Sandia National Laboratories
N. Hines[1,2,a)], D. Lamppa[1], J. Schwarz[1], D. Rose[3], T. Awe[1], M. Gilmore[2]
[1]Sandia National Laboratories, Albuquerque, NM, USA
[2]University of New Mexico, Albuquerque, NM, USA
[3]Voss Scientific, Albuquerque, NM, USA
[a)]Corresponding Author Email: nhines@sandia.gov

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

Introduction

- TW-class accelerators, like Sandia National Laboratories' (SNLs) Z machine, experience current loss within their inner Magnetically Insulated Transmission Line (MITL) and convolute regions.
  - Fully relativistic PIC and MHD simulations predict that electrode plasmas on the order of $10^{15} - 10^{17}$ cm^{-3} constitute the primary source of shunted current across the Anode-Cathode (A-K) gap [1].

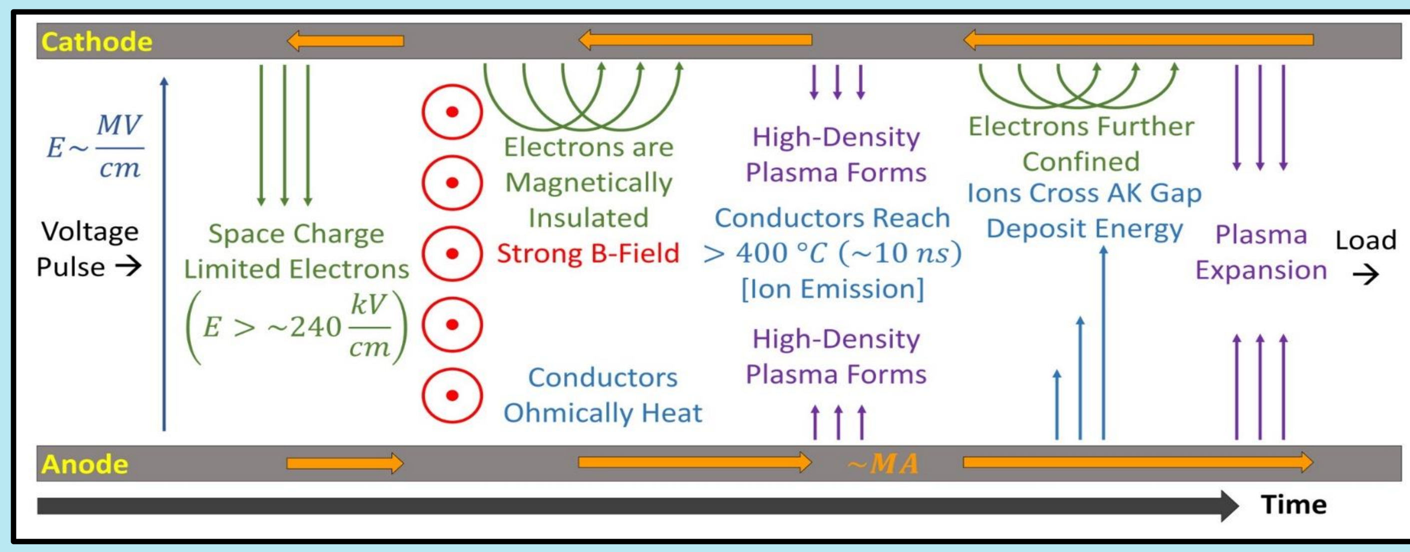


Fig. 1: Diagram of a lossy MITL

- To study similar electrode plasmas [2], a parallel plate platform has been developed [3] for Sandia's 1 MA Mykonos accelerator [4].
- To measure the free electron areal density of relatively low-density plasmas with fast time resolution, a collinear Second-Harmonic Orthogonally Polarized interferometer (SHOPi) diagnostic has been developed with a sensitivity reaching $\langle n_e L\rangle_{min} = 2 \times 10^{14}$ cm^{-2} and up to $\Delta\langle n_e L\rangle_{max} = 2 \times 10^{17}$ cm^{-2} ns^{-1} [5].

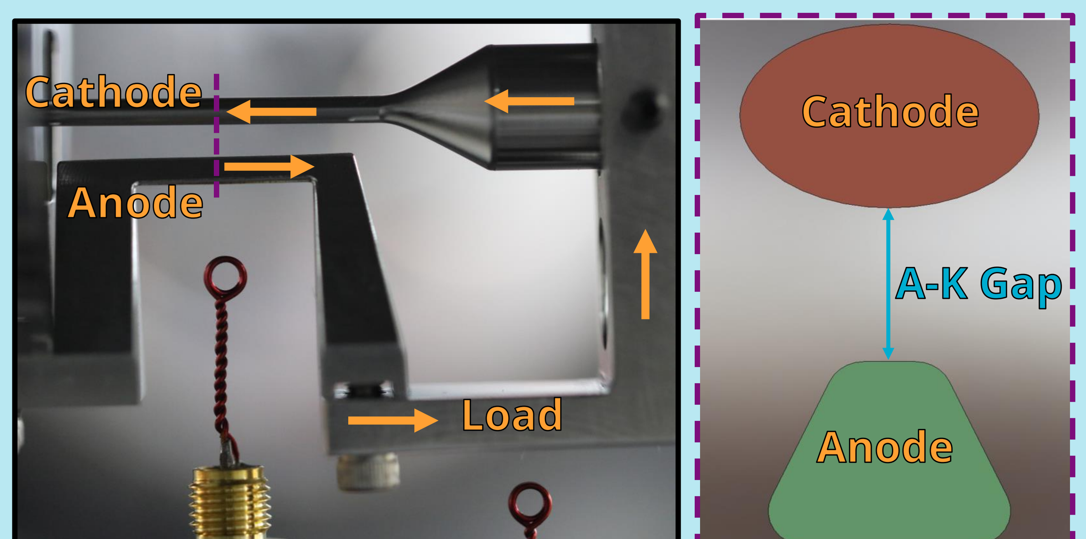


Fig. 2: Mykonos' parallel plate hardware

Experimental Setup

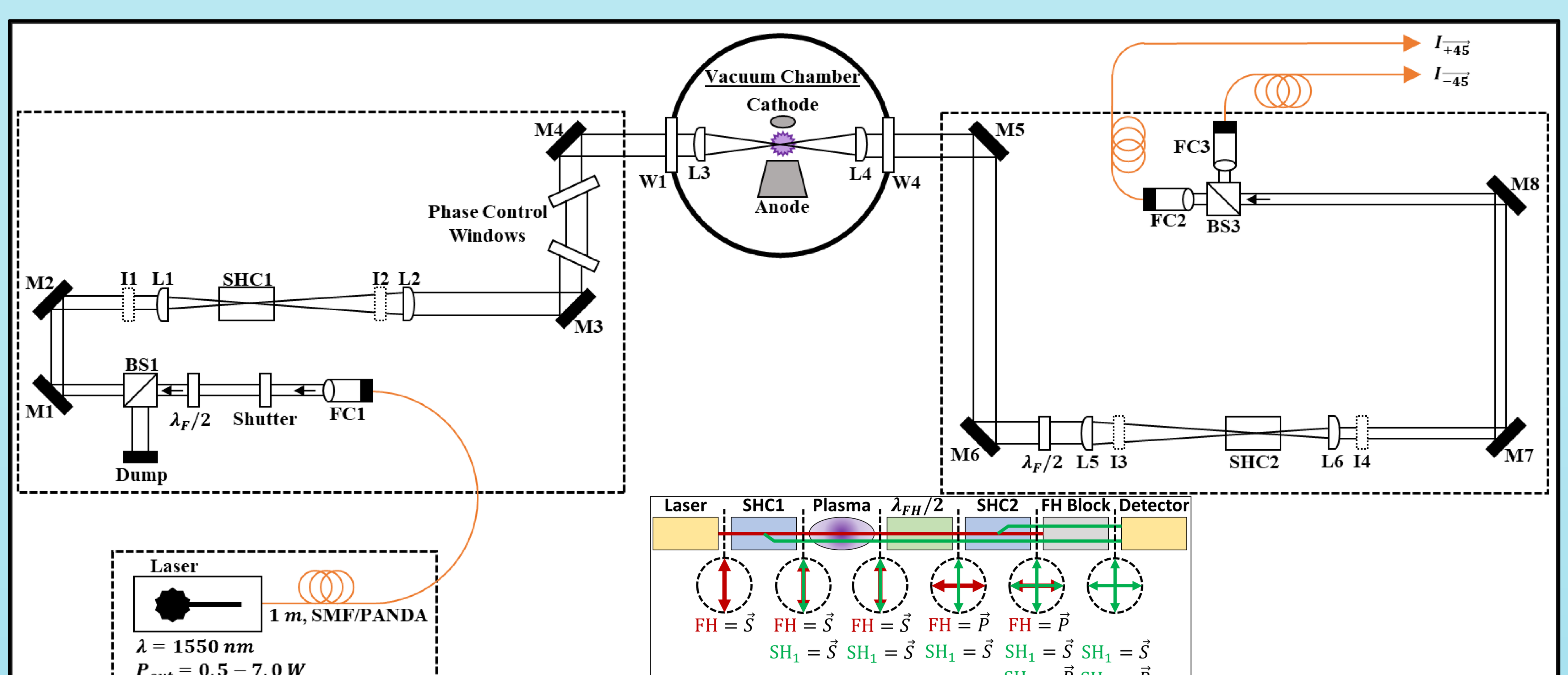
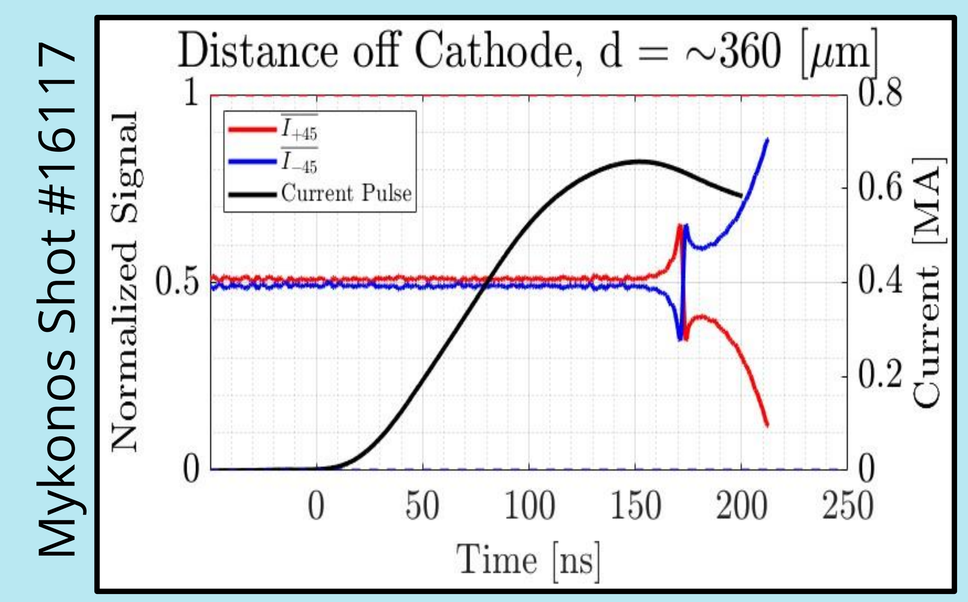


Fig. 3: SHOPi Diagnostic optical diagram.

Mykonos Data



- The detected intensities are a function of the relative phase of the two interfering second-harmonic beams, $\Delta\phi$, via

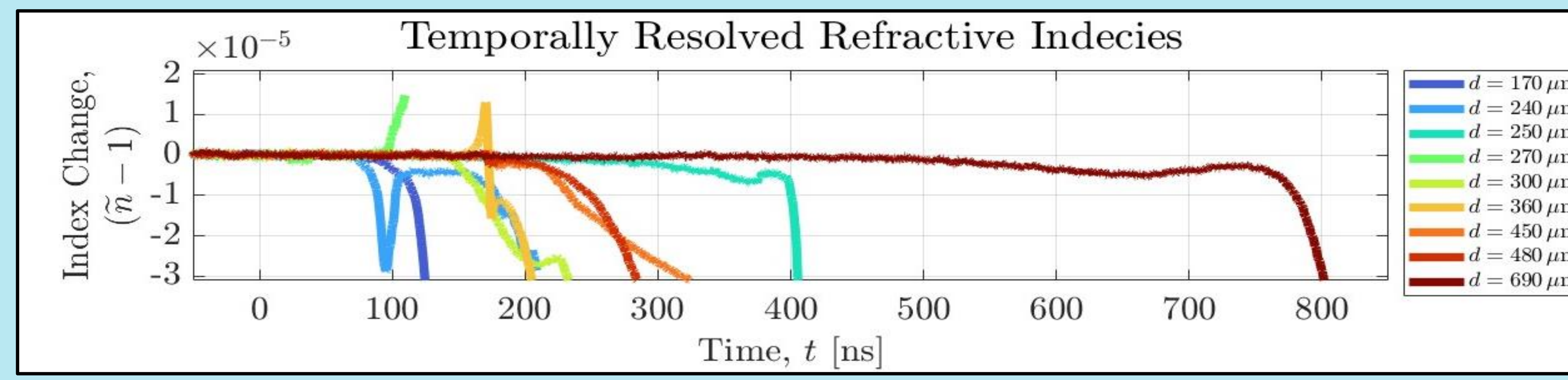
$$I_{\overrightarrow{\pm 45}} = \frac{I_{SH1}}{2} + \frac{I_{SH2}}{2} \pm \sqrt{I_{SH1} I_{SH2}} \cos(\Delta\phi) \ ,$$

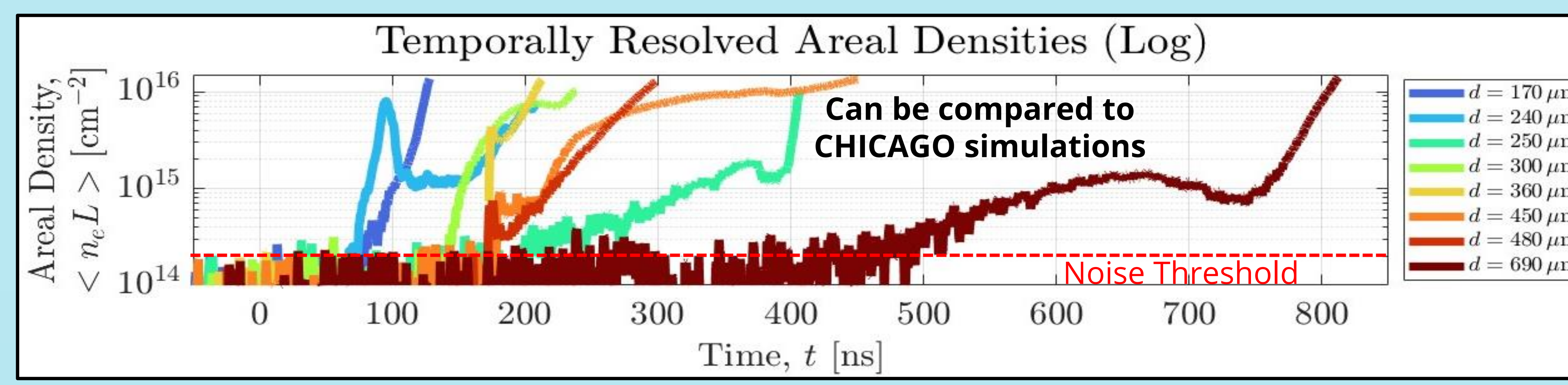
where

$$\Delta\phi = 2\phi_{FH} - \phi_{SH} \ .$$

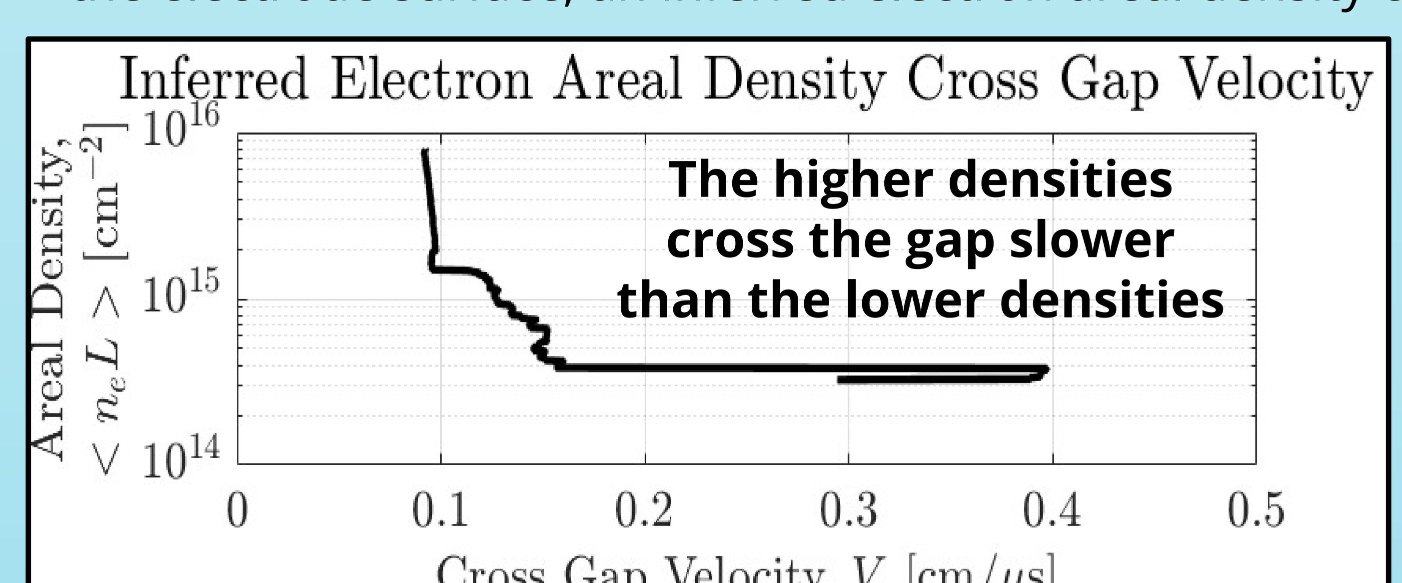
- The free electron areal density, $\langle n_e L\rangle$, can be calculated from the tracked phase, $\Delta\phi$, of detected signals, $I_{\overrightarrow{+45}}$ and $I_{\overrightarrow{-45}}$, via

$$\langle n_e L\rangle \approx \frac{2.366 \times 10^{19}}{\lambda_{FH}} \Delta\phi \ .$$





- Using the above temporally resolved areal density data in conjunction with the probing beams' distance off the electrode surface, an inferred electron areal density cross gap velocity can be calculated.



References

1. N. Bennett, et al., Electrode plasma formation and melt in Z-pinch accelerators, Physical Review Accelerators and Beams, 26 (2023) 040401.
2. D.B. Sinars, et al., Review of pulsed power-driven high energy density physics research on Z at Sandia, Physics of Plasmas, 27 (2020).
3. D. Lamppa, et al., Assessment of Electrode Contamination Mitigation at 0.5 MA Scale, SAND2021-12691, Sandia National Laboratories, Albuquerque, NM, (2021).
4. M.G. Mazarakis, et al., High-current linear transformer driver development at Sandia National Laboratories, IEEE transactions on plasma science, 38 (2010) 704-713.
5. N.R. Hines, et al., A fiber-coupled dispersion interferometer for density measurements of pulsed power transmission line electron sheaths on Sandia's Z machine, Review of Scientific Instruments, 93 (2022) 113505.

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

SAND2024-04738C