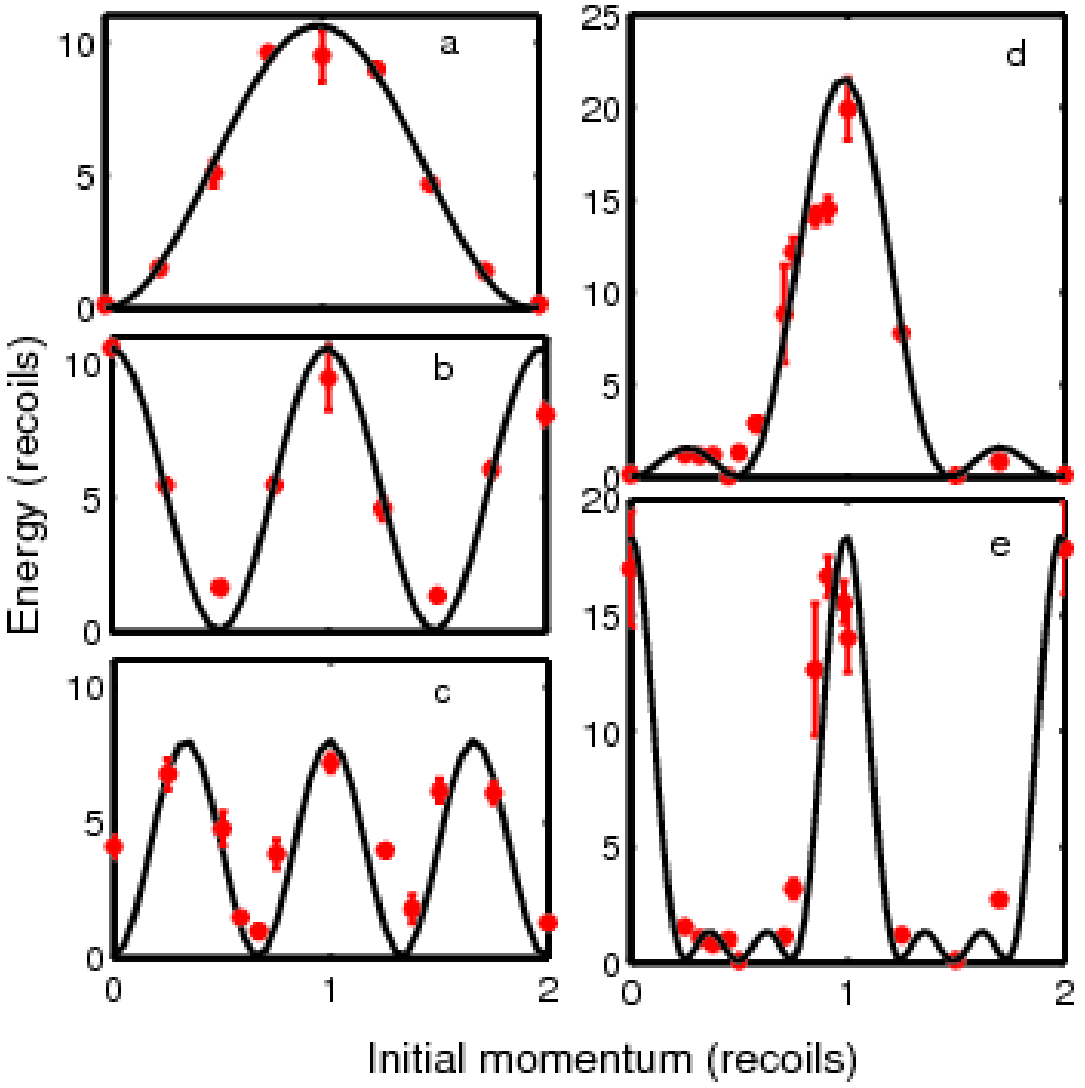
(a) Two kicks k=2π

(b) Two kicks k=4π

(c) Two kicks k=6π

(d) Four kicks k=2π

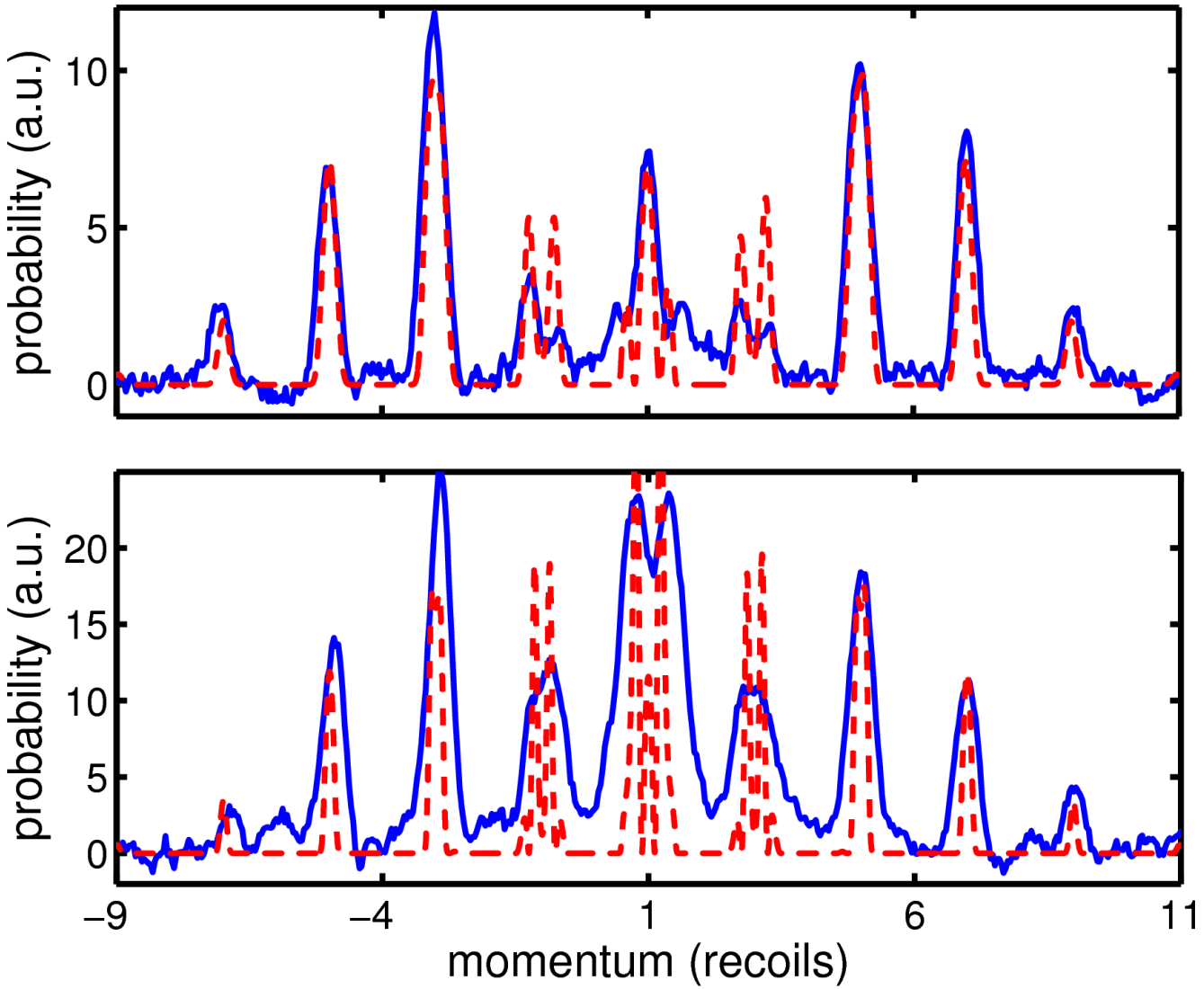
(e) Four kicks k=4π



Momentum Distributions

- Four kicks:
- k=2π

k=4π

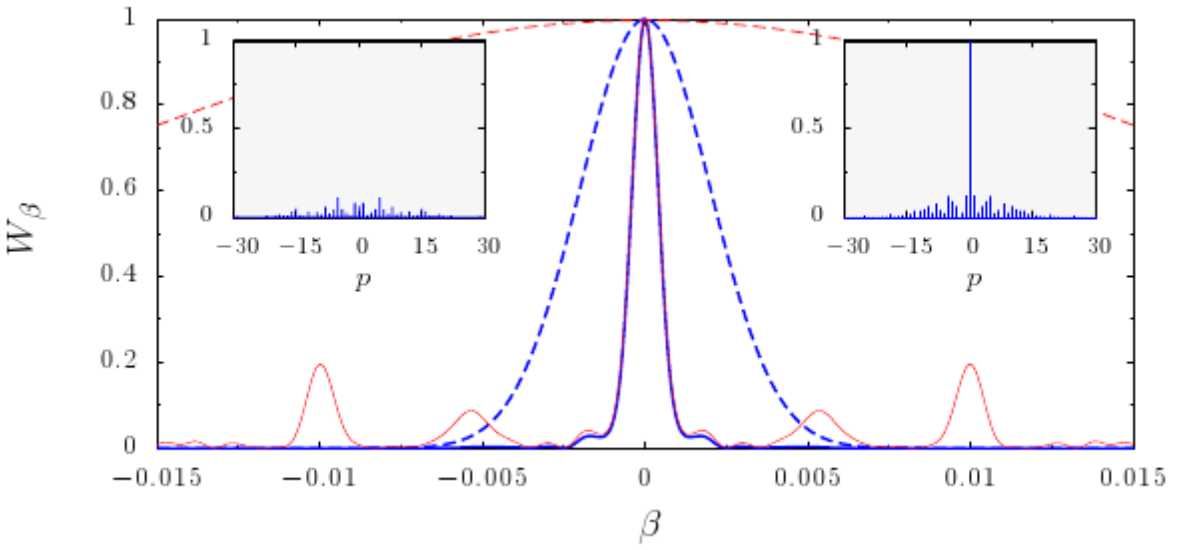


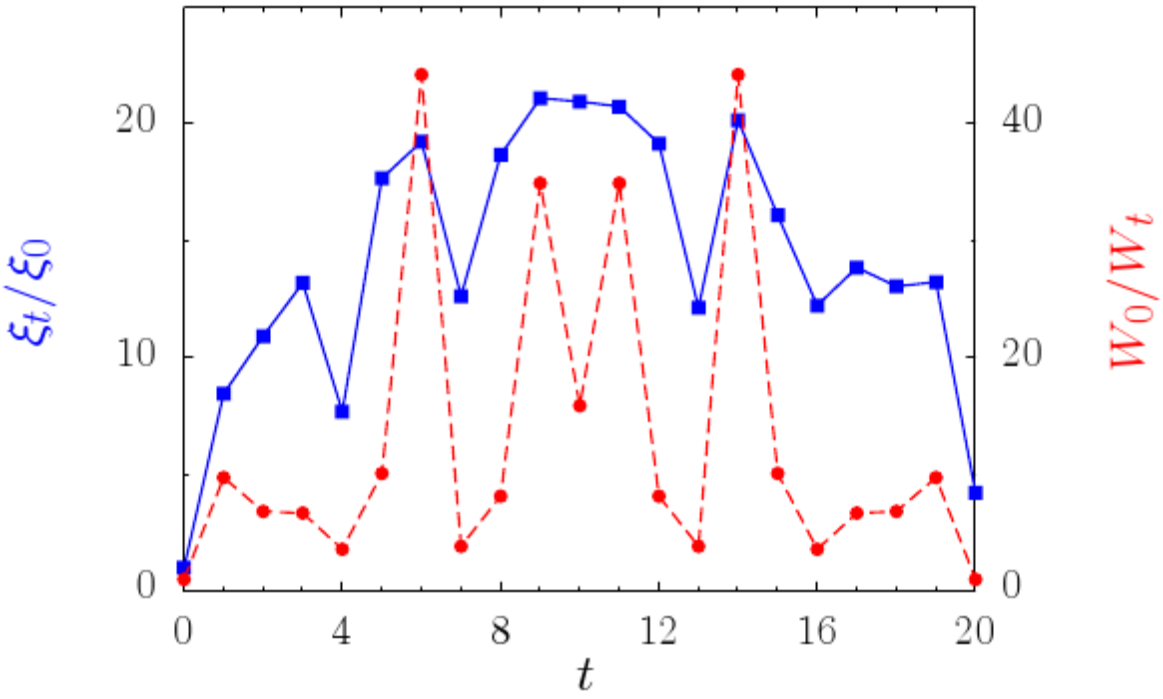
Loschmidt time reversal

- Reverse chaotic behaviour
- Kick period 4π-ε
- After *n* kicks, reverse
  - Electric field
  - Order of propagation and interaction
  - ε
- This only works p=*0*

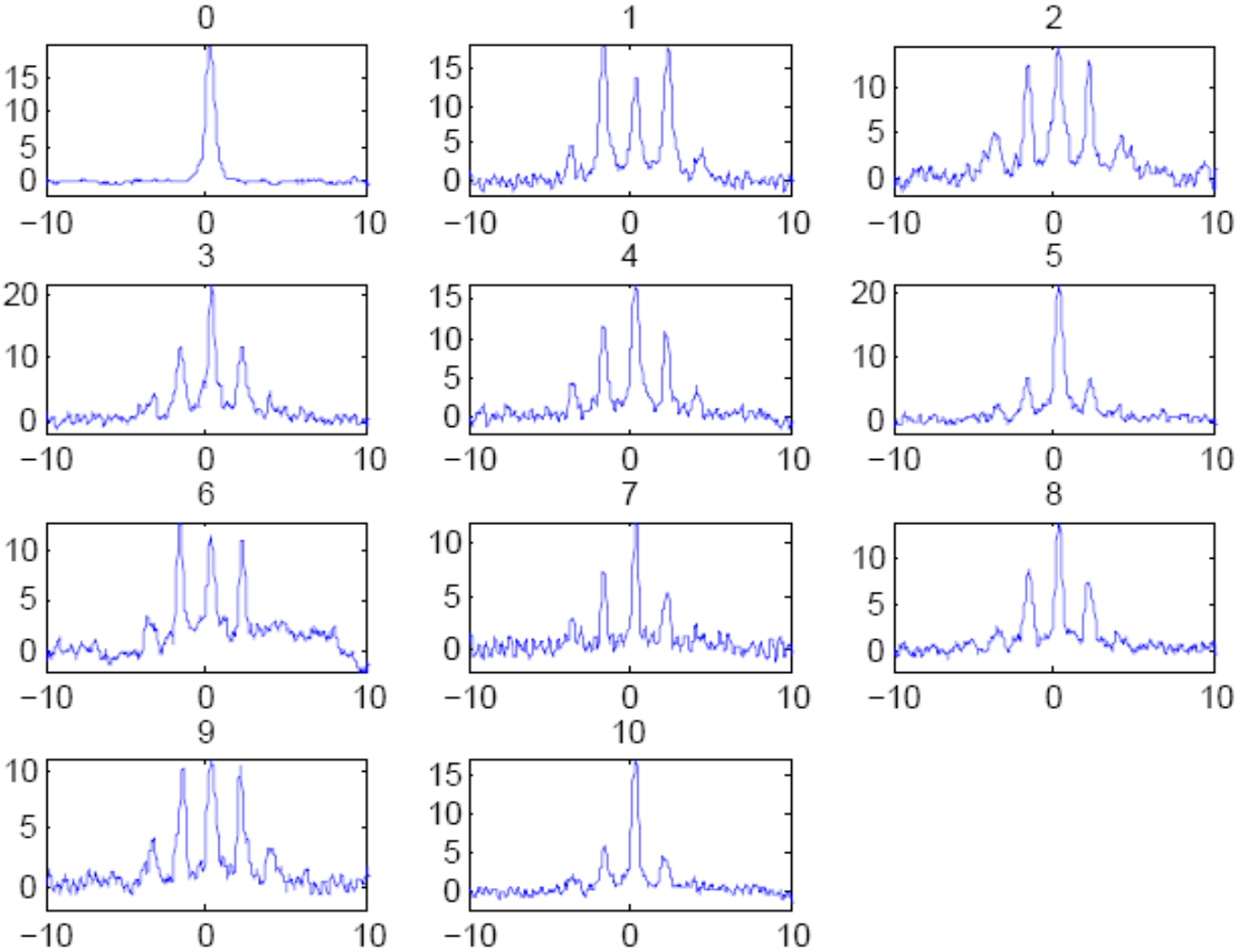
Predictions

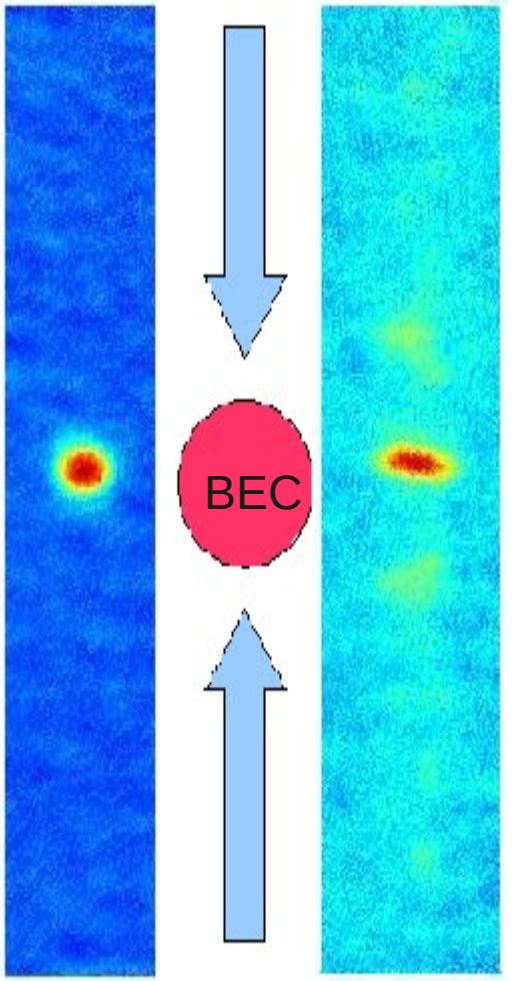
- High resolution velocity filter
- PRL 100 044106





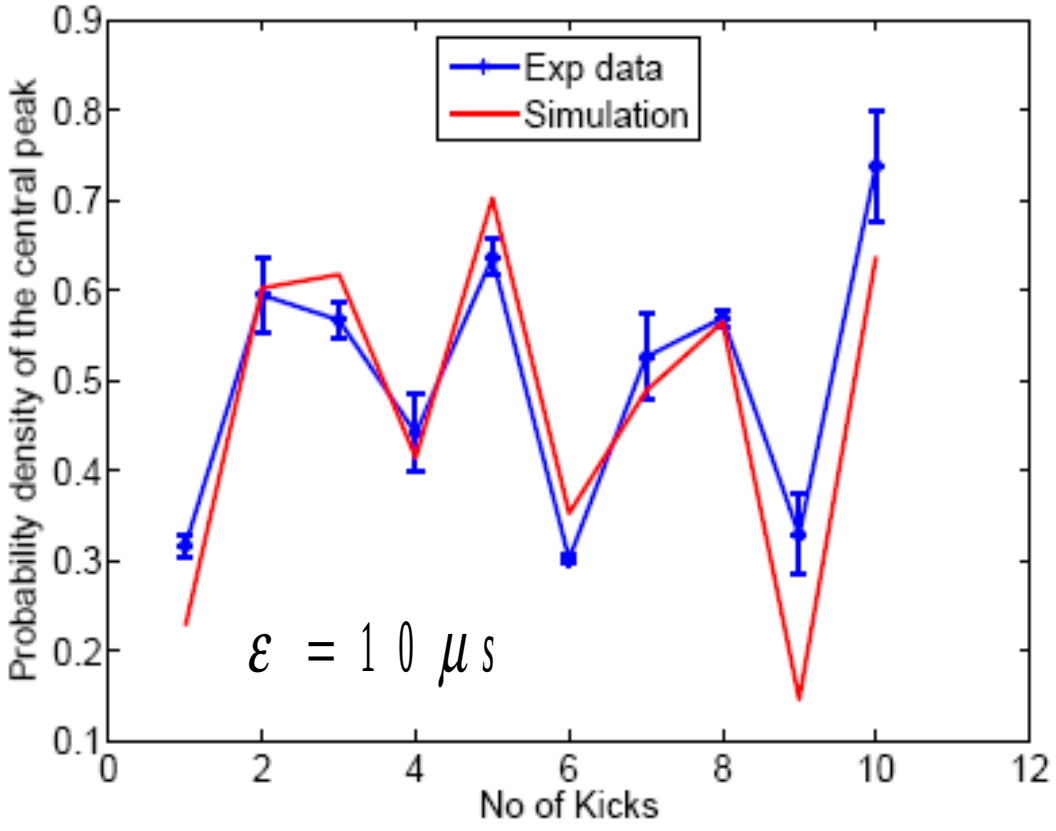
Loschmidt echo





Current Issues

- BEC is not all that cold
- Limited resolution
- Sensitive to gravity



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Future experiments

- Mean field effects in the QKR
- Ring BECs
- Calorimetry of a BEC
- Splitting the BEC into many
- Quantum logic

Thanks!

- Delta kicked rotor experiments on initial velocity dependence
- Loschmidt echos