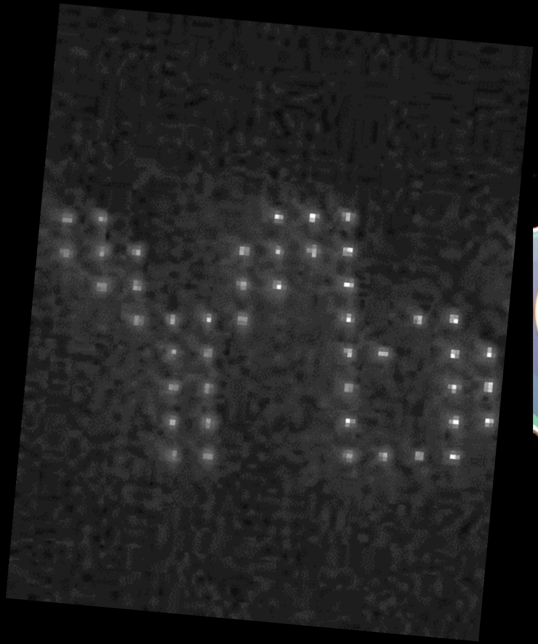
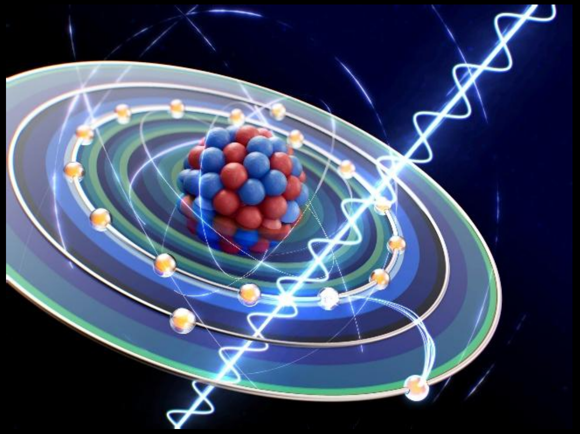
# ICEPP-QUP
# Quantum Workshop 2026

Koshiba Hall
University of Tokyo
5/18 2026

# New Physics Search Using Ultracold Atoms





**Kyoto University**

**Yoshiro Takahashi**

# Kyoto University Quantum Optics Group

Quantum Sensing

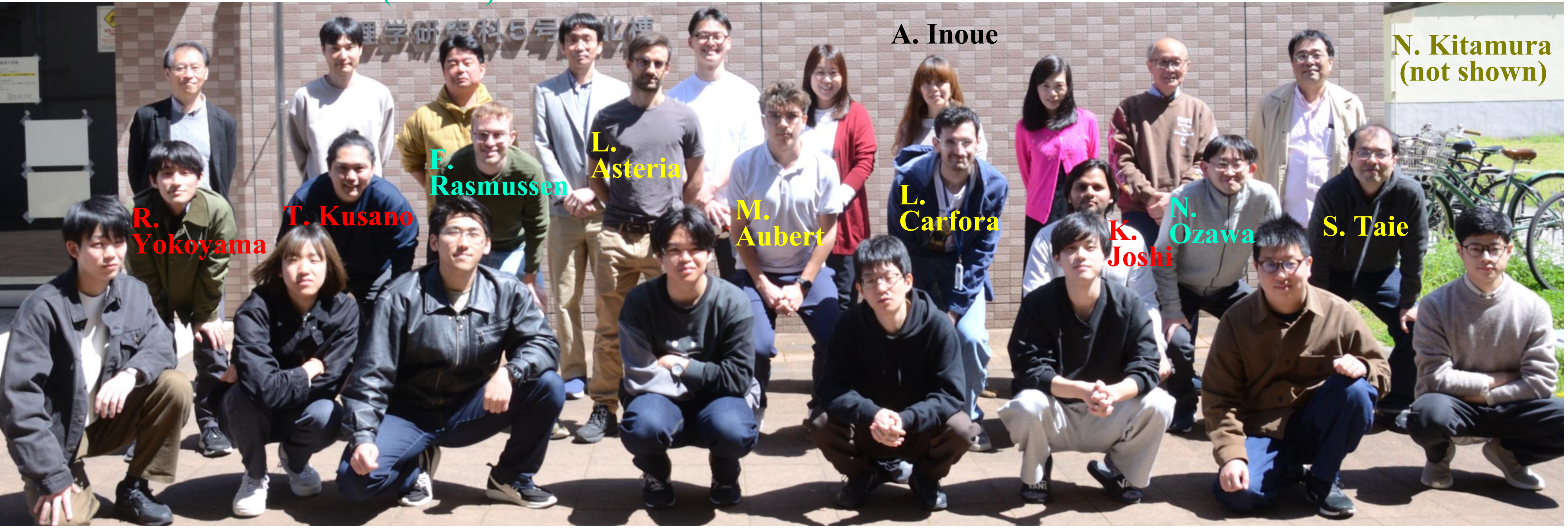
Quantum Computing

Quantum Simulation

Theory Collaborators:
M. Tanaka (Osaka)
Y. Yamamoto (KEK)
A. Sunaga (Hokkaido)
R. Takagi (Tokyo)

Chih-Han Yeh (→nano QT)

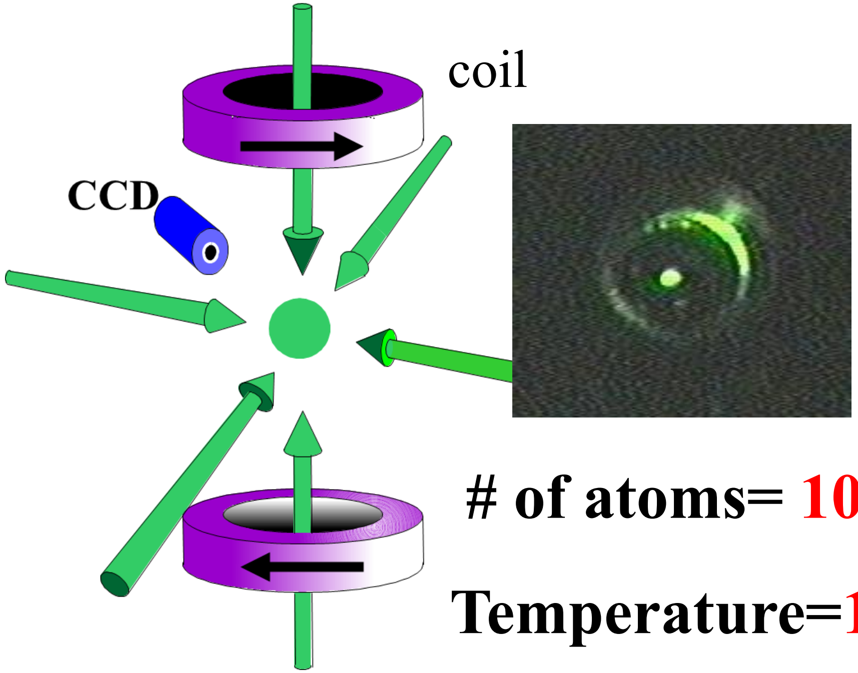
YT K. Ono T. Takano (Hakubi) K. Shibata M. Yasuhara K. Terakawa Uchida Y. Takasu




S. Moda M. Yamamoto M. Oka Y. Kawamura S. Kanai T. Kashimoto Y. Nishikawa R. Asano

# Laser Cooling and Trapping of Neutral Atoms

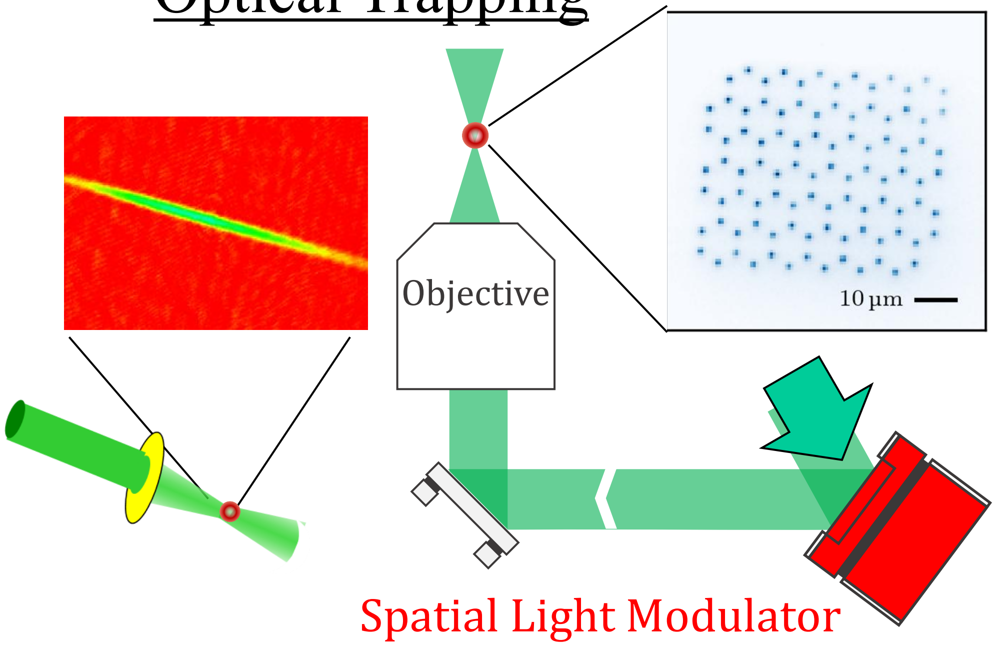
## Magneto-Optical Trapping



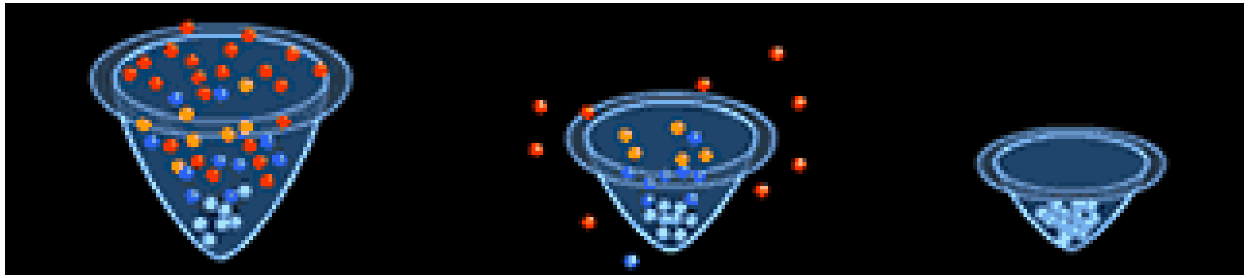

# of atoms= $10^8$

Temperature=12μK

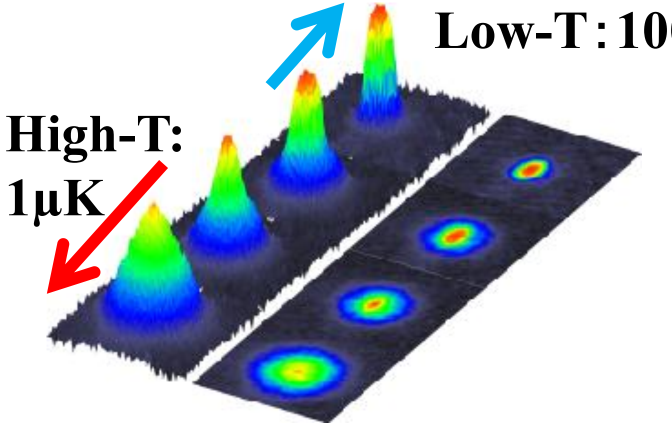
## Optical Trapping



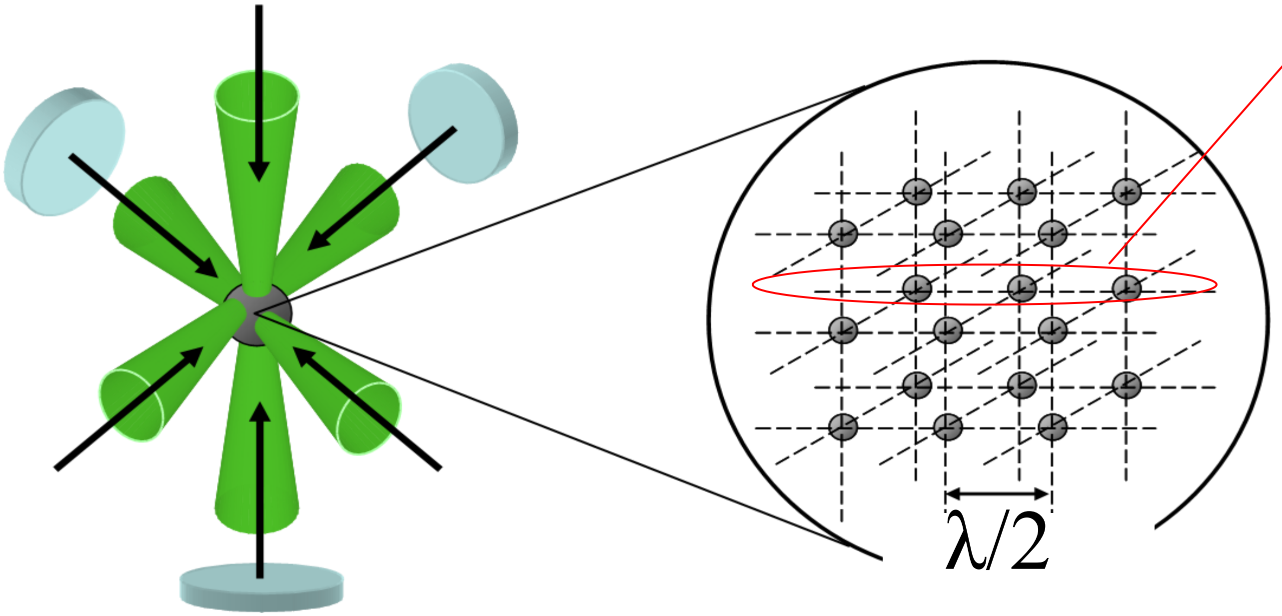

## Evaporative Cooling

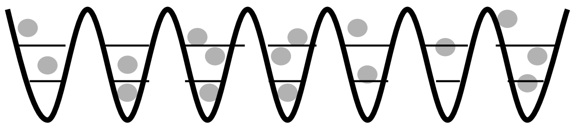


## "Bose-Einstein Condensation"



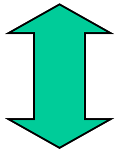
# Optical Lattice Quantum Simulation



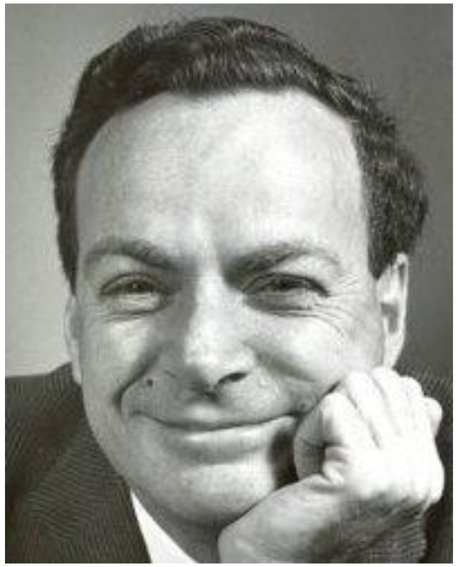



$$V_o(x) = V_o \sin^2(k_L x)$$

**Ultracold Atoms moving in Optical Lattice**



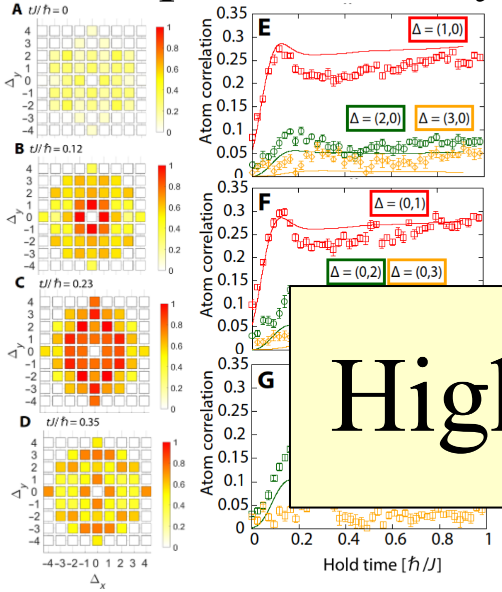
**Solid： Electrons moving in Crystaline Lattice**



R. Feynman

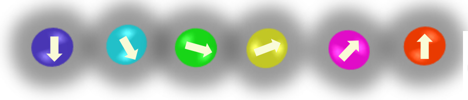
http://ijinwarosu.seesaa.net/article/169371287.html

## Nonequilibrium Dynamics

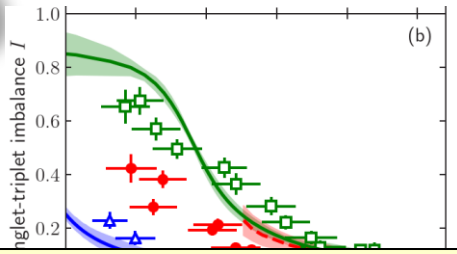



(Takasu *et al.*, Sci.Adv.2020
Honda *et al.*, Sci.Adv.2025)

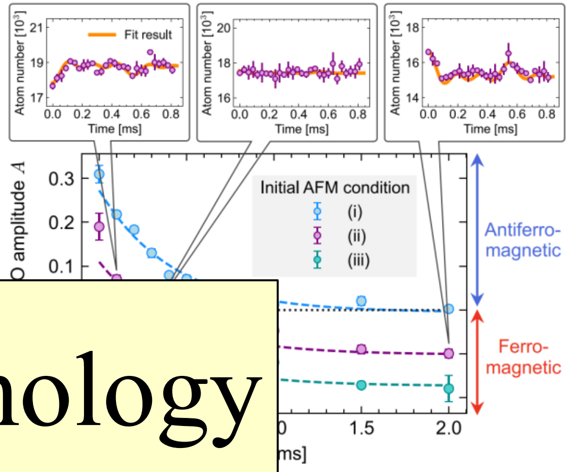
## SU(N)Quantum Magnetsim



Lowest Temperature
of cold Fermi gas

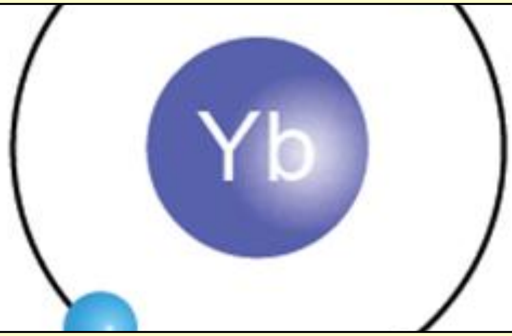


## Open Quantum System

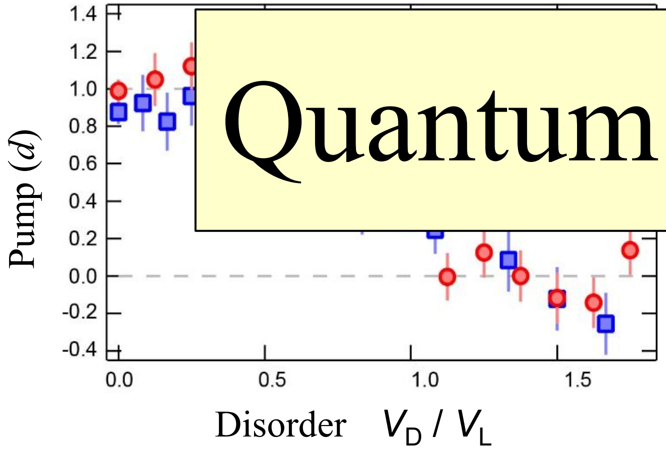



# High-Level Quantum Control Technology

(Honda *et al.*, PRL2023,
Tomita *et al.*, Sci.Adv.2017
Tsuno *et al.*, Nat.Com.2025)



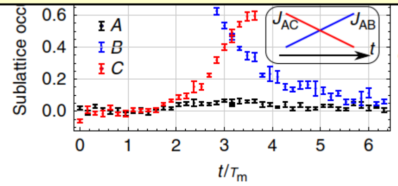

## Topology/disorder



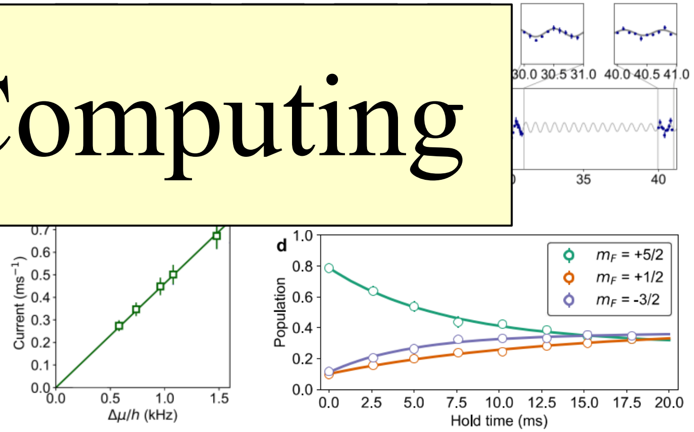

(Nakajima *et al.*, Nat.Phys.2021)

## Quantum transport

# Quantum Sensing / Quantum Computing




(Taie *et al.*, Nat. Com.2020
Kumar *et al.*, PRAL2021)




(Ono *et al.*, Nat.Com.2021, PRAL2021)

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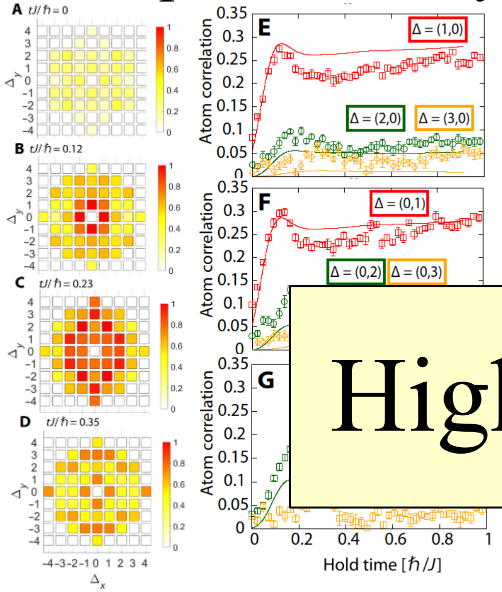


(Takasu *et al.*, Sci.Adv.2020
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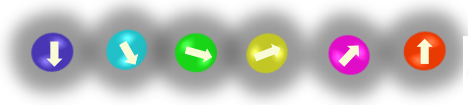

Lowest Temperature
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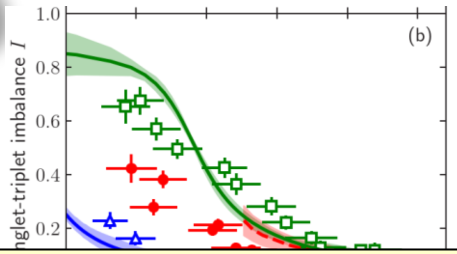
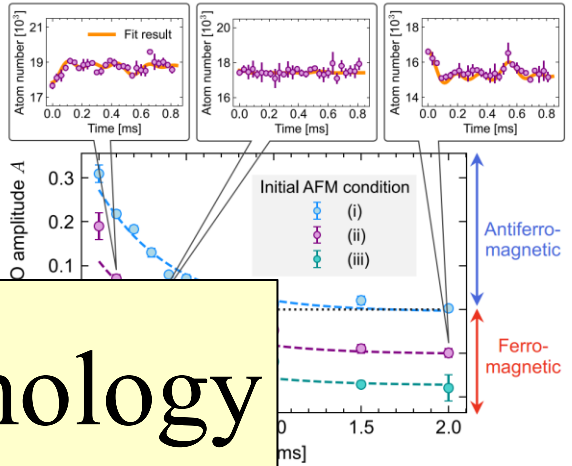


## Open Quantum System




(Honda *et al.*, PRL2023,
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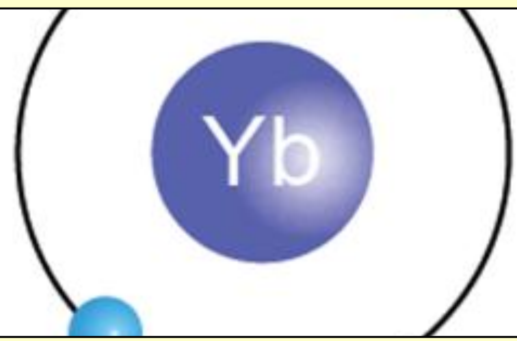
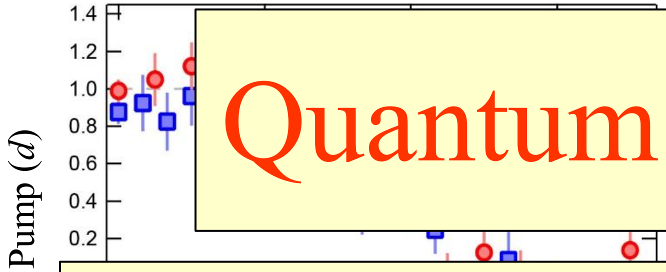
Tsuno *et al.*, Nat.Com.2025)

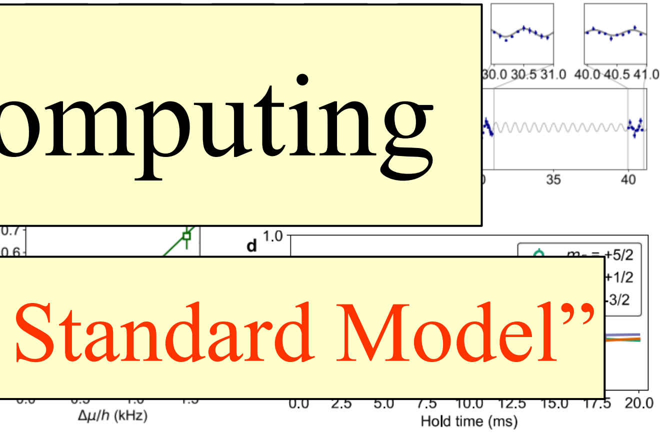
# High-Level Quantum Control Technology




## Topology/disorder




## Quantum transport




# Quantum Sensing / Quantum Computing

## "Quantum Sensor for New Physics Beyond the Standard Model"

(Nakajima *et al.*, Nat.Phys.2021)

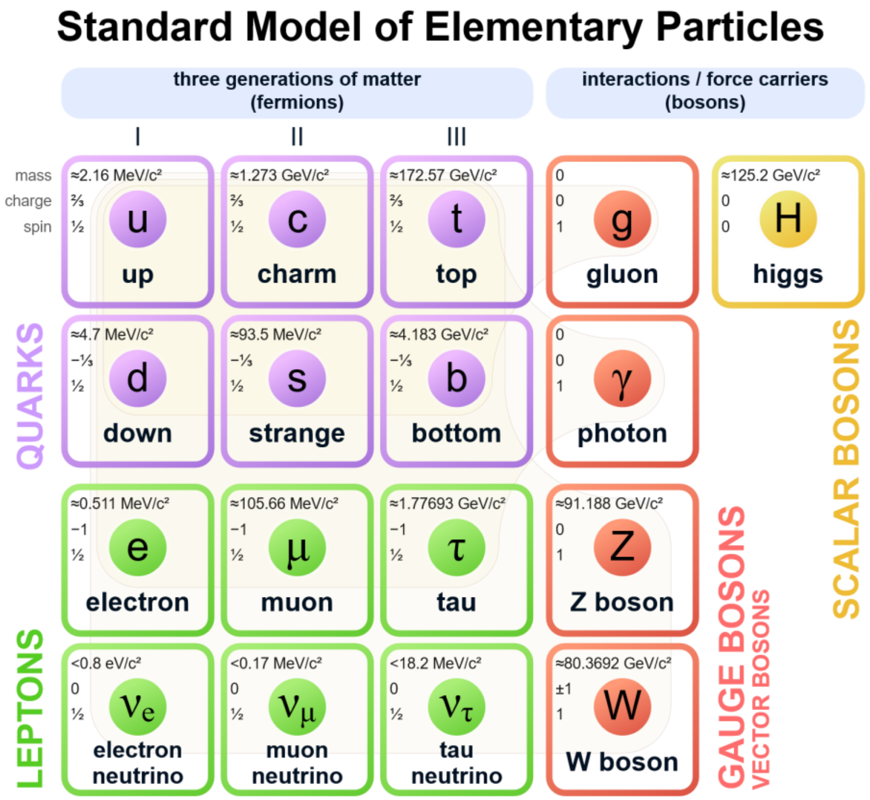
(Taie *et al.*, Nat. Com.2020
Kumar *et al.*, PRAL2021)

(Ono *et al.*, Nat.Com.2021, PRAL2021)

# Standard Model and New Physics

## Standard Model (SM)

- Explain three fundamental forces (electromagnetic, weak, strong interactions)
- Describe a lot of particle-physics phenomena



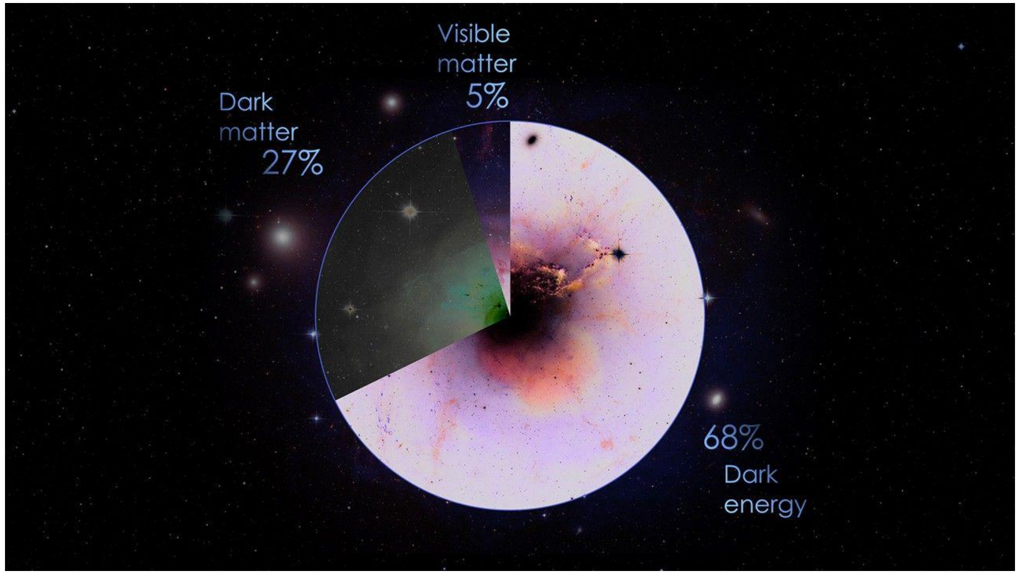

Cited from Wikipedia

Review: Phys. Rev. D, **110**, 030001 (2024).

## Problems of SM

- ☐ Hierarchy problem
- ☐ Unification of SM and general relativity
- ☐ Dark matter and dark energy

95% of the universe cannot be explained.




Cited from NASA website

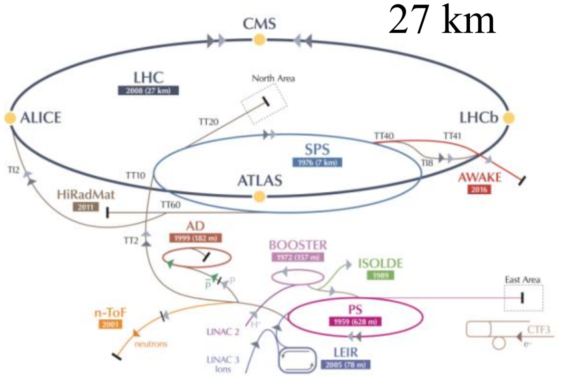
New Physics beyond the Standard Model must exist.

# Standard Model and New Physics

## Accelerator experiments

e.g.) Large Hadron Collider (LHC) at CERN

27 km




Cited from the CERN website


## Cosmological observation

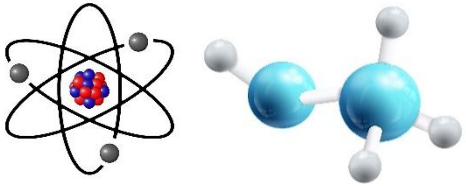
e.g.) Simons Observatory

Cited from the Simons Observatory website


## Low-energy precision measurements

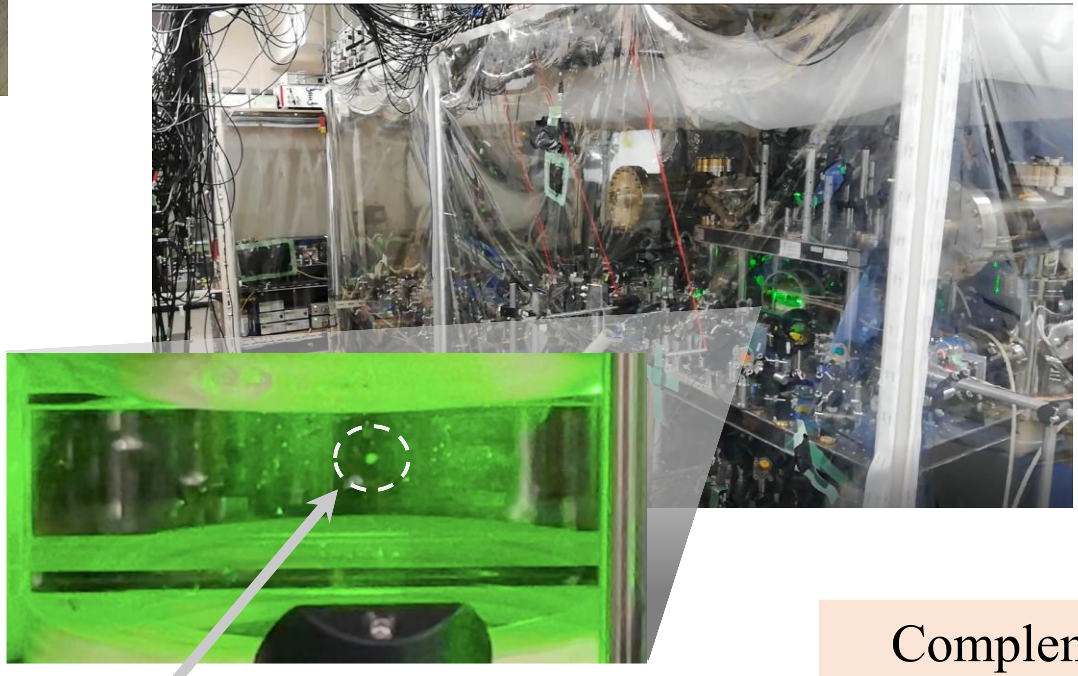
Review: Rev. Mod. Phys. **90**, 025008 (2018).

- Based on AMO (atomic, molecular and optical) physics



- Table-top experiments

  e.g.) Our apparatus (~100 m$^2$)

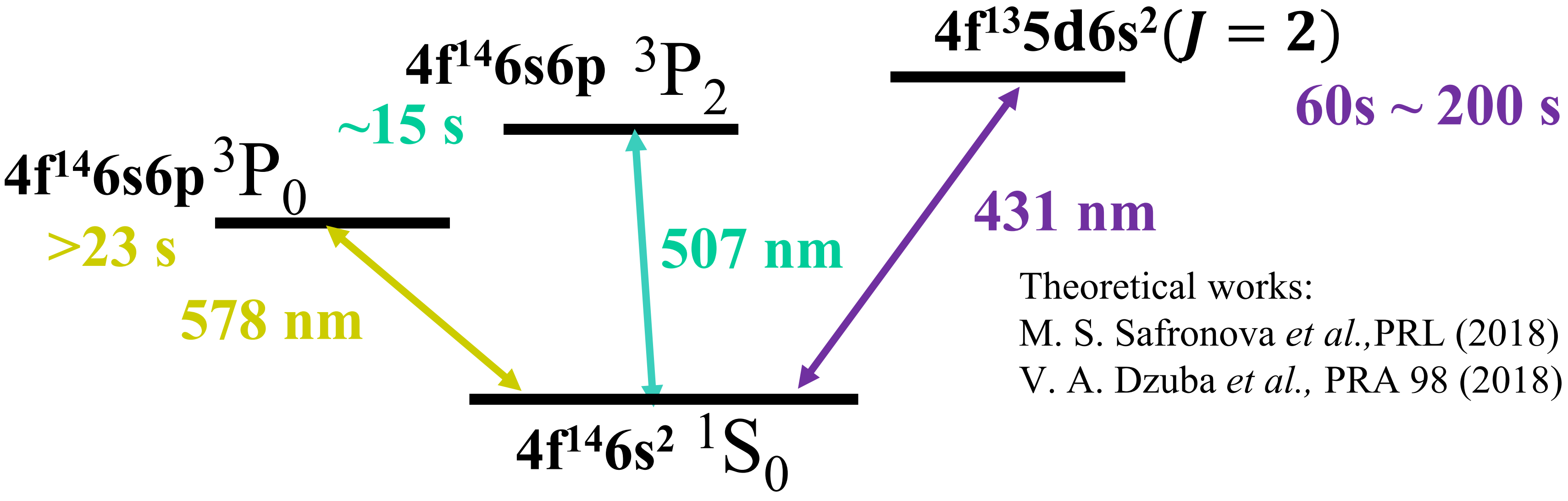


~$10^7$ Yb atoms trapped by laser light

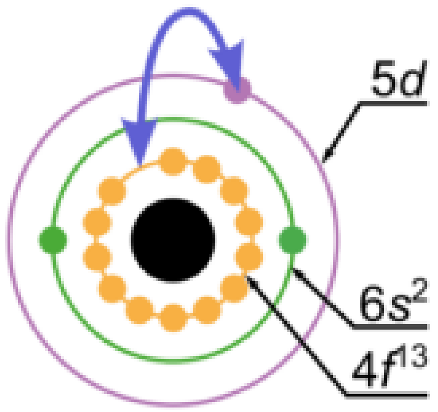
Complementary to other approaches

# Quantum Sensor for New Physics

**Yb Atom: *Long-Lived Metastable States (>10 s) & Ultra-narrow Optical Transitions* (~mHz)**




Theoretical works:
M. S. Safronova *et al.*,PRL (2018)
V. A. Dzuba *et al.*, PRA 98 (2018)




✓ Very sensitive to several kinds of new physics！

- Parity-, Time-Reversal-Violating nuclear moment (MQM): $\hat{H}_{\mathrm{MQM}} = -\sum_{i,j} \frac{1}{6} \mathcal{M}_{ij} (\nabla \mathcal{B})_{ij}$

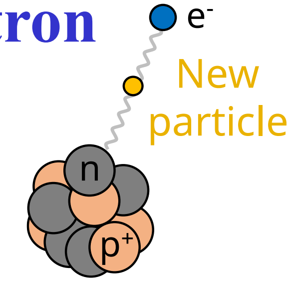
  [A. Sunaga *et al*, NJP(2024), V. V. Flambaum *et al*, PRL(2014)]

- Time variation of fine-structure constant $\alpha$ [M. S. Safronova *et al.*,PRL (2018), V. A. Dzuba *et al.*, PRA 98 (2018), Z-M. Tang, et al., PRA (2023)]
- Violation of local Lorentz invariance: SM extension [R. Shaniv, *et al.*, PRL (2018)]
- **New boson mediating a force between electrons and neutrons** [T. Ishiyama, *et al.*, Nature Photonics.2026]

# Quantum Sensor for New Physics

## "*Precision Isotope-Shift Measurement*"

Searching for **a New Particle** mediating a force between **Neutron** and **Electron**




Delaunay *et al.*, PRD **96** 093001 (2017), Berengut *et al.*, PRL **120** 091801 (2018)

$$V(r) = (-1)^{s+1} y_e y_n \exp(-mcr/\hbar)/(4\pi r)$$

$s$=0 or 1:spin $m$: new particle mass

**"Constraining new physics models with isotope shift spectroscopy"** [C. Frugiuele *et al.*, PRD **96** (2017)]

## Z' vector boson from $U(1)_{B-L}$

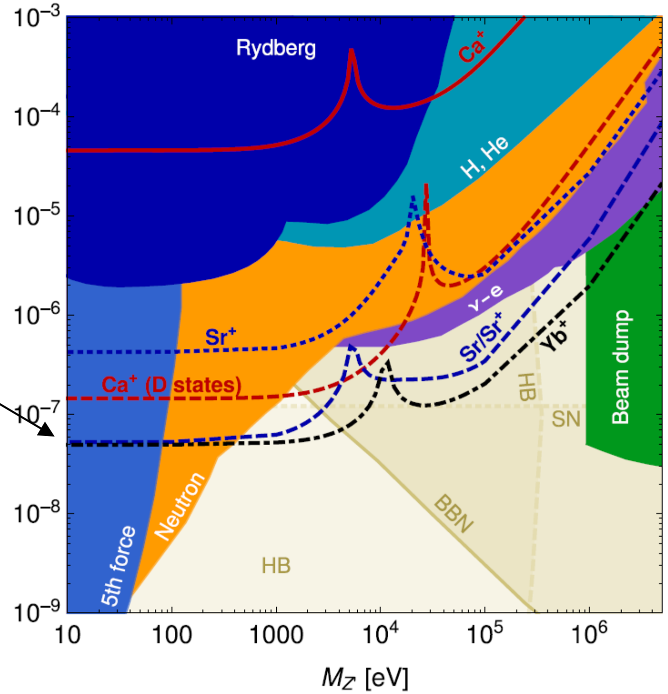
- $B$(Baryon)-$L$(lepton) number conservation

→ New gauge boson: Z'

→ (heavy) right-handed neutrino

$$g_{B\text{-}L}{}^2 = y_e y_n$$

1Hz precision




## Higgs portal

- New boson mixed with Higgs bosons

## Chameleon field

- Density dependent scalar field

→screening effect (dark-energy)

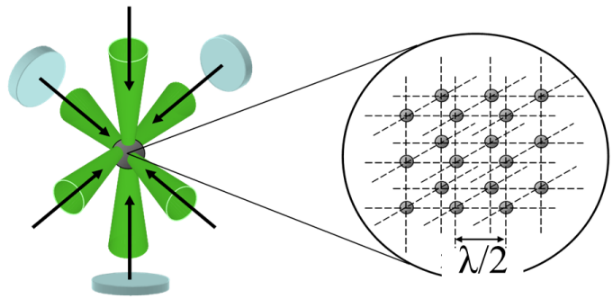
→ avoid constraints from fifth-force experiments

$$\delta H|_n = -\frac{m_e m_N}{4\pi r M^2}$$

$$M > \sqrt{\frac{m_e m_n}{y_e y_n|_{\min}}} \approx 500 \text{ TeV} \approx 2.5 \times 10^{-13}\ M_{Pl}$$

# Quantum Sensor for New Physics

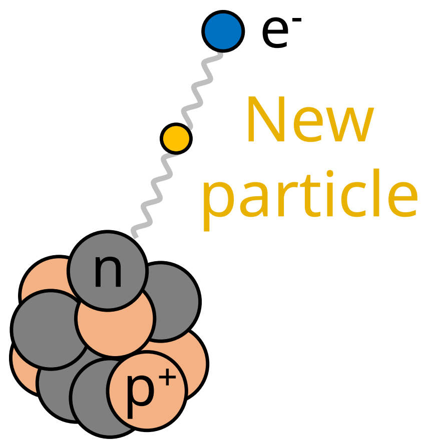
*"Precision Isotope-Shift Measurement"*




"Each atom is localized in each site of Deep 3D optical lattice"

Searching for **a New Particle** mediating a force between **Neutron** and **Electron**

Delaunay *et al.*, PRD **96** 093001 (2017), Berengut *et al.*, PRL **120** 091801 (2018)




$$V(r) = (-1)^{s+1} y_e y_n \exp(-mcr/\hbar)/(4\pi r)$$

*s*=0 or 1:spin *m*: new particle mass

## Isotope shift between isotope pairs (*A'*, *A*) for a transition *λ*

$$\nu_\lambda^{A'A} = K_\lambda \delta\mu^{A'A} + F_\lambda \delta\langle r^2\rangle^{A'A} + H_\lambda \delta\eta^{A'A} + \alpha_{NP} X_\lambda (A' - A)$$

Mass shift | Field shift | Higher-order Field shift | New Particle shift

- ✓ Inverse nuclear mass difference: $\delta\mu^{AA'} = 1/m_{A'} - 1/m_A$
- ✓ Nuclear mean square charge radii difference: $\delta\langle r^2\rangle^{AA'} = \langle r^2\rangle^{A'} - \langle r^2\rangle^{A}$
- ✓ Quadratic field shift: $[\delta\langle r^2\rangle^2]^{A'A} = (\delta\langle r^2\rangle^{A'A_0})^2 - (\delta\langle r^2\rangle^{AA_0})^2$
- ✓ Next-leading-order Seltzer moment: $\delta\langle r^4\rangle^{A'A} = \langle r^4\rangle^{A'} - \langle r^4\rangle^{A}$

$$\alpha_{NP} = (-1)^{s+1} y_e y_n/(4\pi\hbar c)$$

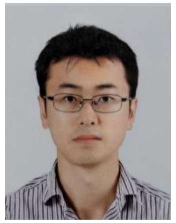
$$X_\lambda = \frac{c}{2\pi}\int_0^\infty dr\,\delta\rho_\lambda(r)\frac{e^{-\frac{mcr}{\hbar}}}{r}$$

$$\delta\rho_\lambda(r) = 4\pi r^2(|\psi_e(r)|^2 - |\psi_g(r)|^2)$$

# Isotope Shift and King Linear Relation


W. H. King, *J. Opt. Soc. Am* **53,** 638 (1963)
K. Mikami *et al*., Eur. Phys. J. C **77**, 896 (2017)
J. C. Berengut *et al.,* Phys. Rev. Res. 2, 043444 (2020)


King Plot Approach:

M. Tanaka Y. Yamamoto

<u>Generalized King Relation:</u> three transitions $\lambda_1$, $\lambda_2$, and $\lambda_3$

$$\begin{cases} \nu_{\lambda_1}^{A'A} = K_{\lambda_1}\delta\mu^{A'A} + F_{\lambda_1}\delta\langle r^2\rangle^{A'A} + H_{\lambda_1}\delta\eta^{A'A} \\ \nu_{\lambda_2}^{A'A} = K_{\lambda_2}\delta\mu^{A'A} + F_{\lambda_2}\delta\langle r^2\rangle^{A'A} + H_{\lambda_2}\delta\eta^{A'A} \\ \nu_{\lambda_3}^{A'A} = K_{\lambda_3}\delta\mu^{A'A} + F_{\lambda_3}\delta\langle r^2\rangle^{A'A} + H_{\lambda_3}\delta\eta^{A'A} \end{cases}$$

Mass shift Field shift Higher-order Field Shift

$$\Rightarrow \nu_{\lambda_3}^{A'A} = f_{\lambda_1}\nu_{\lambda_1}^{A'A} + f_{\lambda_2}\nu_{\lambda_2}^{A'A} + k_\mu\delta\mu^{A'A}$$

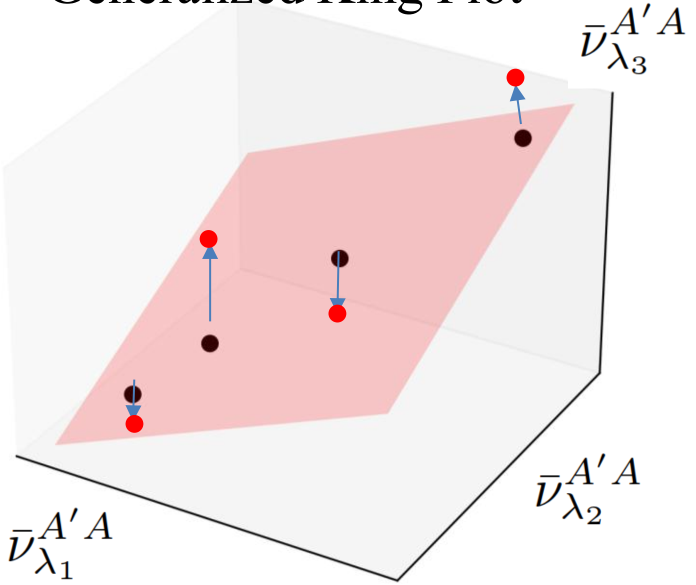
or

$$\bar{\nu}_{\lambda_3}^{A'A} = f_{\lambda_1}\bar{\nu}_{\lambda_1}^{A'A} + f_{\lambda_2}\bar{\nu}_{\lambda_2}^{A'A} + k_\mu$$

$$z = a\ x + b\ y + c$$

modified Isotope shift: $\bar{\nu}_\lambda^{AA'} \equiv \nu_\lambda^{AA'}/\delta\mu^{AA'}$

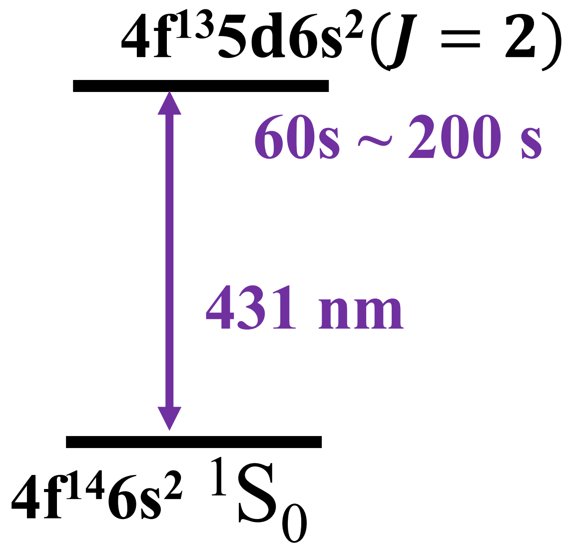
"Generalized King Plot"



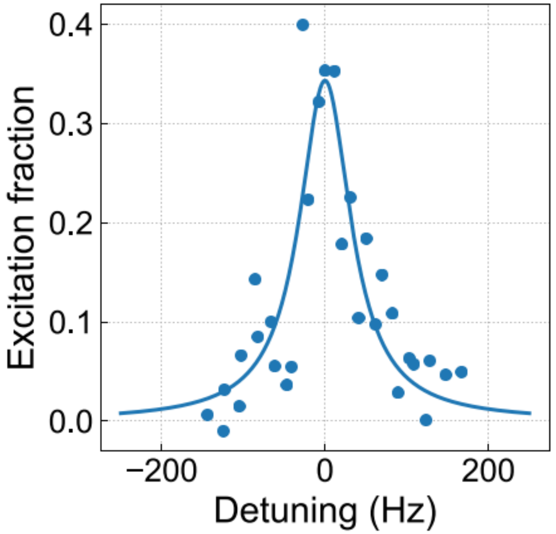

**Nonlinearity of King relation should be seriously considered as a signature of new particle**

# Successful Observation of New Clock Transition

[T. Ishiyama, *et. al.,* PRL (2023)][T. Ishiyama, *et al.,* Nat. Phot.2026]
related work by A. Kawasaki *et al.,*

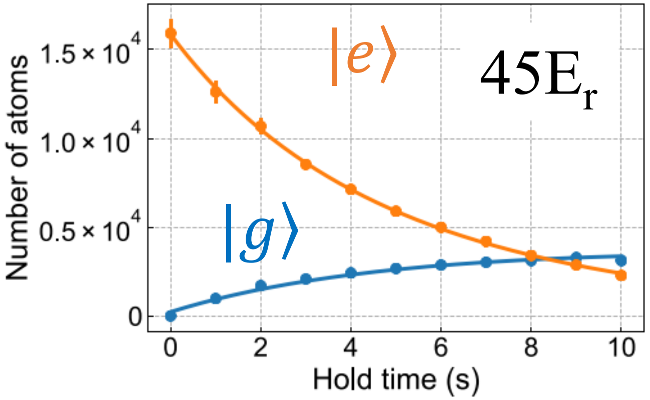



< 60 Hz

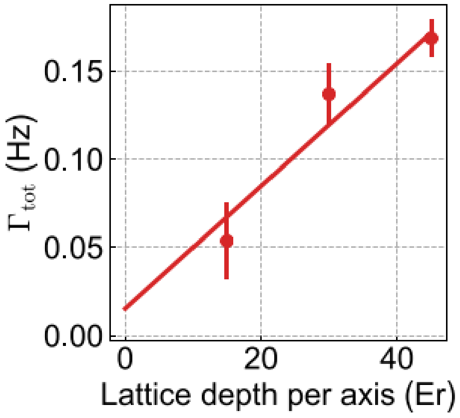



■ Lifetime τ = 66 s (BBR-limited)

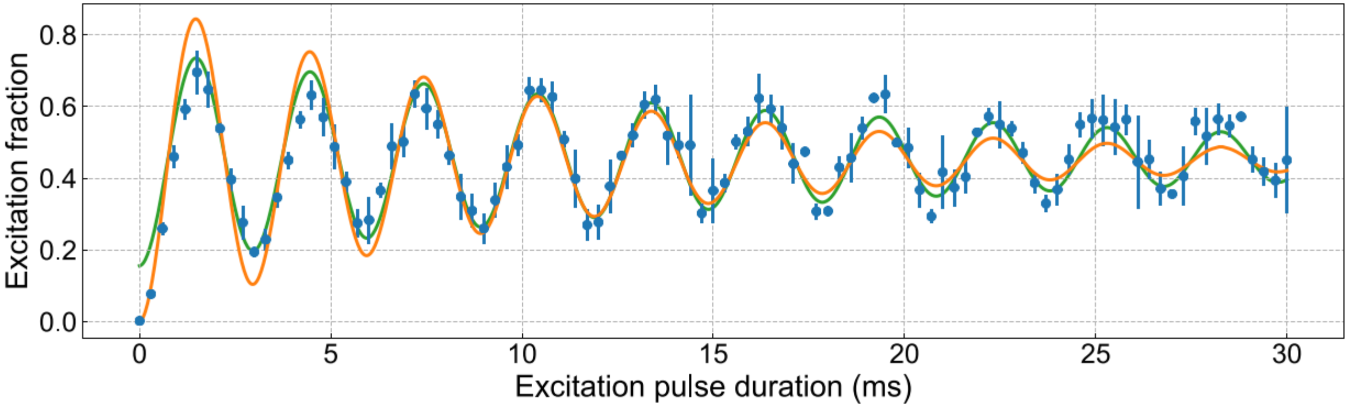
relaxation dynamics




extrapolation




■ Rabi oscillation 335.9(5) Hz, decay time: 20.1(1.9) ms




M2 transition moment: Experiment

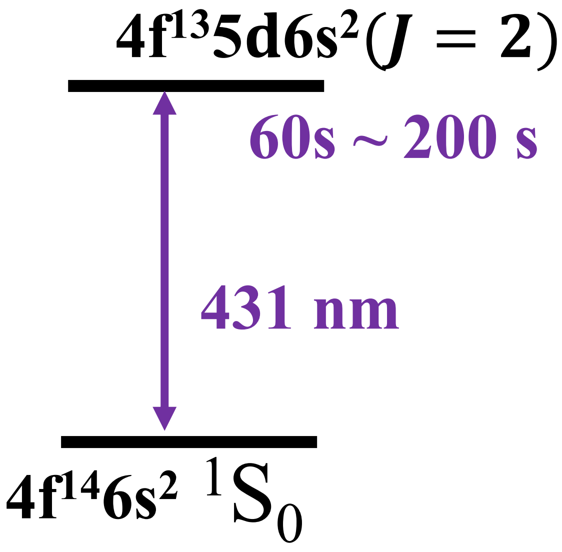
$\langle J_e|Q_2^m|J_g\rangle = 1.69(9)\times 10^{-33}$ Am$^3$

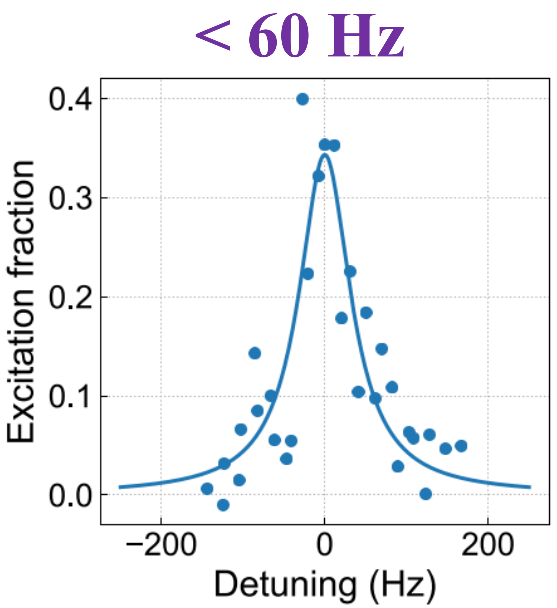
M2 transition moment: Theory
[V. A. Dzuba *et al.,* PRA(2018)]

$\langle J_e|Q_2^m|J_g\rangle = 1.3\times 10^{-33}$ Am$^3$

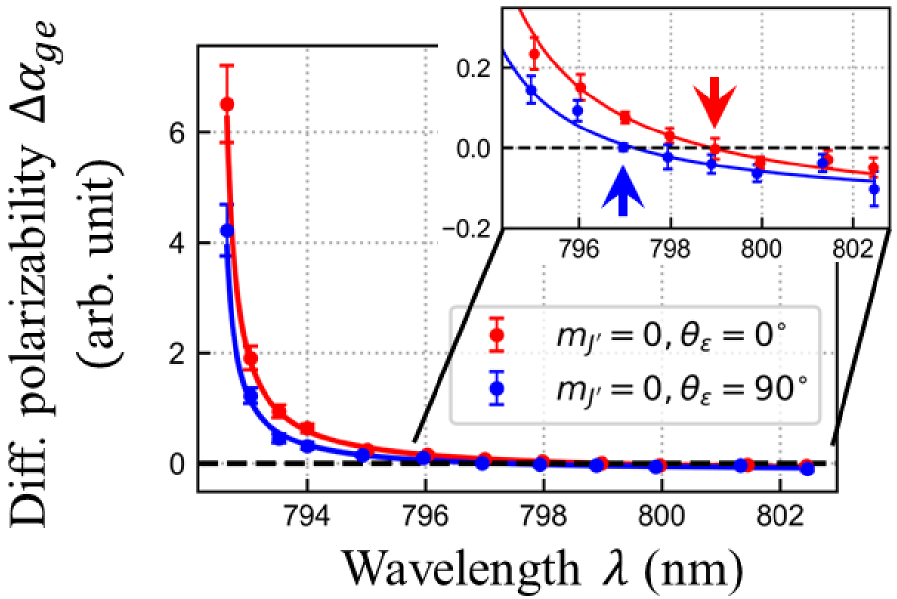
# Successful Observation of New Clock Transition

[T. Ishiyama, *et. al.,* PRL (2023)][T. Ishiyama, *et al.,* Nat. Phot.2026]




■ magic wavelength $\lambda_{magic} = 797.206(2)$ nm

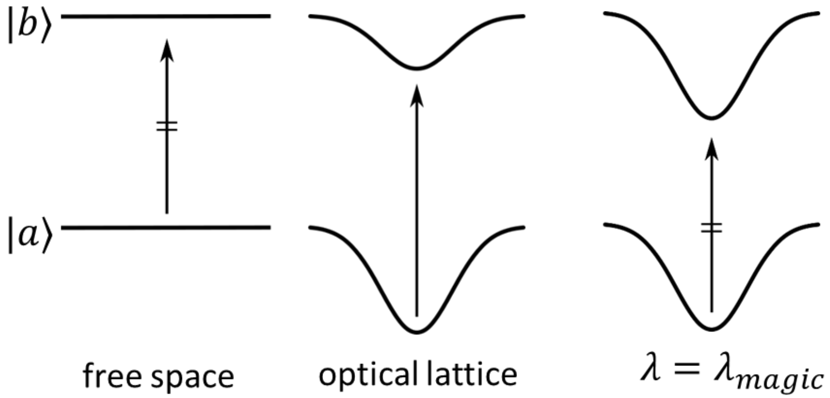



Magic wavelength lattice

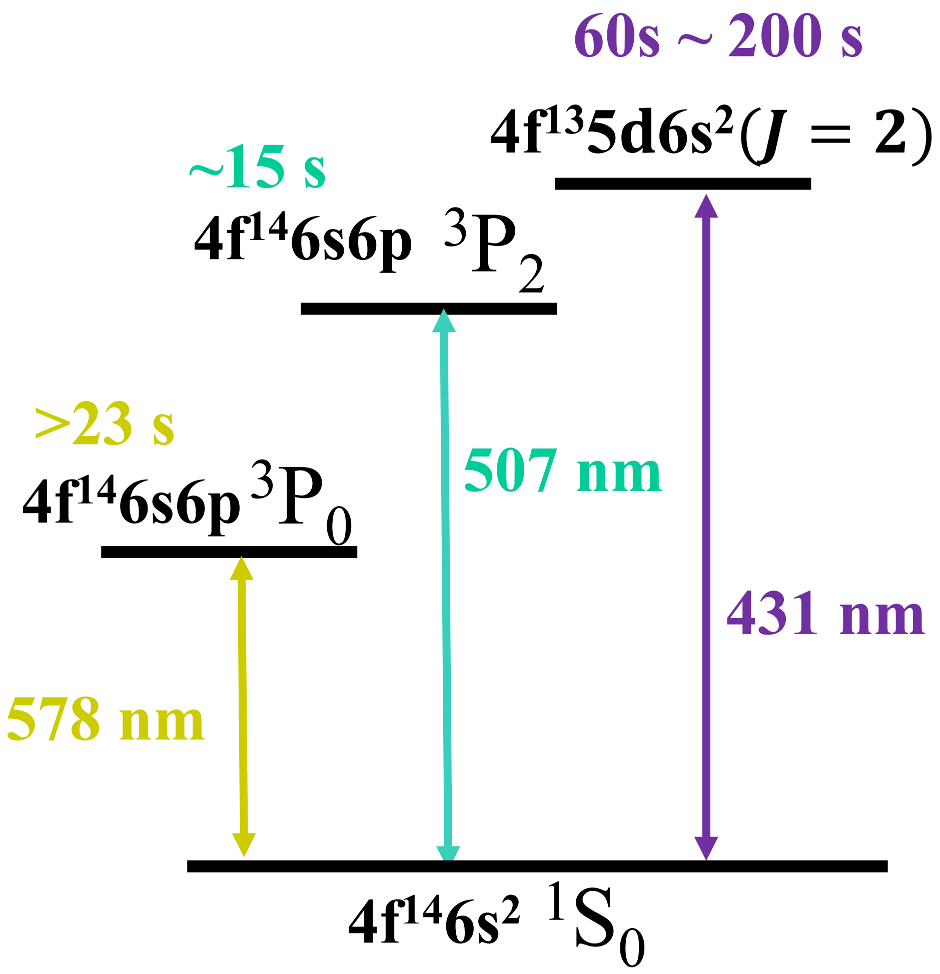
Polarizability $\alpha_a(\lambda)$

$$h\Delta\nu_a = -\frac{1}{2\epsilon_0 c}\alpha_a(\lambda)I$$

- $\Delta\nu_a$ : Light shift of state $|a\rangle$
- $I$ : Laser intensity
- $\lambda$ : Laser wavelength



# Precision Measurement of Isotope Shifts (~ppb)




$^1S_0$- $^3P_0$: 578nm [K. Ono, *et al.*, PRX.2022]

| Isotope pair (A’, A) | Isotope Shift $\nu^{A'A}$ (Hz) |
|---|---|
| (168,170) | 1 358 484 476.2 $(2.2)_{tot}$ $(0.2)_{stat}$ $(2.1)_{sys}$ |
| (170,174) | 2 268 486 592.6 $(1.9)_{tot}$ $(0.3)_{stat}$ $(1.9)_{sys}$ |
| (172,174) | 992 714 586.6 $(2.1)_{tot}$ $(0.4)_{stat}$ $(2.0)_{sys}$ |
| (174,176) | 946 921 774.9 $(2.9)_{tot}$ $(0.3)_{stat}$ $(2.8)_{sys}$ |

$^1S_0$- $4f^{13}5d6s^2(J = 2)$: 431nm [T. Ishiyama, *et al.*, Nature Photonics.2026]

| | |
|---|---|
| (176,174) | 1 115 770 095.3 $(5.8)_{tot}$ $(1.0)_{stat}$ $(5.7)_{sys}$ |
| (174,172) | 1 180 617 657.6 $(5.2)_{tot}$ $(0.7)_{stat}$ $(5.1)_{sys}$ |
| (174,170) | 2 810 665 685.1 $(8.0)_{tot}$ $(1.2)_{stat}$ $(7.9)_{sys}$ |
| (174,168) | 4 564 600 618.9 $(6.7)_{tot}$ $(1.7)_{stat}$ $(6.5)_{sys}$ |

$^1S_0$- $^3P_2$: 507nm [T. Ishiyama, *et al.*, arXiv: 2601.08487 ]

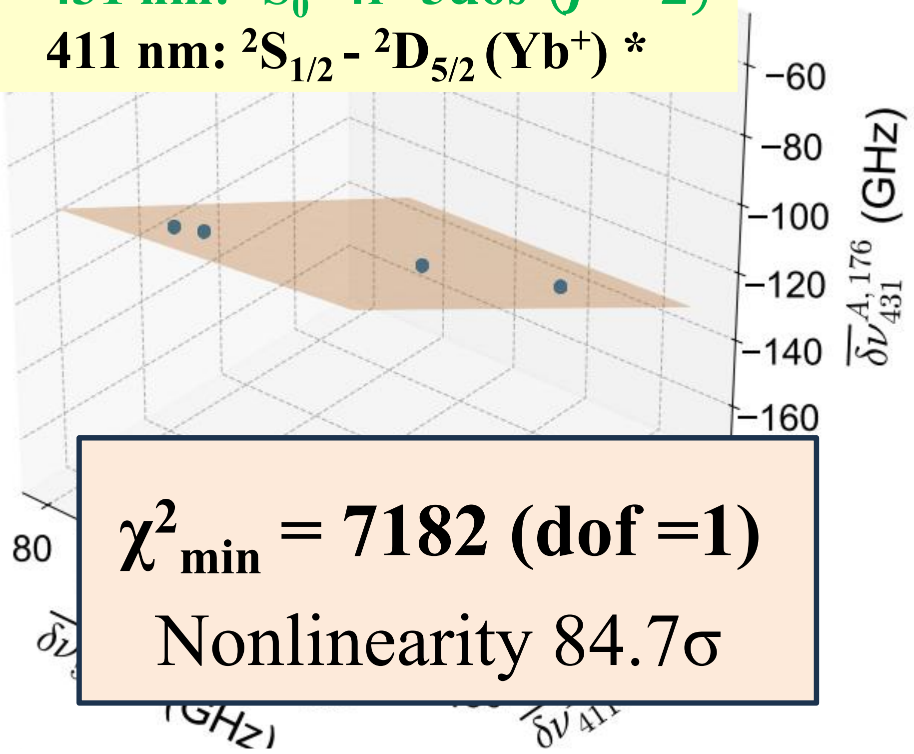
| | |
|---|---|
| (168, 174) | 3 677 546 251.3(6.8) |
| (170, 174) | 2 300 235 711.8(5.7) |
| (172, 174) | 1 006 735 627.8(4.9) |
| (176, 174) | -960 303 320.6(7.0) |

# 3D King Plot and Implication for New Physics

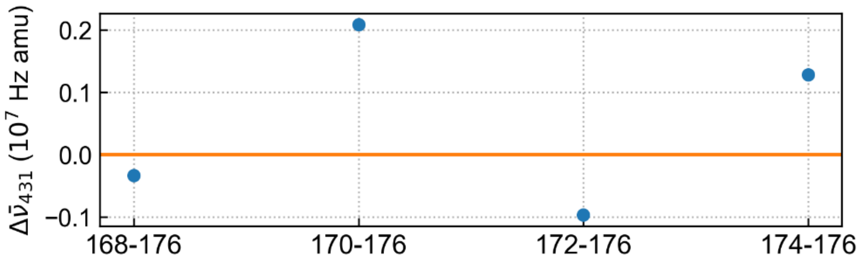
[K. Ono, *et al.*, PRX.2022]
[T. Ishiyama, *et al.*, arXiv: 2601.08487 ]

**3D King plot** [T. Ishiyama, *et al.*, Nat. Phot.2026]

**578 nm: $^1S_0$- $^3P_0$**
**431 nm: $^1S_0$- $4f^{13}5d6s^2(J = 2)$**
**411 nm: $^2S_{1/2}$ - $^2D_{5/2}$ (Yb$^+$) ***



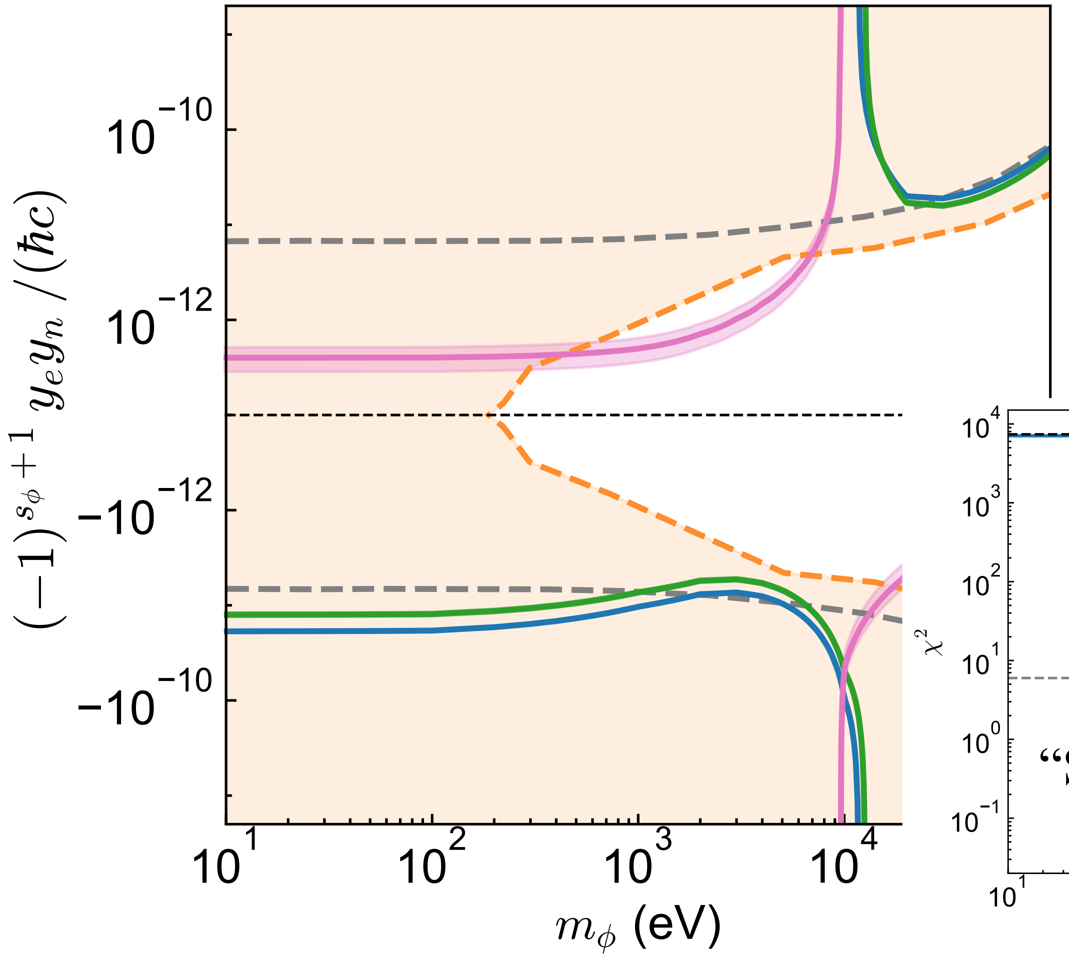

**$\chi^2_{min}$ = 7182 (dof =1)**
Nonlinearity 84.7σ




Error bars are smaller than the marker size

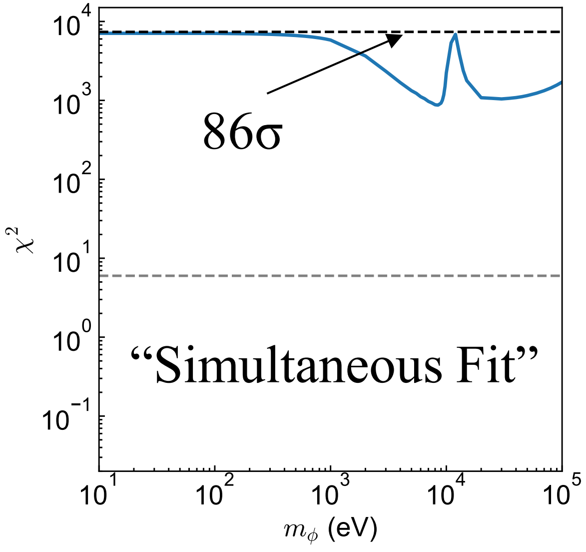
*[M. Door, *et al.*,PRL(2024)]

$$V(r) = (-1)^{s+1} y_e y_n \exp(-mcr/\hbar)/(4\pi r)$$




➢ (411*, 431, 578)
➢ (411*, 467*, 578)
➢ (467*, 507, 578)

IS for Ca$^+$ **




n-scat. × $(g\text{-}2)_e$ (the best terrestrial bound)

**[A. Wilzewski, *et al.*, PRL2025]

# 3D King Plot and Implication for New Physics

[K. Ono, *et al.*, PRX.2022]
[T. Ishiyama, *et al.*, arXiv: 2601.08487 ]

<u>3D King plot</u> [T. Ishiyama, *et al.*, Nat. Phot.2026]

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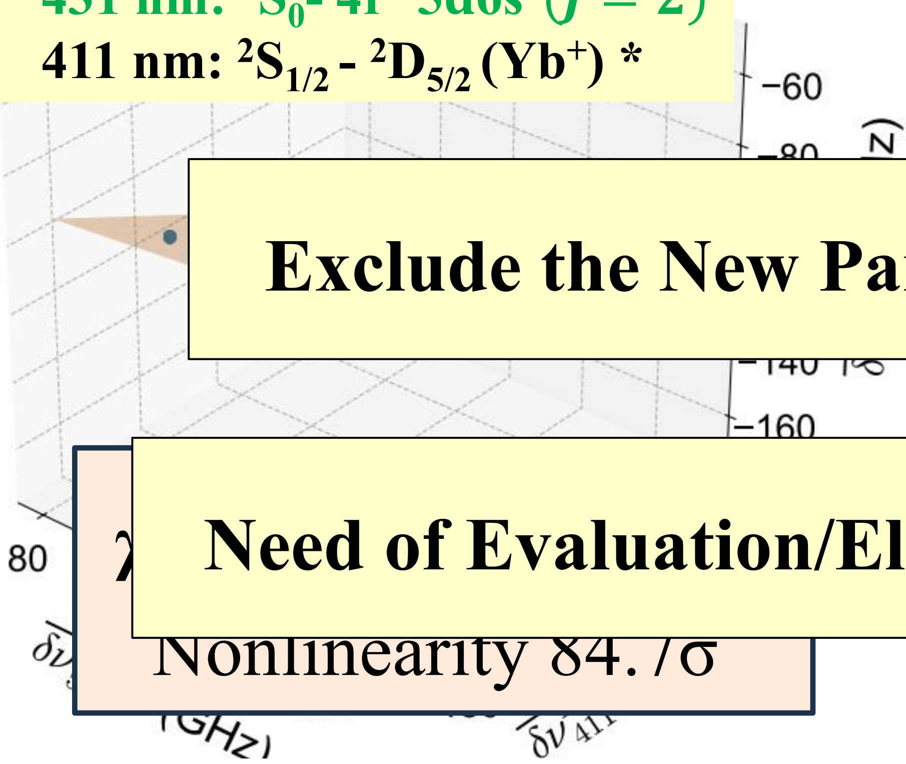
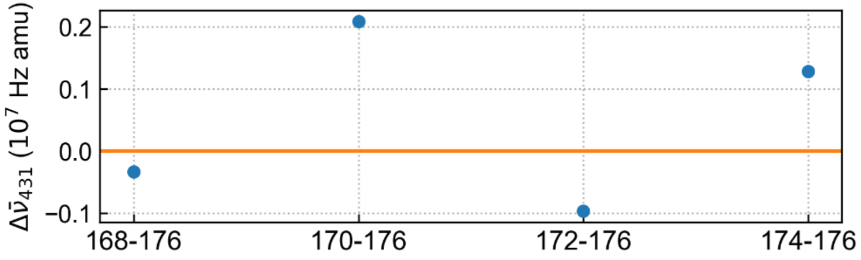



**Exclude the New Particle Interpretation of 3D King Nonlinearity**

**Need of Evaluation/Elimination of SM Contributions of Nonlinearity**

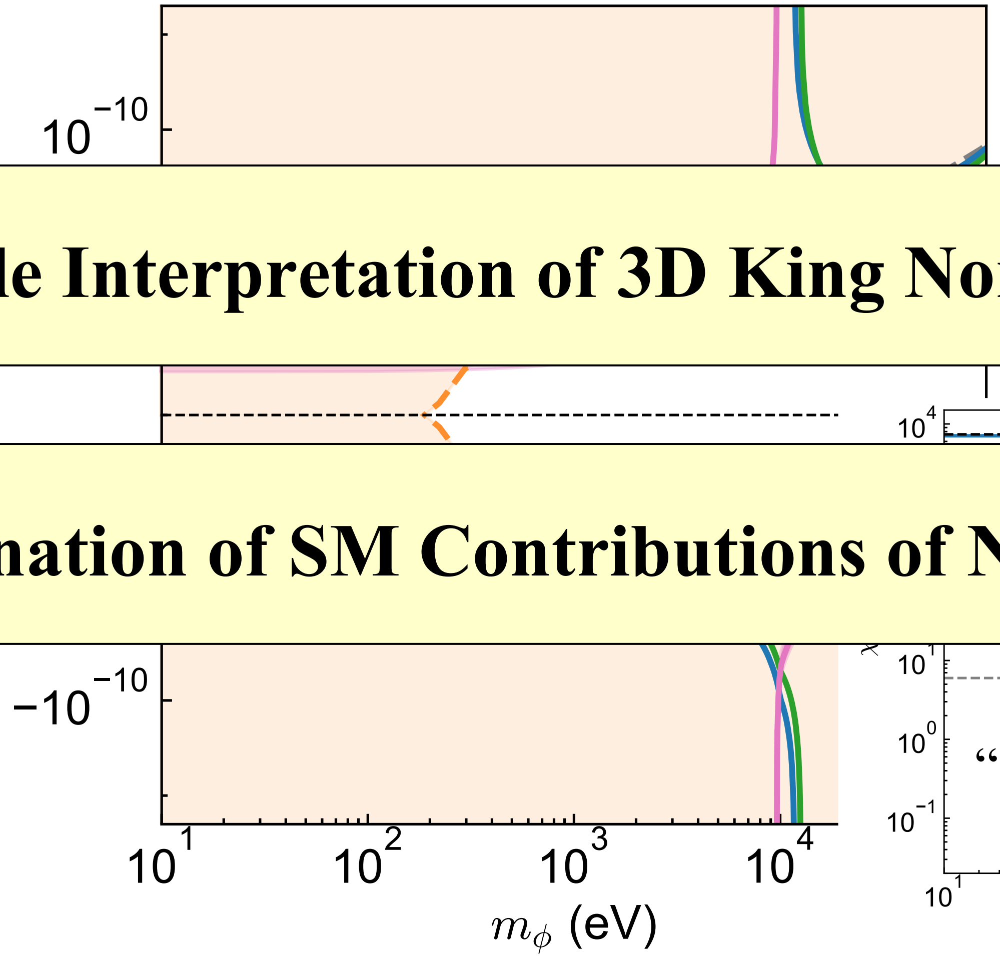
χ
Nonlinearity 84.7σ



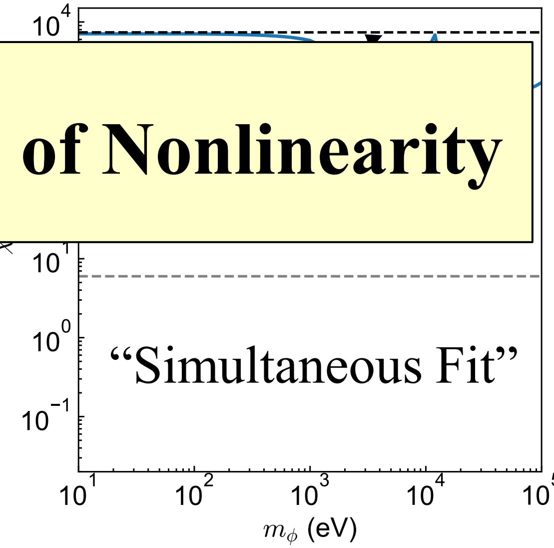

Error bars are smaller than the marker size

*[M. Door, *et al.*,PRL(2024)]

$$V(r) = (-1)^{s+1} y_e y_n \exp(-mcr/\hbar)/(4\pi r)$$




- (411*, 431, 578)
- (411*, 467*, 578)
- 78)




n-scat. × $(g\text{-}2)_e$ (the best terrestrial bound)

**[A. Wilzewski, *et al.*, PRL2025]

# 3D King Plot and Implication for New Physics

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3D King plot [T. Ishiyama, *et al.*, Nat. Phot.2026]

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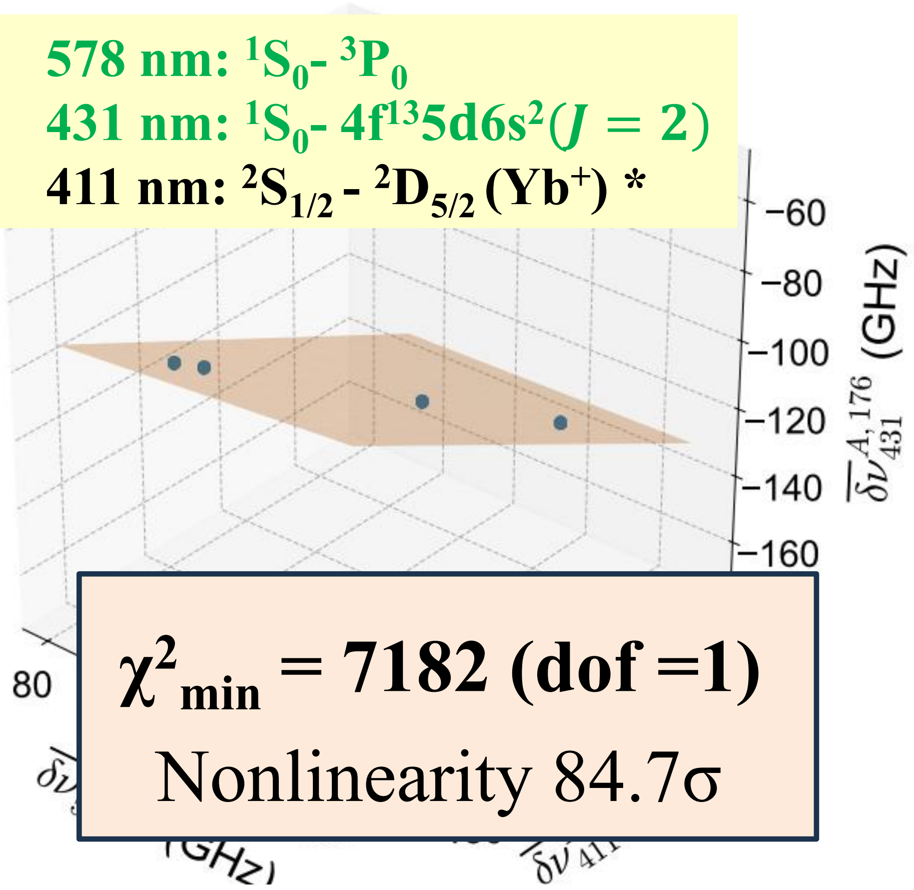


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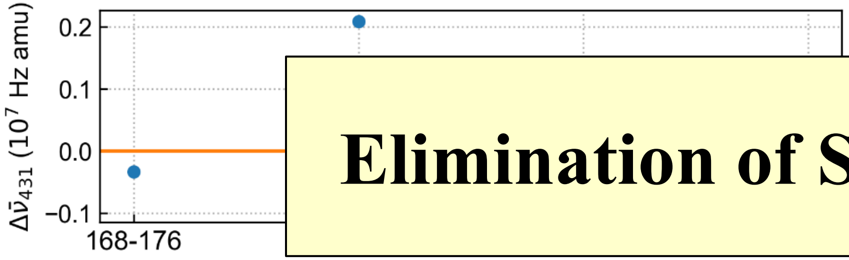
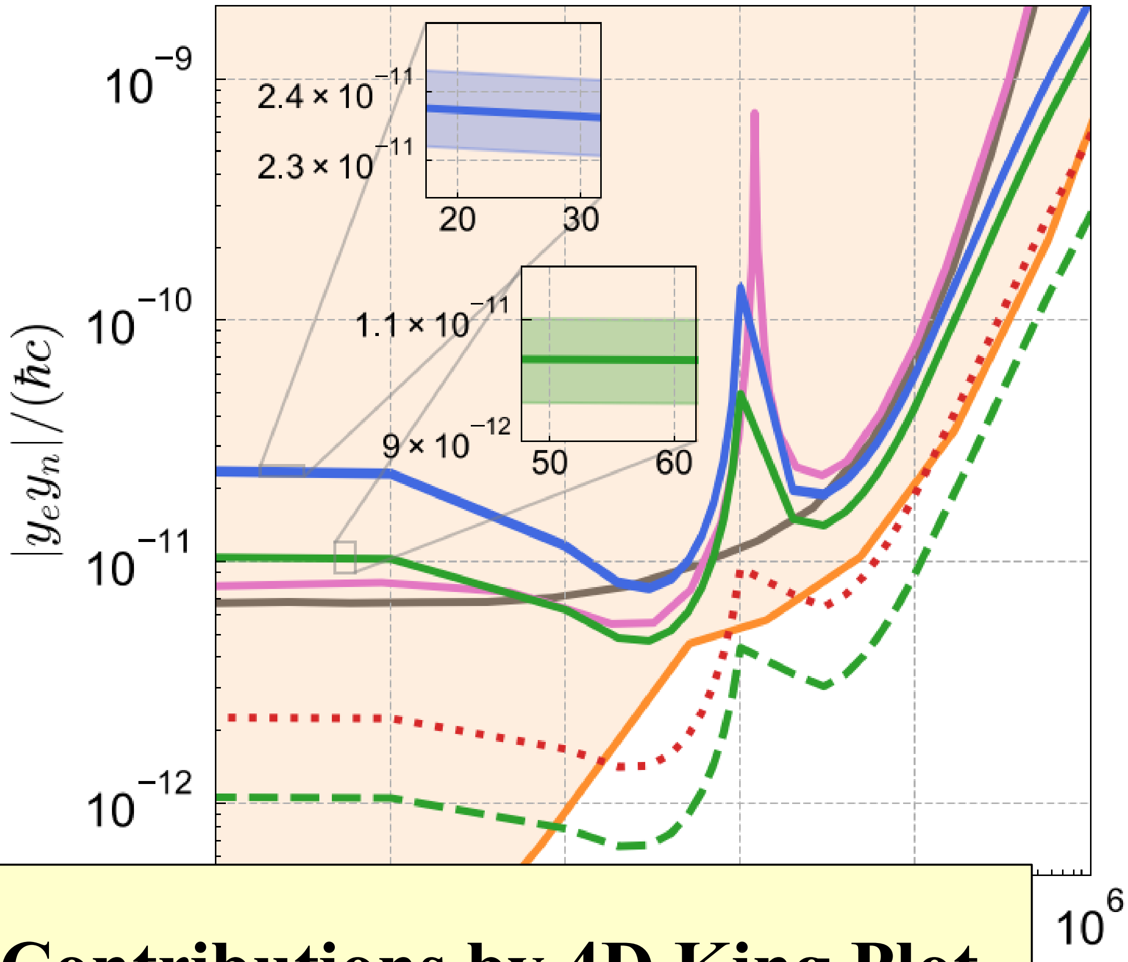



Error bars are smaller than the marker size

*[M. Door, *et al.*,PRL(2024)]

$$V(r) = (-1)^{s+1} y_e y_n \exp(-mcr/\hbar)/(4\pi r)$$




- (411*, 431, 578)
- (467*, 431, 578)

IS for $Ca^+$ **

theory-input (QFS) in 4D

theory-input (QFS) in 4D (minimum Nonlinearity)

$^{166}$Yb projected sensitivity

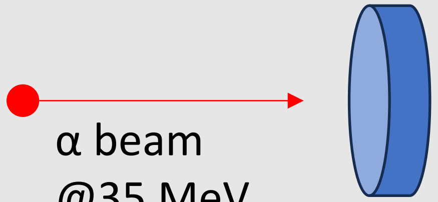
... terrestrial bound)

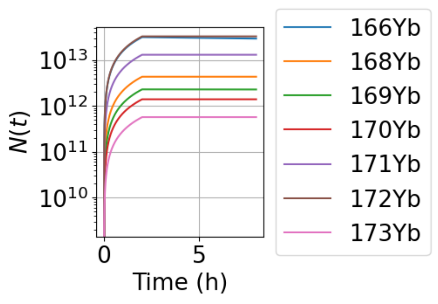
**Elimination of SM Contributions by 4D King Plot**

**[A. Wilzewski, *et al.*, PRL2025]

# Radioactive $^{166}$Yb($T_{1/2}$~56.7h): collaboration with Haba G in Riken

① Nuclear fusion $^{164}$Er (α, 2n) $^{166}$Yb




~$10^{13}$ produced

Similar reaction channel:
M. Saito et al., Appl. Radiat. Isot. 154, 108874 (2019).

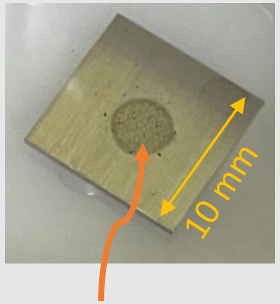
② Chemical processing + electroplating

Dissolve

Separate

Dry

Electroplate




$Yb_2O_3$ on Pt plate
(mock stable sample)

Chemical separation of Yb-169 from Tm [A. Nambu et al., RIKEN APR 57, 155 (2024)]
achieved Tm reduction by 192.56 mg → 2.3 μg

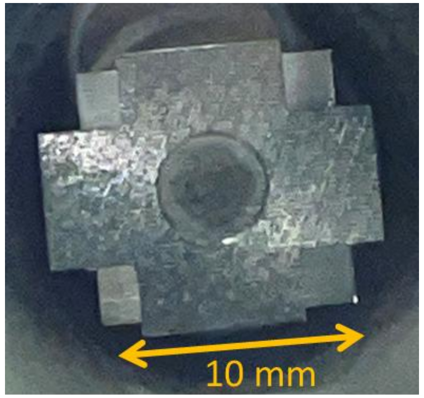
## Expected composition

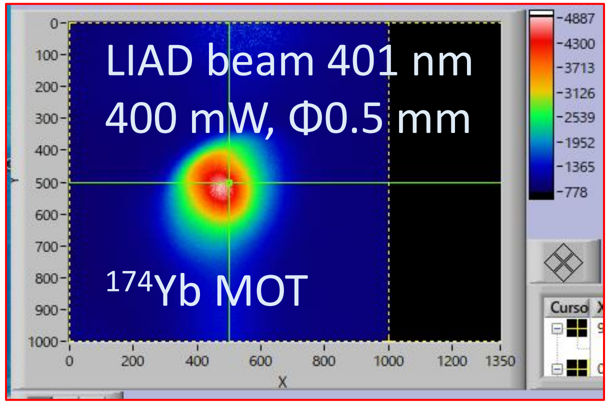
| Yb-166 | Yb-168 | Yb-169 | Yb-170 | Yb-171 | Yb-172 | Yb-173 |
|---|---|---|---|---|---|---|
| $1.1 \times 10^{13}$ | $2.2 \times 10^{12}$ | $1.1 \times 10^{12}$ | $7.0 \times 10^{11}$ | $6.5 \times 10^{12}$ | $1.6 \times 10^{13}$ | $2.8 \times 10^{11}$ |
| 29% | 5.8% | 2.9% | 1.9% | 17% | 42% | 0.74% |

+ $3\times10^{15}$ Er atoms (+ impurities)

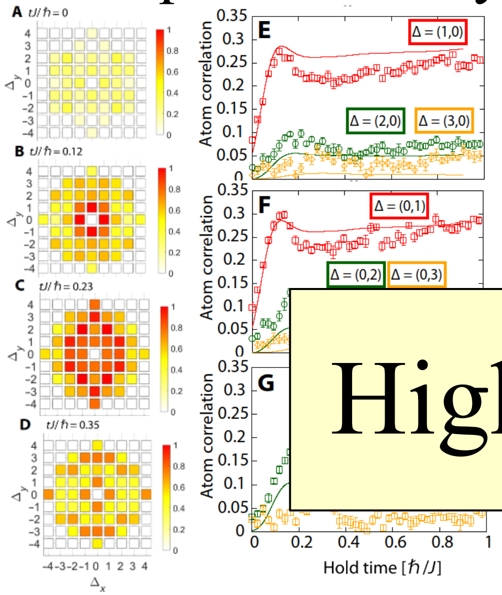
③ Extraction with light-induced atom desorption (LIAD) and MOT

Test Sample with stable Yb



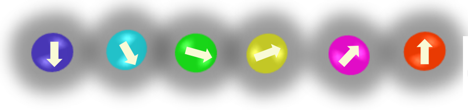



## Nonequilibrium Dynamics

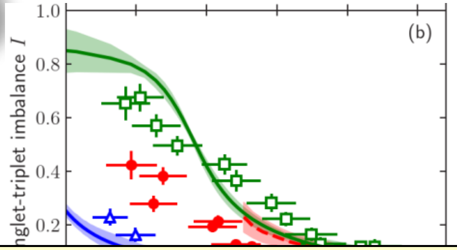



(Takasu *et al.*, Sci.Adv.2020)
Honda *et al.*, Sci.Adv.2025

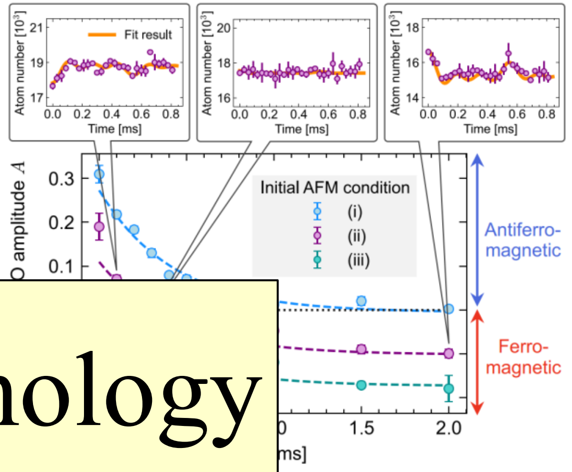
## SU(N)Quantum Magnetsim



Lowest Temperature
of cold Fermi gas

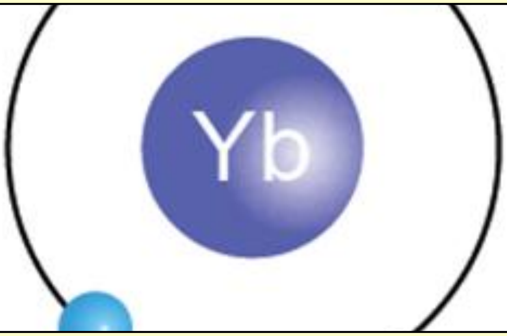


## Open Quantum System

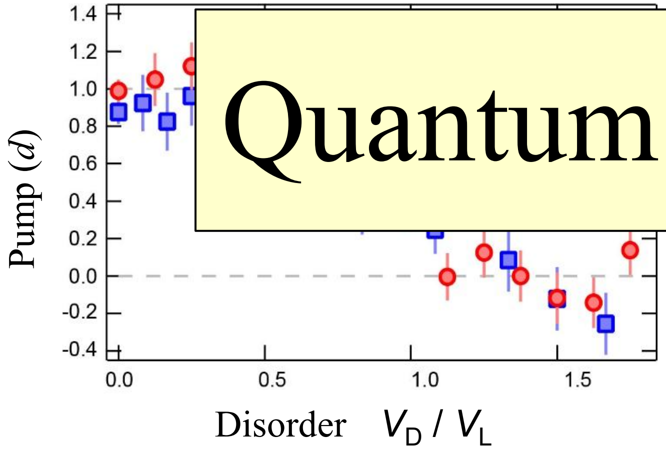



(Honda *et al.*, PRL2023,
Tomita *et al.*, Sci.Adv.2017
Tsuno *et al.*, Nat.Com.2025)

# High-Level Quantum Control Technology

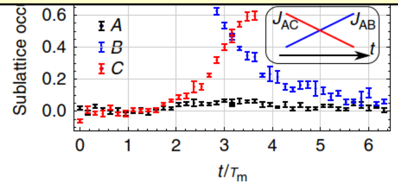



## Topology/disorder



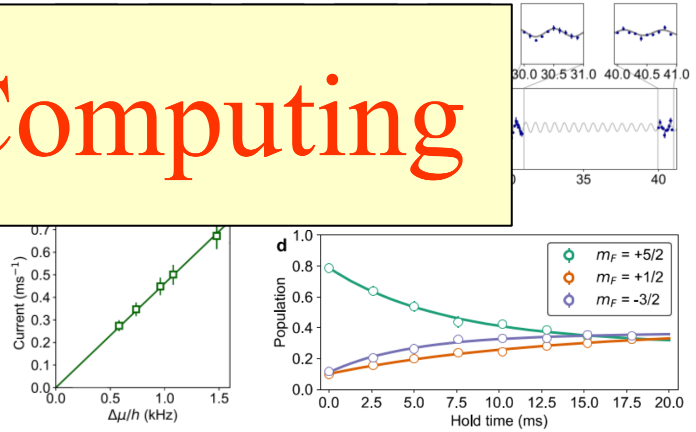

(Nakajima *et al.*, Nat.Phys.2021)

# Quantum Sensing / Quantum Computing




(Taie *et al.*, Nat. Com.2020
Kumar *et al.*, PRAL2021)

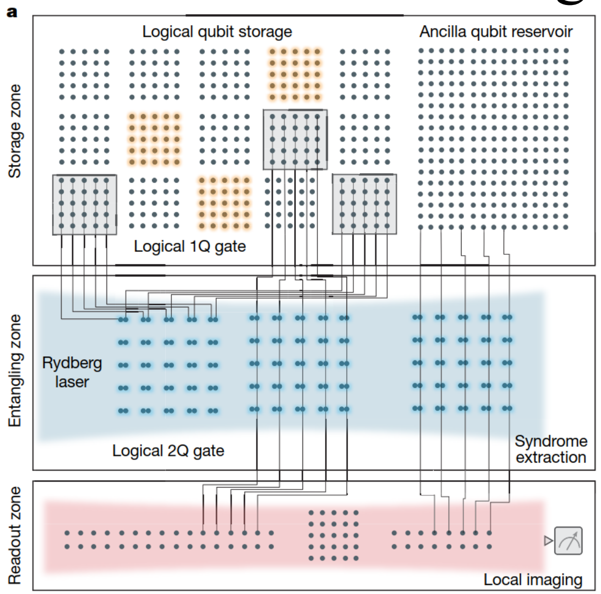
## Quantum transport

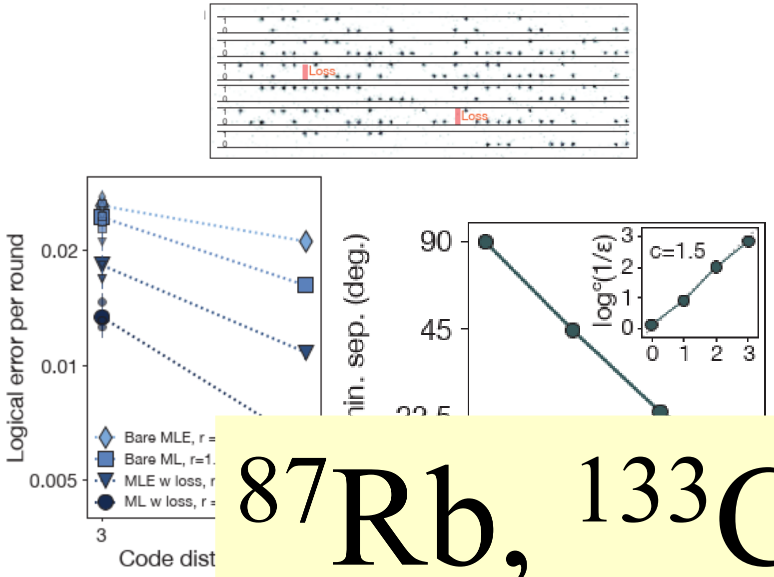



(Ono *et al.*, Nat.Com.2021, PRAL2021)

# Atom Tweezer Array for Quantum Computing

## Reconfigurable atom array

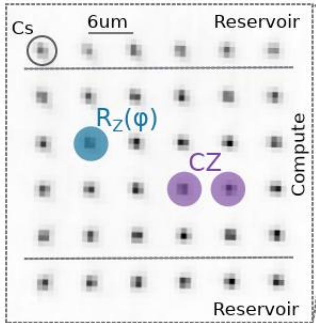


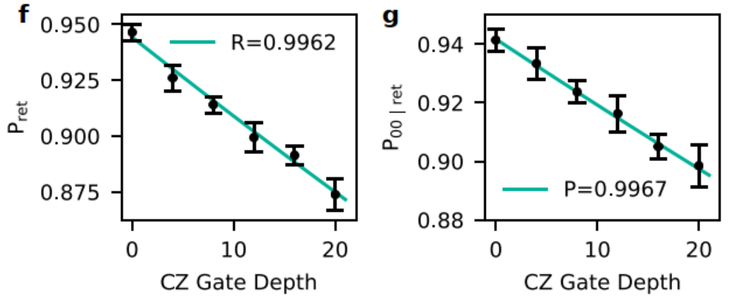




# $^{87}$Rb, $^{133}$Cs

D. Bluvstein, *et al.,* Nature 626,58 (2024), arXiv:2506.20661

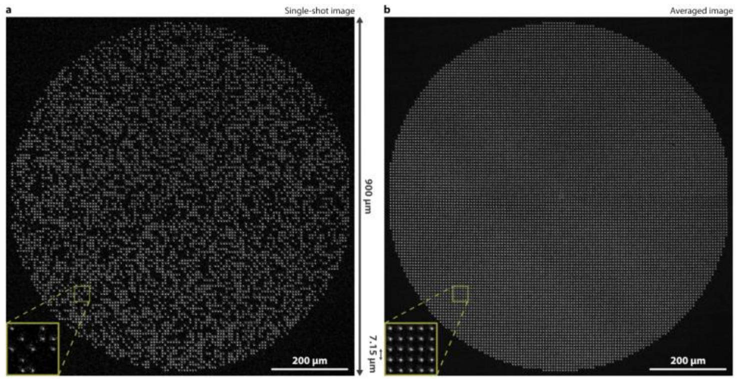
## Individually addressable atom array



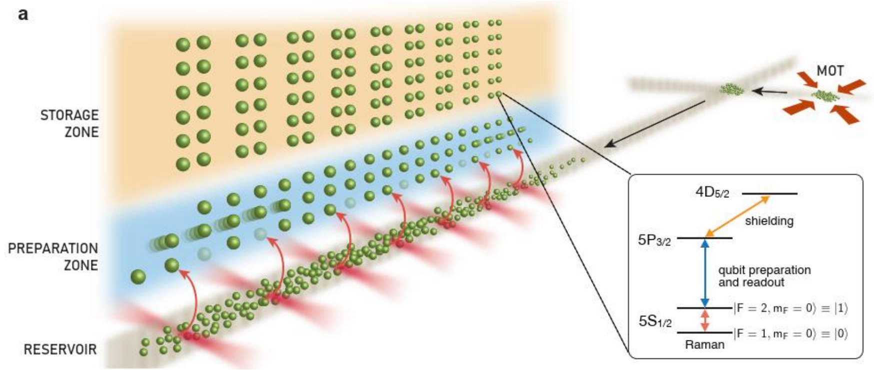

A.G. Radnaev, *et al.,* arXiv:2408.08288

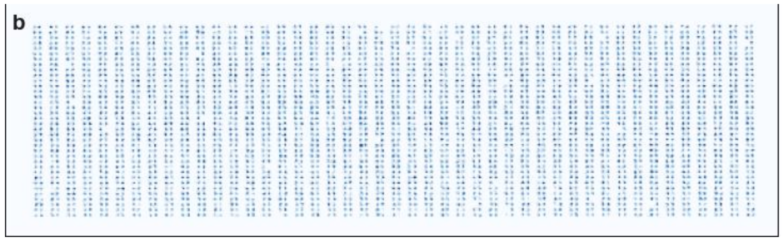
## >6000 atom array




H.J. Manetsch, *et. al.,* Nature arXiv:2403.12021

## Continuous loading of 3,000 qubit

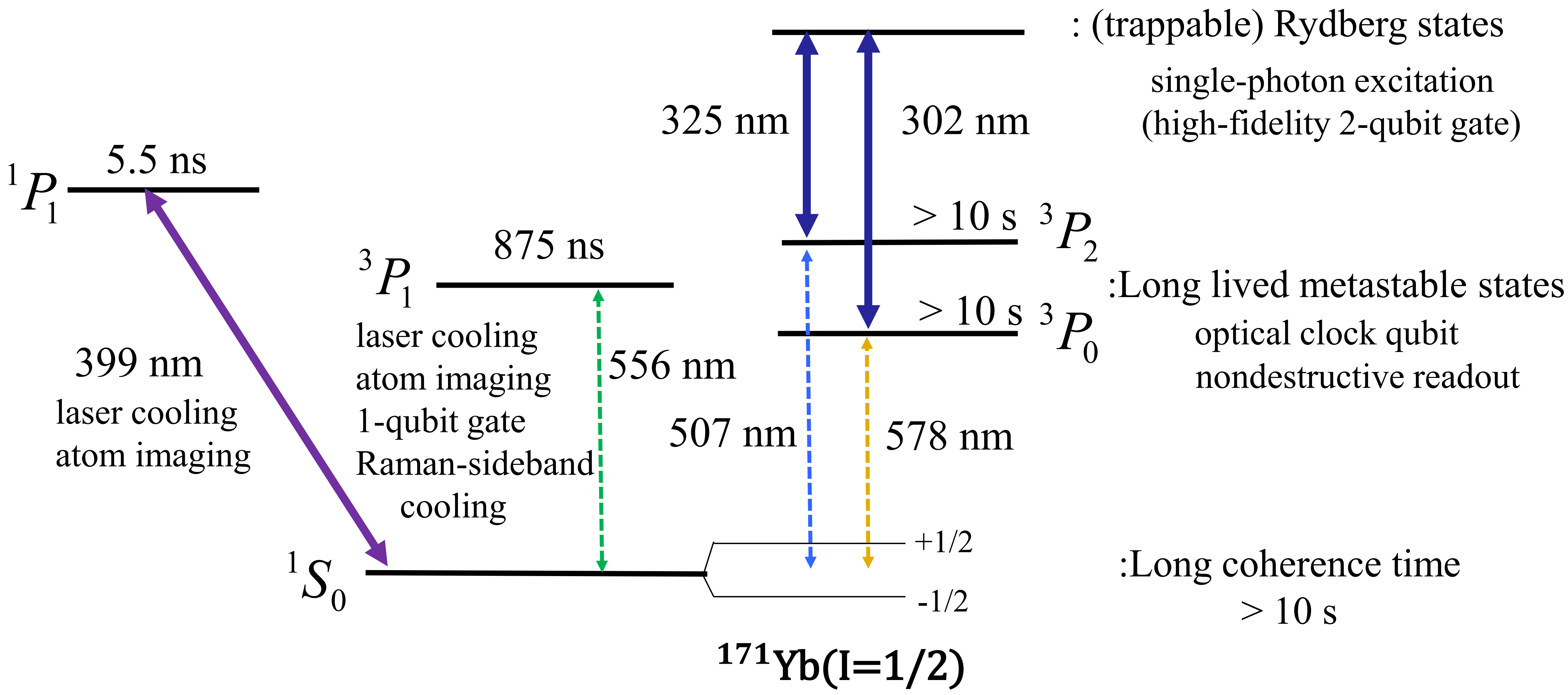



N-C. Chiu, *et al.,* Nature, arXiv:2506.20660

# Advantages of Ytterbium Atoms for Quantum Computing

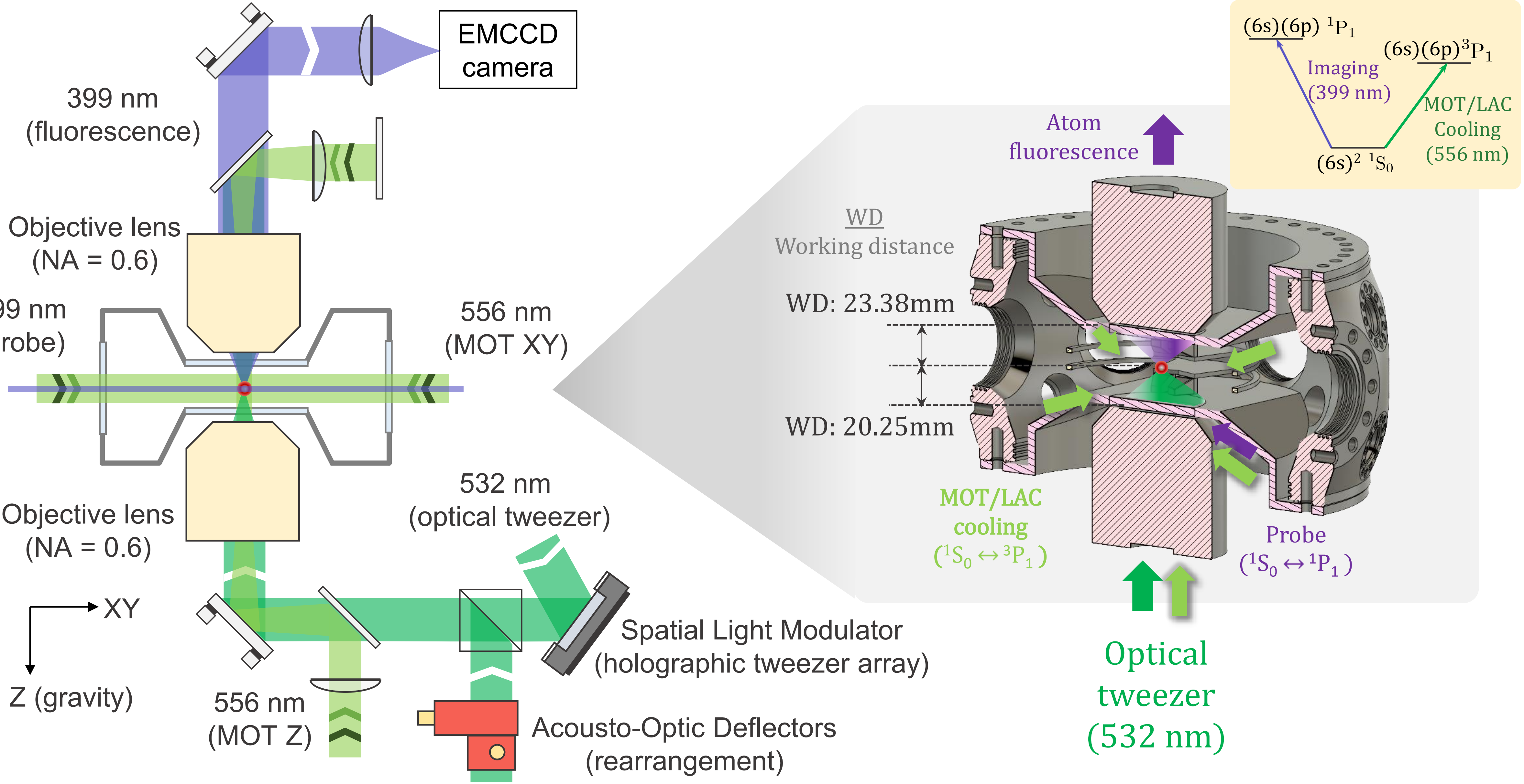
## Rich Internal Degrees of Freedom




JILA, Princeton, Illinoi, Atom Computing, Hamburg, LENS, LMU, nanoQT, *Google (A. Kaufman)*?…

# Development of Ytterbium Atom Tweezer Array

## Schematic of our experimental setup

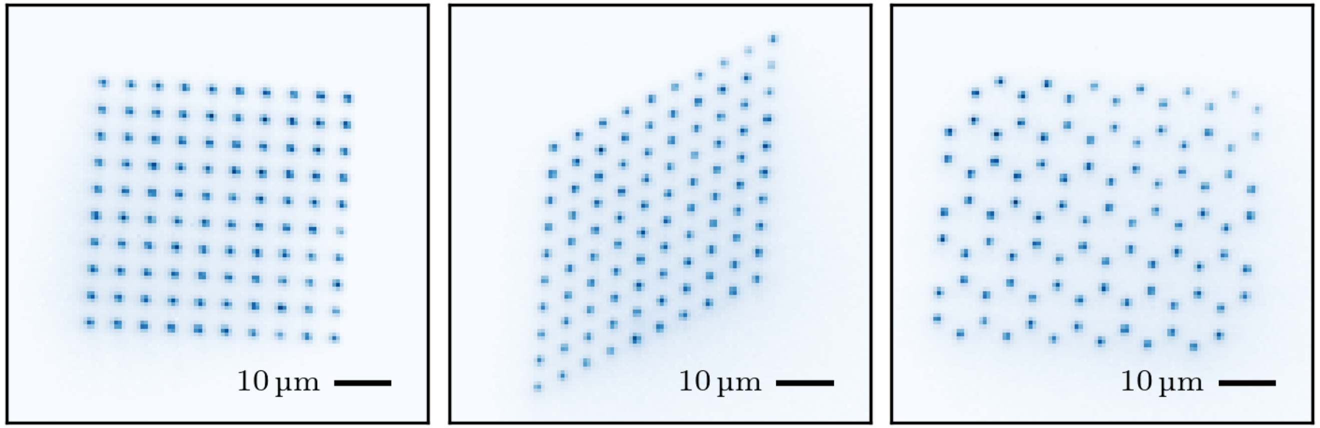


# Development of Ytterbium Atom Tweezer Array

## Demonstrate basic performances

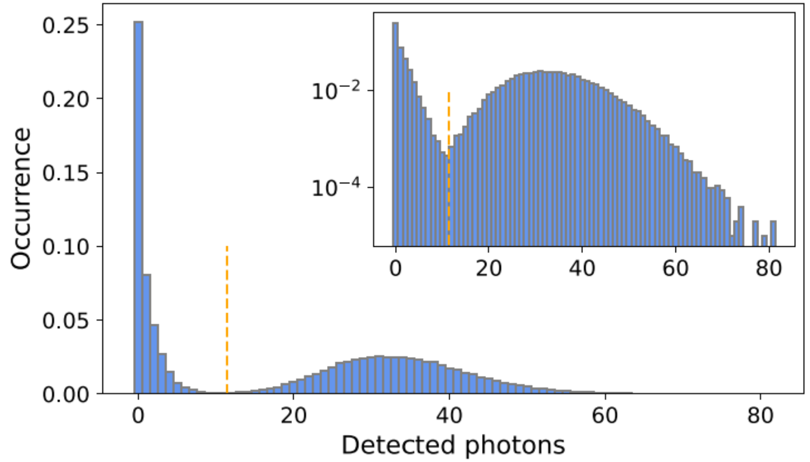
### Holographic Tweezer Array

2D 196-atom array




discrimination fidelity: **0.9992**

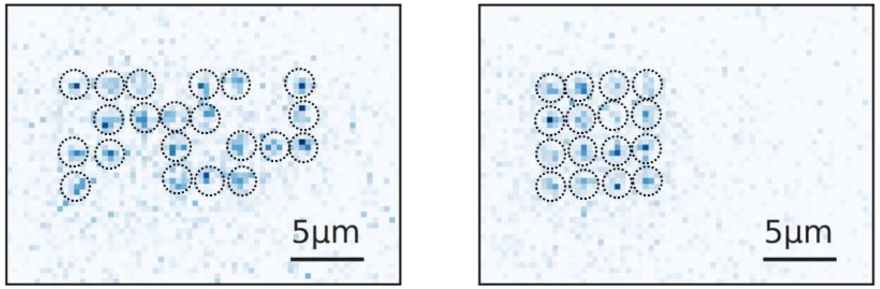
survival probability: **0.988**




### Defect-free array by rearrangement

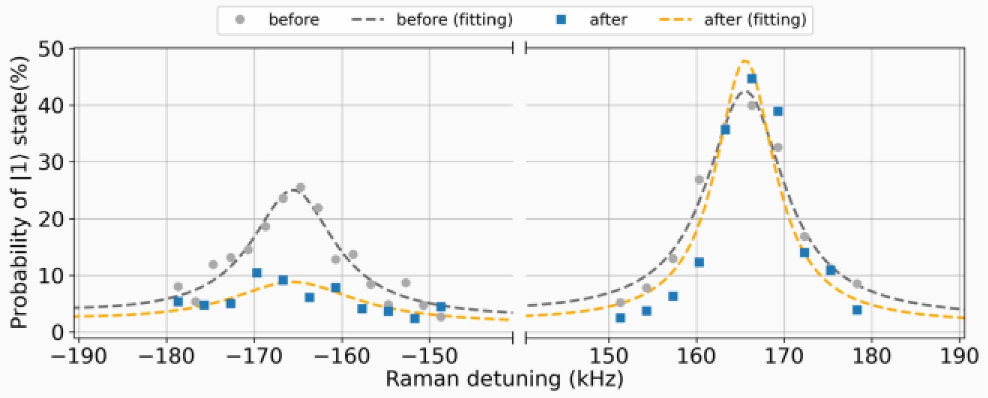
First shot

Second shot




### Raman Sideband Cooling

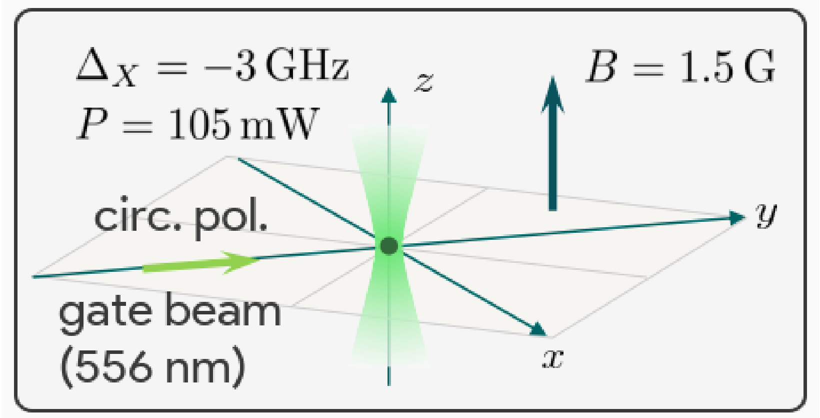
$n_x$=1.6(2)→**0.20(4)** $n_y$=1.7(6)→**0.18(4)**



# Development of Ytterbium Atom Tweezer Array

**Demonstrate basic performances**

## Nuclear Spin Qubit : $^{171}$Yb(I=1/2)



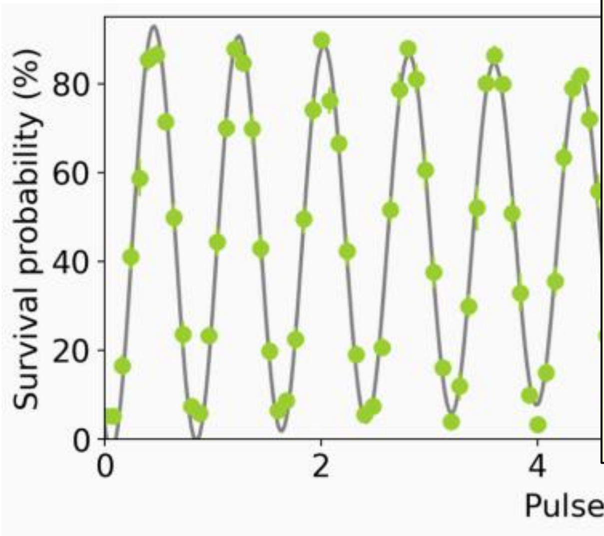

Single qubit operation by circularly polarized beam: fictitious magnetic field

No motional coupling

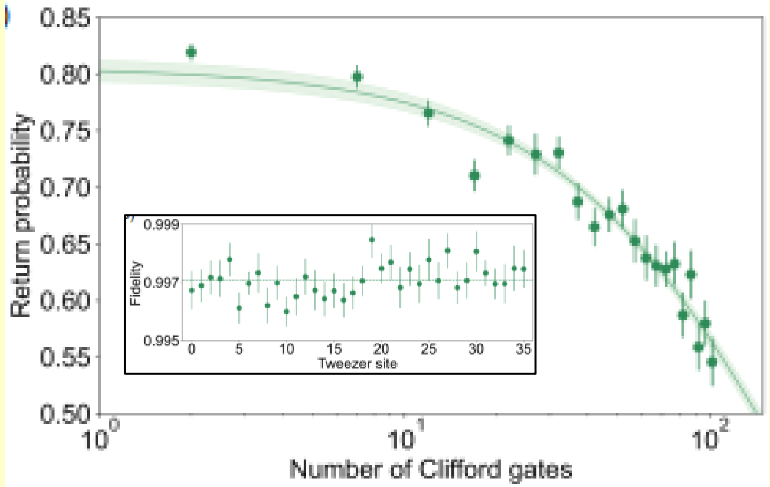
Fast (**1.3MHz**) Rabi

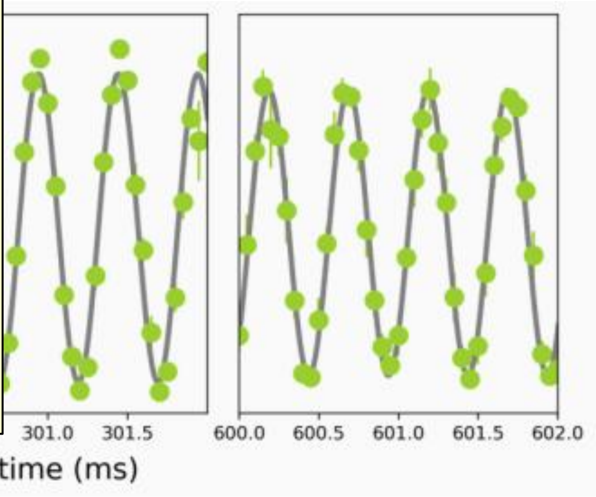
**(1.2) s** coherence time

al Decoupling Pulses




Randomized Benchmarking : **F=0.99877(4)**



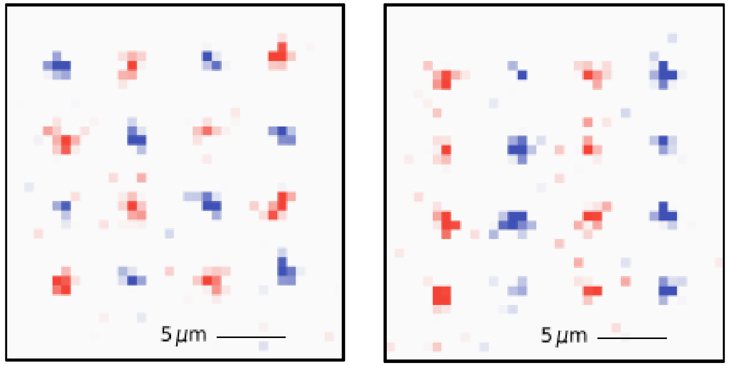
# Advantages of Ytterbium Atoms for Quantum Computing

## Rich Variety of Isotopes

| | $^{168}$Yb (0.13%) | $^{170}$Yb (3.05%) | $^{171}$Yb (14.3%) | $^{172}$Yb (21.9%) | $^{173}$Yb (16.2%) | $^{174}$Yb (31.8%) | $^{176}$Yb (12.7%) |
|---|---|---|---|---|---|---|---|
| | **Boson** | **Boson** | **Fermion** | **Boson** | **Fermion** | **Boson** | **Boson** |
| nuclear spin: | I=0 | I=0 | I=1/2 | I=0 | I=5/2 | I=0 | I=0 |

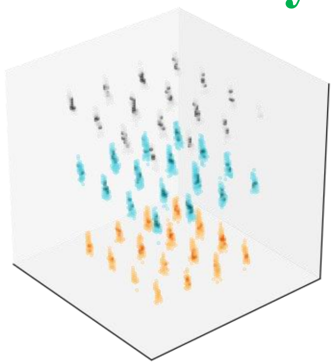
### Dual Isotope Tweezer Array

defect-free array($^{171}$Yb $^{174}$Yb)



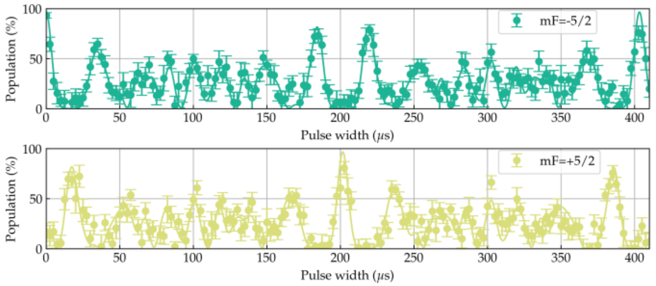

[Y. Nakamura *et. al.*, PRX2024]

### Plane-Selective 3D Array



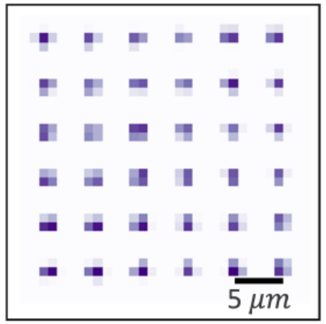
[T. Kusano *et. al.*, PRRL2025]

### Spin-Cat Qubit




[T. Kusano *et. al.*, arXiv: 2602.22883]

### Fast Imaging

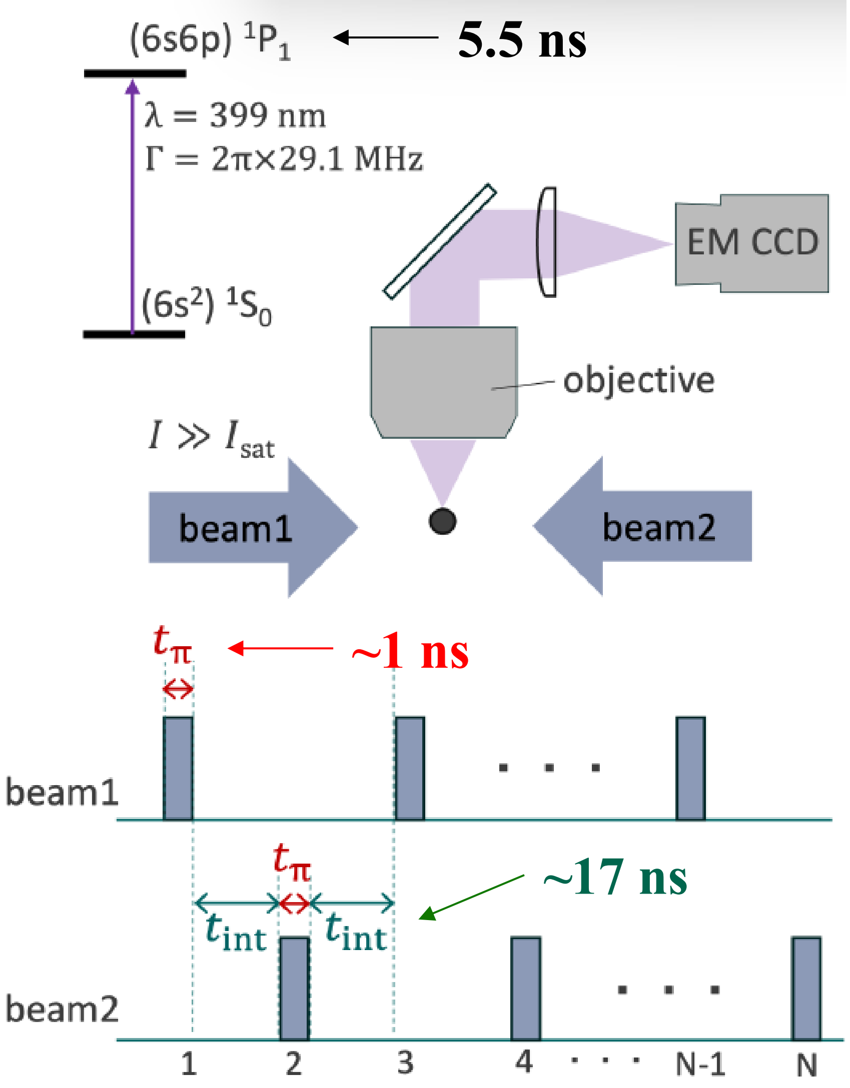



[R. Yokoyama *et. al.*, in preparation]

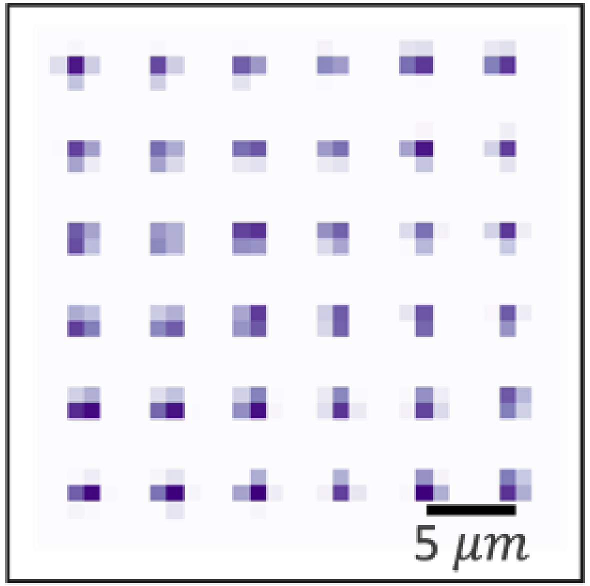
# Development of Ytterbium Atom Tweezer Array

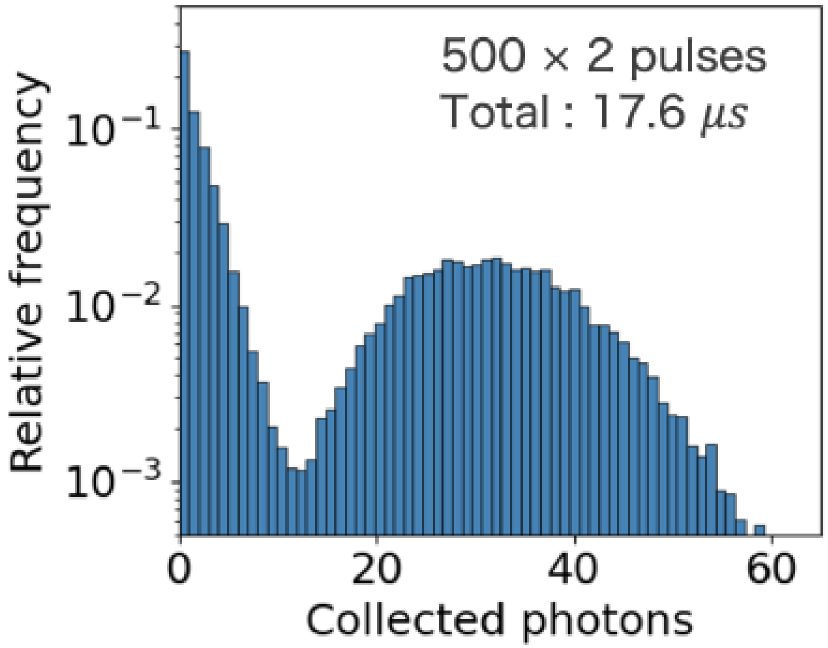
## Minimally Destructive Fast Imaging with Coherent Excitation

[R. Yokoyama, *et. al.*, in preparation]




- ✓ Readout Time : **17.6 µs** (≪ 20 *ms*)
- ✓ Discrimination Fidelity : **99.89**(5) %
- ✓ Minimal Heating **138 nK/photon** (< **307 nK/photon** :former scheme)
- ✓ Number of pulses : **1000**
- ✓ Survival Probability : **98.80**(44) %



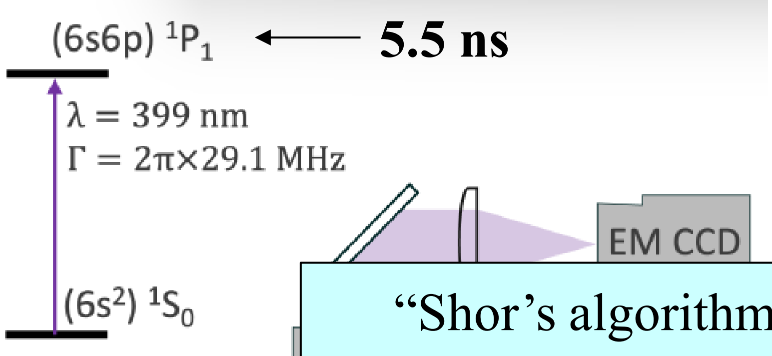



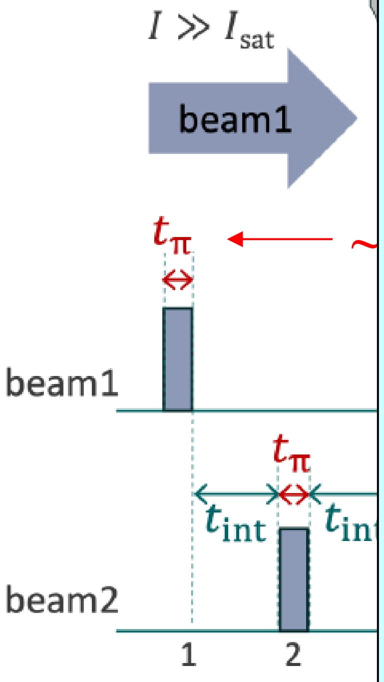
# Development of Ytterbium Atom Tweezer Array

## Minimally Destructive Fast Imaging with Coherent Excitation

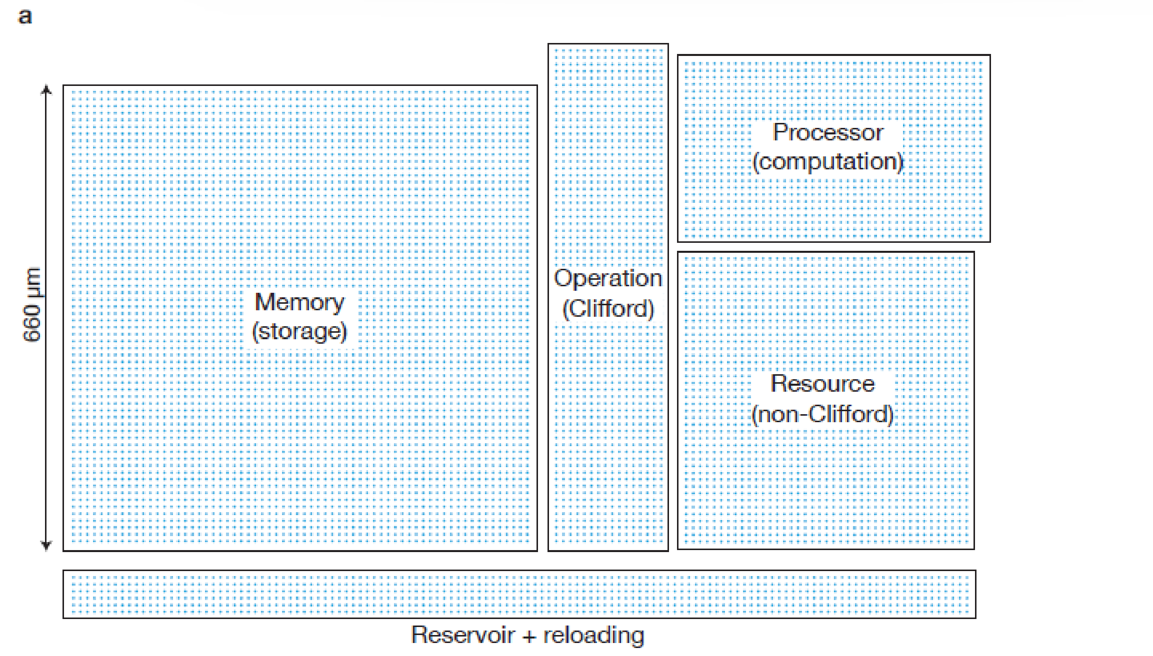
[R. Yokoyama, *et. al*., in preparation]

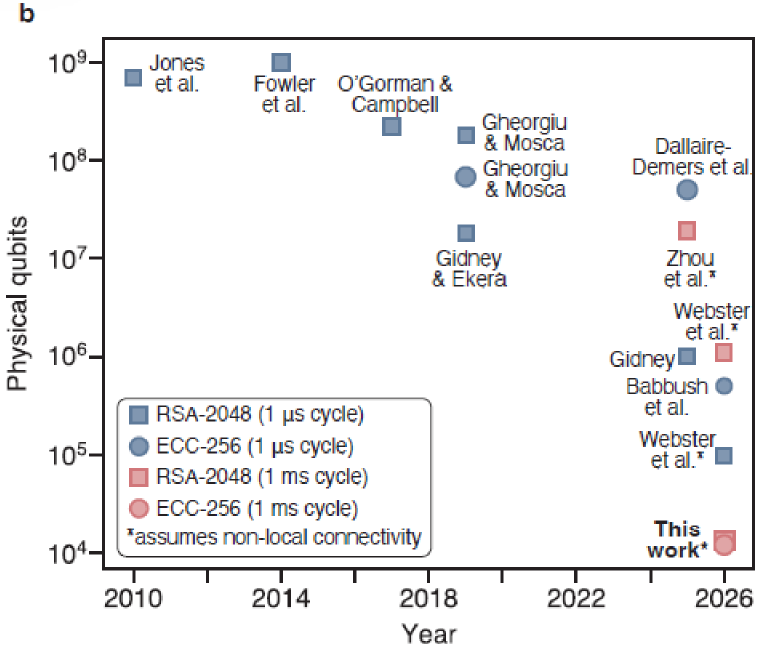
- ✓ Readout Time : **17.6 μs** (≪ 20 *ms*)
- ✓ Discrimination Fidelity : **99.89**(5) %
- ✓ Minimal Heating **138 nK/photon** (< **307 nK/photo**n :former scheme)
- ✓ Number of pulses : **1000**
- ✓ Survival Probability : **98.80**(44) %




"Shor's algorithm is possible with as few as 10,000 reconfigurable atomic qubits"
M. Cain *et al*., arXiv:2603.28627 (Oratomic/Caltech): **one QEC cycle: 1ms !**



# Summary

## Yb Quantum Sensor for New Physics

$4f^{14}6s^2\ {}^1S_0$ - $4f^{13}5d6s^2$ (J=2) new optical transition

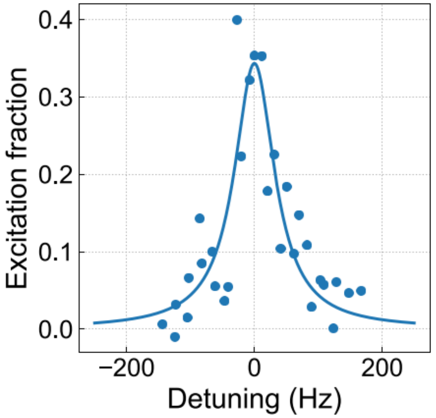
[T. Ishiyama, *et. al.,* PRL 130, 153401 (2023)]

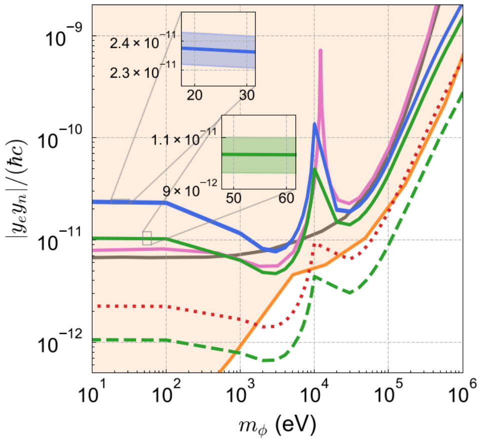
precision isotope-shift measurements and King plot analysis

[K. Ono, *et al.,* PRX (2022)]

[T. Ishiyama, *et al.,* Nat. Phot.2026]

[T. Ishiyama, *et al.,* arXiv: 2601.08487 ]




Search for dark photon with Yb Rydberg atoms [S. Chigusa, *et al.,* PRL**136**, 151801(2026)]

## Yb tweezer array for Quantum Computing

hybrid tweezer array

[Y. Nakamura *et. al.*, PRX 14, 041062(2024)]

plane selective control of 3D array

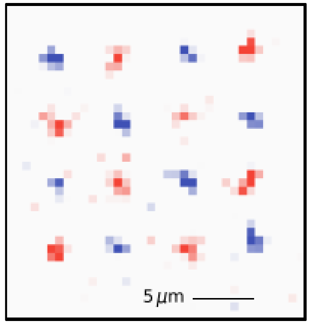
[T. Kusano *et. al.*, PRR 7, L022045(2025)]

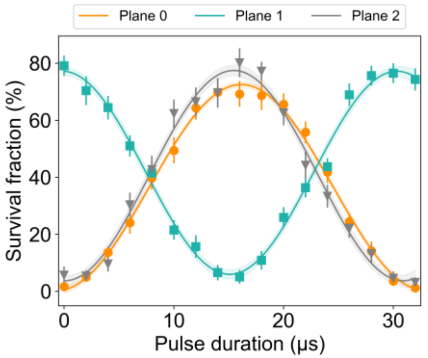
spin cat qubit

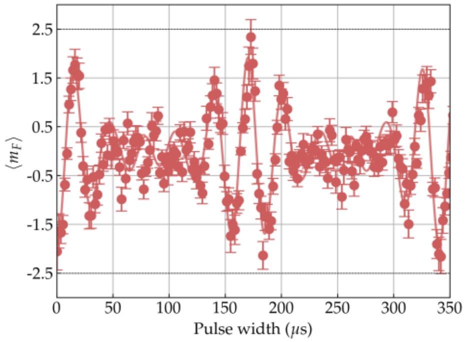
[T. Kusano *et. al.*, arXiv: 2602.22883]

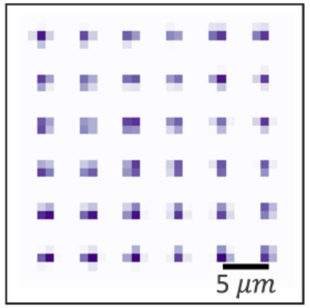
minimally destructive fast imaging

[R. Yokoyama *et. al.*, in preparation]



# *Thank you very much for attention*

16 August Mount Daimonji at Kyoto