Integrated photonics for photon mediated entanglement generation and sub-Doppler cooling

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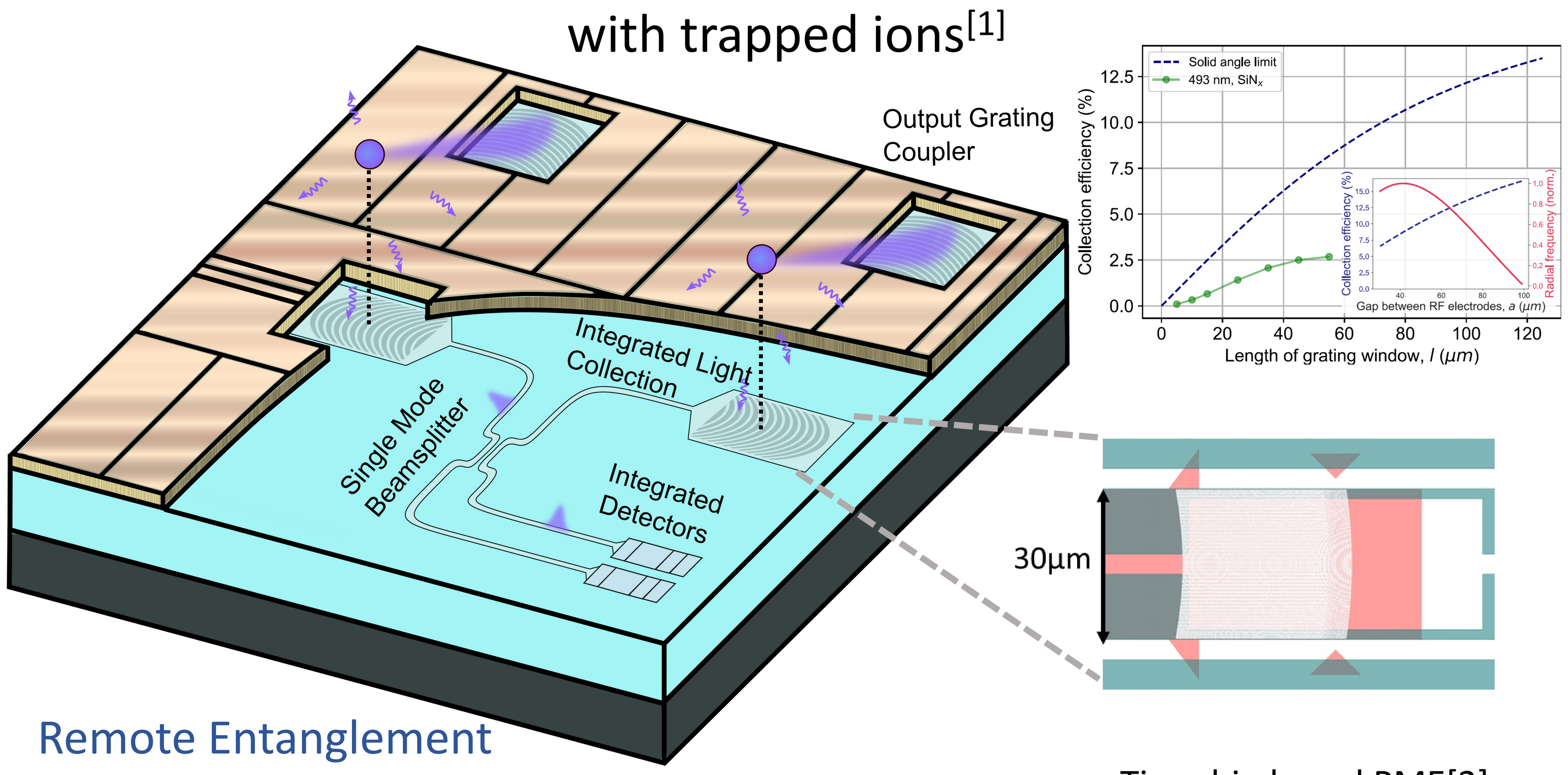
Motivation

1. Entanglement between spatially separated ions is a resource that is needed or beneficial in many applications of trapped-ion platforms
2. Spatial constraints limit optical access limiting the scalability of photon mediated entanglement (PME) with trapped-ions

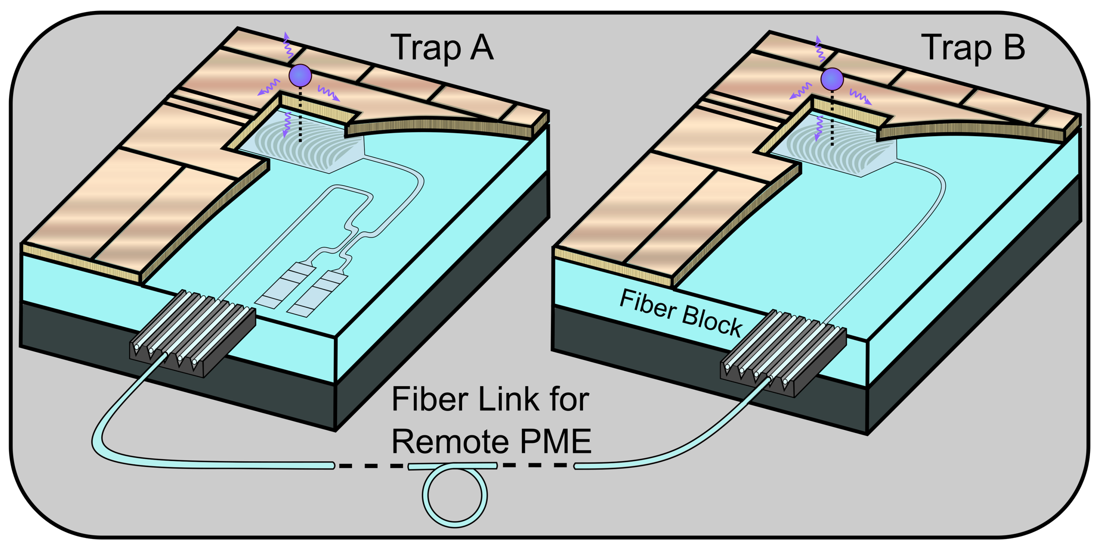
3. Integrating photonic circuits into trapped-ion platforms offers an avenue for scaling-up the number of entangled ion nodes

Vision

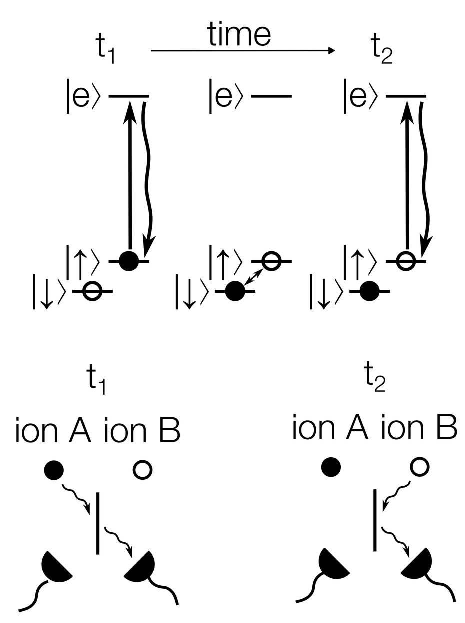
A remote entanglement generation unit cell that can be multiplexed to achieve high-rate entanglement generation with trapped ions[1]



Remote Entanglement Generation



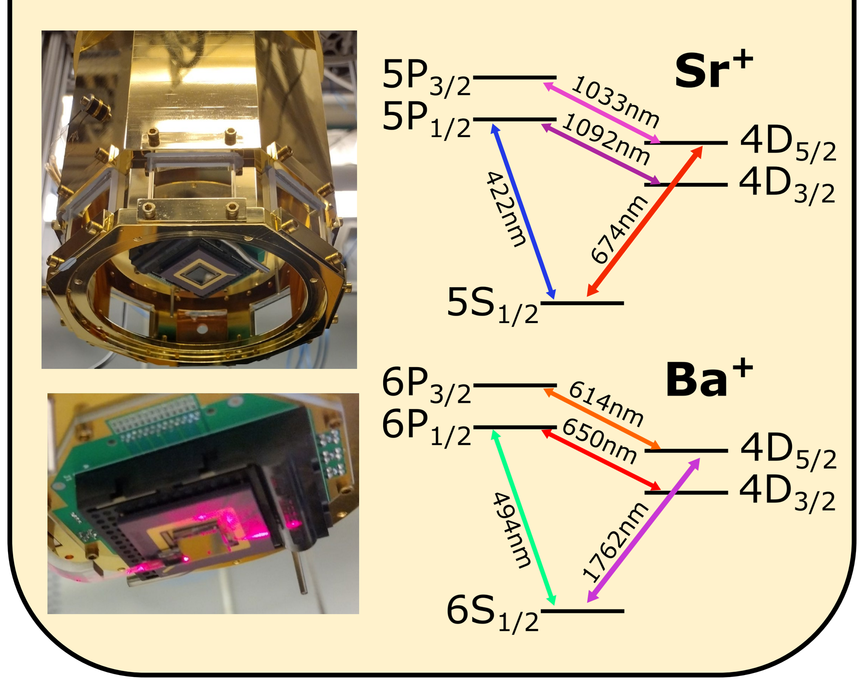
Time-bin based PME[2]



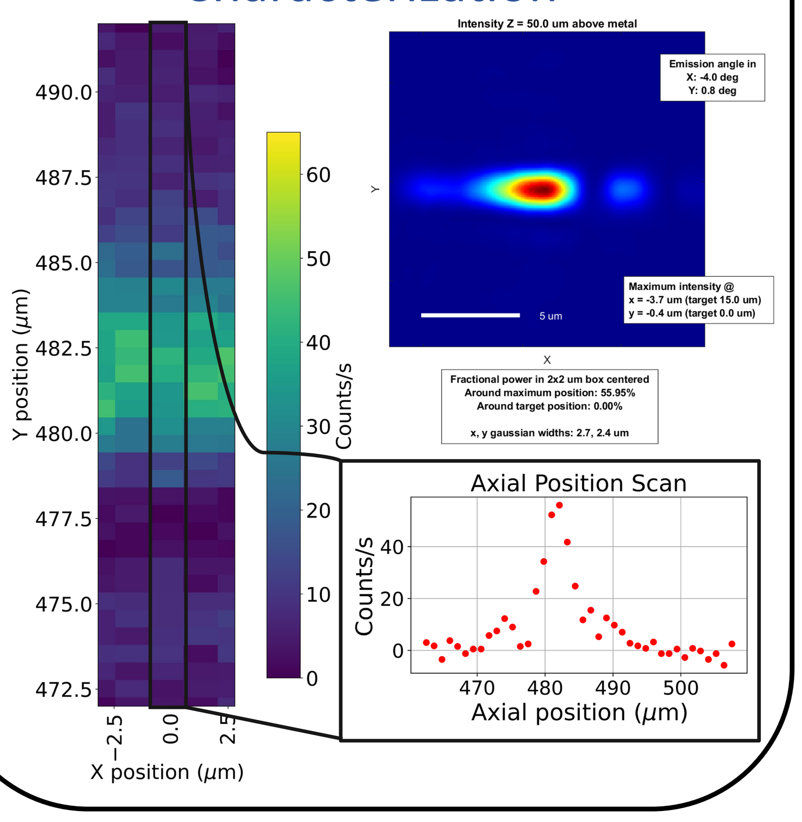
Collaboration between: Sandia National Laboratories

Collaborators from Sandia: M. Gehl, J. D. Hunker, D. Stick

Our System



In-situ and Ex-situ Device Characterization



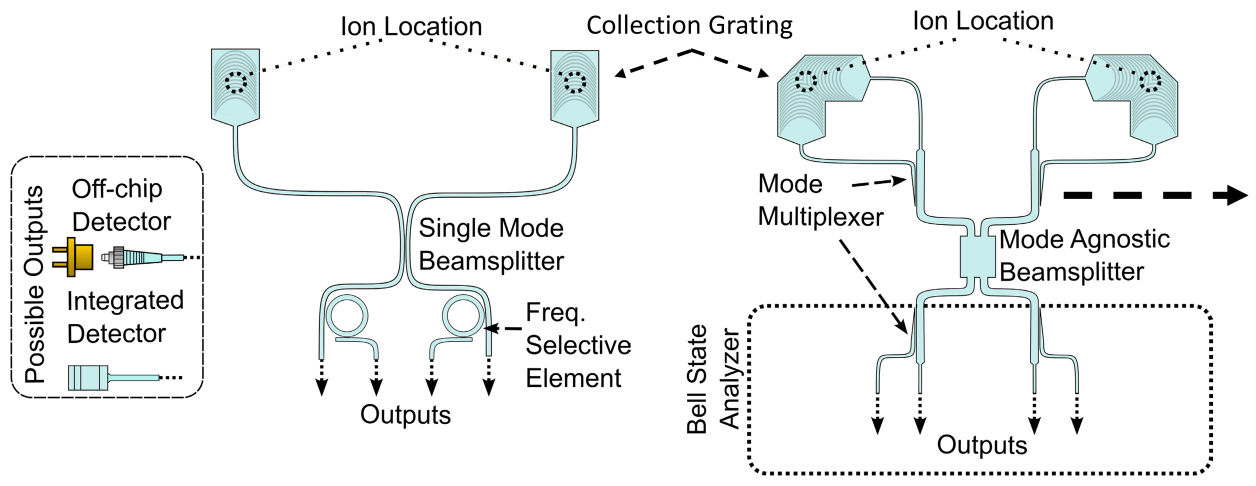
Implementation

Emission gratings for pulsed excitation

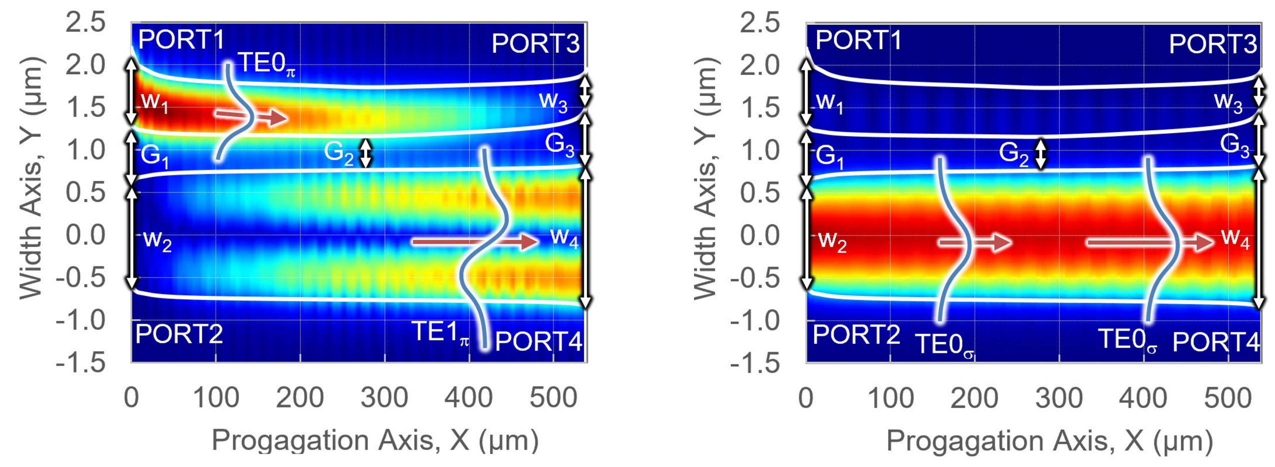
Photon collection gratings

Integrated beam splitters

Waveguide-coupled detectors



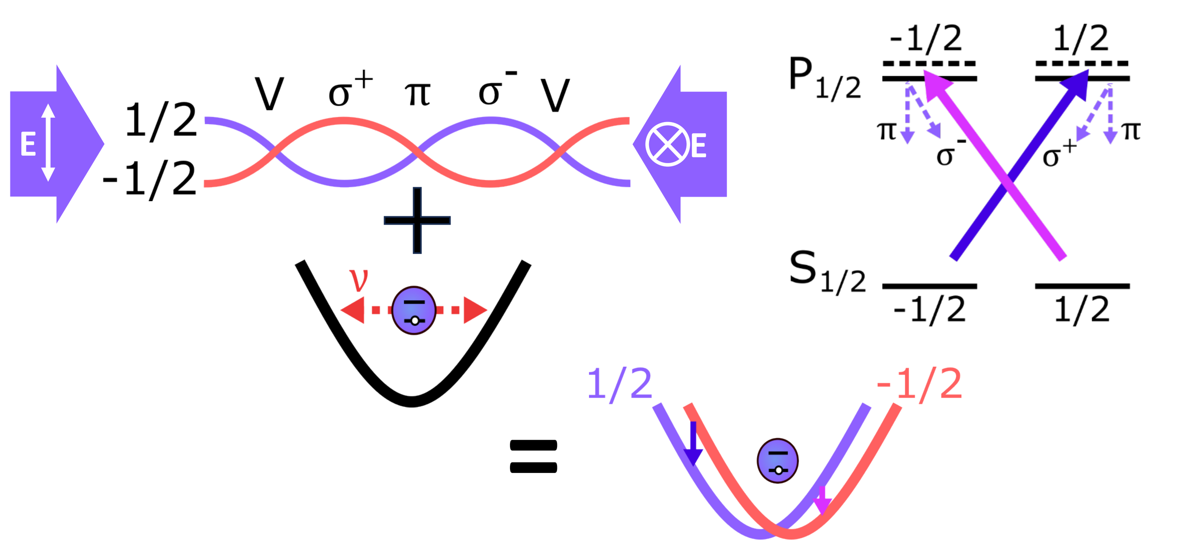
Mode Multiplexer



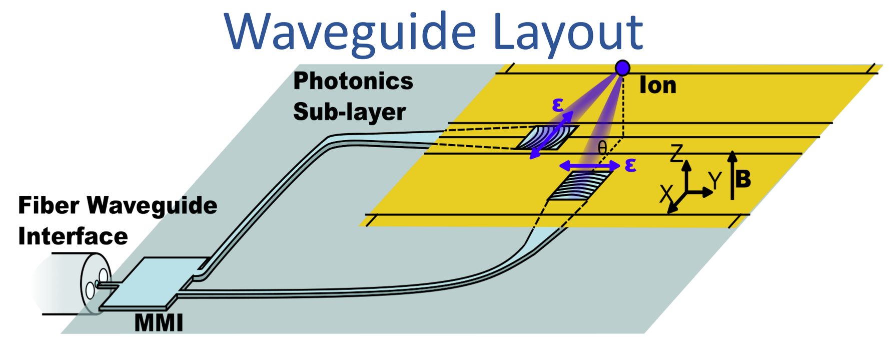
Fast cooling and state preparation

We are developing and testing structures to deliver light of different polarizations for:

- Fast state preparation
- Remote entanglement generation pulses
- EIT cooling [3]
- Polarization gradient cooling [4,5]*



Waveguide Layout



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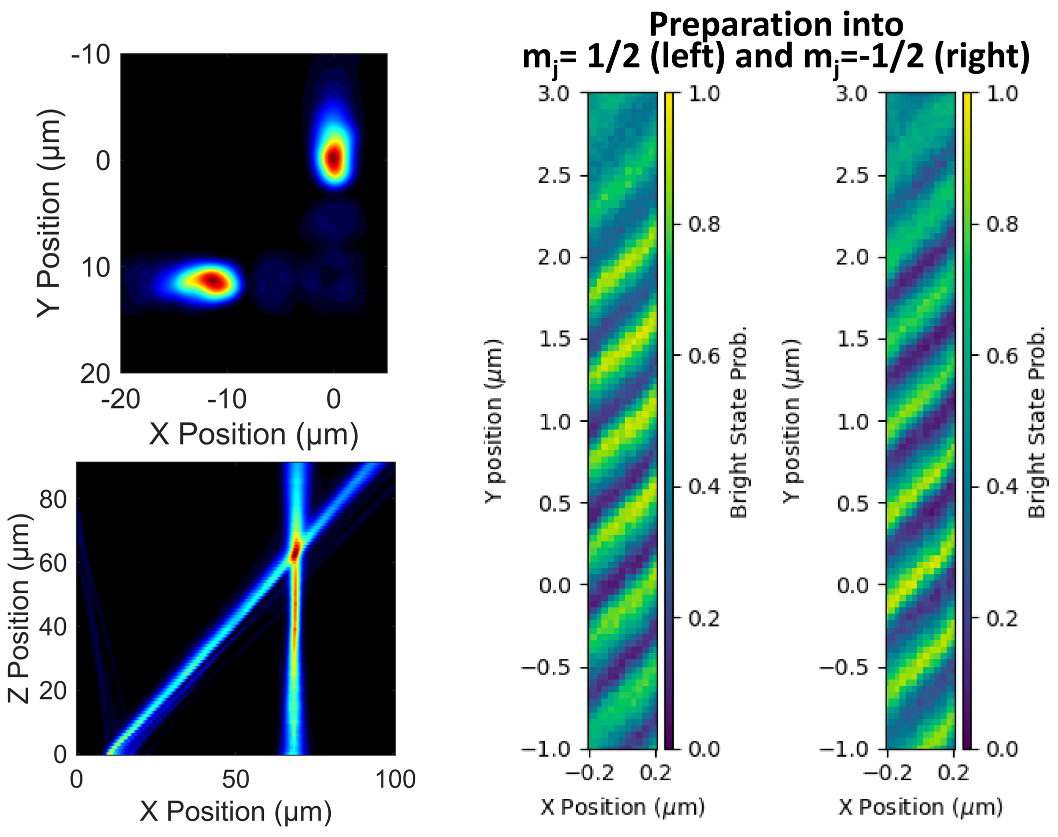

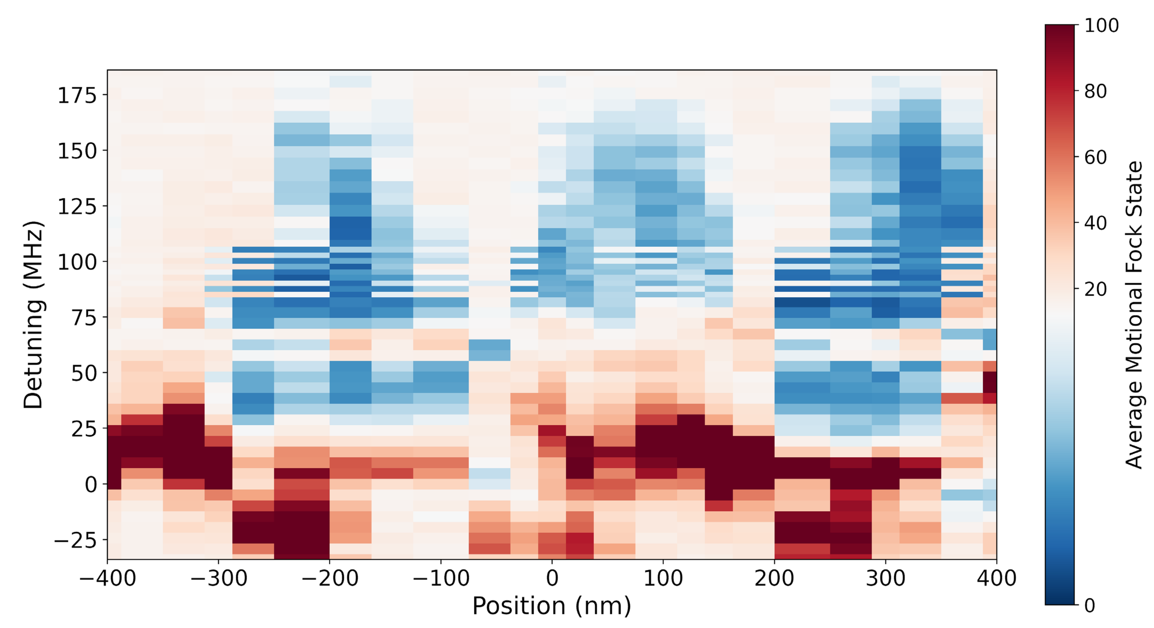

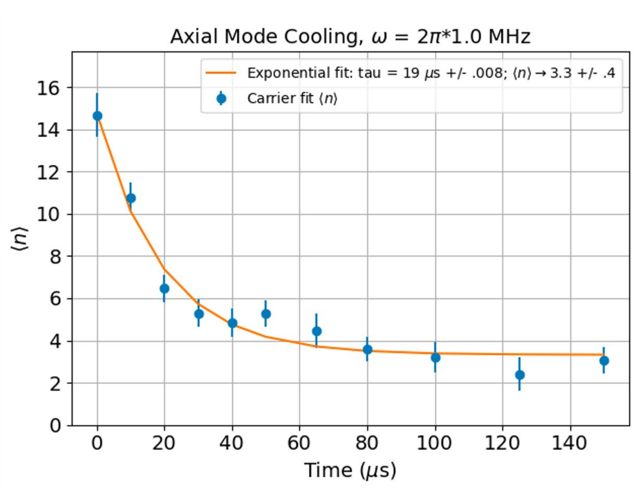

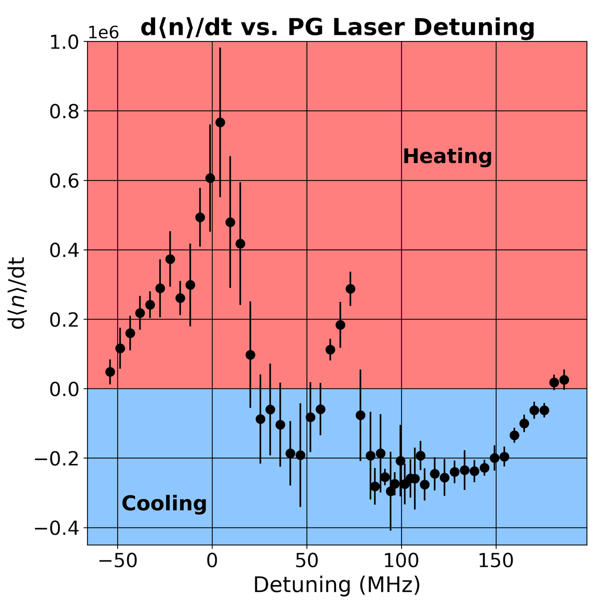

Consequences

Modular quantum computing in a single vacuum system with up to 100 kHz links

Quantum repeaters for long distances when combined with coherent frequency conversion

Improved run time of quantum algorithms by reducing the time spent sideband cooling

Refs.

[1] Knollmann, F. W., et al. "Integrated photonic structures for photon-mediated entanglement of trapped ions." *arXiv preprint arXiv:2401.06850* (2024).
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[4] Cirac, Juan Ignacio, et al. "Laser cooling of trapped ions with polarization gradients." *Physical Review A* 48.2 (1993): 1434.
[5] Joshi, M. K., et al. "Polarization-gradient cooling of 1D and 2D ion Coulomb crystals." *New Journal of Physics* 22.10 (2020): 103013.

QR codes

Digital version of poster:

[1]Arxiv link: