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13th RQC Colloquium

Ultrafast quantum simulation and quantum computing with ultracold atom arrays at quantum speed limit

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Institute for Molecular Science

June 21, 2023(Wed) **16:00–17:00**(JST)

This colloquium will be held in HYBRID format.

Venue: **Wako Welfare and Conf. 2F Large Meeting Room** @ RIKEN, and Zoom

To attend online, register at https://krs2.riken.jp/m/rqc_registration_form

Many-body correlations drive a variety of important quantum phenomena and quantum machines including superconductivity and magnetism in condensed matter as well as quantum computers. Understanding and controlling quantum many-body correlations is thus one of the central goals of modern science and technology. My research group has recently pioneered a novel pathway towards this goal by exciting strongly interacting ultracold Rydberg atoms, far beyond the Rydberg blockade regime, by using an ultrafast laser pulse [1-6]. We first applied our ultrafast coherent control with attosecond precision [2,3] to a random ensemble of those Rydberg atoms in an optical dipole trap, and successfully observed and controlled their strongly correlated electron dynamics on a sub-nanosecond timescale [1]. This new approach is now applied to arbitrary atom arrays assembled with optical lattices or optical tweezers that develop into a pathbreaking platform for quantum simulation and quantum computing on an ultrafast timescale [4-6].

In this ultrafast quantum computing, we have recently succeeded in executing a controlled-Z gate in only 6.5 nanoseconds at quantum speed limit, where the gate speed is solely determined by the interaction strength between two atomic qubits [6]. This is the fastest record of a controlled gate, a conditional two-qubit gate essential for quantum computing, faster than any other controlled gates with cold-atom hardware by two orders of magnitude. It is also two orders of magnitude faster than the noise from the external environment and operating lasers, whose timescale is in general 1 microsecond or slower, and thus can be safely isolated from the noise.

References: [1] N. Takei *et al.*, *Nature Commun*. **7**, 13449 (2016). Highlighted by *Science* **354**, 1388 (2016); *IOP PhyscisWorld.com* (2016). [2] H. Katsuki *et al.*, *Acc. Chem. Res*. **51**, 1174 (2018). [3] C. Liu *et al.*, *Phys. Rev. Lett*. **121**, 173201 (2018). [4] M. Mizoguchi *et al.*, *Phys. Rev. Lett.* **124**, 253201 (2020). [5] V. Bharti *et al.*, *arXiv*:2201.09590 (2022). [6] Y. Chew *et al.*, *Nature Photonics* **16**, 724 (2022). (Front Cover Highlight)

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