1-19, Ohmori PJ, Ohmori-PI, Institute for Molecular Science, Sylvain de Léséleuc

moonshot 大森 PM

大規模・高コヒーレンスな動的原子アレー型・誤り耐性量子コンピュータ

Cold-atom-based quantum computer: roadmap

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Project Structure

Management team

- PM: Prof. Kenji Ohmori
- Administration (sub-PMs, secretaries)
- Legal & IP (public bid, contracting, patents)
- Industrialization / commercialization (support by NINS desk)
- Outreach (websites, events, internships, collaborations)

Project Investigators

- Cold-atom: [Ohmori, Sylvain, Tomita] @ IMS (Rubidium)
  Takahashi @ Kyodai (Ytterbium)
  Fukuhara @ RIKEN (Strontium)
- Laser: Taira @ IMS
- Software: Yoshimura @ Hitachi
- Others in contracting stage

Project Goals

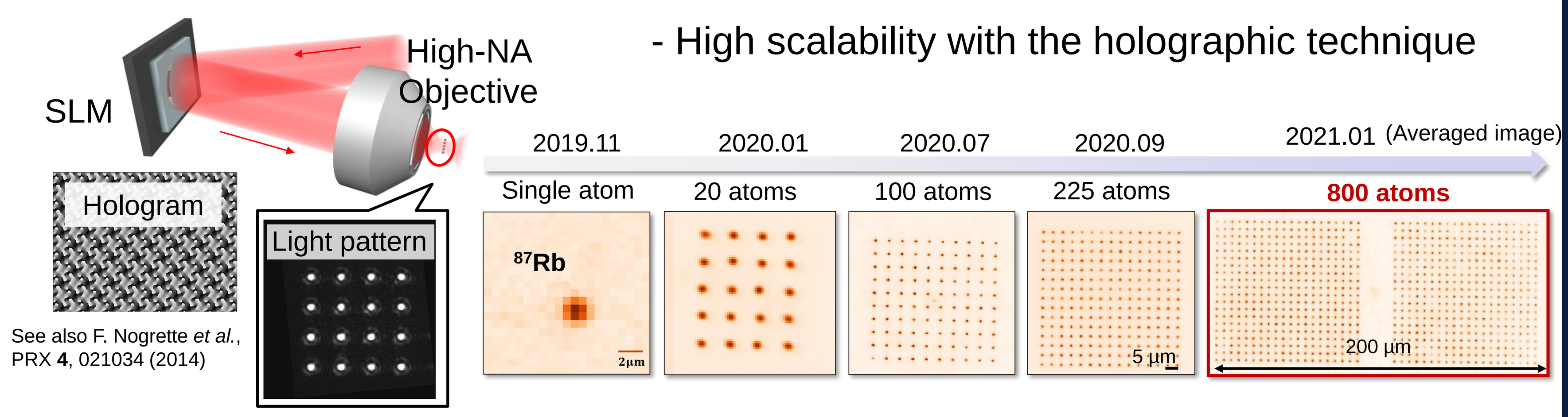
Implement a "dynamical qubit array" in which a large number of cold-atom qubits are assembled with optical tweezers and moved arbitrarily at high speed to perform gate operations as well as error detections and corrections.

Close industry-academia collaborations: all components will be integrated and packaged to achieve unprecedentedly high stability and usability.

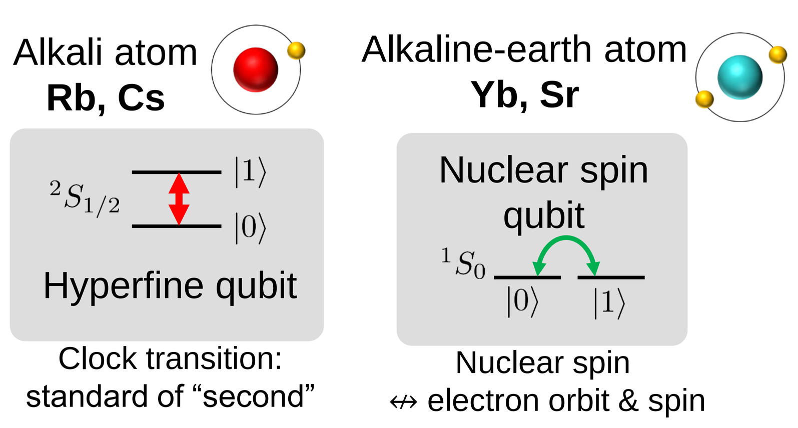
Characteristics of Cold-Atom QC

Optical tweezers array

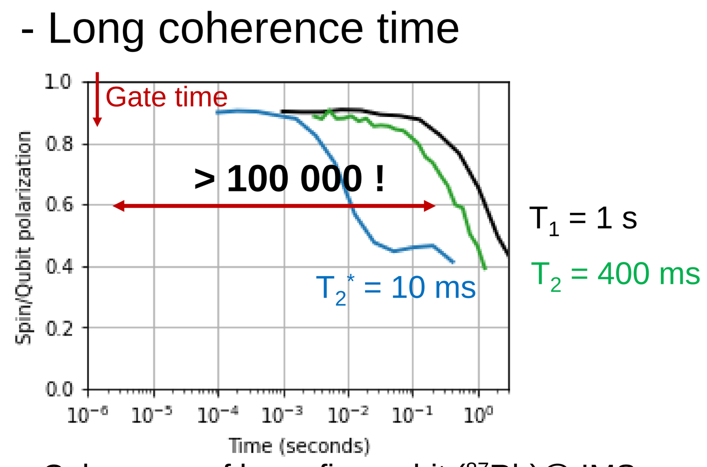
- High scalability with the holographic technique



Moveable Atomic Qubit

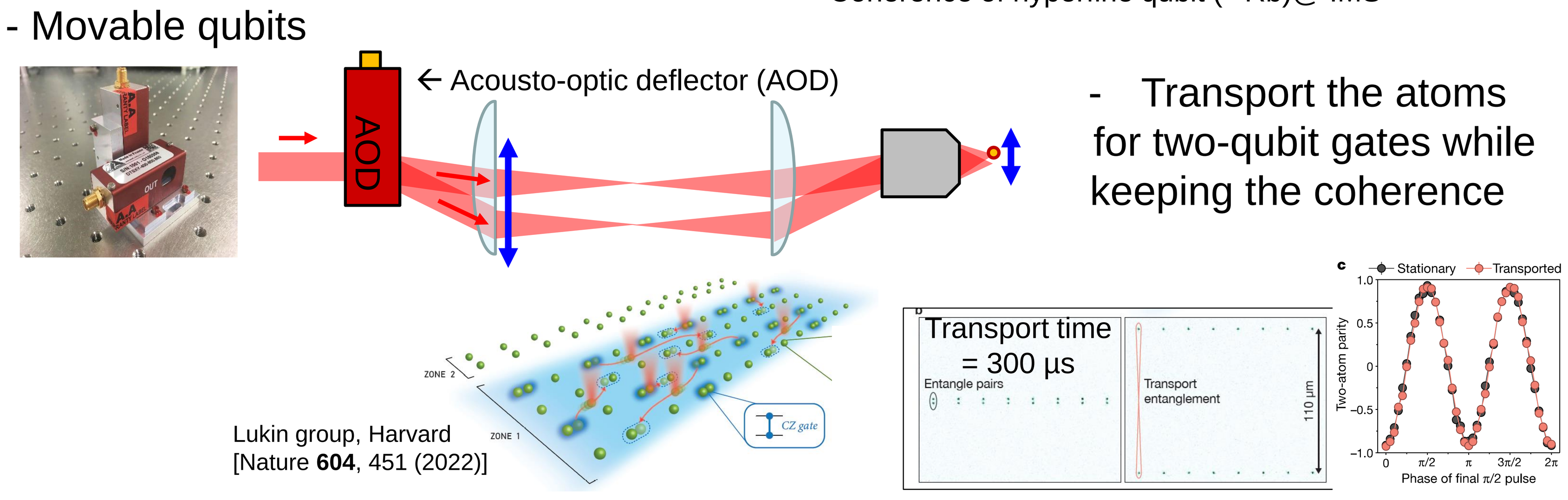


- Long coherence time



Coherence of hyperfine qubit (^{87}Rb)@ IMS

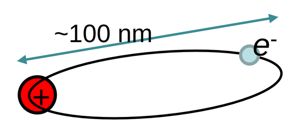
- Movable qubits



- Transport the atoms for two-qubit gates while keeping the coherence

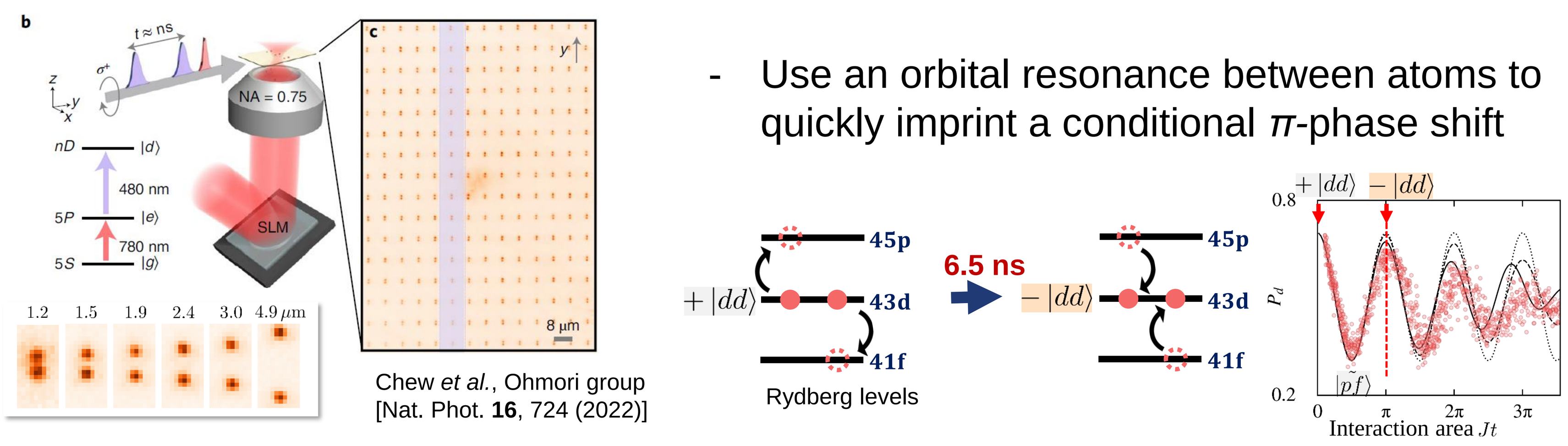
(Ultrafast) Gate with Rydberg atoms

- Rydberg state



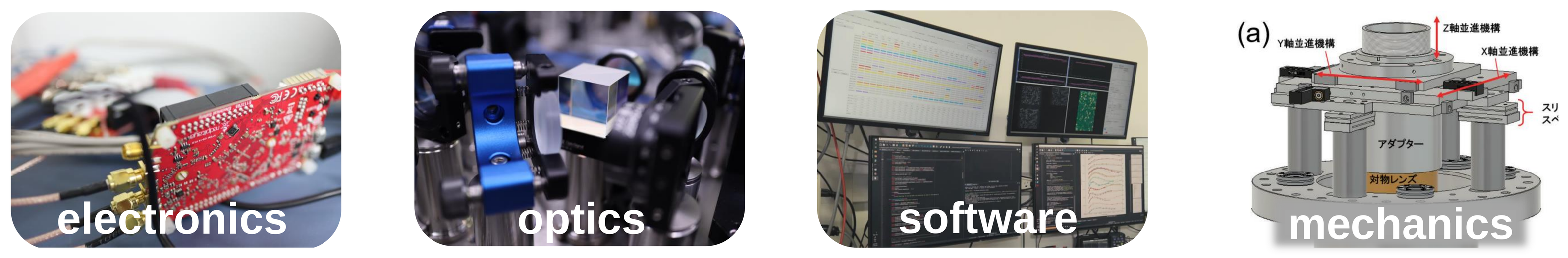
- ✓ Short atomic distance + absolute zero temperature
- ✓ Large orbit, large dipole → dipole-dipole interaction
- ✓ Strong interaction: blockade gate (µs)
  direct-interaction gate (ns)

- Use an orbital resonance between atoms to quickly imprint a conditional π-phase shift

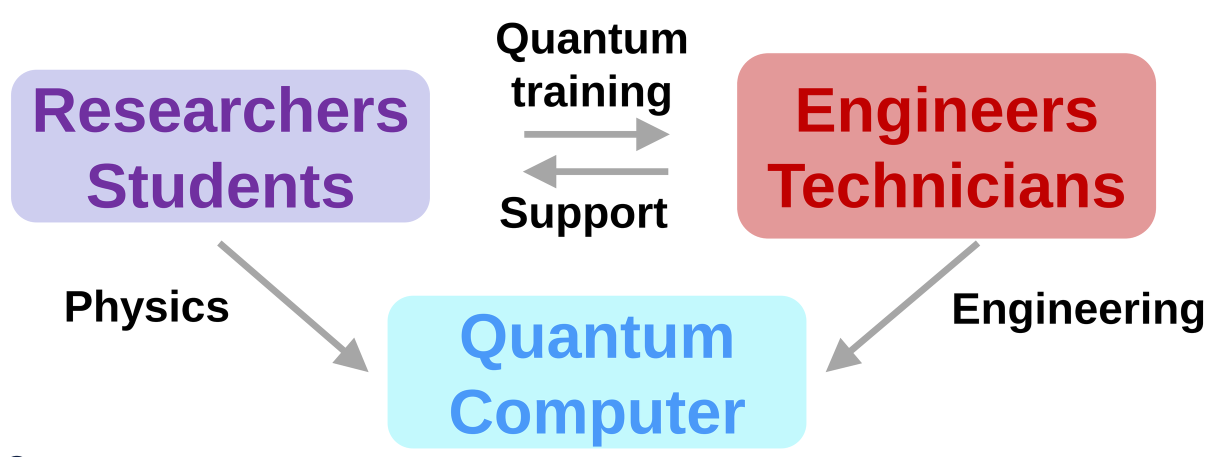


Chew et al., Ohmori group [Nat. Phot. 16, 724 (2022)]

Engineering & Technical Team



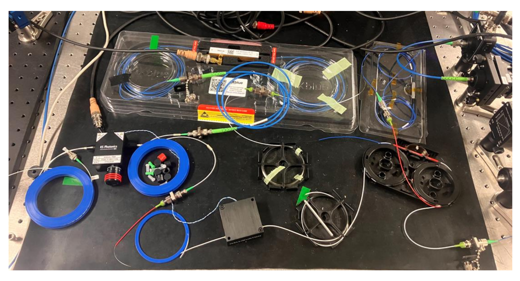
Cold-atom-based QC are complicated systems in which not only physics but various technologies are involved and intricately intertwined. To support our research, we are training an engineering and technical team specialized in the above topics.



Optics

Use fiber-based devices for compact and reliable optical systems.
A technician is being trained to make advanced, fiber-based, optical circuits such as a laser noise canceller or an ultrafast switch.

Ex.: interferometer circuit

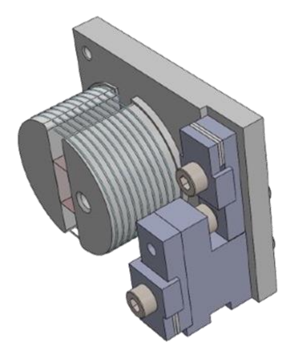


- ✓ easy to assemble using a conventional fiber fusing machine. One month of training is sufficient to work alone.
- ✓ free-space optics (EOM, AOM, attenuators, …) can be replaced.
- ✓ compact, scalable and stable systems

Mechanics

Design and construct mechanical components which are unavailable to purchase.
A specialist in mechanical engineering is now working with us.

Ex.: fiber stretcher



- ✓ 3D CAD design of various components.
- ✓ Advanced processing machinery in the institute, including metal processing and 3D printing.
- ✓ Collaboration with fiber technician to construct a much more integrated system, such as a fiber noise canceller.

Perspectives

Strengthen the staff: laboratory assistants, electronics and software engineers.
Collaborate within the cold-atom Moonshot and with other platforms projects.
Train engineering and technical staff to support quantum computers.

Outreach & Collaboration activities

Attract and train the new generation

- outreach in high-schools (open-day campus, GIGA school event, on-site lectures)
- discovery internship for undergrads (summer/winter-breaks, part-time jobs)
- master internships for national and international students
- graduate-school sessions on cold-atom technologies and QC
- financial supports during studies, job perspectives in quantum industry

Emphasize Moonshot on the international scene

- attract young international talents (MOU for internships/exchange, PhD programs)
- communicate public Moonshot results at international conferences

Create a vibrant community of researchers

- Network: laboratory visits, exchange of students/researchers, seminars.
- Share knowledge: technical workshops, online discussions, collaborative projects.
- Online QC operation: widen the cold-atom QC user community

Link the Moonshot projects

Various technologies can be shared across Moonshot QC platforms
- Theory: error detection and correction, gate protocols, quantum algorithms
- Software: full stack from user-level to machine-level
- Hardware: optical systems (lasers, optical circuits), electronics