Design and performance characterization of a high-throughput, high-resolution streak tube designed for ultrafast x-ray spectroscopy

A. E. Raymond[1], S. McPoyle[1], N. Pelepchan[1], J. Hassett[1], R. Boni[1]
[1]Laboratory for Laser Energetics, University of Rochester, Rochester, NY, USA

Corresponding Author Email: araymond@lle.rochester.edu

The inertial confinement fusion (ICF) and high-energy-density (HED) physics communities rely on streak-camera-based diagnostics for picosecond-resolved x-ray spectroscopy and 1D-streaked x-ray imaging, but the performance of legacy streak tube designs is increasingly inadequate for modern experiments. Achieving sufficient spatial and temporal resolution has required severe internal electron aperturing, reducing the signal level at the detector: a throughput reduction beyond what is required to ameliorate space charge broadening. Compromises in the electron-optics design to maintain a compact size and preserve temporal resolution also resulted in significant geometric distortion of the signal at the detector, reducing resolution and complicating data analysis.

To address the limitations in signal level, resolution, distortion, and active photocathode area, the Laboratory for Laser Energetics (LLE) is developing the BHx streak tube: a next-generation instrument incorporating a modernized electron-optical design. The BHx design employs a novel bowtie-profile slot anode to enable the use of a flat 25-mm photocathode, using an aberration-compensated final focusing lens using an in-line conductive grid to mitigate spherical aberration while preserving electron throughput. Additionally, off-axis corrective electrodes are implemented for both the swept and imaging directions. A prototype unit has been built and is being tested under ultraviolet illumination, demonstrating good agreement between measured and simulated performance under static test conditions [1]. We present the roadmap for continued development and eventual deployment of the BHx streak tube for streaked x-ray spectroscopy in HED experiments. Swept characterization studies of the BHx streak tube prototype using UV illumination are ongoing, towards characterizing and finalizing the deflection system. A full-instrument dynamic simulation platform for the BHx has been developed in COMSOL Multiphysics and SIMION to compare with the experimental results, as well as to identify and mitigate sensitive elements of the design. The BHx will provide high-fidelity, time-resolved measurements in upcoming buried-layer experiments on LLE's MTW-OPAL laser system, strengthening model validation for ICF-relevant high-energy-density plasmas.

This material is based upon work supported by the Department of Energy [National Nuclear Security Administration] University of Rochester "National Inertial Confinement Fusion Program" under Award Number(s) DE-NA0004144.

[1] A. E. Raymond, N. Pelepchan, J. Hassett, R. Boni, "Static characterization of a highly optimized streak tube design incorporating a steering slot anode and an aberration-corrected Einzel lens, " Rev. Sci. Instrum. 96, 103503 (2025).

Specify category (Magnetic confinement fusion, Inertial confinement fusion, High-energy-density plasmas, Space plasmas, Astrophysics or Industrial applications, Others): **High-energy-density plasmas**