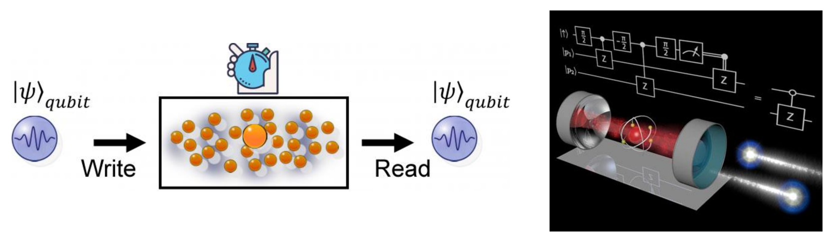
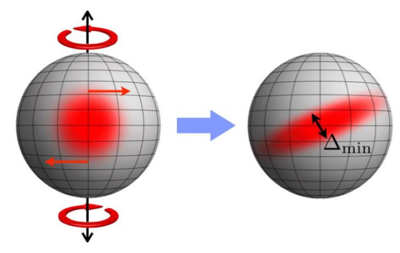
QuSiED:
Quantum Simulation with Engineered Dissipation

Motivation

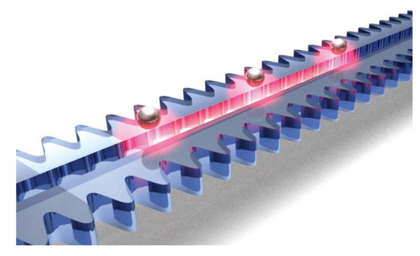
- **Quantum atom-light interfaces** are important foundation for quantum technologies



Q. communication and logic



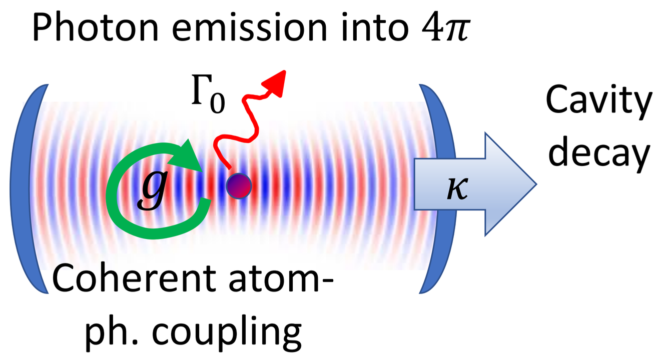
Q. metrology and sensing



Novel platforms for q. simulation

- **Key limitation: large, uncontrolled dissipation** in state-of-the-art platforms

Cavity QED

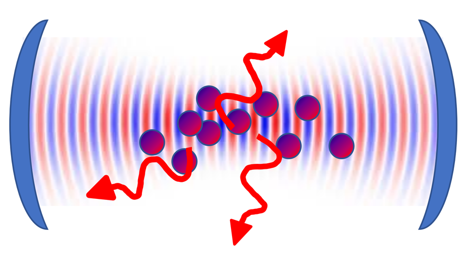


Key parameter:
Cooperativity $C = \frac{g^2}{\kappa\Gamma_0}$

- Errors/infidelities tend to decrease very slowly as function of improving cooperativity in known protocols

Novel approach

- Independent photon emission rate Γ_0 is an **assumption**
- Wave interference implies that emission is complicated function of atom number, positions, and wave function



$\Gamma(N, \{r_i\}, |\psi\rangle)$

- Exploit subspace of strong correlated dissipation $\Gamma(N, \{r_i\}, |\psi\rangle) \to 0$?
- **Polynomial or exponential improvements** in errors/infidelities versus cooperativity?

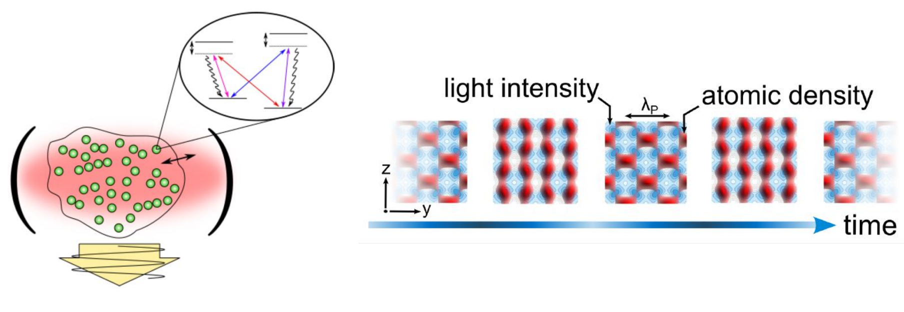
Challenges

Requirements to succeed:

- Achieve deterministic atomic spatial configurations with strong interference in emission (sub-wavelength arrays)
- Robust experimental means to tailor interactions and interface with light
- New theoretical tools and approaches for the challenging problem of many-body correlated dissipation
- Find interesting protocols and dynamics protected and enabled by correlated dissipation

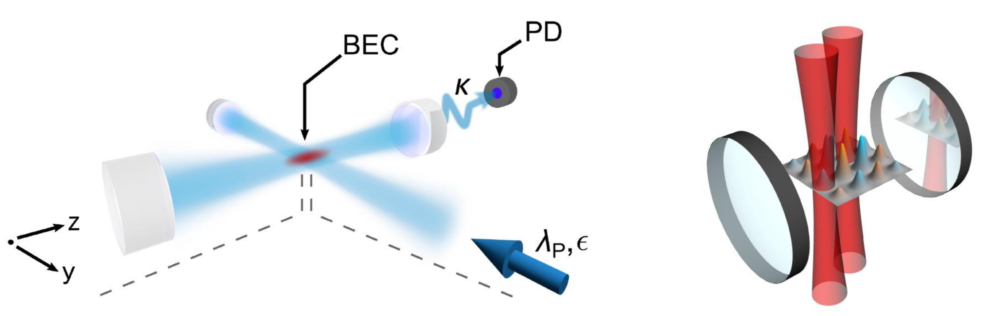
Key objectives

Novel phase transitions and dynamical phases



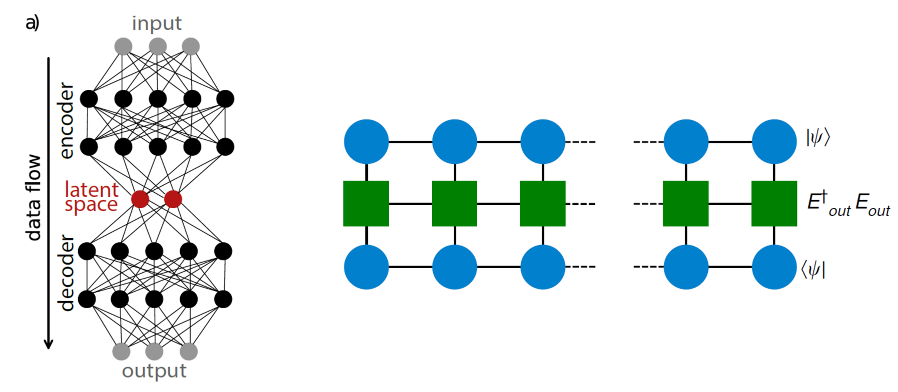
- ✓ Modified Dicke phase transitions w/correlated dissipation
- ✓ Controlling time crystals w/dissipation and feedback
- ✓ Universality classes in dissipative dynamics
- ✓ Stabilization of quantum many-body scars

Novel experimental platforms of QuSiED



- ✓ New, integrated cavity / Yb tweezer array
- ✓ BEC / Mott insulator coupled to cavity

New theoretical methods

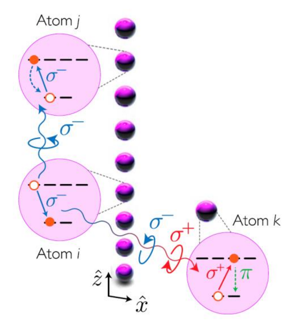


- ✓ Machine learning, neural network modeling
- ✓ Non-equilibrium Green's function techniques
- ✓ Tensor networks
- ✓ Weakly interacting fermion mappings

Theory/Expt interfaces

Quantum metrology

- ✓ Experimental characterization of quantum Fisher information
- ✓ Spin squeezing enabled by correlated dissipation
- ✓ New correlated dark states



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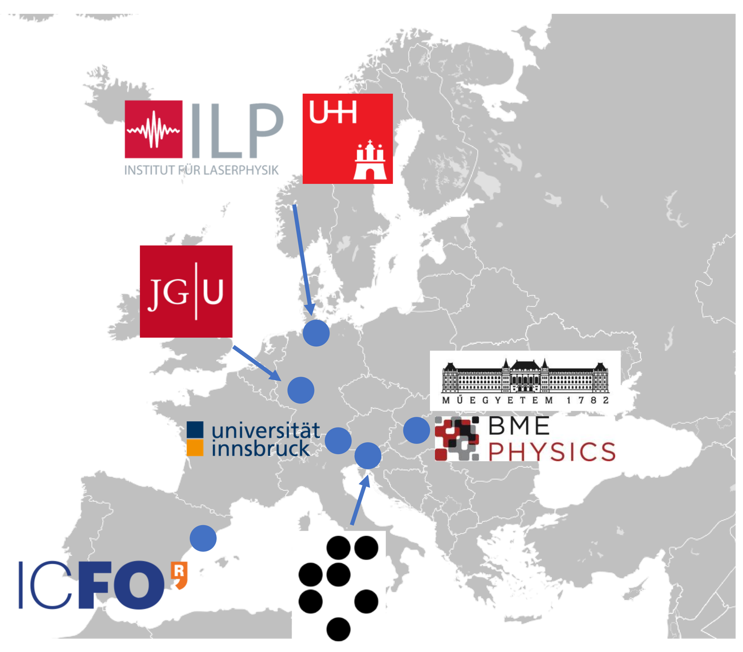

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