Preliminary investigation of the high energy spectrum of pinhole point-projection backlighters

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Introduction

- Laser-produced hot (~MeV) electrons may present many undesirable effects in high-energy-density physics experiments. In particular, the secondary production of high-energy x-rays produces a background that reduces the signal-to-noise in radiographs
- Experiments were performed to study the hot electron-induced high-energy x-ray background present in pinhole point-projection x-ray backlighters
- We present a preliminary analysis on the high-energy x-ray spectra from backlighters, measured with the Bremsstrahlung X-ray Spectrometer (BMXS[1])

The BMXS uses differential filtering to measure the continuous, high-energy x-ray spectrum

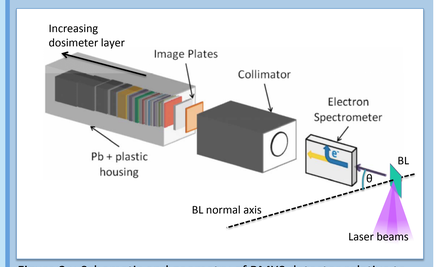

Figure 2a: Schematic and geometry of BMXS detector relative to backlighter target[1]

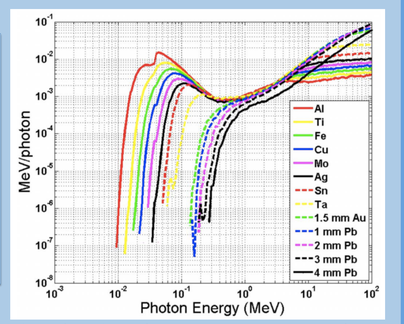

Figure 2b: Dosimeter layer response curves. In general, higher x-ray energies are measured with increasing dosimeter layer[1]

Previous experiments demonstrated the presence of the high-energy background

- The BMXS response is fit with the output of a Monte-Carlo transport code for the full target geometry, retrieving the continuous x-ray spectrum (below)

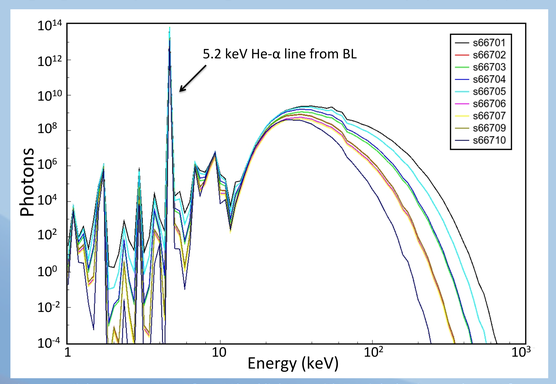

Figure 4: High-energy spectra from V backlighters with Ta pinholes (same shot set from which Fig 2a was taken)

Hot electrons interact with backlighter and physics target, producing high-energy x-rays

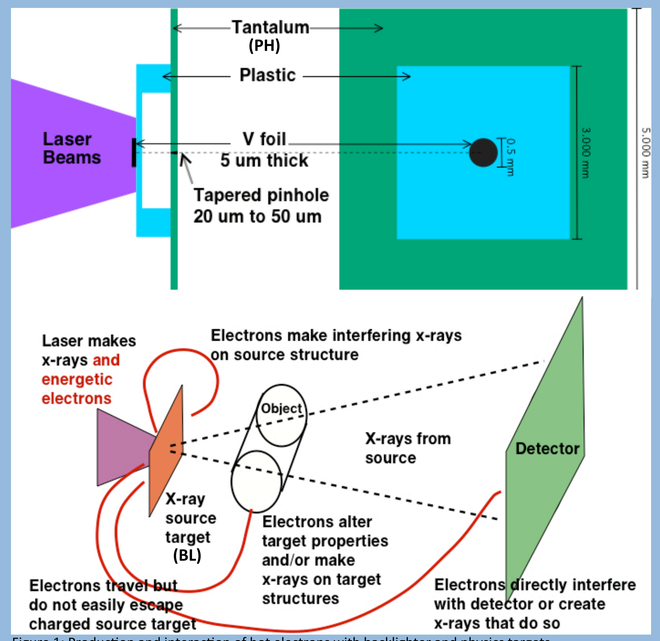

Figure 1: Production and interaction of hot electrons with backlighter and physics targets.

Non-uniform background seen in radiographs of physics experiments, possibly related to high-energy signal, seen in fig. 4.

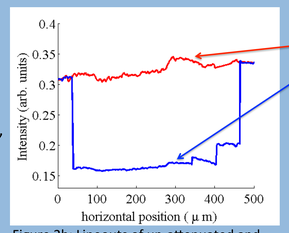

Figure 2b: Lineouts of un-attenuated and attenuated signal

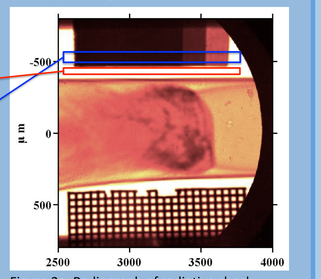

Figure 2a: Radiograph of radiative shock experiment, using V backlighter with Ta pinhole

We have performed experiments disproving the hypothesis that framing the pinhole substrate mitigates the high-energy signal

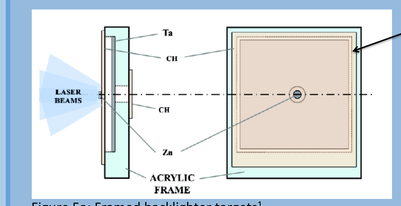

Figure 5a: Framed backlighter targets[1]

Plastic frame added to back of pinhole, under the hypothesis that it will attenuate the high-energy x-rays

BMXS results show that the frame actually **increased** high-energy signal, likely from more electron energy loss in the target

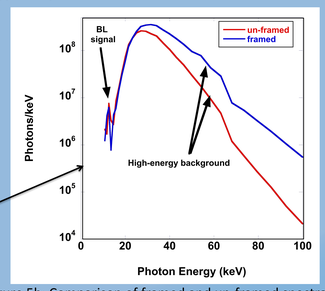

Figure 5b: Comparison of framed and un-framed spectra

Preliminary analysis shows signal level varies with angle

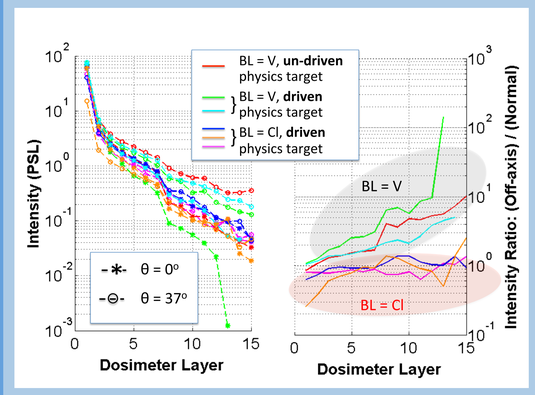

Figure 6: BMXS responses (photo-stimulated luminescence (PSL)) and ratios off and on the backlighter normal axis.

- Angular variation for V backlighters is greater than that for Cl backlighters, using Ta pinholes, suggesting possible dependence of high-energy signal on backlighter material
- For V backlighters, signal 37° off-axis is larger by a factor ranging from 1 – 100, depending on photon energy/dosimeter layer

Changing the pinhole substrate material may change higher energy signal level

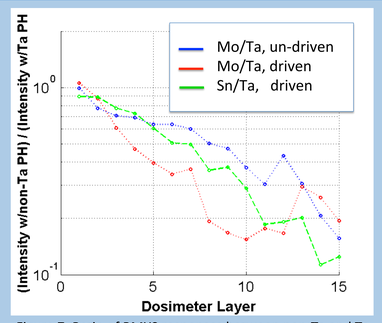

Figure 7: Ratio of BMXS responses between non-Ta and Ta pinhole substrates, using V backlighters only

- High-Z pinhole substrates collimate primary low-energy x-rays for imaging purposes
- The on-axis high-energy signal decreases with lower Z of the pinhole substrate, especially as x-ray energy increases
- Mo and Sn substrates may offer a decrease in the high-energy signal by a factor of 10^{-1}, and still have high enough Z for low-energy collimation

Conclusions and future work

- High-energy x-ray signal is consistently seen when using pinhole point-projection backlighters, producing unwanted noise in the response of radiographic diagnostics
- The signal depends on pinhole substrate atomic number
- Conventional wisdom that the high-energy background radiates into 4pi is shown to be false and angular variation may vary with backlighter material
- Back out continuous x-ray spectra from dosimetric response data, with the aid of the Monte Carlo radiation transport code for angular and pinhole substrate comparison

References:

1. Chen, C. D., et al. (2008). A Bremsstrahlung spectrometer using k-edge and differential filters with image plate dosimeters. The Review of scientific instruments, 79(10), 10E305.
2. Krauland, C. M., et al. (2012). An evaluation of high energy bremsstrahlung background in point-projection x-ray radiography experiments. The Review of scientific instruments, 83(10), 10E528.

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