Innsbruck Physics Colloquium

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

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 with nearby ultracold atoms excited with an ultrashort laser pulse to a Rydberg state far beyond the Rydberg blockade regime [1-7]. 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 [4-7].

In this ultrafast quantum computing, as schematically shown in Fig. 1, we have recently succeeded in executing a controlled-Z gate, a conditional two-qubit gate essential for quantum computing, in only 6.5 nanoseconds at quantum speed limit, where the gate speed is solely determined by the interaction strength between two qubits [5]. This is faster than any other two-qubit 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. Moreover, this two-qubit gate is faster than the fast two-qubit gate demonstrated recently by “Google AI Quantum” with superconducting qubits [8].

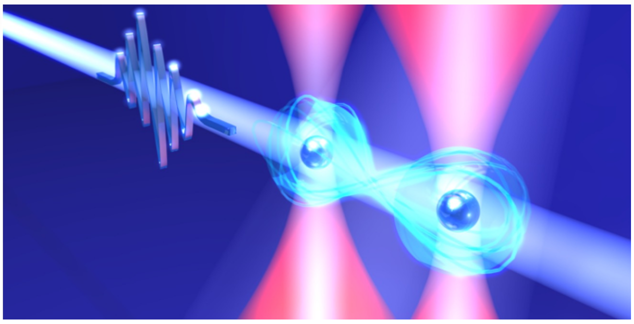

Figure 1. Conceptual diagram of the ultrafast two-qubit gate for quantum computing with cold atoms. Two single atoms captured in optical tweezers (red light) with a separation of a micrometer are entangled with an ultrafast laser pulse (blue light) shone for only 10 picoseconds [5]. Image source: Dr. Takafumi Tomita (IMS).

References

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Tuesday, 30.04.2024, at 16:30 h, HS C (Technik)

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Organisation: K. Erath-Dulitz, H.-C. Nägerl, T. Schrabback