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Trapped ions: A precise toolbox for quantum engineers[1]

DIETRICH LEIBFRIED, NIST Boulder

This talk will give an overview of recent work in quantum engineering with trapped ions and the exciting prospects that steady progress in this field has opened up for future research. Internal states of trapped ions have remarkable quantum coherence that lies at the heart of both the currently most precise atomic clocks and their excellent suitability as the physical keepers of quantum information. The ions' charge offers a strong handle to confine them in deep trapping potentials for very long times and to move them and manipulate their quantum state of motion with great precision. Most importantly, Coulomb coupling between several ions is utilized for high quality quantum logic gates and for producing entangled quantum states of unprecedented complexity. Optical transitions efficiently couple trapped ions to the electromagnetic vacuum that provides an almost perfect entropy sink. This enables precise initialization of internal and motional degrees of freedom without the need for low temperature experiments. The unique combination of features of trapped ions has recently led to advances in several fields, especially in quantum information processing and precision tests of fundamental physics. Perhaps most notably, it has spawned a multitude of novel experimental techniques that could also be leveraged (for example) towards quantum-enabled sensors, quantum simulation, novel spectroscopy methods, cavity QED with ions, coupling atomic physics systems to solid-state systems and the quantum coherence of well isolated mesoscopic systems. All these possibilities have in common that they expand our ability to control the quantum world. If history is any guide, such expanded abilities might well lead to more, possibly unforeseen applications and intriguing insights into some of the most fundamental questions.

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