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Staggered-immersion cooling of a quantum gas in optical lattices ZHEN-SHENG YUAN, University of Science and Technology of China, BING YANG, HUI SUN, Physikalisches Institut, Universitt Heidelberg, CHUN-JIONG HUANG, HAN-YI WANG, YOU-JIN DENG, HAN-NING DAI, JIAN-WEI PAN, University of Science and Technology of China — Cooling many-body systems to ultralow temperatures has revolutionized the field of quantum physics. In the nanokelvin regime, strongly correlated quantum gases in optical lattices provide a clean and controllable platform for studying complex many-body problems. However, the central challenge towards revealing exotic phases of matter and creating robust multi-particle entangled states is to further reduce the thermal entropy of such systems. Here we realize efficient cooling of ten thousand ultracold bosons in staggered optical lattices. By immersing Mott-insulator samples into removable superfluid reservoirs, thermal entropy is extracted from the system. Losing only less than half of the atoms, we lower the entropy of a Mott insulator by 65-fold, achieving a record-low entropy per particle of 0.0019 k_{B} (k_{B} is the Boltzmann constant). We further engineer the samples to a defect-free array of isolated single atoms and successfully transfer it into a coherent many-body state. This uniform controllable system with over ten thousand addressable qubits can be used for generating large and robust entangled states. For the gapless fermionic phases, our method could dramatically improve the efficiency of entropy transport, giving access to lower-temperature regimes for observing the d-wave superfluid phase. This method opens up an avenue for exploring novel quantum matters and promises practical applications in quantum information science.

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