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## Towards Entanglement-Enhanced Metrology with Trapped Ions

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Single-ion optical atomic clocks have reached fractional uncertainties of 1 part in  $10^{-18}$  [1], but reaching this level of uncertainty requires long averaging times. Using  $n$  uncorrelated ions, the same uncertainty could be obtained  $n$  times quicker. If these  $n$  ions could be placed in an entangled state however, speed-ups beyond this standard quantum limit are in principle possible with the potential to produce results up to  $n^2$  times faster [2].

We trap strings of  $^{88}\text{Sr}^+$  ions in a microfabricated monolithic linear rf trap with a three-dimensional electrode geometry [3]. This design provides 7 operation zones, plus a separate loading zone, each of which can hold ions in a deep potential well with low heating rates. The trap design and vacuum package provide a high degree of optical access available on both sides of the chip wafer.

To perform entanglement-enhanced metrology the ionic clock/qubit transition is driven by a laser that possesses two important properties: an extremely narrow linewidth around a stable optical carrier, and a low level of noise power at frequencies a motional trap frequency detuned from the optical carrier. We have realised a high power ultrastable 674 nm laser for the optical qubit in  $^{88}\text{Sr}^+$  based on a commercial Titanium-Sapphire laser system. We have measured Allan deviation at the 1 Hz level out to beyond 100 s averaging time and frequency noise below a white noise level of a few  $\text{Hz}/\sqrt{\text{Hz}}$  out to 10 MHz from the carrier.

We have recently performed our first entangling operations on pairs of trapped ions, using a Molmer-Sorensen interaction on the optical transition to generate a maximally entangled state with initial fidelities of 96%. The steps required to produce larger entangled states and use them for entanglement-enhanced metrology will also be covered.

[1] S. Brewer et al., Phys. Rev. Lett. **123**, 033201 (2019)

[2] V. Giovannetti et al., Science **306**, 1330 (2004)

[3] G. Wilpers et al., Nature Nanotech **7**, 572 (2012)

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