Small Quantum: Prof. Enrico Rossi – Quantum Materials

Quantum computing -> Anyons/Majoranas

To build a quantum computer we need Fault Tolerant qubits

We need error correction → 1 logical qubit -> 1000 or more physical qubits

Error correction codes: **Surface codes**

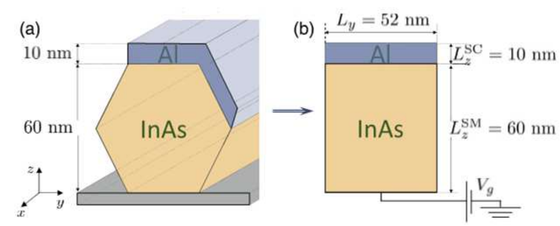
Kitaev realized that when using surface codes the state of a bit is really encoded in a topological state of the array of physical qubits

Why not to use systems that are intrinsically topological?

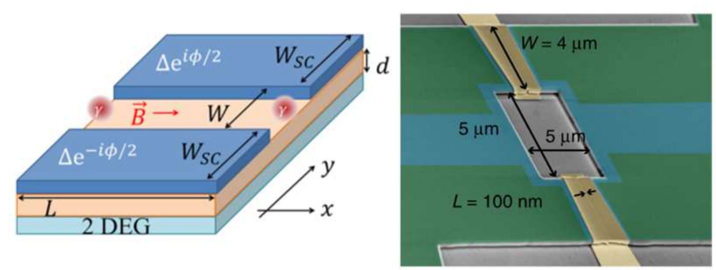
Topological superconductors: they have ground-state non-abelian anyons.
No excited states are used to encode information -> No decoherence

Two Possible Platforms for Fault Tolerant Qubits Based on Topological Quantum Materials

Majorana nanowires



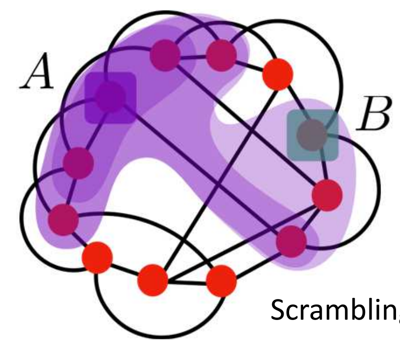
Topological Josephson junctions



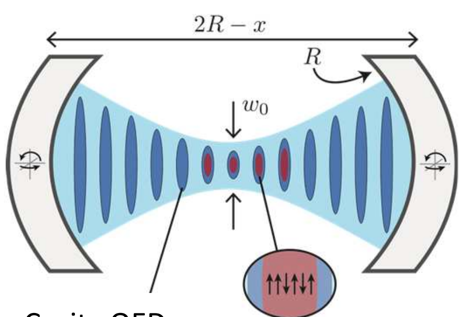
Small Quantum: Prof. Gregory Bentsen – Many-body quantum dynamics and quantum information scrambling

Quantum Information Scrambling

- Delocalization of information, info encoded into many-body entanglement
- Useful for hiding / protecting information from noise or eavesdroppers



Scrambling

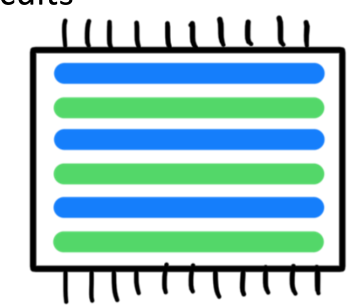


Cavity QED

Quantum Simulation

- Platforms: cavity QED, cold neutral atoms —> nonlocal interactions
- Simulating models of quantum gravity, nonlocal many-body systems

Brownian Circuits



Quantum Advantage

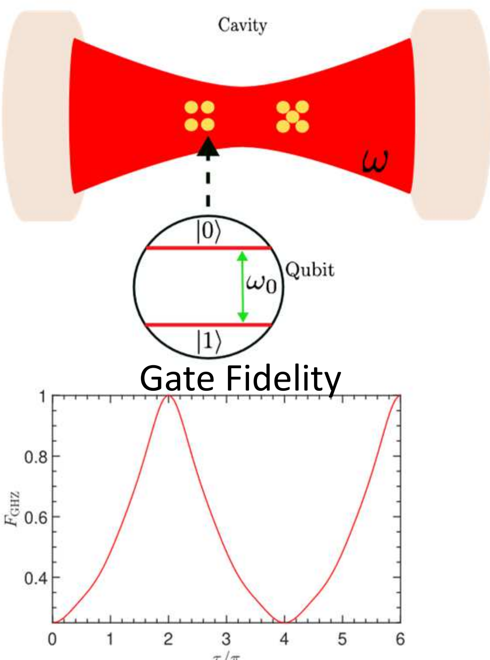
- What can *noisy* quantum devices do that classical devices cannot?
- Random circuit sampling with Brownian circuits

Small Quantum: Prof. Ebubechukwu Ilo-Okeke
Neutral Atom Technologies: Exploring Quantum frontiers with Atoms

We manipulate and control the quantum states of atoms to:

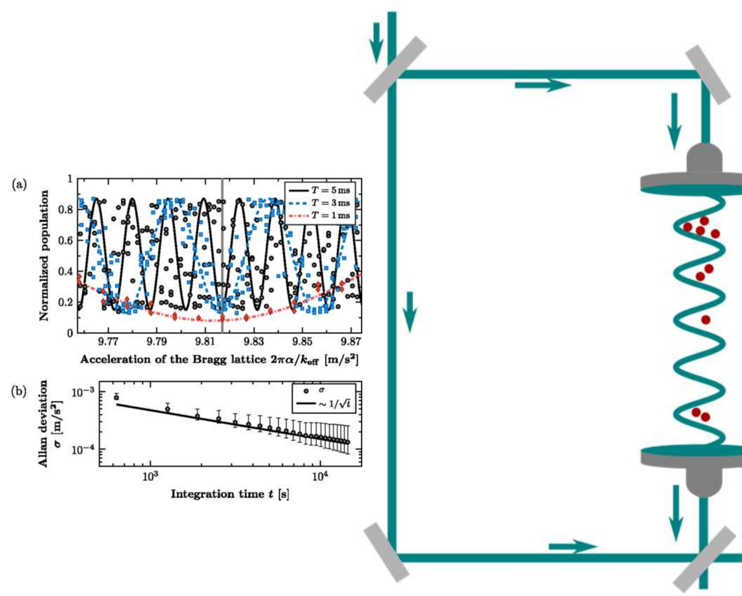
- ☐ Build quantum technologies like atomic clocks and sensors
- ☐ Design efficient quantum algorithms and gates
- ☐ Explore superposition and entanglement for computation.

Neutral atom entanglement



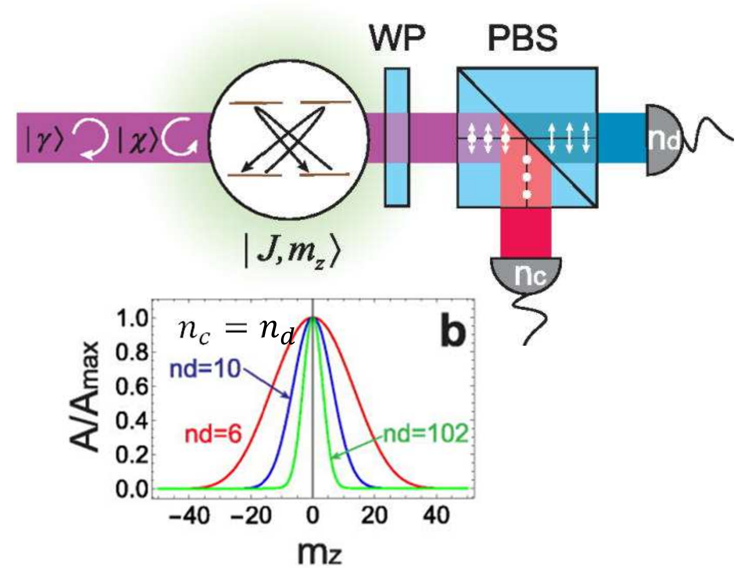
Designing quantum gates for many-atom entanglement

Linear Force Sensing with Atoms



Using atoms to measure tiny forces with precision

Quantum non-demolition measurement of atom ensembles



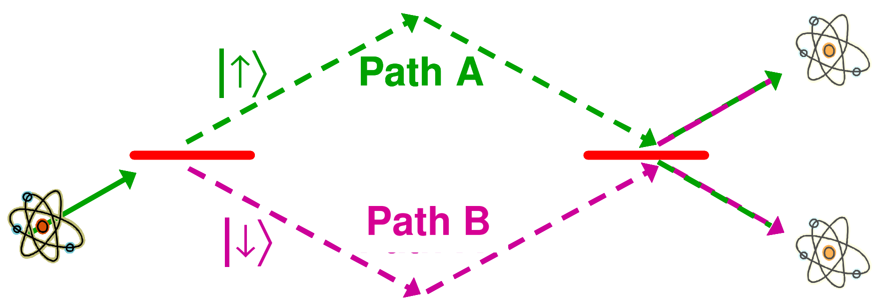
Detecting quantum states with minimal destruction

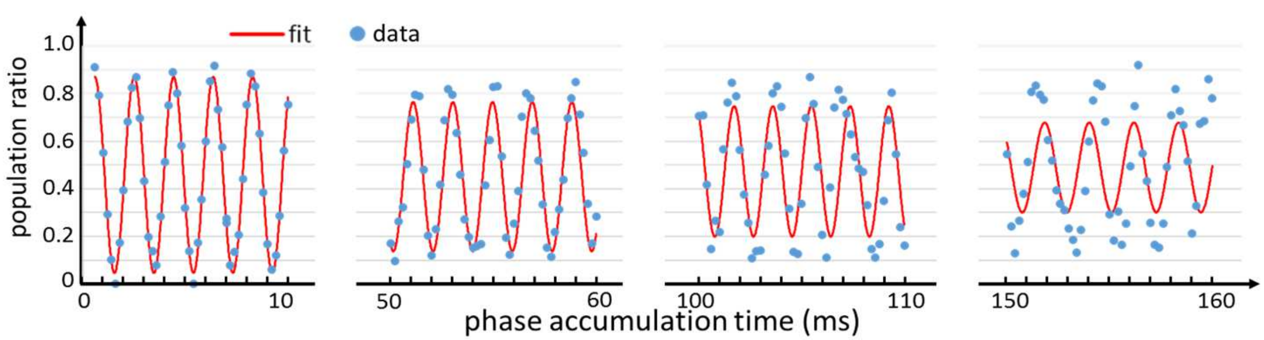
Small Quantum: Prof. Seth Aubin – Cold quantum atoms in quantum wells

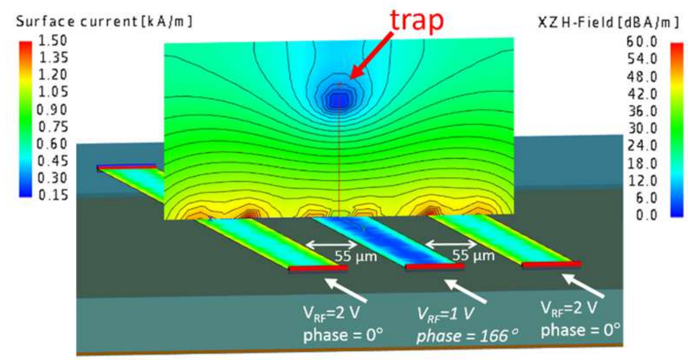
Spin-dependent interferometer.

→ An ***"atomic clock"*** with spatially separated clock states.

→ Designed to work with ultracold thermal atoms, quantum gases.

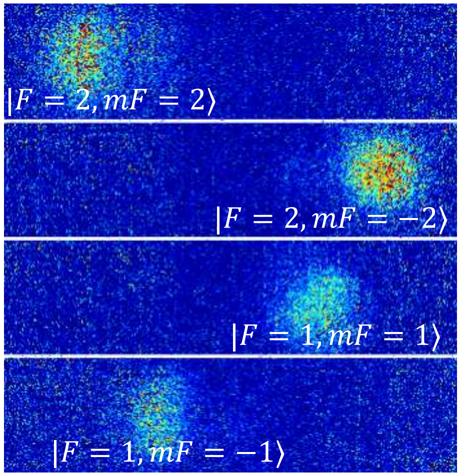






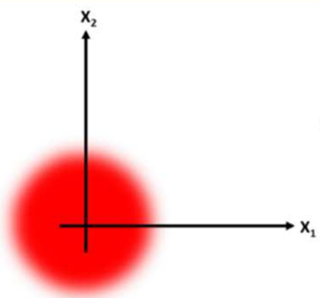
[FEKO EM simulations at 6.8 GHz]

RF chip trap (spin-dependent)



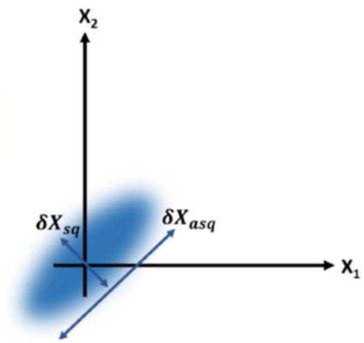
Small Quantum: Profs. Eugeniy Mikhailov and Irina Novikova – Hot quantum atoms and quantum lignt

Coherent vacuum

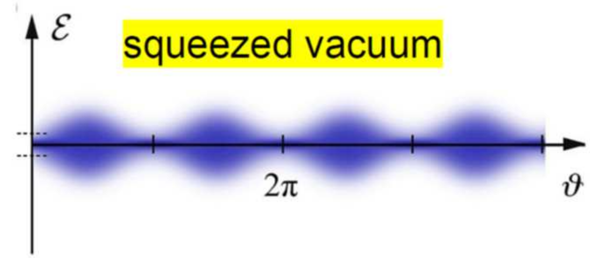


Quadrature squeezing

$$\hat{S}|\alpha\rangle = e^{\xi(\hat{a}\hat{a}-\hat{a}^\dagger\hat{a}^\dagger)}|\alpha\rangle$$

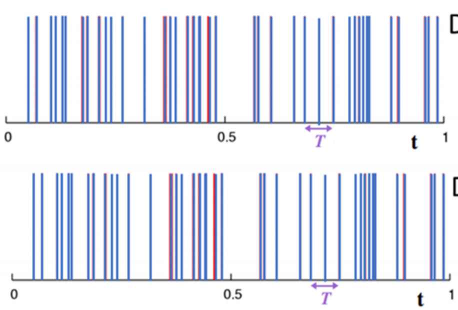


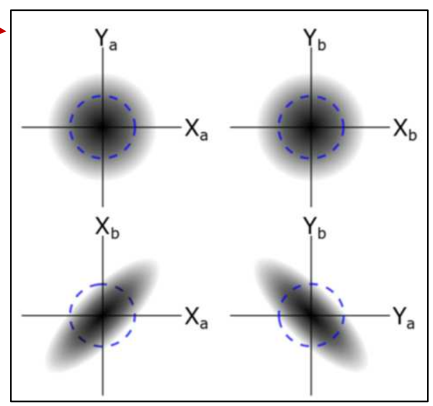
squeezed vacuum



Two-mode squeezing

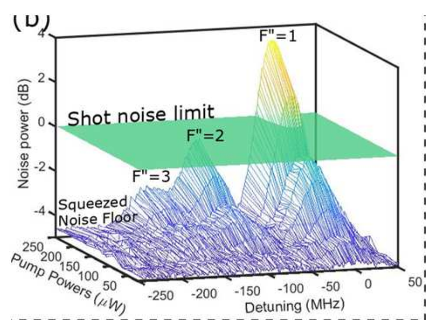
$$\hat{S} = e^{\xi(\hat{b}^\dagger\hat{a}^\dagger-\hat{a}\hat{b})}$$



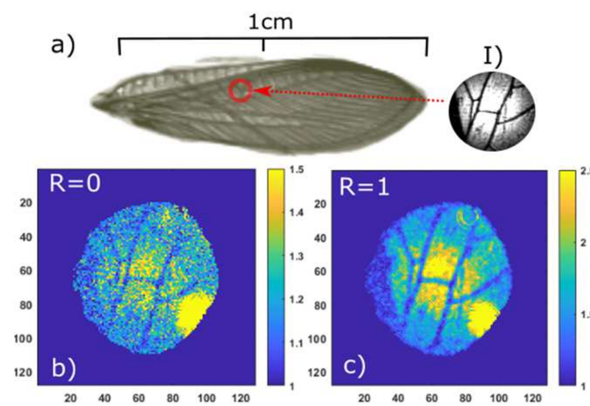


Applications

Quantum-enhanced measurements

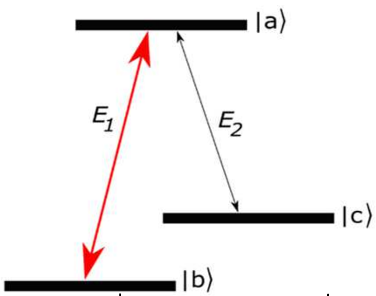


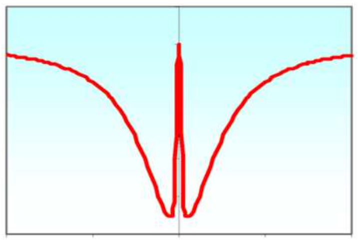
Quantum-noise imaging



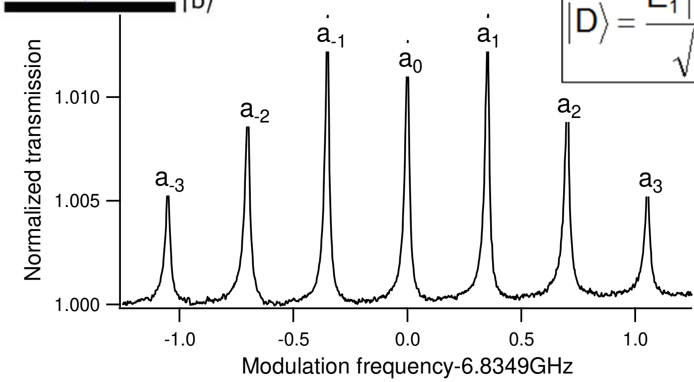
Small Quantum: Profs. Eugeniy Mikhailov and Irina Novikova – Hot quantum atoms and quantum light

Precise measure of electron spin energy levels: precision magnetometry





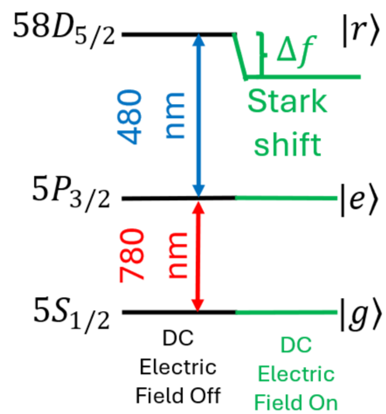
$$|D\rangle = \frac{E_1|b\rangle - E_2|c\rangle}{\sqrt{E_1^2 + E_2^2}}$$

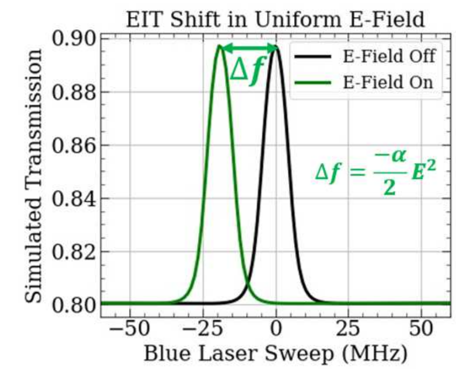


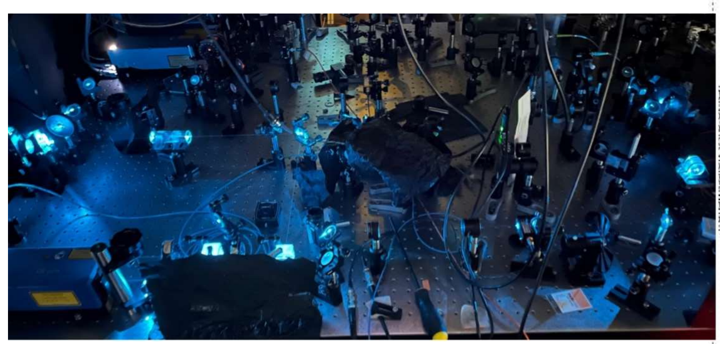
Compact clock: stability 10^{-12}

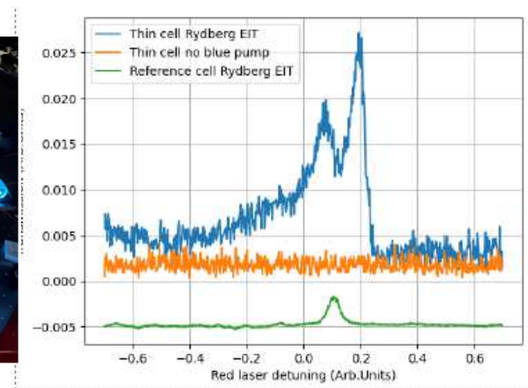
Magnetometer: sensitivity 10pT and potentially 100fT in small volume

Precise measure of highly excited (Rydberg) states: precision electrometry



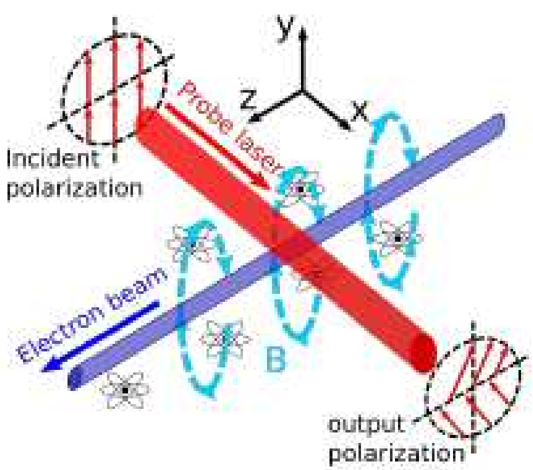


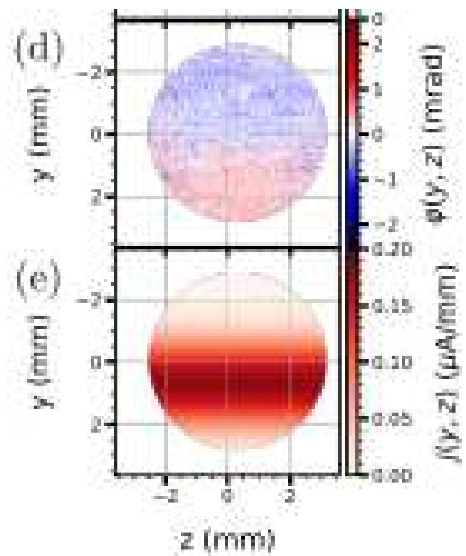




Broader applications of quantum

Quantum Electron Tracker
Mikhailov, Novikova, Aubin, Averett





Quantum Electric field Detector in Plasmas
Novikova, Mikhailov, Aubin, Mordijck