Ring-Shaped Distributions of Quasimonoenergetic Electron Beams Generated via Density Discontinuities in a Two-Stage Gas Cell

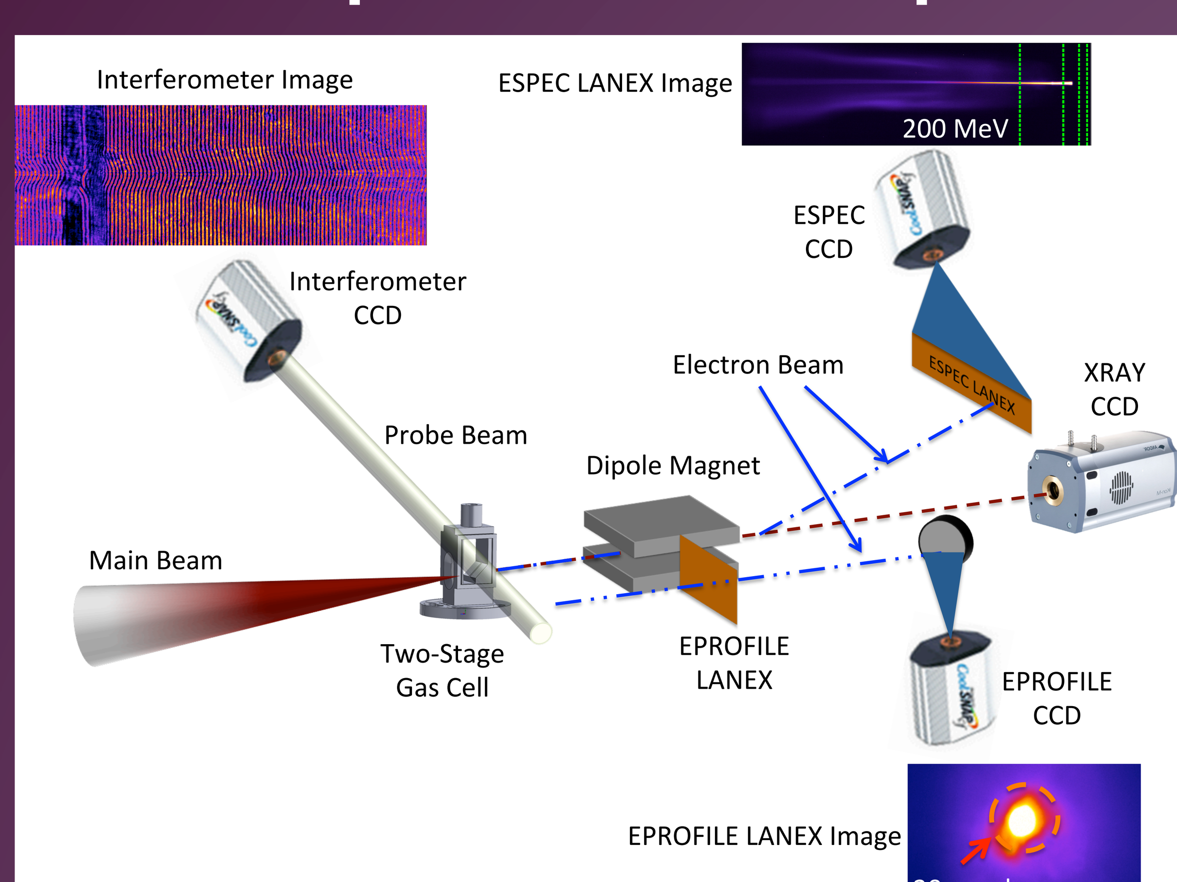
Z. Zhao[1], K. Behm[1], V. Petrov[2], S. Kalmykov[3], V. Chvykov[1], B. Hou[1], A. Maksimchuk[1], V. Yanovsky[1], A.G.R. Thomas[1], and K. Krushelnick[1]

[1] Center for Ultrafast Optical Science, University of Michigan, Ann Arbor, MI
[2] Nuclear Engineering and Radiological Sciences, University of Michigan, Ann Arbor, MI
[3] Department of Physics and Astronomy, University of Nebraska – Lincoln, Lincoln, NE

Abstract

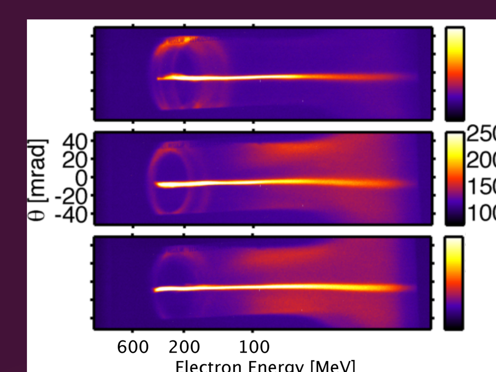
Ring-shaped distributions of quasimonoenergetic electron beams were generated using an opposing flow two-stage gas cell. These electron "halos" were created using both ionization injection and self-injection mechanisms with charge on the order of several pC. The average ΔE/E of the halos decreased to a minimum of 7% as the laser pulse duration was increased from 84 to 130 fs. The average number of photons per electron was also consistently higher when the halos were present, up to almost an order of magnitude increase. In addition, the angular spread decreased with increasing acceleration length in the gas cell. Measurements of the electron density showed that the halos have only appeared when the density in the 1st stage was higher compared with the 2nd stage, regardless of laser power or acceleration lengths in the gas cell. It is postulated that these structures are formed as the laser crosses a steep density perturbation, similar to a hydrodynamic shock, created from the opposing gas flows between the gas cell stages. Such well-defined angular distributions of monoenergetic electrons may prove useful for plasma-based X-ray sources.

Experimental Setup

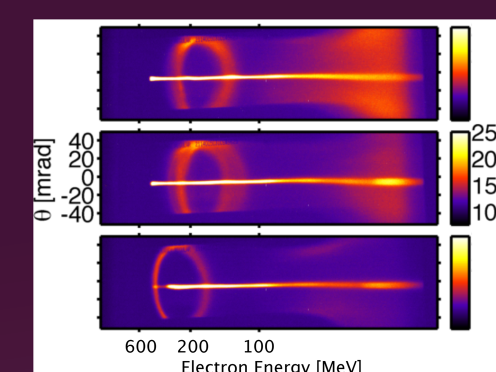


Experimental Results

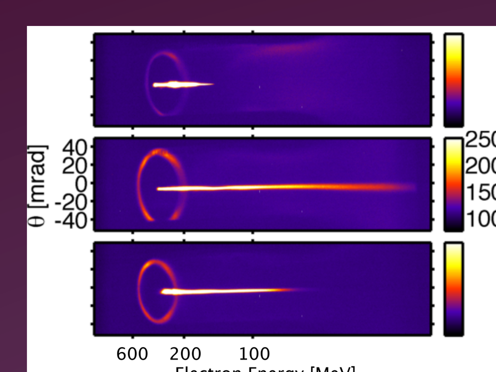
Electron Spectrometer Images and Pulse Duration Measurements



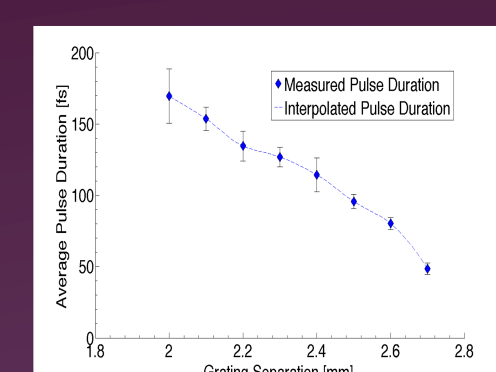
a) τ_L = 49 fs



b) τ_L = 105 fs

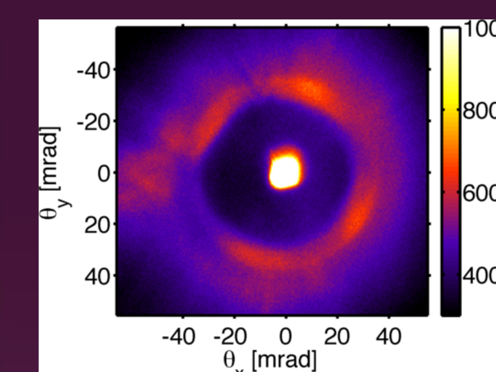


c) τ_L = 135 fs

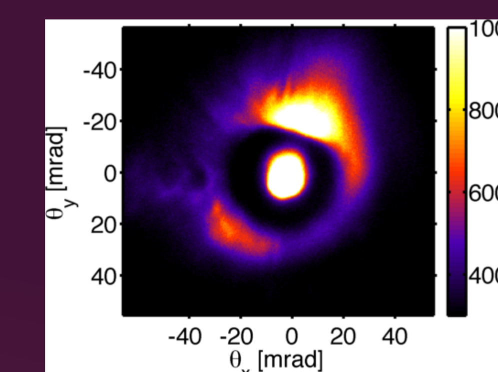


d) Grating Scan

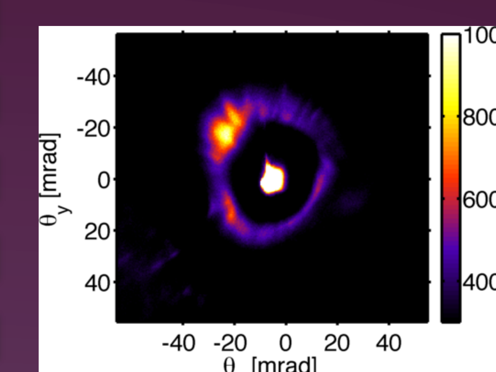
Electron Profile Images and Acceleration Length Scan



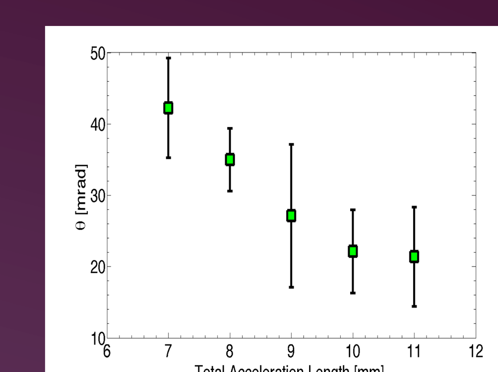
a) L = 8 mm



b) L = 9 mm

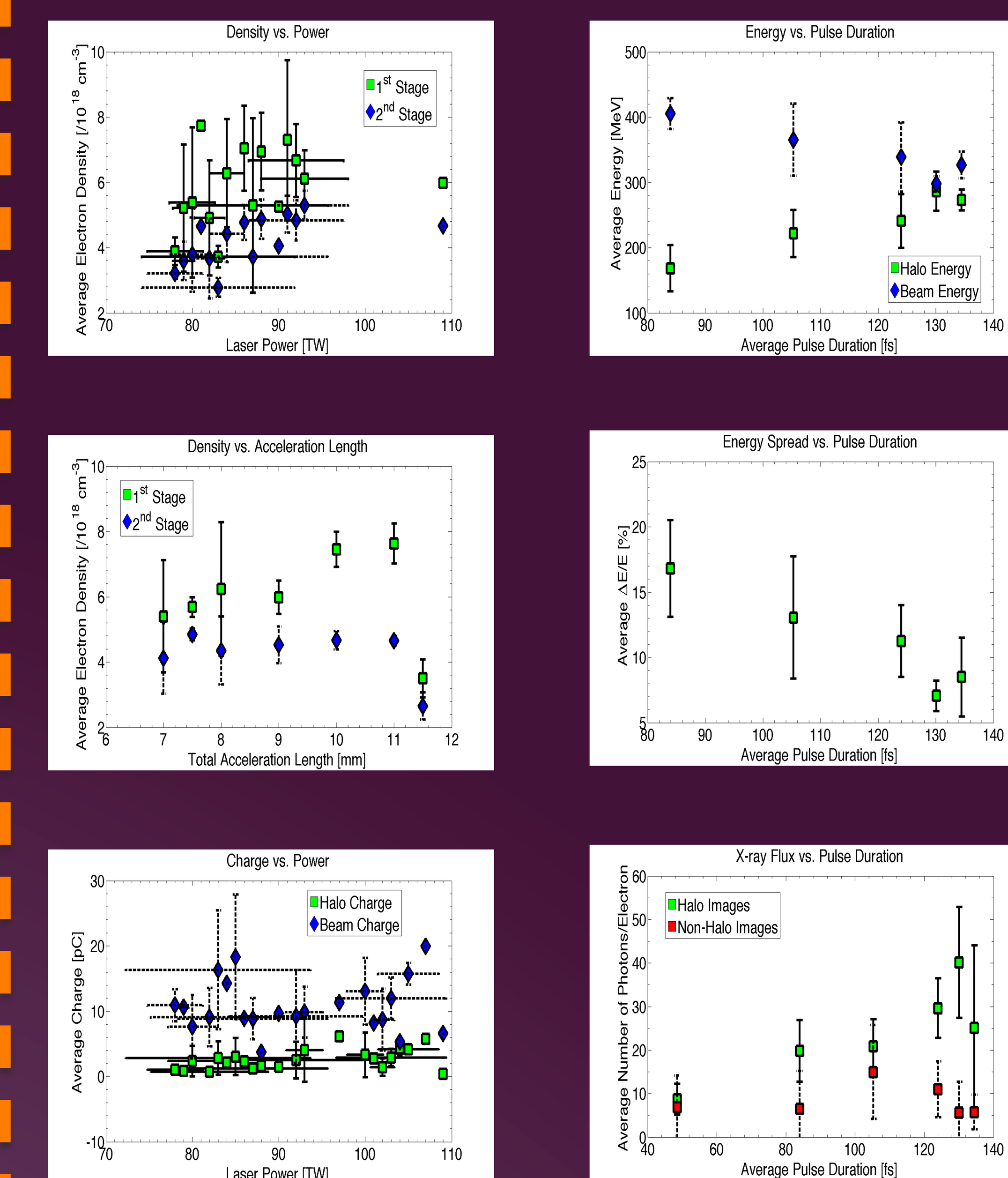


c) L = 10 mm

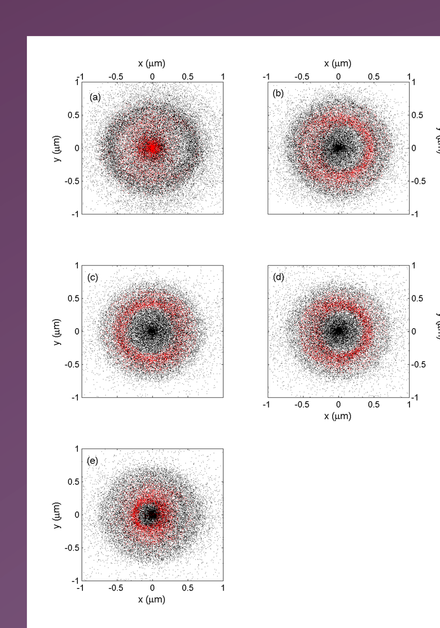


d) Acceleration Length Scan

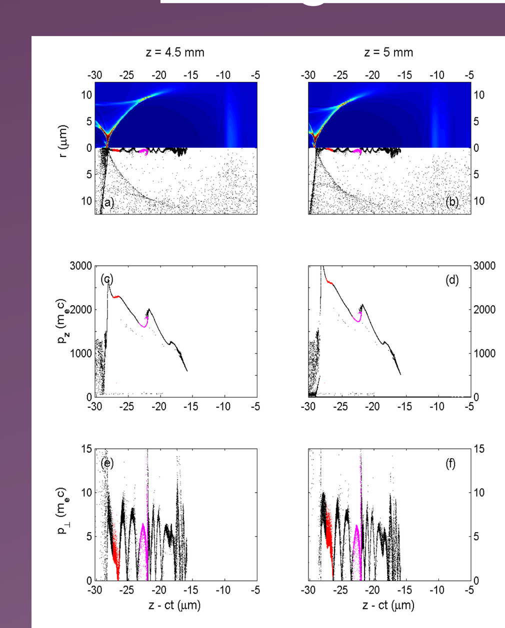
Trends



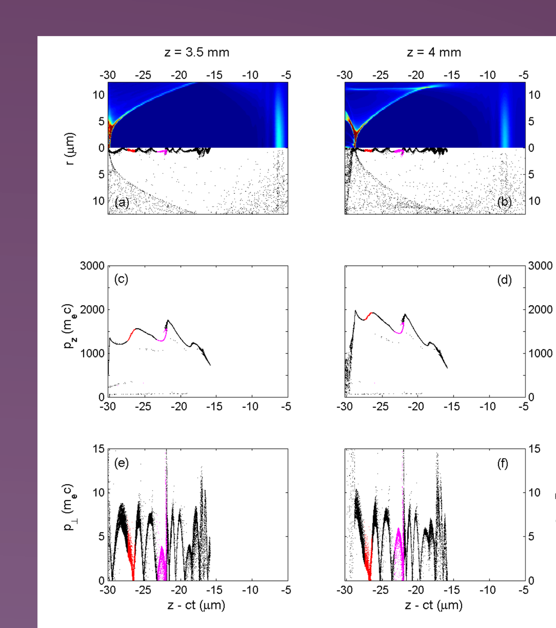
3D Particle-in-Cell Simulations Using WAKE



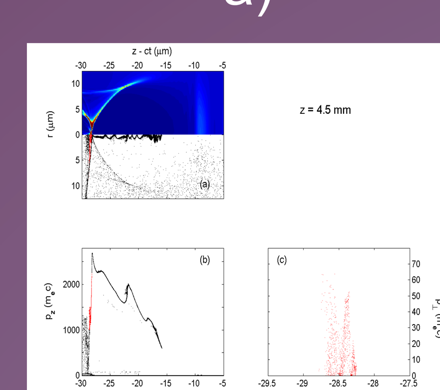
a)



b)



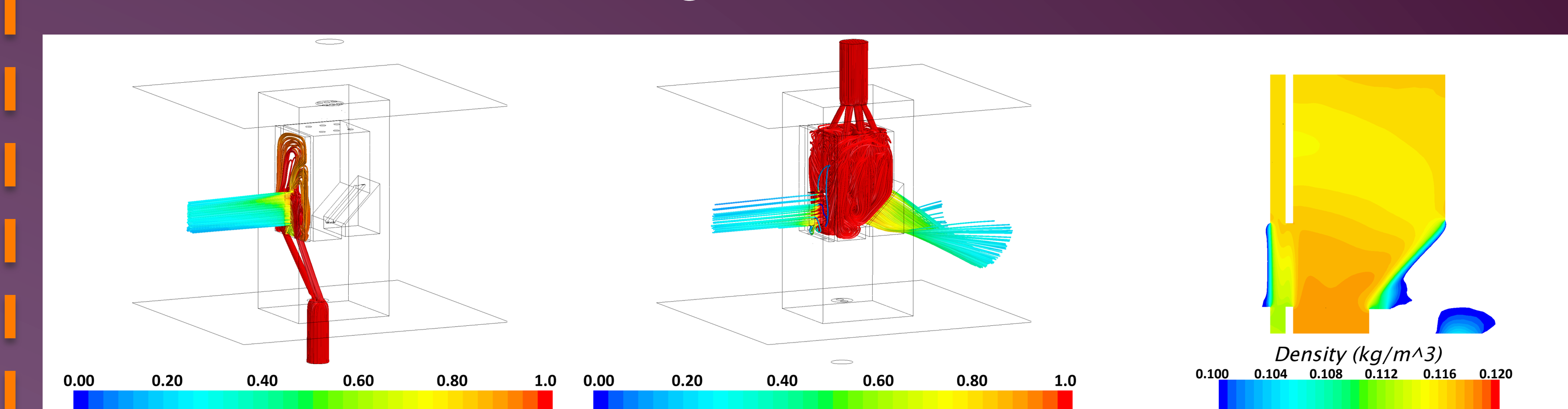
c)



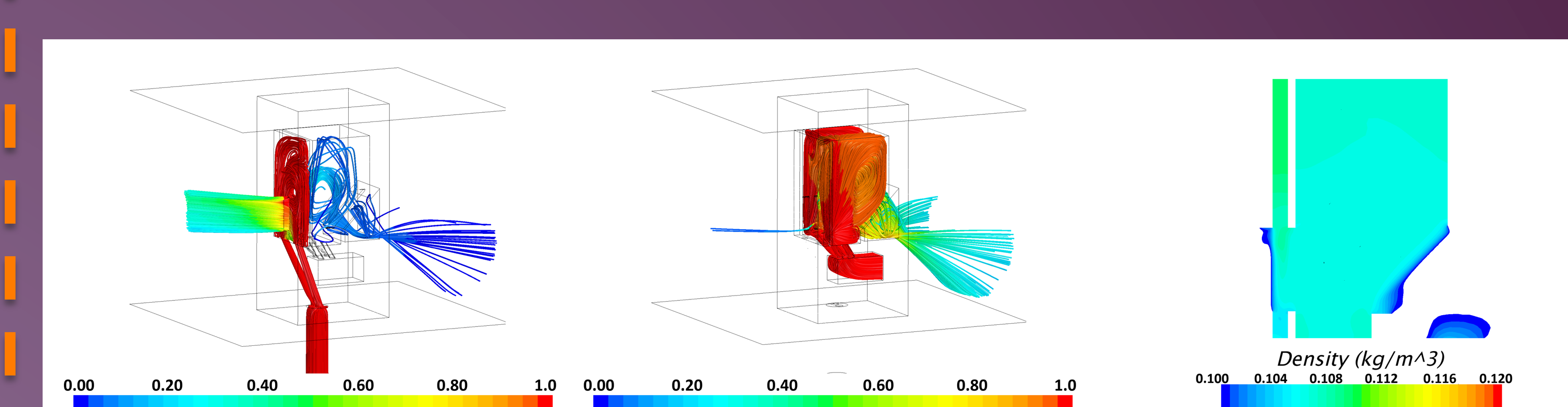
d)

a) Evolution of ring electrons after density discontinuity; b,c) Evolution of electrons inside the first bucket with low transverse momentum; d) Evolution of electrons ejected from the first bucket with high transverse momentum

3D Computational Fluid Dynamics Simulations Using STAR-CCM+



a) 1st Stage, Opposing Flow b) 2nd Stage, Opposing Flow c) Steady State Gas Density, Opposing Flow



d) 1st Stage, Same Flow e) 2nd Stage, Same Flow f) Steady State Gas Density, Same Flow

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