Quantum Cellular Automata (QCA) and non-equilibrium phases of quantum matter

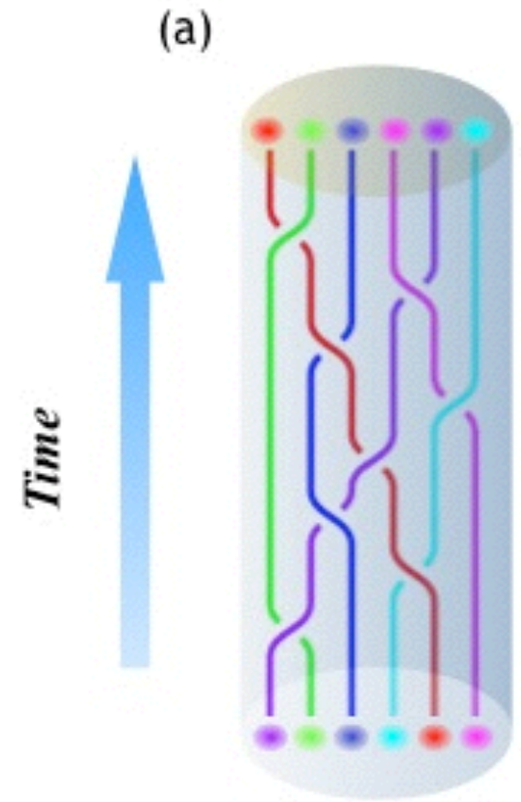
Lukasz Fidkowski

Zero temperature equilibrium phases of quantum matter

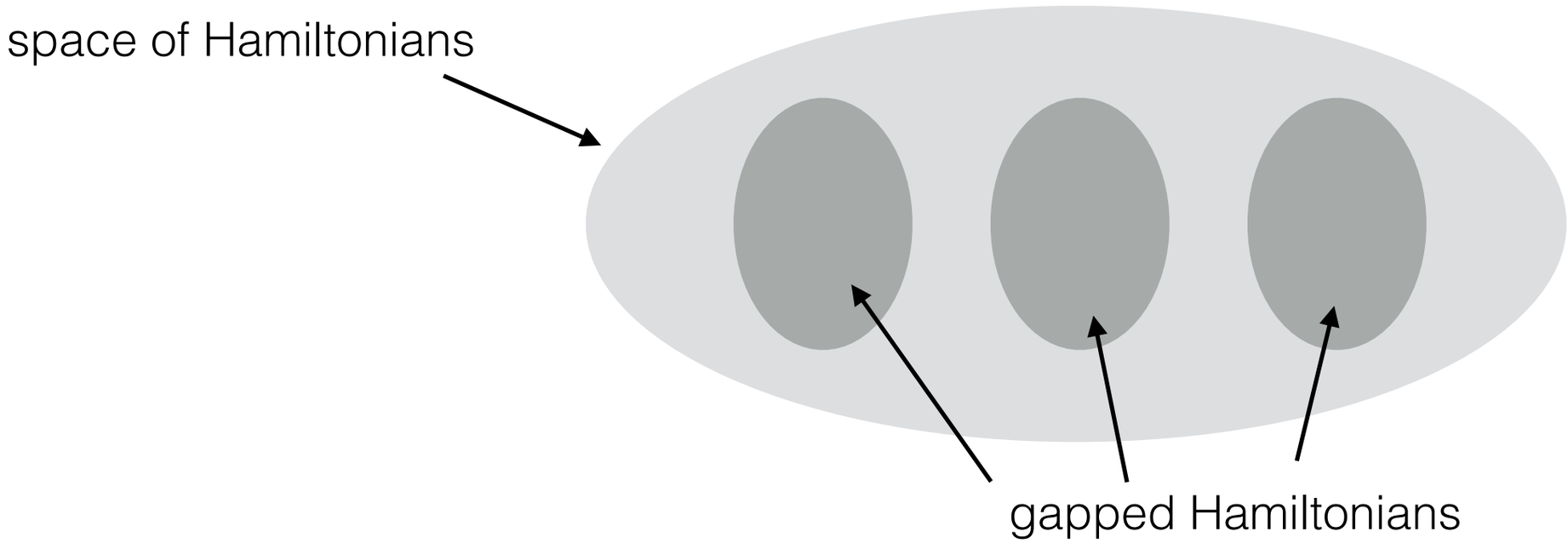
- physics of the ground state

- topological phases: characterized by spectrum of anyons

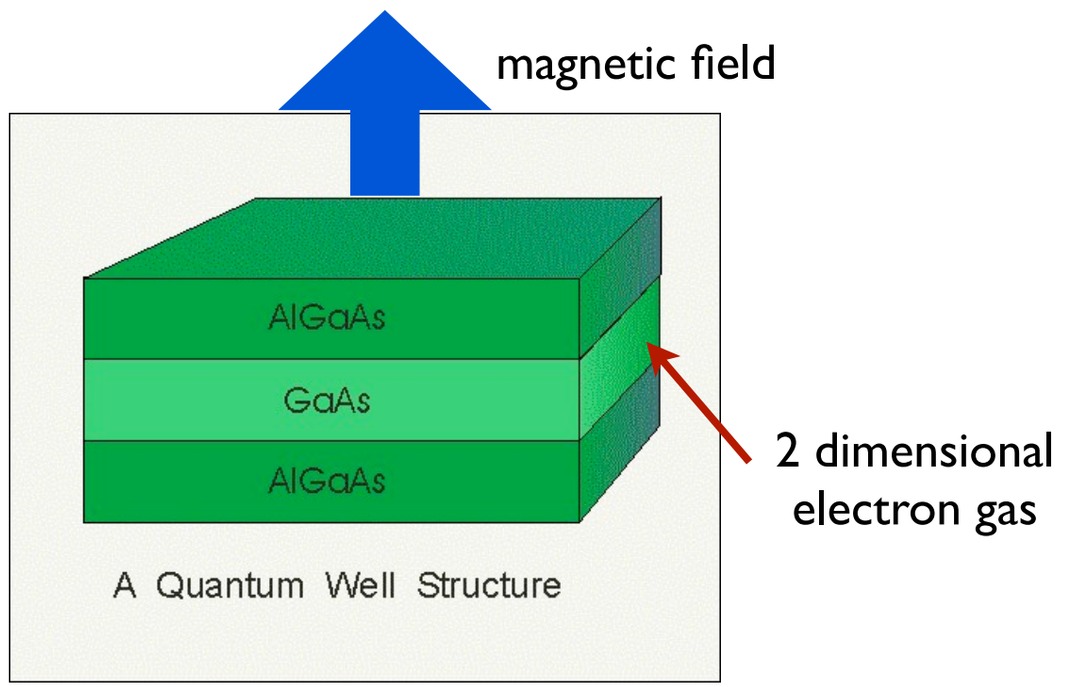
2d: unitary modular tensor categories, all the math you heard about yesterday



Zero temperature equilibrium phases of quantum matter

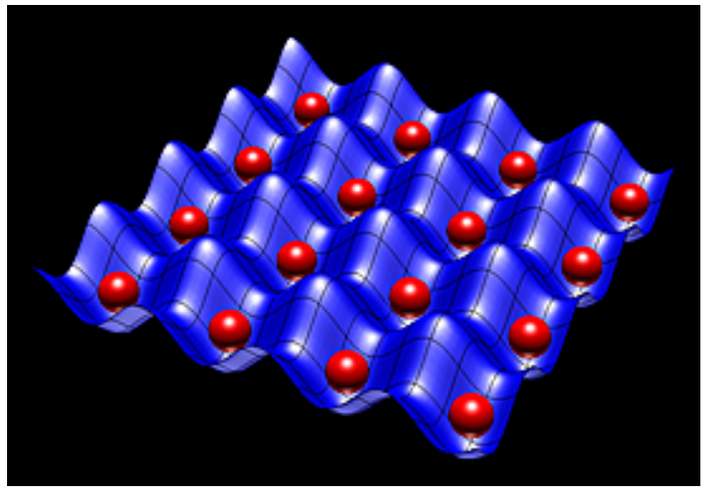


- physical realization: 2d electron gas in semiconductor quantum wells:



New designer quantum systems

Alkalai atoms in optical lattice:



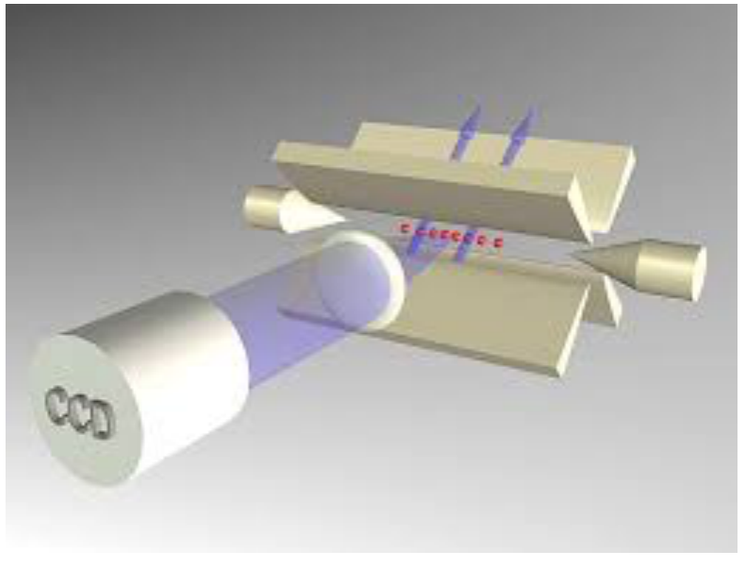
nist.gov

→ Mott insulator - superfluid transition

Quantum anti-ferromagnetism

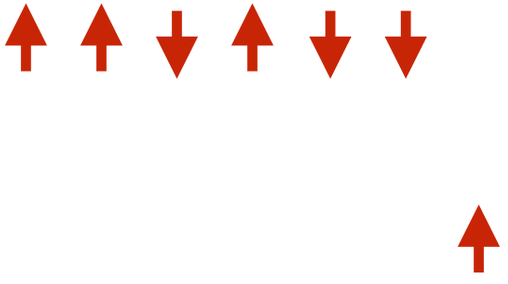
Greiner 2017

Trapped ions:



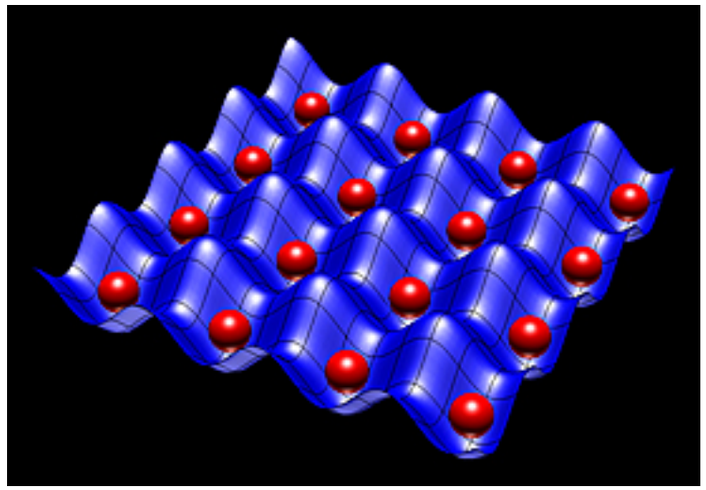
quantumoptics.at

→ effective Ising spin chain:



New designer quantum systems

Alkalai atoms in optical lattice:



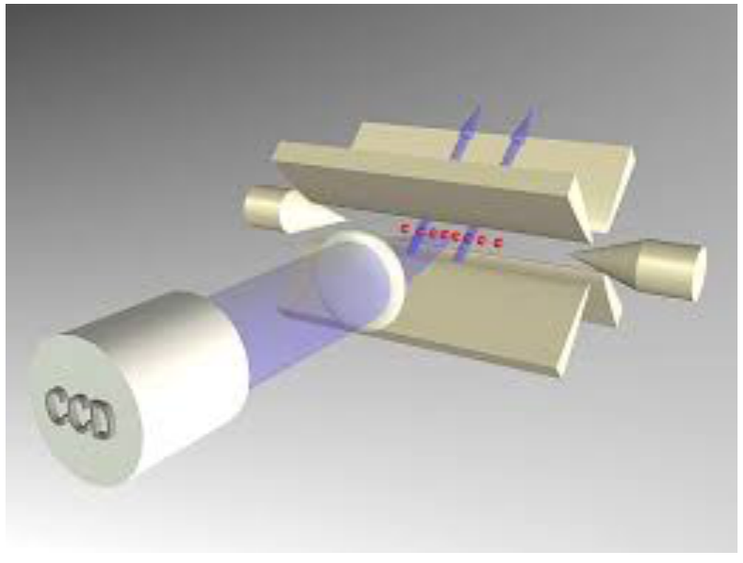
nist.gov

→ Mott insulator - superfluid transition

Quantum anti-ferromagnetism

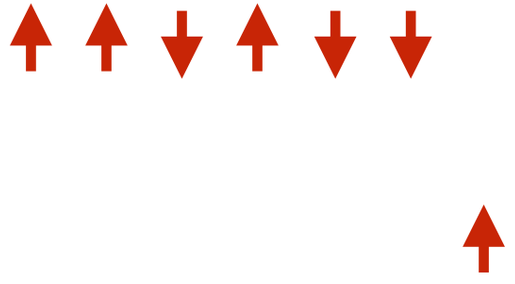
Greiner 2017

Trapped ions:



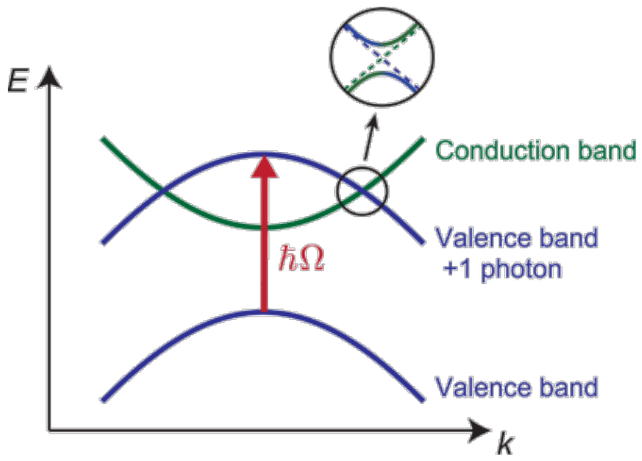
quantumoptics.at

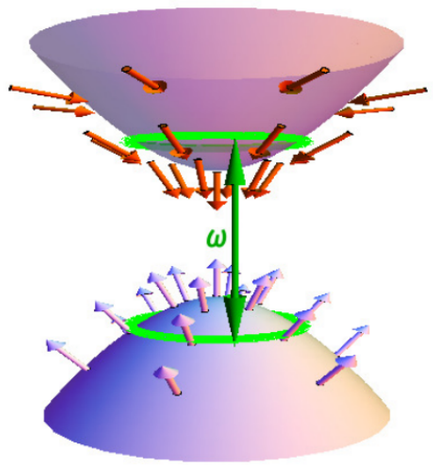
→ effective Ising spin chain:



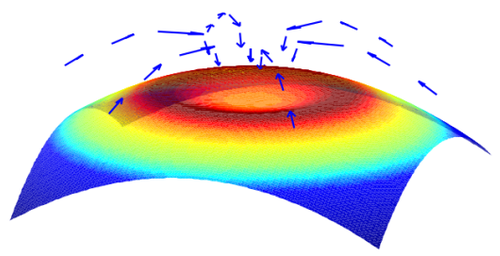
- many advantages but difficult to cool to ground state

Floquet driven systems



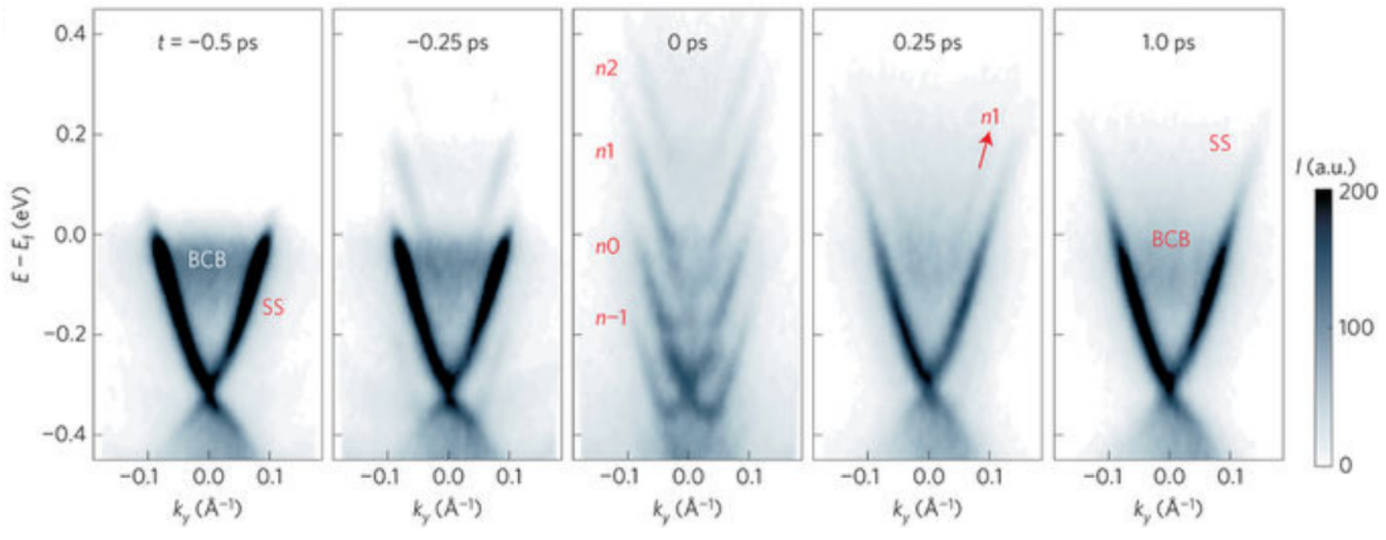


trivial



topological

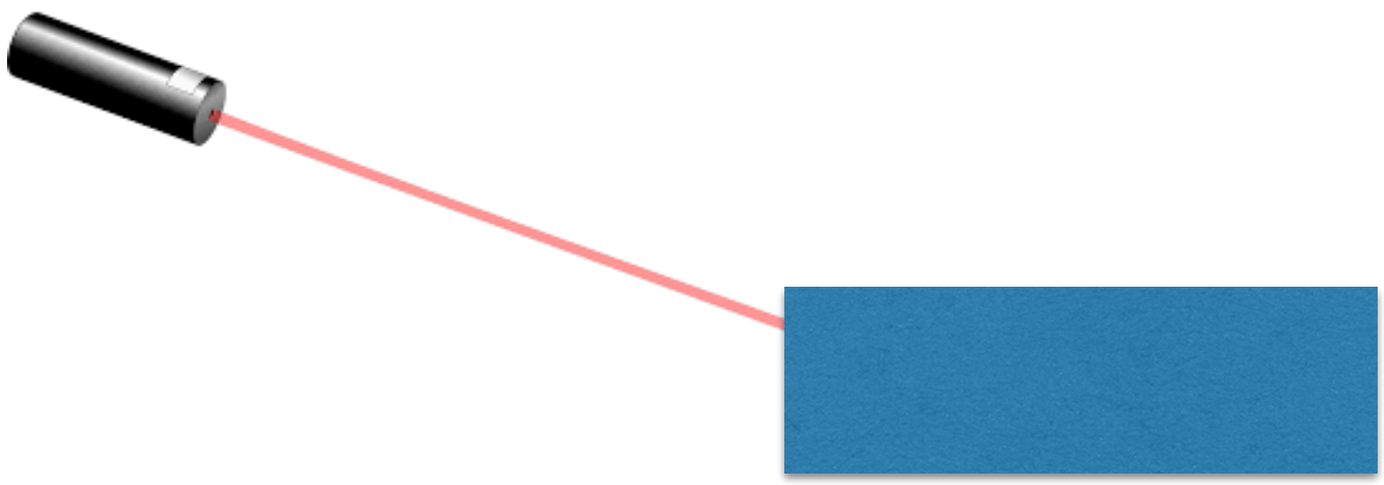
Lindner, Galitski, Refael 2010



Nuh Gedik group, Nature Physics
12, 306–310 (2016)

Floquet driven systems

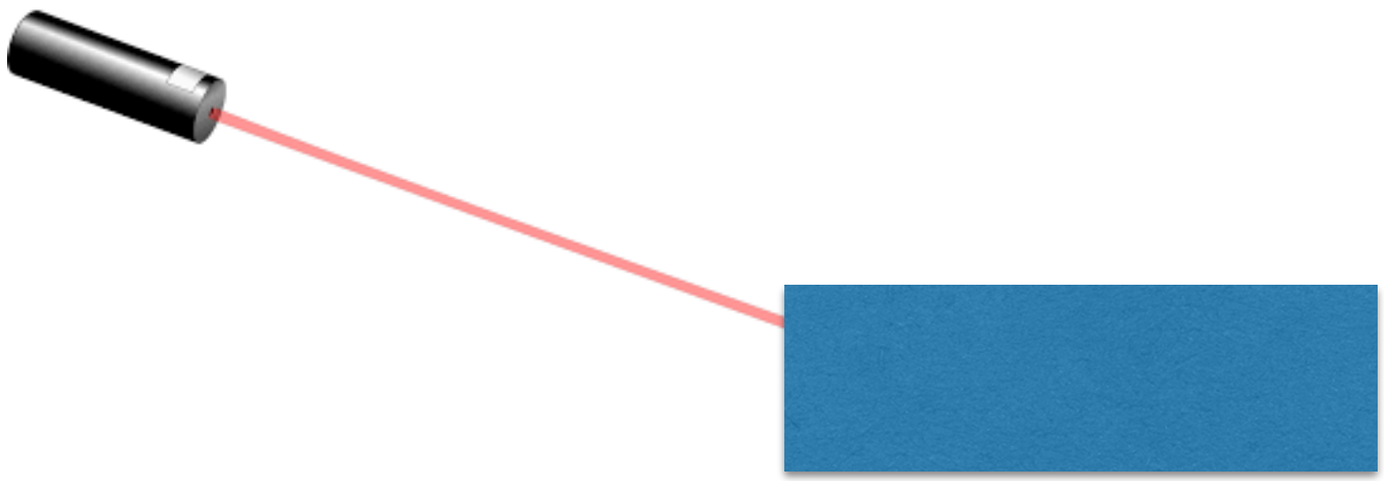
$$H(t+T) = H(t) \qquad U_F = T\exp\left(i\int_0^T H(t)dt\right)$$



Floquet driven systems

$$H(t+T) = H(t) \qquad U_F = T\exp\left(i\int_0^T H(t)dt\right)$$

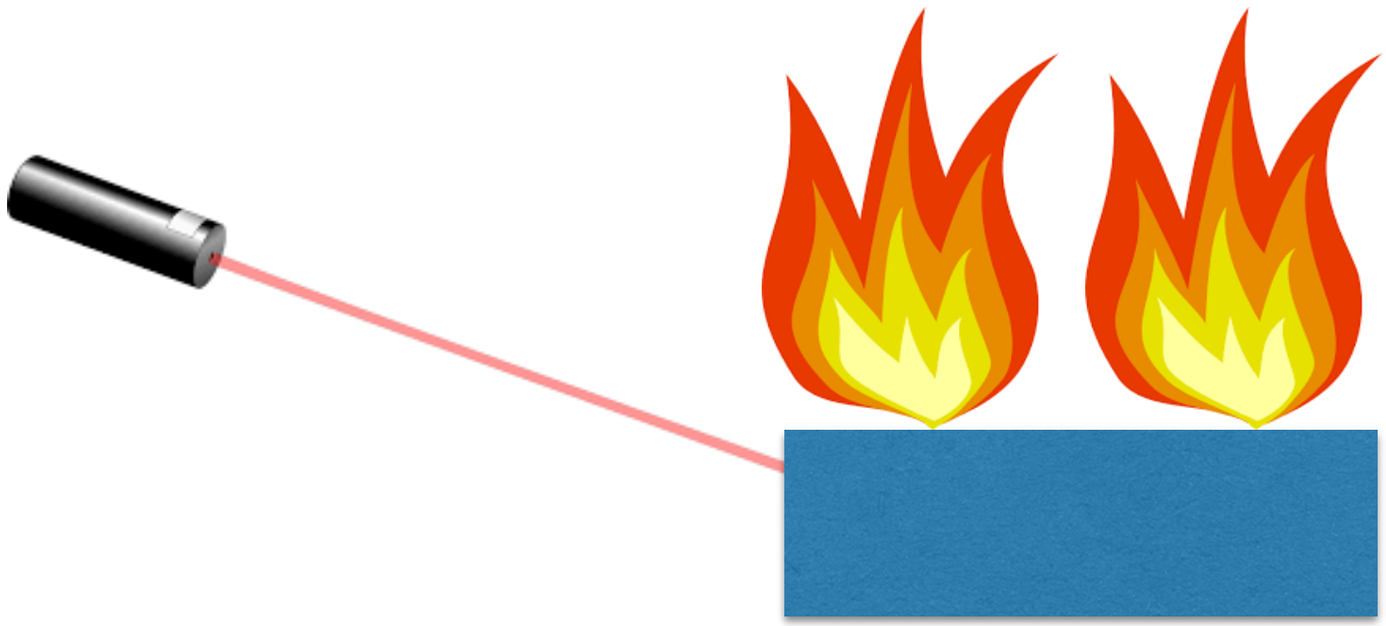
Heating problem:



Floquet driven systems

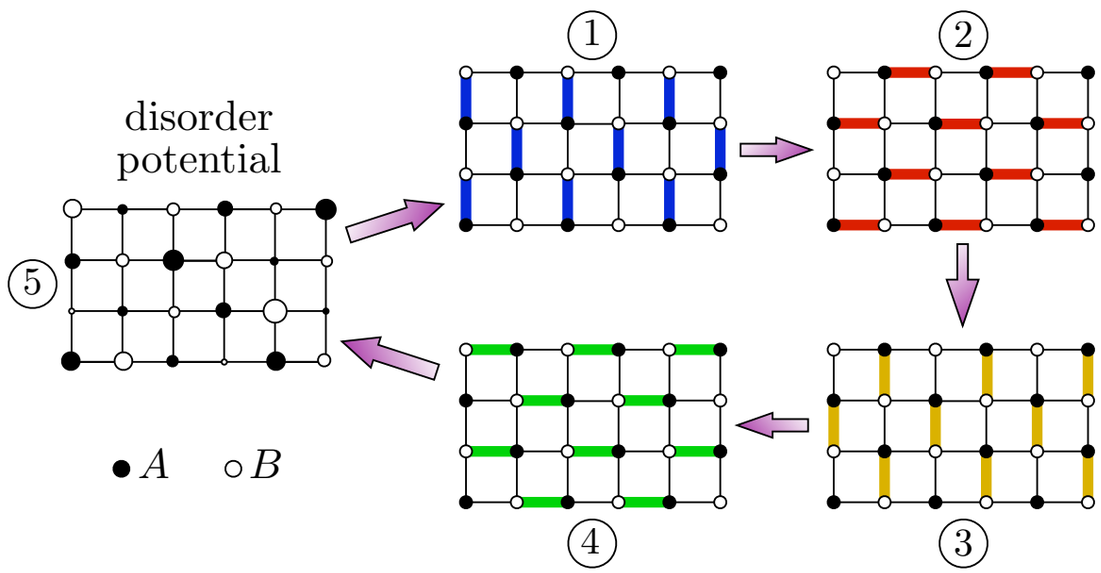
$$H(t+T) = H(t) \qquad U_F = T\exp\left(i\int_0^T H(t)dt\right)$$

Heating problem:



Example of Chiral Floquet model:

- free fermion `anomalous Floquet-Anderson insulator'



Rudner, Lindner, Berg, Levin '13;
Titum, Berg, Rudner, Refael, Lindner '16

figure from Titum, Berg, Rudner, Refael, Lindner,
Phys. Rev. X 6, 021013 (2016)

- after one time step nothing happens in the bulk, but a translation occurs on the edge

- replace fermion sites by bosonic spins (of arbitrary Hilbert space dimension p) and hopping by swap gates => get ind(Y)=p

- stable to interactions and all symmetry breaking in Floquet-MBL setting

Analogy

Quantum Hall system (equilibrium)		MBL Floquet system
Bulk gap	⟷	Bulk Many body localized
Low energy field theory for the 1d edge	⟷	Locality preserving unitary Y on the 1d edge
lack of 1d UV completion for low energy edge theory (e.g. chiral anomaly)	⟷	Impossibility of writing Y as the Floquet evolution of a 1d driving Hamiltonian