Ultrafast quantum simulation and quantum computing with ultracold atom arrays

Kenji Ohmori
ohmori@ims.ac.jp
Institute for Molecular Science, National Institutes of Natural Sciences (NINS), Japan

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, very recently, we have succeeded in executing a controlled-Z gate in only 6.5 nanoseconds [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

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