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Velocity Map Imaging Ultracold Plasma Dynamics

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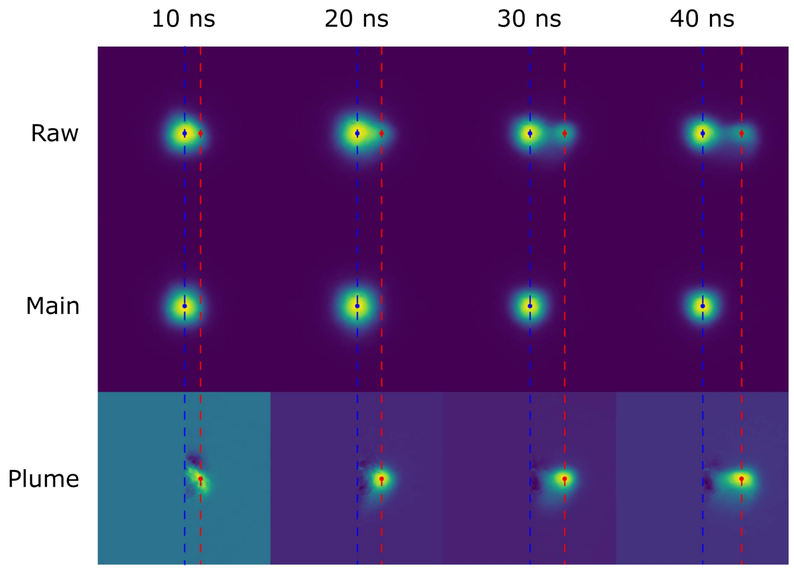
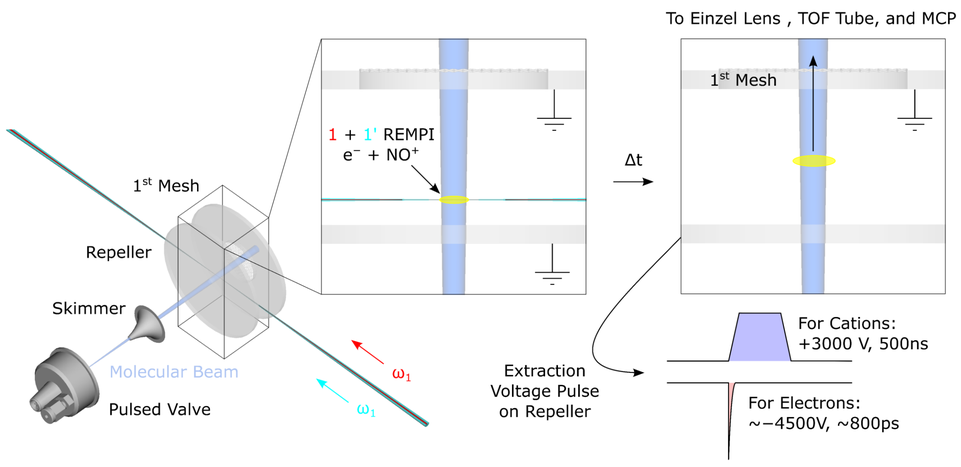
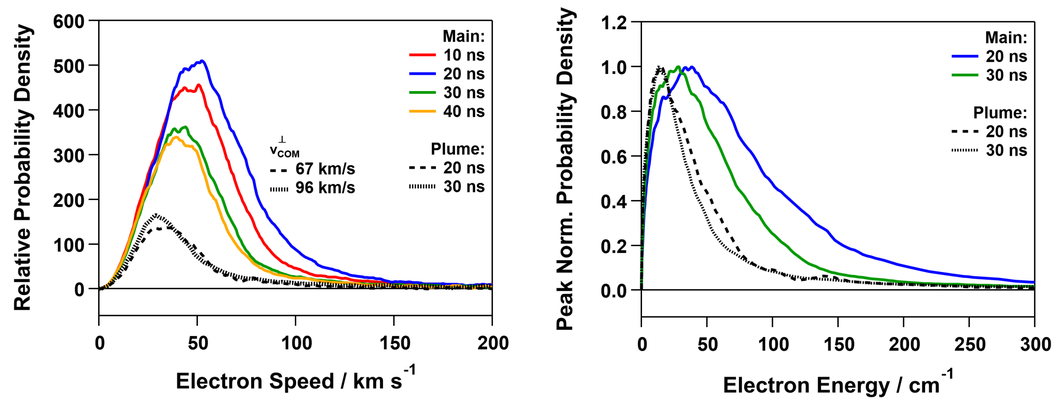
"Ultracold plasmas" produced by laser photoionization of atoms or molecules in a magneto-optical trap or supersonic beam can produce initial electron (ion) temperatures in the mK (μK) range with charged particle densities that enter or approach a "strong coupling" regime where foundational statistical plasma theories break down. Absorption and fluorescence imaging experiments dominate existing dynamical studies and report a clear need for the development of methods to study the time-resolved electron energy distribution before the onset of ballistic expansion into vacuum (< 1 μs). Here we report initial results toward this goal using velocity map imaging.



Time-resolved velocity mapped images of the evolving 1+1' REMPI plasma during the initial stages of plume formation. Images for the main peak are obtained by mirroring the left half of the raw images. Images for the plume peak are obtained by subtracting the main image from the raw image.

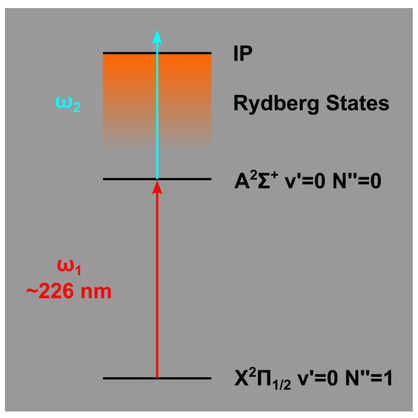
Schematic of the velocity map imaging plasma spectrometer



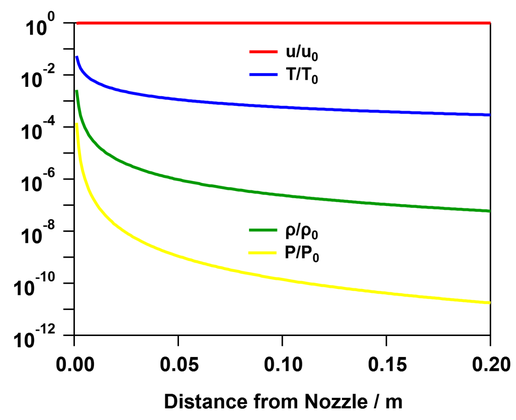


Velocity and energy distributions for the electrons extracted from the main plasma and plume.

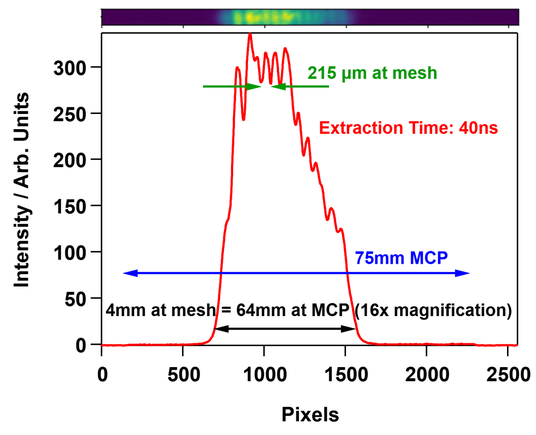
Energy level diagram for 1+1' REMPI of NO

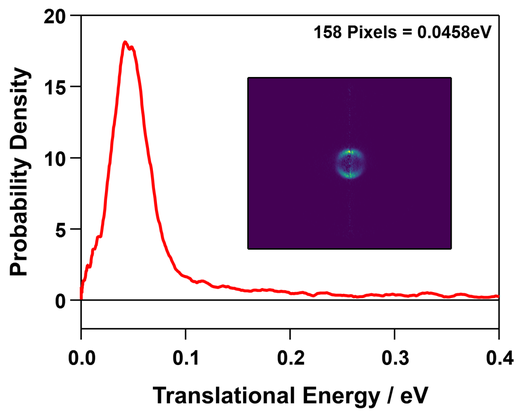


Hydrodynamic predictions at the interaction region for 50% NO in He



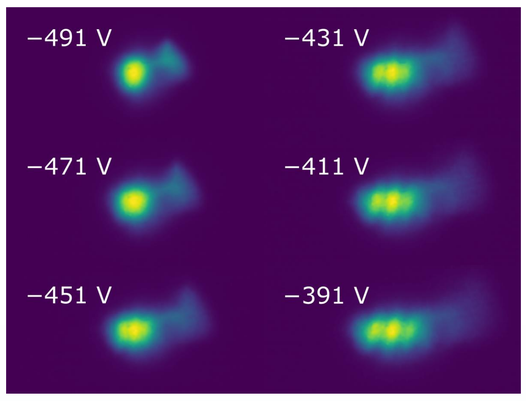
A horizontal slice containing a spatial image of the plasma at 40 ns (center plate of Einzel lens at 0 V) is shown above a plot obtained by vertically binning this slice.

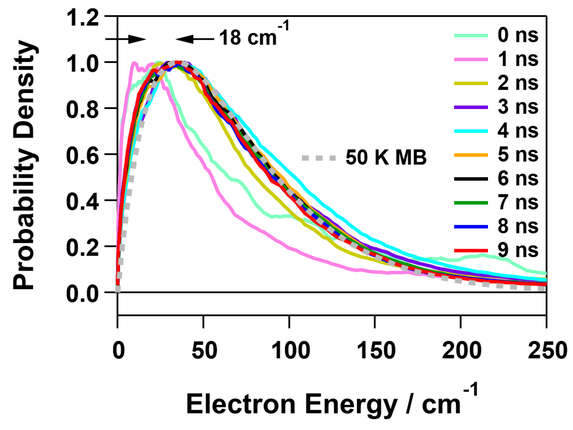




Abel-inverted velocity map image and translational energy distribution of 0.0458 eV electrons generated from 1+1' REMPI of NO under conditions where the ionizing laser does not generate a plasma.

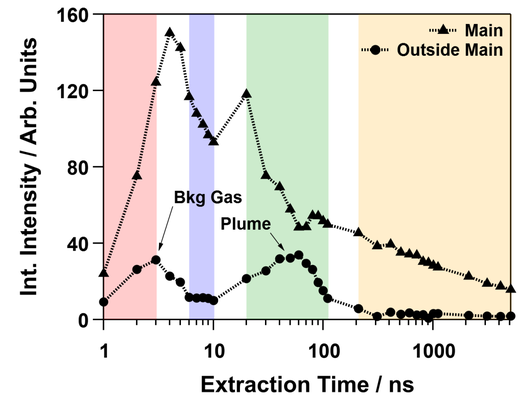
Lowering the voltage on the center plate of the Einzel lens moves the image from a velocity- mapped condition (–500V) toward a spatially mapped condition (0 V). The plume is highly spatially delocalized to the right of main plasma.





Velocity distributions obtained from the main plasma peak as a function of extraction time. 50 K Maxwell-Boltzmann velocity distribution for comparison.

Integrated intensity of the main VMI peak (filled triangles) and the region outside of the main VMI peak (circles). Different phases in the lifetime of the plasma are highlighted.



Acknowledgement

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