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A collinear Second-Harmonic Orthogonally Polarized (SHOP) interferometer for MITL gap plasma measurements on Sandia's Mykonos accelerator

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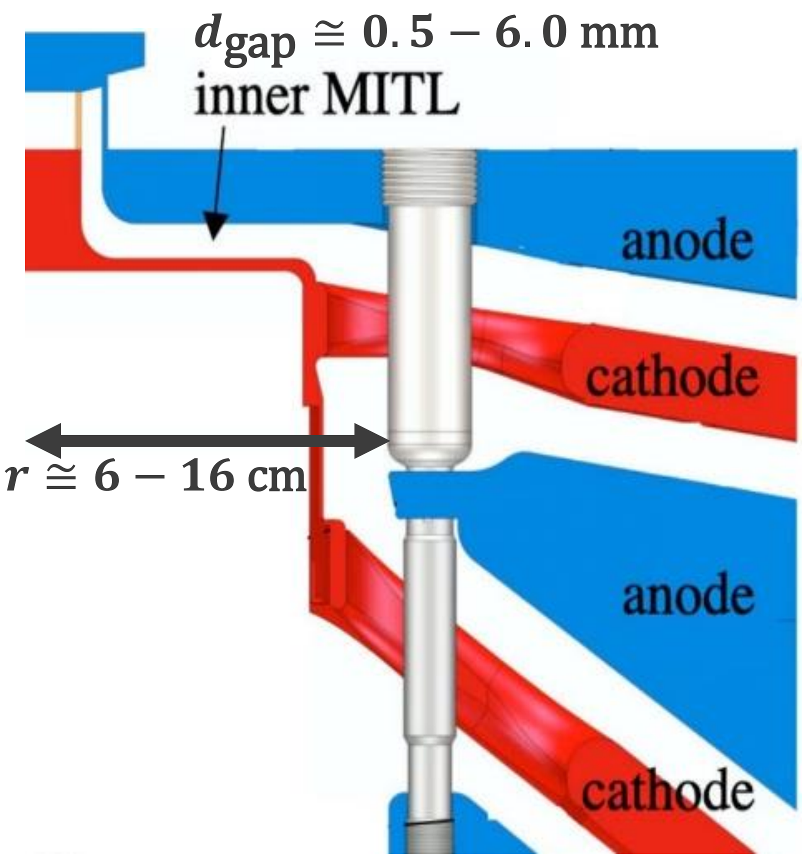
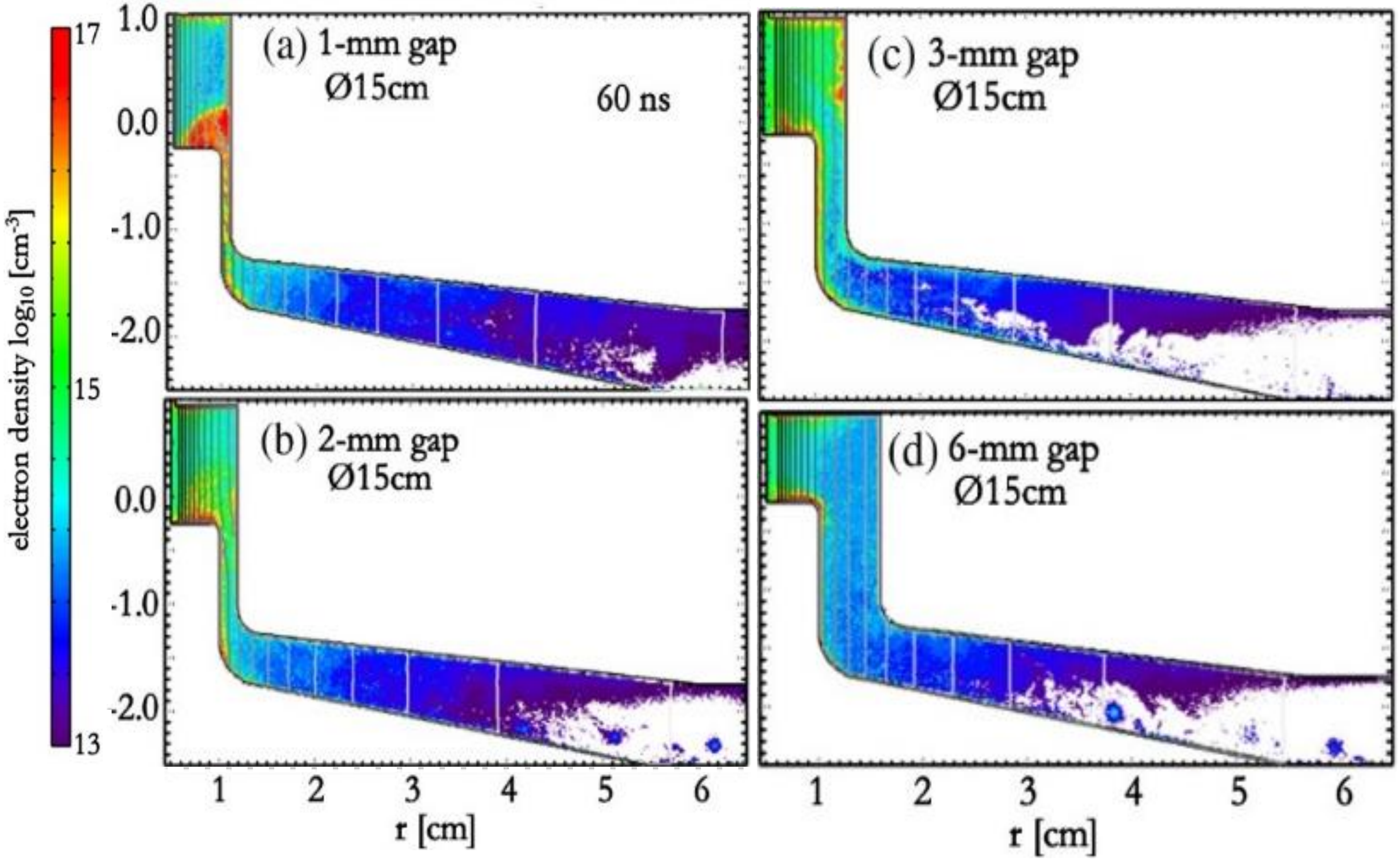
Z's inner MITL experiences current loss from charged particle cross-gap flow with expected e^- densities of $10^{13} - 10^{17}\ \mathrm{cm}^{-3}$

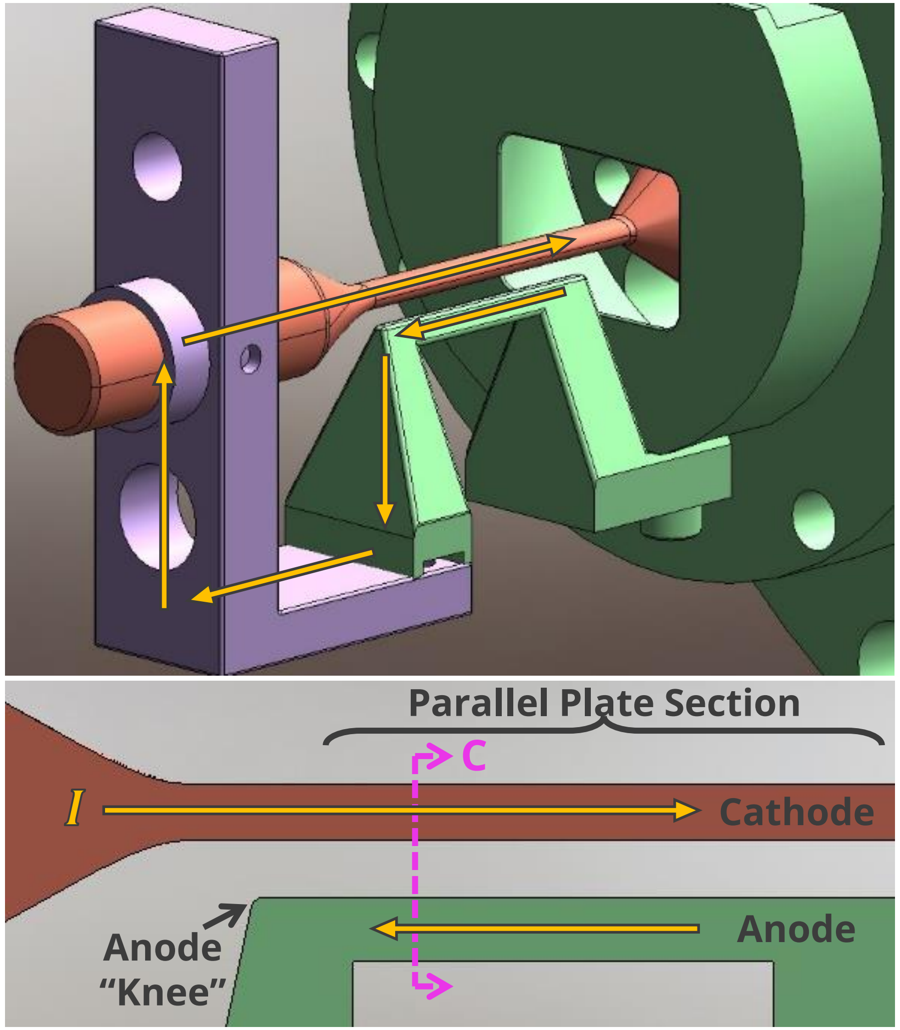


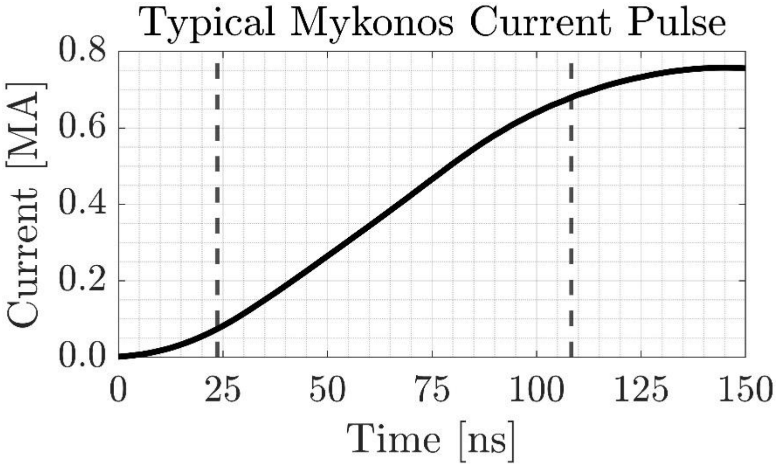


[1] W. A. Stygar et al., "55-TW magnetically insulated transmission-line system: Design, simulations, and performance," Phys. Rev. Accel. Beams, vol. 12, no. 12, p. 120401, 12/07/2009.

[2] N. Bennett, D. R. Welch, G. Laity, D. V. Rose, and M. E. Cuneo, "Magnetized particle transport in multi-MA accelerators," Physical Review Accelerators and Beams, vol. 24, no. 6, p. 060401, 06/23/2021.

An Existing platform on Mykonos provides diagnostically accessible A-K gap geometry scaled to match Z's inner MITL field strengths





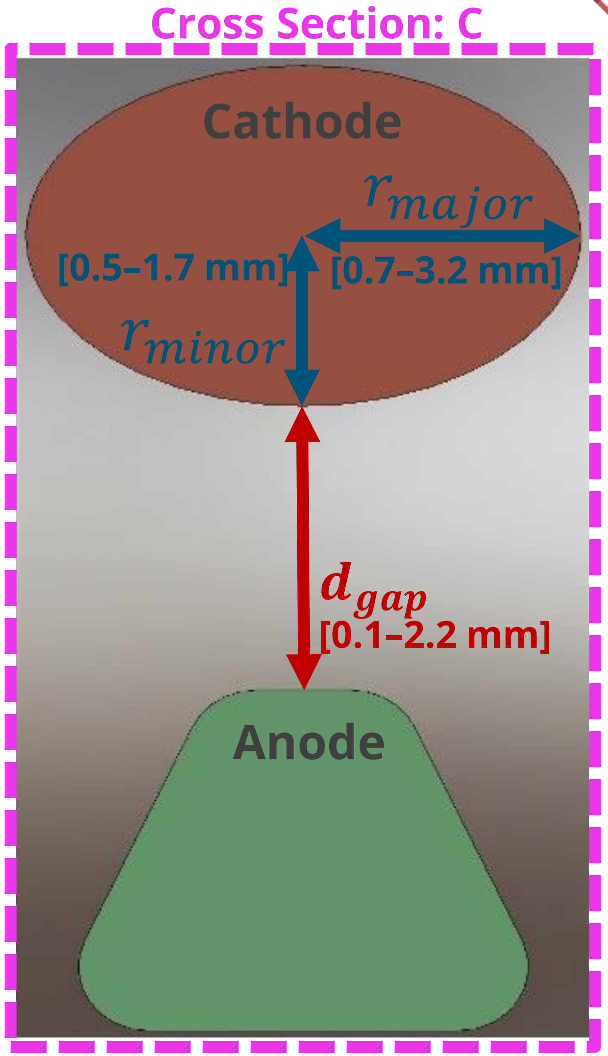
$t_{Rise} \approx 85$ ns

$1/d_{gap} \propto |\vec{E}|$ (electric field)

$|\vec{E}| \sim 0.5\text{-}5$ MV/cm

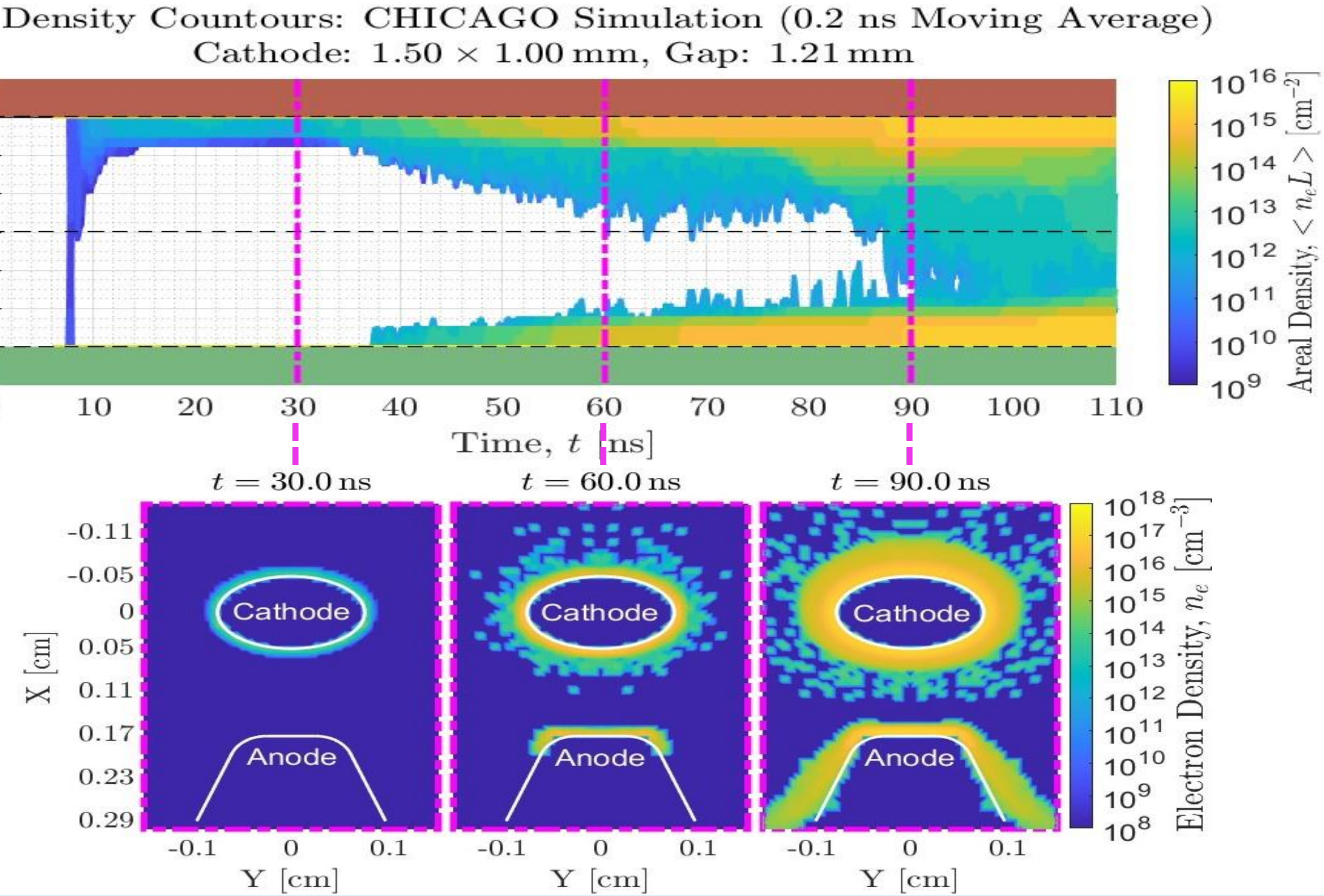
$1/r_{major}, 1/r_{minor} \propto |\vec{J}| \propto |\vec{B}|$

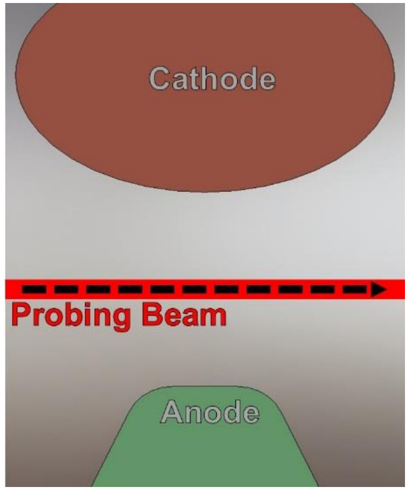
$|\vec{B}| \sim 50\text{-}500$ T



[6] D. Lamppa, S. Simpson, B. Hutsel, M. Cuneo, G. Laity, and D. Rose, "Assessment of Electrode Contamination Mitigation at 0.5 MA Scale," Sandia National Lab.(SNL-NM), Albuquerque, NM (United States), 2021.

3D CHICAGO simulation of Mykonos' parallel plate hardware highlights densities 10^9–$10^{17}\mathrm{cm}^{-3}$ (10^{10}–$10^{16}\mathrm{cm}^{-2}$ line-averaged)



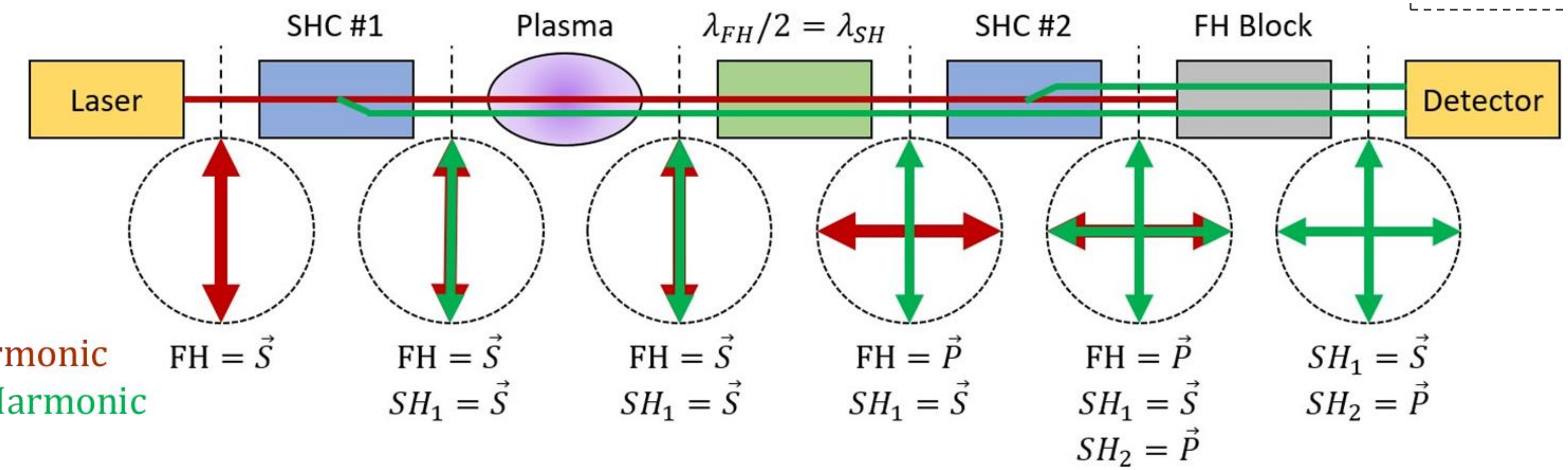


The colinear SHOP interferometer correlates a signal’s phase to the plasma’s line-averaged (areal) electron density.

FH & SH experience different phase delays ($\Delta\phi_{FH}$ & $\Delta\phi_{SH1}$) when passing through plasma

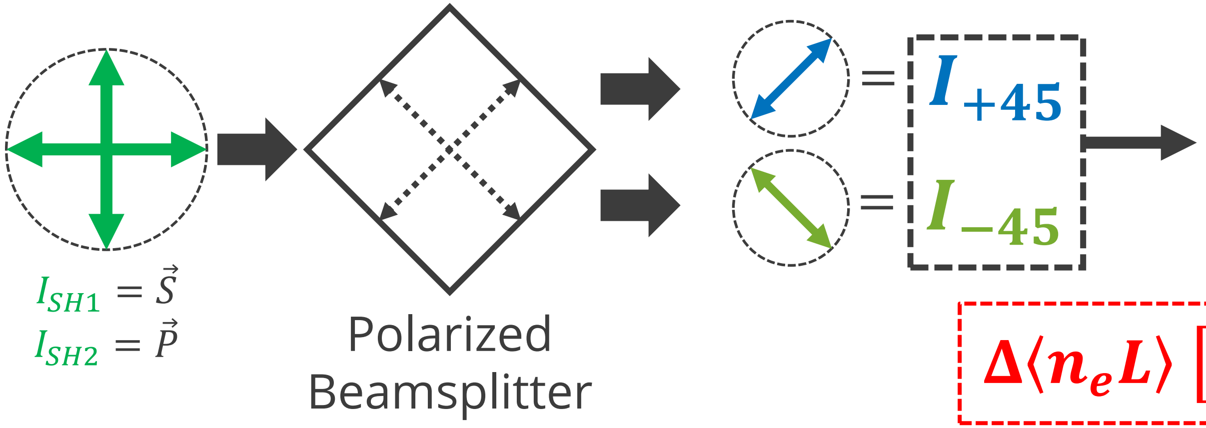
$$(2\Delta\phi_{FH} - \Delta\phi_{SH1}) = \Delta\Phi$$

Basic Design:



FH = First–Harmonic
SH = Second–Harmonic

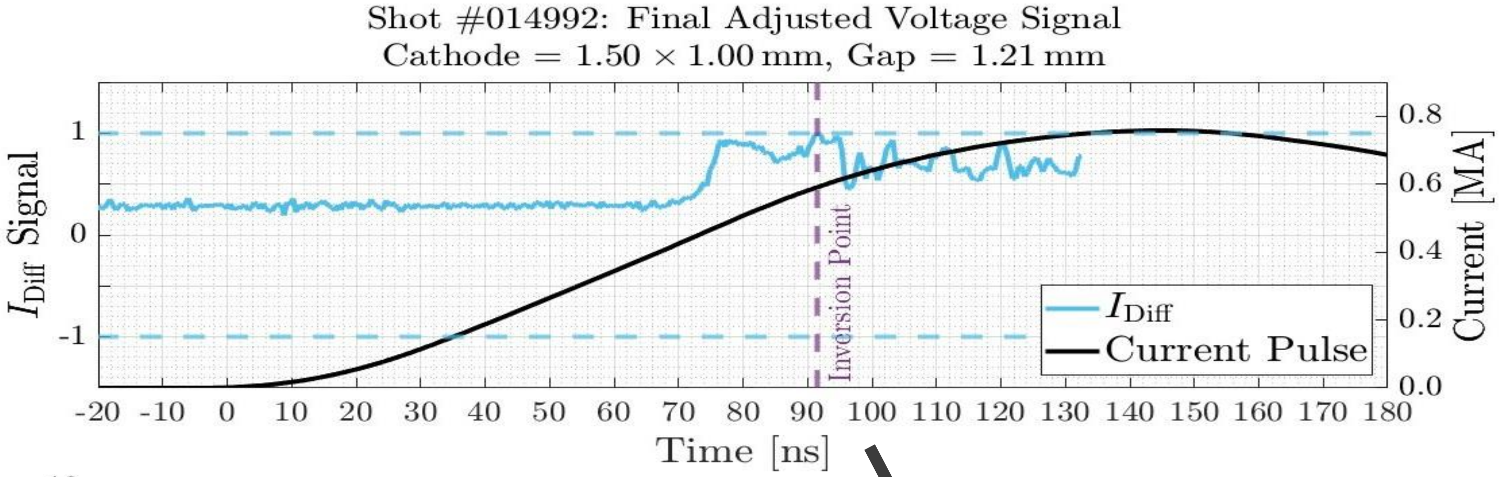
Detection:

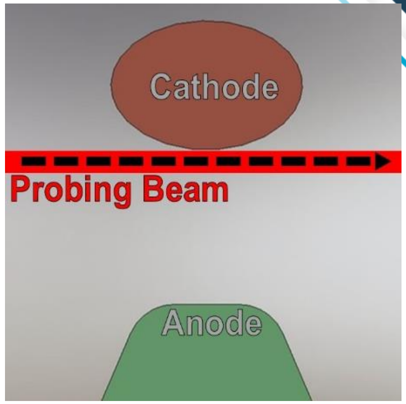


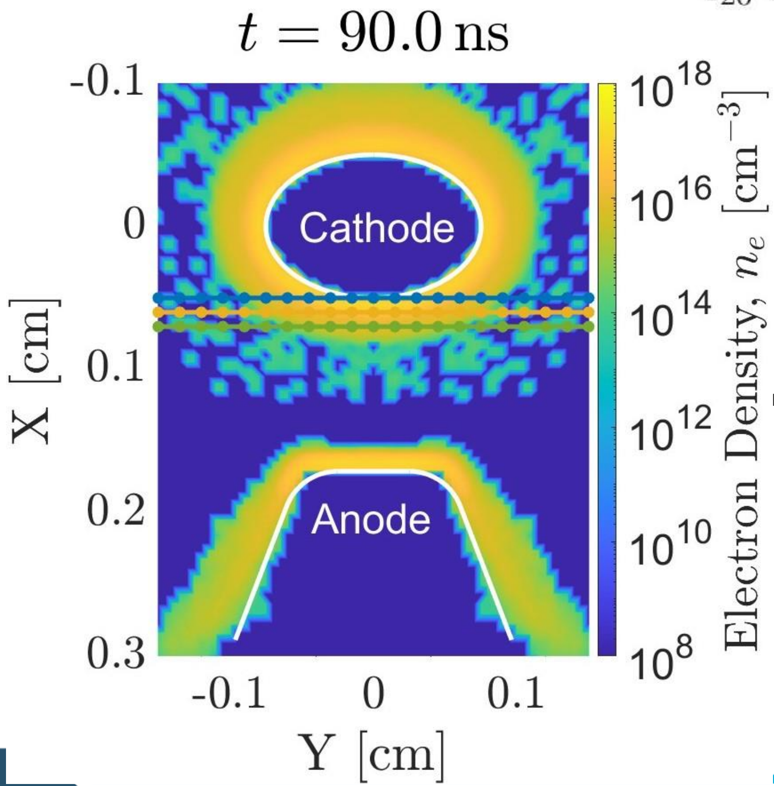
$$I_{DIFF} = I_{+45} - I_{-45} = 2\sqrt{I_{SH1} I_{SH2}} \cos(\Delta\Phi - \phi_0)$$

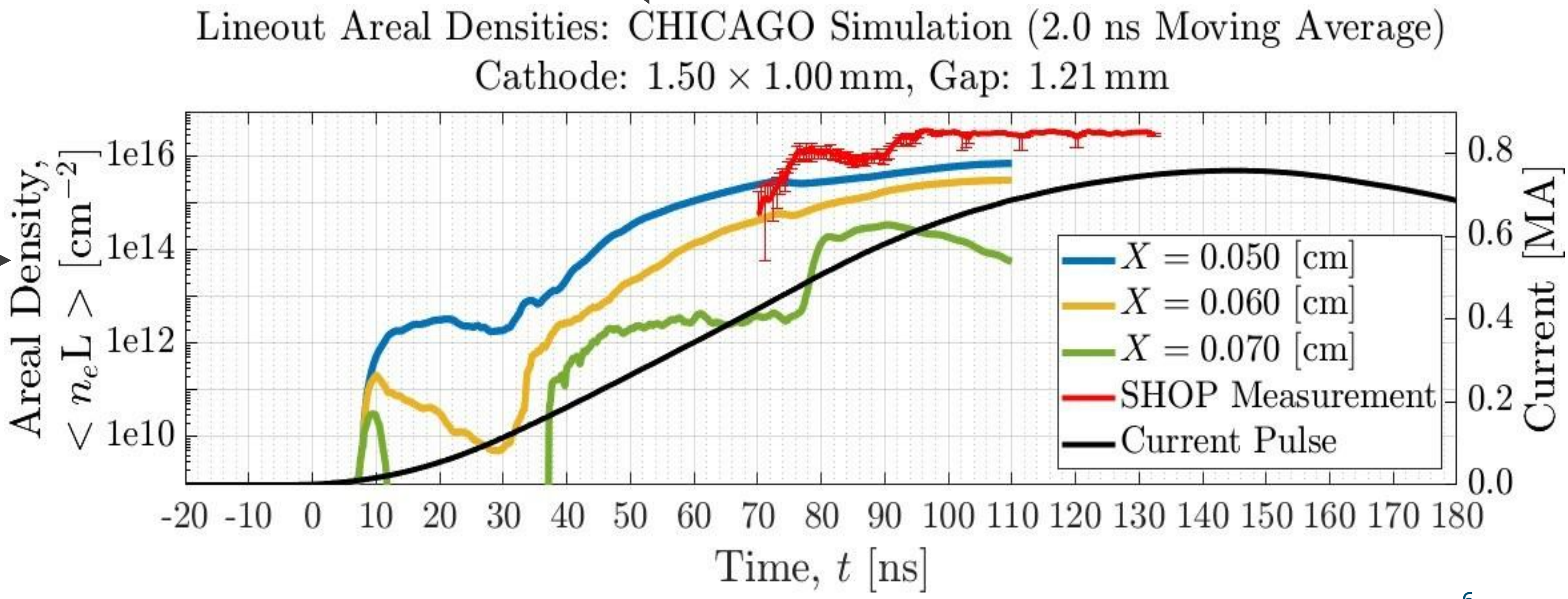
$$\Delta\langle n_e L\rangle \, [\mathrm{cm}^{-2}] = (1.53 \times 10^{16})\Delta\Phi$$

Initial Mykonos parallel plate experiment makes first temporally resolved areal density measurement

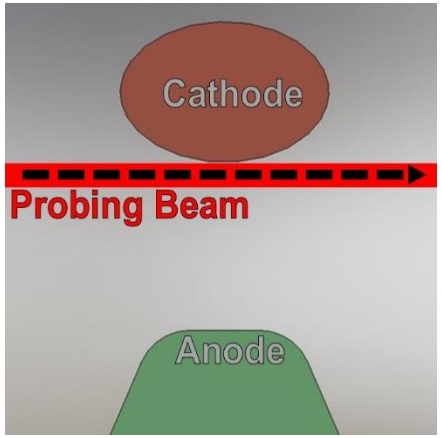


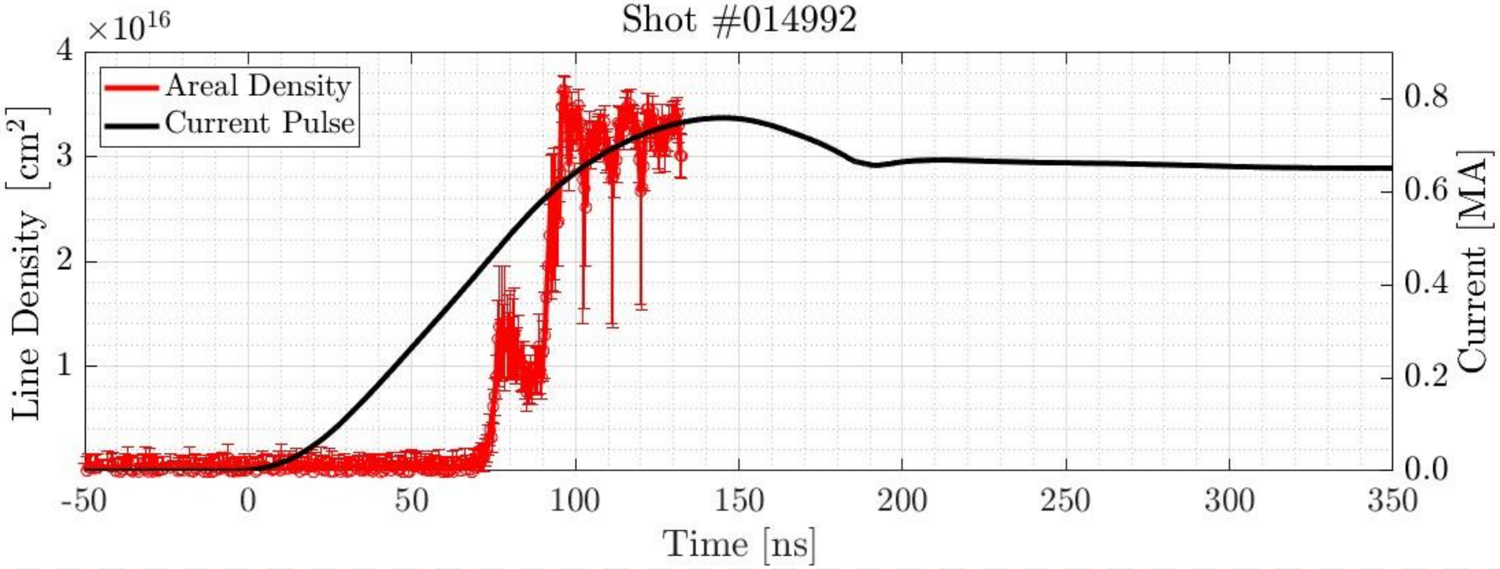


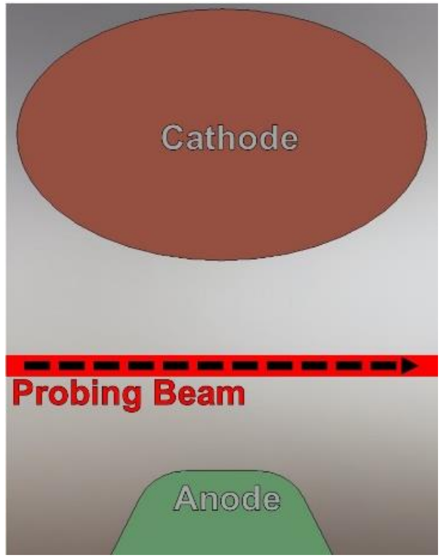


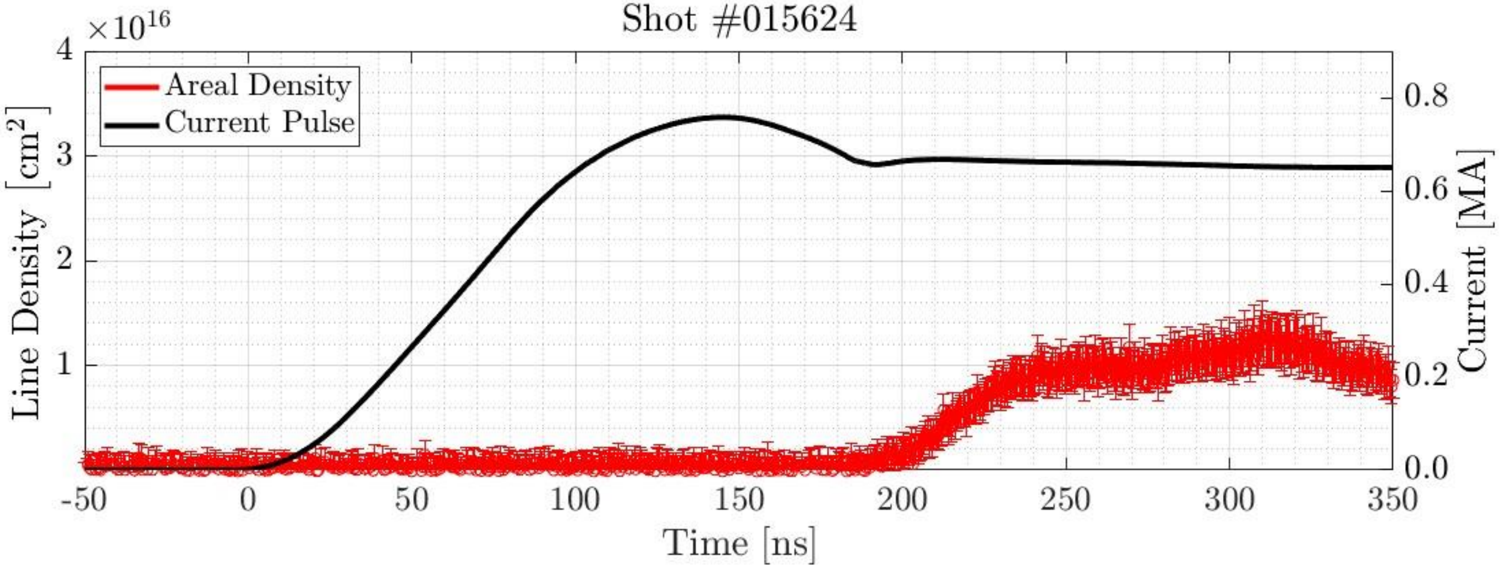


Differences in probing location and/or A-K geometry create variation in plasma formation and electron areal density









Conclusion

- A colinear second-harmonic orthogonally polarized interferometer has been developed.

  Phase Sensitivity (noise_{rms}): 56 mrad @ sin(0) $\langle n_e \text{L}\rangle_{min} = 8.5 \times 10^{14}\ \text{cm}^{-2}$

  Bandwidth: 2 GHz $\Delta\langle n_e \text{L}\rangle_{max} = 1.9 \times 10^{17}\ \text{cm}^{-2}\text{ns}^{-1}$
- The first temporally resolved areal density measurement was taken on a parallel-plate Magnetically Insulated Transmission Line (MITL).
  - Comparisons to CHICAGO PIC simulations can be made.
  - There are measurable areal density differences between various probing locations and A-K gap geometries.
- Improvements for future experiments:
  - Increased certainty in probing beam size and location.
  - Increase signal-to-noise ratio for better phase sensitivity (lower minimum detectable areal density).
  - Measurements made in various other locations of parallel plate geometry.