Trapped ion quantum processor units (ionQPUs) for scalable quantum computers: developments and quality improvements

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Quantum computing is a cutting-edge field that processes and stores information differently than classical computers. It relies on quantum bits (qubits) that can exist in multiple states simultaneously due to superposition. This enables quantum computers to perform complex calculations at unparalleled speeds and tackle intractable problems.
Surface ion traps, operating at cryogenic temperatures, are crucial for developing quantum computers. They confine individual charged atoms (ions) above a micro-fabricated chip using RF and DC voltages. By manipulating the quantum states of these trapped ions, we can create qubits with exceptional coherence and fidelity. Currently, surface ion traps can operate with around 100 ions, but scaling up to 100 000+ ions is necessary to achieve quantum supremacy.
A major challenge in scaling up these devices is power loss due to RF voltage. Two mechanisms contribute to this loss: dielectric loss in the substrate and resistive heating of the metal electrodes. To address this, a project funded by IPCEI aimed to minimize dielectric loss by transferring from silicon to fused silica substrates, which have a lower loss tangent (approximately a factor of 1e4). An ion trap was successfully fabricated on fused silica and shipped to the start-up “Oxford Ionics”, where Calcium ions were trapped.
The project also focused on reducing resistive power loss in the metal electrodes. The residual resistivity ratio (RRR) was used to measure this loss. It is defined as the quotient of the specific resistivity of a material at room temperature and zero Kelvin. By employing high-purity deposition methods, adjusting deposition parameters, and using a highly pure Al target, the RRR was increased from 7 to 199, a significant improvement.