Symmetry-breaking and energy transport in microscopic gain-loss systems

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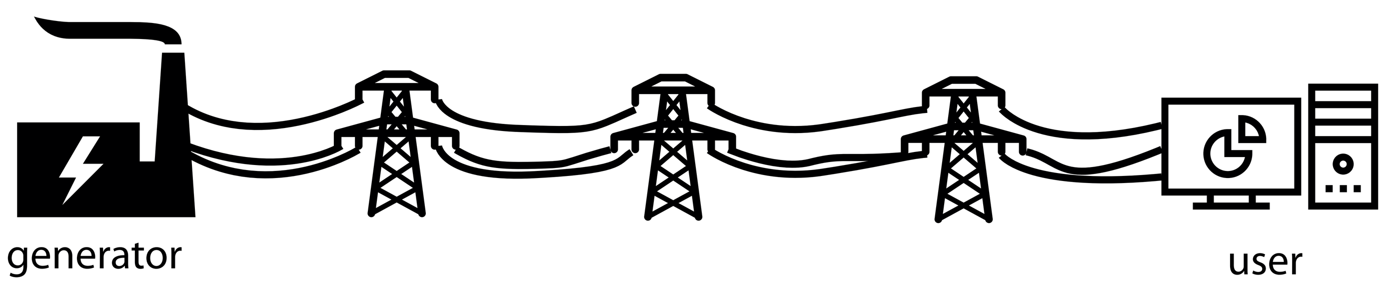
Energy transport in microscopic networks

Conventional energy transport

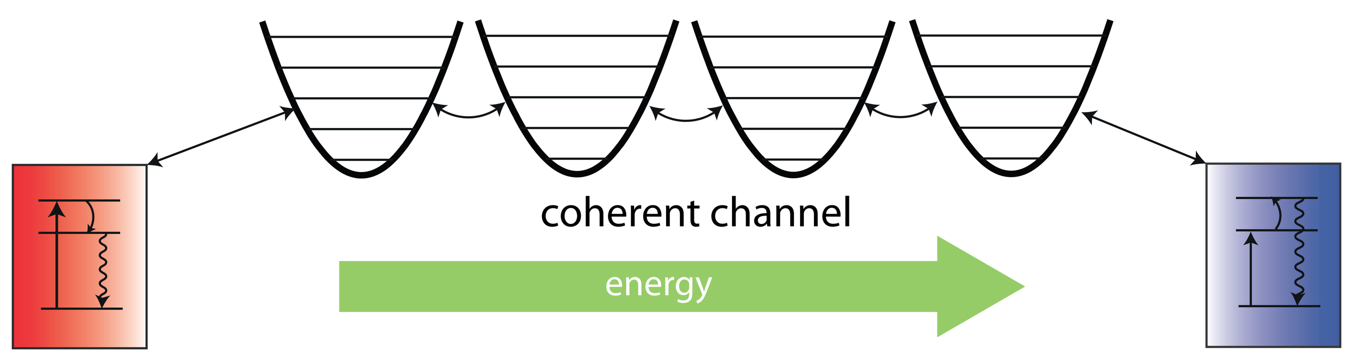


Ohm's law

$$j \propto \nabla U$$

energy transfer proportional to the gradient of potential

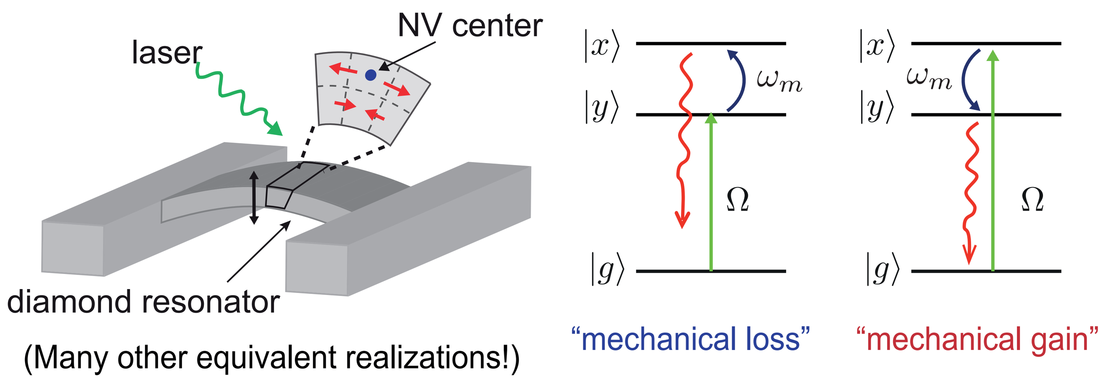
What is the energy transport at microscopic level?



energy transport between two quantum machines

Implementation

Phonon lasing/cooling in diamond [1]:

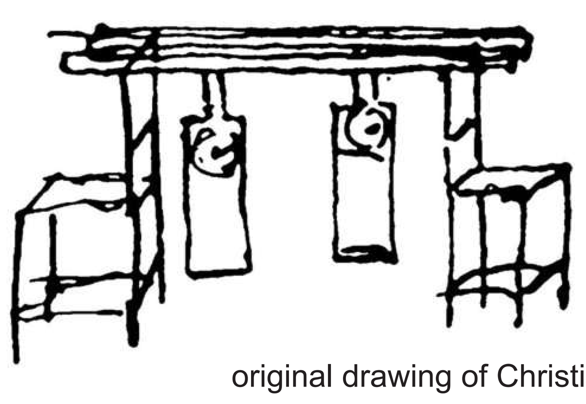


(Many other equivalent realizations!)

[1] K. V. Kepesidis, S. D. Bennett, S. Portolan, M. D. Lukin, P. Rabl, Phys. Rev. B 88, 064105 (2013)

Synchronization in gain/loss systems

Classical synchronization of two pendulum clocks



original drawing of Christiaan Huygens

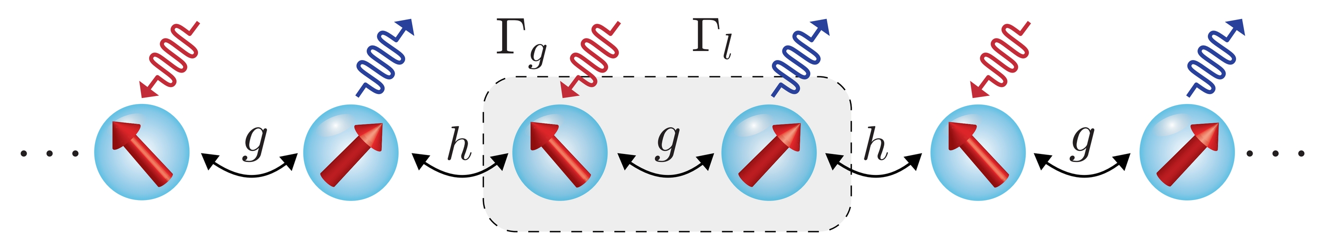
What is the synchronization between quantum systems with gain and loss?

Non-equilibrium magnetic phases in spin lattices with gain and loss

Motivation

Do quantum phases/phase transitions induced by dissipation exist?

Model



spin chain with alternating gain and loss

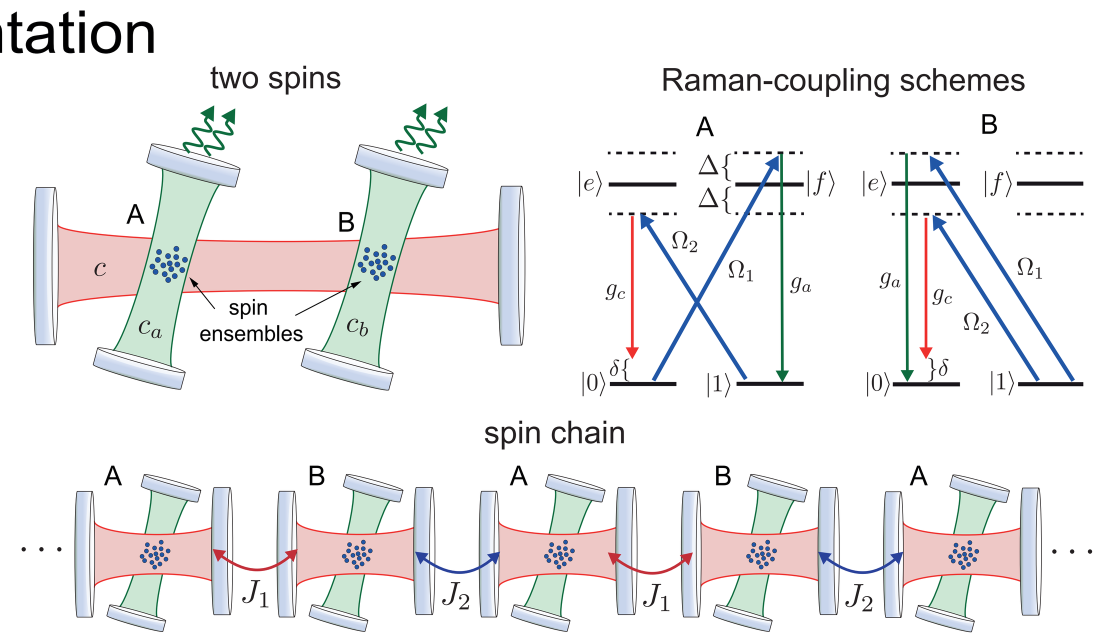
Master equation

$$\dot\rho = -i[\mathcal{H},\rho] + \tilde\Gamma_g \sum_n \mathcal{D}[S_+^{1,n}] + \tilde\Gamma_l \sum_n \mathcal{D}[S_-^{2,n}].$$

Hamiltonian

$$\mathcal{H} = \tilde g \sum_n \; S_+^{1,n} S_-^{2,n} S_-^{1,n} S_+^{2,n} + \tilde h \sum_n \; S_+^{2,n} S_-^{1,n+1} + S_+^{2,n} S_-^{1,n+1}$$

Implementation



PT-symmetry breaking in open quantum systems

Classical PT-symmetric system

Parity $\mathcal{P}(A\otimes B)\mathcal{P}^{-1} = B\otimes A$

Time reversal $\mathcal{T}_c i \mathcal{T}_c^{-1} = -i$

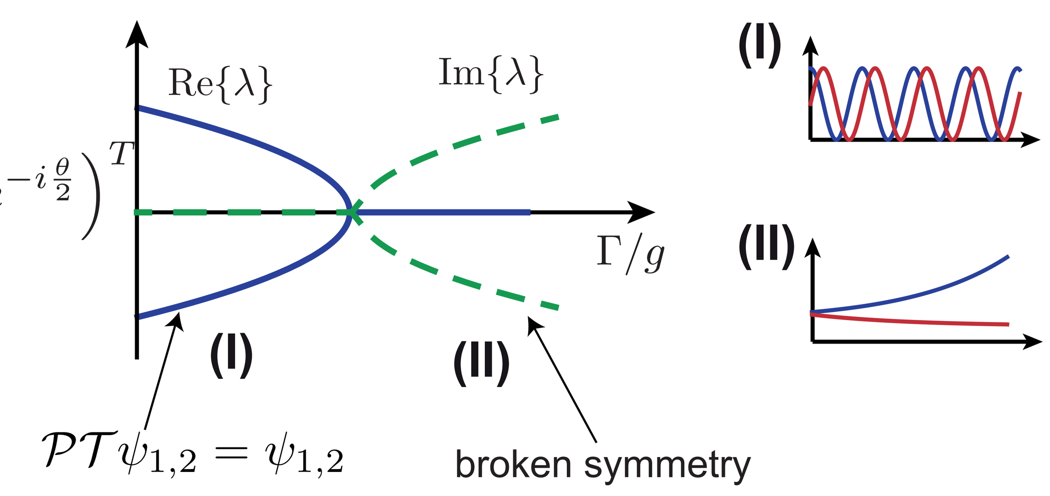
$$H = \begin{pmatrix} i\Gamma & g \\ g & -i\Gamma \end{pmatrix}$$

Eigenvalues: $\lambda_{1,2} = \pm\sqrt{g^2 - \Gamma^2}$

Eigenvectors:

$$\psi_{1,2} = \left(e^{i\frac{\theta}{2}}, \pm e^{-i\frac{\theta}{2}}\right)^T$$

$$\sin(\theta) = \Gamma/g$$



How is PT-symmetry breaking defined for open quantum systems?