Phase-stable polarization gradient cooling of trapped ions

Ethan R. Clements†, Zhaoyi Li, Felix Knollmann, Sabrina Corsetti, Ashton Hattori, Milica Notaros, Reuel Swint, Tal Sneh, May E. Kim, Aaron D. Leu, Patrick T. Callahan, Thomas Mahony, Gavin N. West, Cheryl Sorace-Agaskar, Dave Kharas, Robert McConnell, Colin D. Bruzewicz, Isaac L. Chuang, Jelena Notaros, and John Chiaverini

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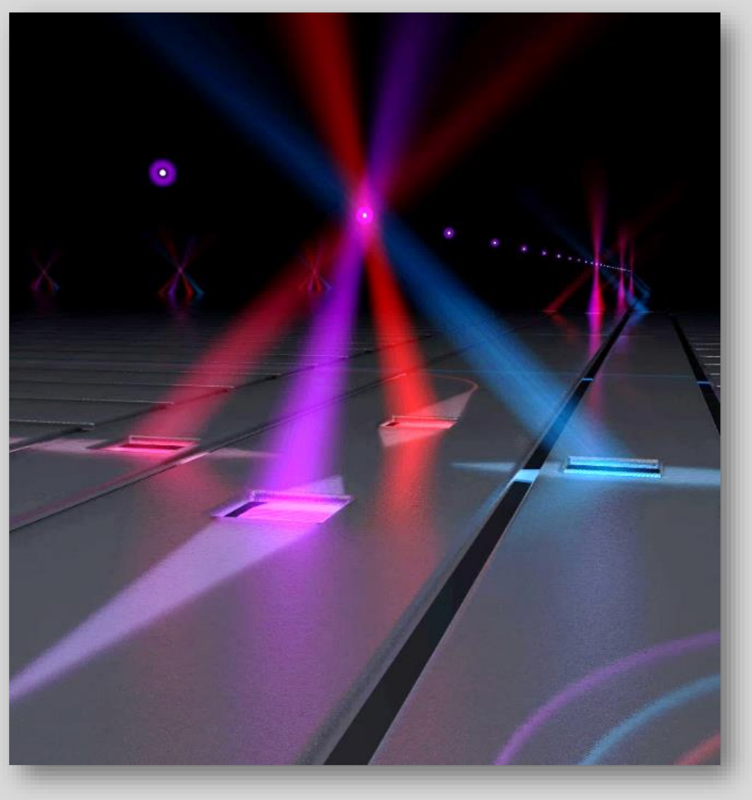
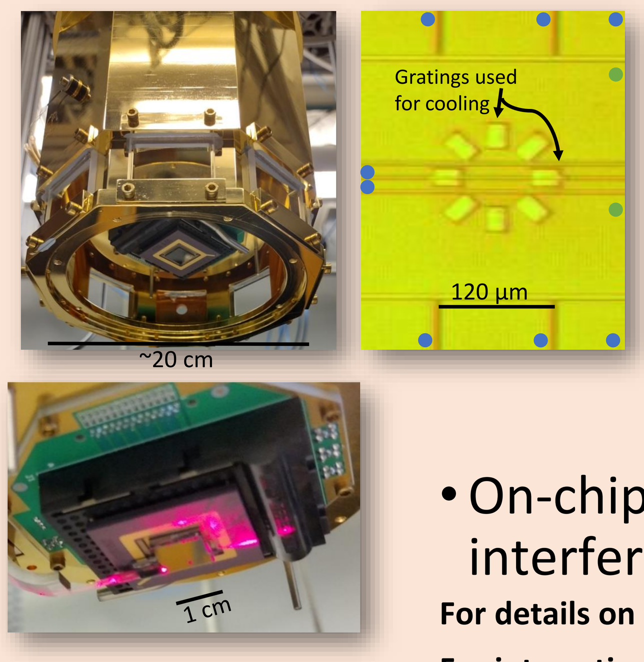
Motivation

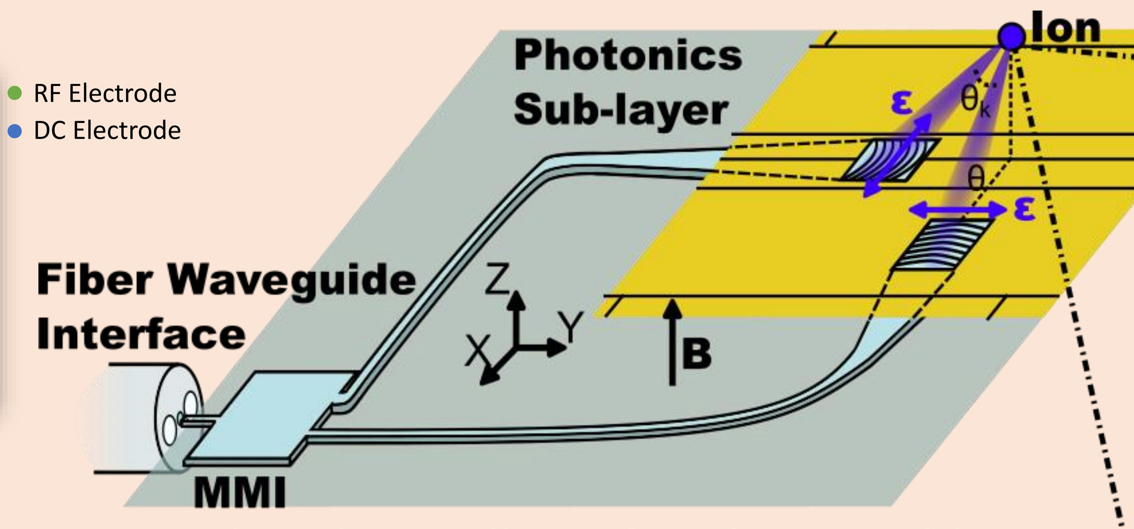
We are developing and testing ion-trap integrable photonic structures to deliver light of different polarizations for fast and power efficient cooling and state preparation.

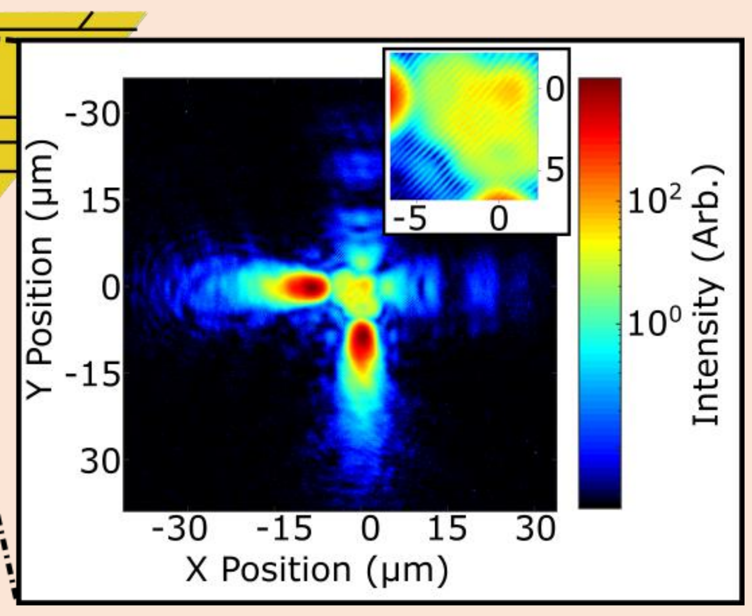


One cooling method that fulfills the low power constraint is polarization gradient cooling [1,2,3]. While this method has been used widely in the atomic physic community phase stable implementations of this method have not been demonstrated. Here we present phase-stable polarization gradient cooling which is enabled by the stability afforded by trap-integrated photonics [4].

Experimental Overview







- On-chip waveguide splitter allows for phase-stable interference of the two beams at the ion location

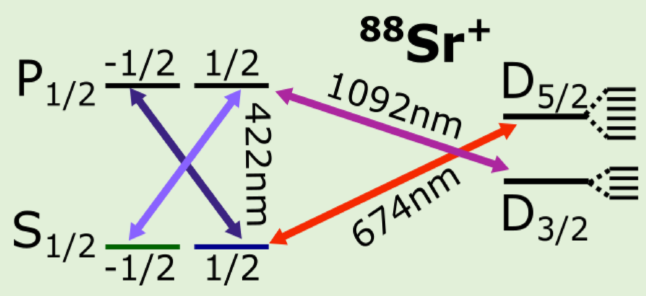
For details on photonics design see S. Corsetti's poster! – S3.1

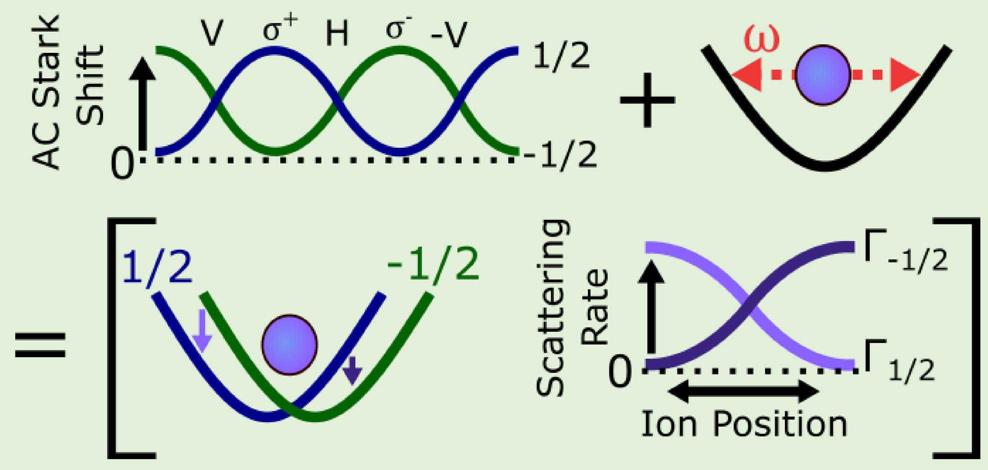
For interesting results on integrated light collection see F. Knollmann's poster! – S3.10

Explanation of Cooling Process

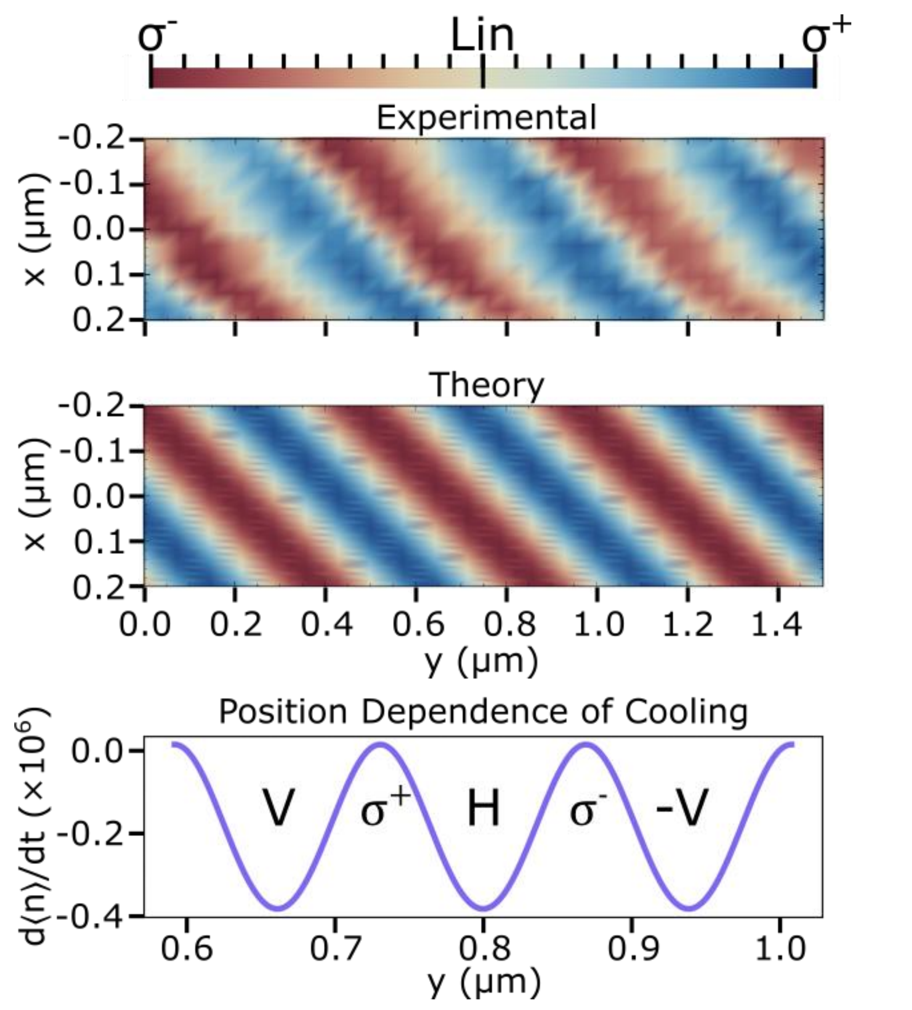
A position-dependent energy difference to cool the ion

- Created using an AC stark shift on the electronic ground state manifold
- Scattering is a function of ion position
- When combined with the state dependent trapping potential leads to Sisyphus effect

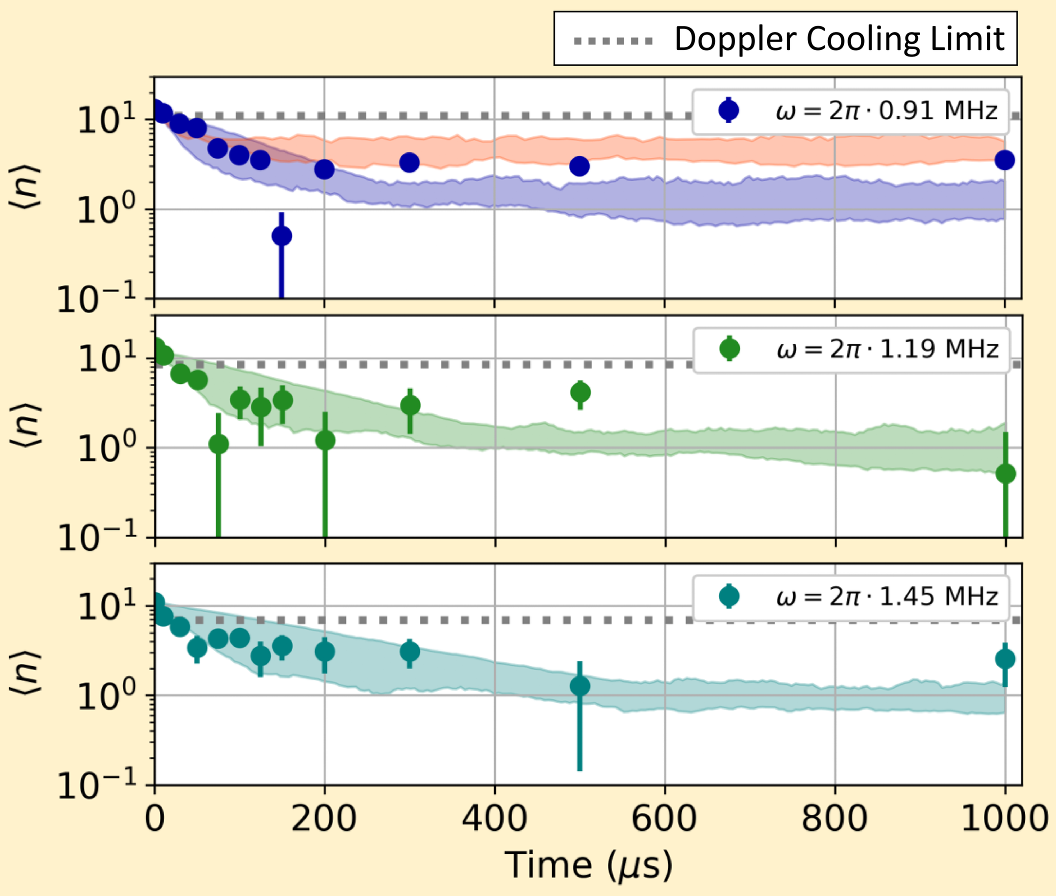




Ion Imaging of Polarization Gradient

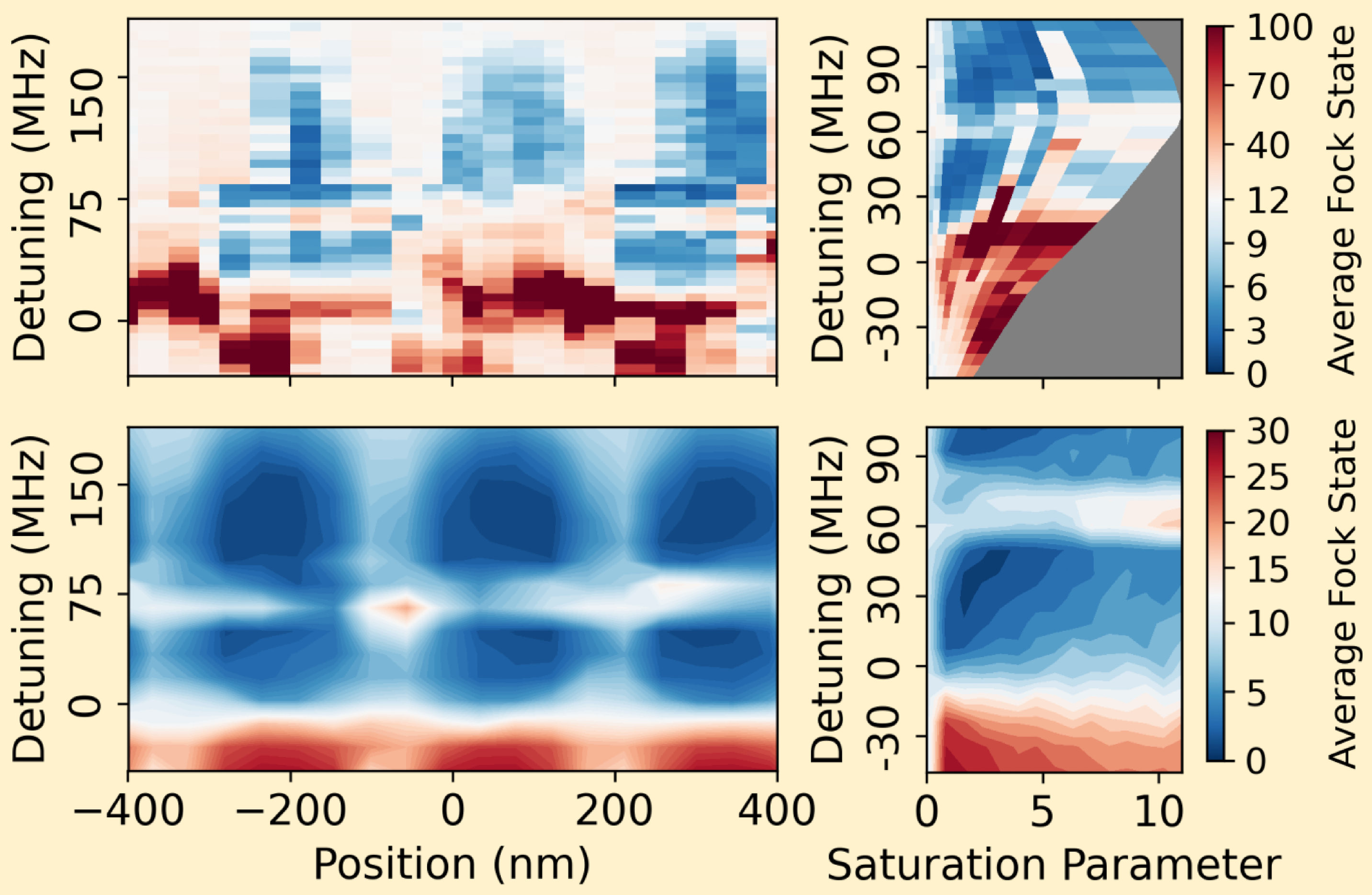


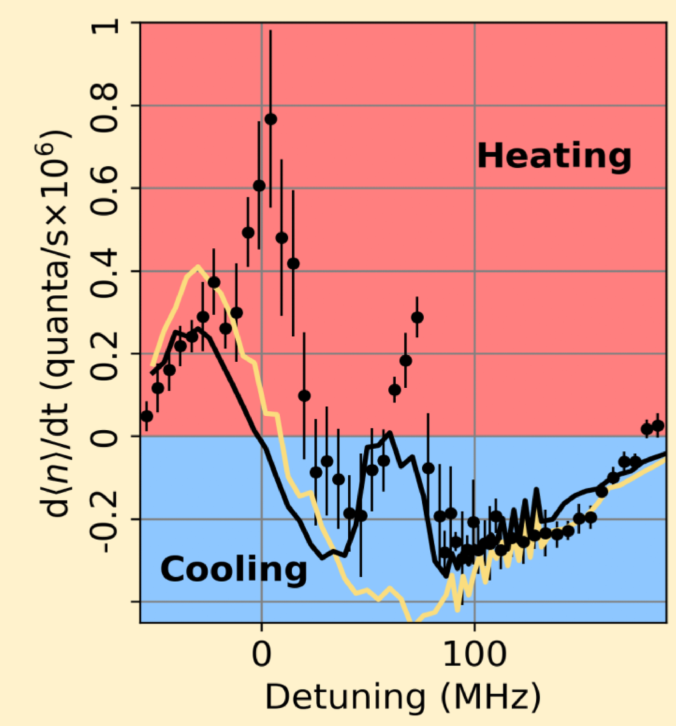
Time-dependence of Cooling



- Achieve ⟨ n ⟩ < 3 for axial modes in ~100μs
- Motional frequency dependence is consistent with theory

Experimental vs. Theoretical Cooling Parameter Space





- Saturation Parameter given by:

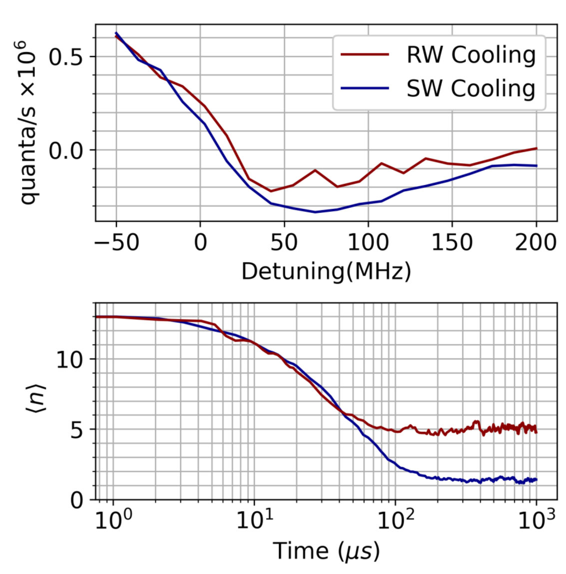
$$s = \frac{\Omega^2/2}{\delta^2 + \Gamma^2/4}$$

Ω = Rabi Frequency
δ = Laser Detuning
Γ = Linewidth of driven transition

- Regions with lower temperatures correspond to locations with maximum polarization gradient
- Position dependence of cooling consistent with modelling of a phase-stable polarization gradient
- Saturation parameter of 2 corresponds to an optical power of ~5 nW for a beam waist of 1.5μm in our expt.

Outlook

- Experimental comparison of running-wave and phase stable polarization gradient cooling
- Studies of cooling with longer ion chains
- Potential cooling benefits resulting from larger state space and additional coupling?
- Implementation of EIT-Cooling using integrated photonics [5,6]



Refs.

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QR codes

Arxiv links:

[3] [4]

Digital version of poster: