Novel Ion Traps for Deterministic Ion Implantation and Transport Operations for Scalable Quantum Information

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Microstructured ion traps allow for the deterministic, high resolution implantation of individual laser-cooled ions, and can operate with sympathetically cooled ion species, isotopes or ionic molecules. They therefore offer the basis of an atomic nano-assembler - a device capable of placing an exactly defined number of atoms or molecules with sub millikelvin energies into solid state substrates with sub-nanometre precision in depth and lateral position.

Motivated by the general interest in tailored solid-state quantum materials, I present our steps towards deterministic generation of colour centres or quantum dots that can be placed in well-defined geometries to exploit their mutual coupling.

For realizing scalable quantum information experiments with segmented ion traps, the fast and cold transport of ions has been a long awaited goal. I will present results on shuttling operations where an ion is transported within only a few motional trap cycles, over a distance more than 200 μm, thus about 10^4 times its wave packet size, while arriving back in vibrational ground-state. We show that quantum information can be stored in the spin-motion entanglement before, and retrieved safely back after its fast travel. Controlling sequential multiples of cold transports, each less than 10 μs, we are demonstrating building blocks for fast and scalable ion quantum processing.