GXD3 at CEA, October 2015

conclusions and go forward proposals

CEA-NNSA Diagnostics workshop

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On behalf of the framing camera teams
The LLNL-CEA collaboration on framing camera flat fields has been very fruitful!

Applying different methods to a single camera demonstrated flat field equivalence ~25%

This may be sufficient for many experiments

Both teams have identified challenges to our methods that impact our detailed understanding of framing camera operation

We have identified remediation plans to address most of these

Going forward LLNL intends to build a lab similar to the CEA UV lab

Preferably in collaboration with CEA to share best practices

We should confirm improved equivalence between methods once mitigations are implemented

We are interested in further collaborations regarding other performance parameters such as:

- camera-to-camera sensitivity; energy sensitivity; spatial resolution
Flat fielding is important because x-ray framing camera gain is very non uniform

- XRFC consists of a microchannel plate (MCP) active area coated with 2-4 pulsed microstriplines for temporal gating.
- Each strip receives an independent voltage pulse that may be slightly different from the others (G~V^{15-25}, so small variations are significant!)
- Losses throughout strip cause “droop”: gain loss from entrance to exit
- Because of cross-talk between microstrips, local gain depends on operating conditions (bias voltage and inter-stripe timing)

CEA and LLNL use different techniques to create a flat field image
This collaboration is about evaluating the different techniques

IF framing camera data is used quantitatively, spatial variations in gain (ie “flat field”) must be known!
We brought GXD3 to CEA-Arpajon in October, 2015

CEA and LLNL use different techniques to create a flat field image. This (portion of the) collaboration is about evaluating the different techniques with a single camera.
Direct X-ray Method: Single Exposure to X-rays (NIF)

Uniformly illuminate active area for entire measurement
Signal to Framing Camera is mostly 8-9 keV x-rays
Adjust observed image for time-dependent flux based on SPIDER or Dante Measurement

Au Sphere Target

Square laser pulse

Flat Field Image

Spectrum to GXD

Streaked signal

Relative Gains

UV Flat-field Construction: Multiple Exposures summed to recreate a single exposure (CEA)

Short pulse UV laser (25ps; 213 nm)
Multiple exposures span entire framing camera window
Images Summed

UV Gate Profile: Multiple Exposures to short UV laser analyzed in temporal space (NSTEC (and CEA))

Very short pulse UV laser (t<1ps; 200 nm)
Multiple exposures span entire framing camera window
Data analyzed for gain(time) at each location

Gate Profile Data Set: intensity (location, delay)
Fit intensity to model for each location

Relative Gains

Pulse velocity and Gate width are also measured

UV flatfields were collected / constructed at four operating conditions to compare to available data

**Experimental Configurations**

<table>
<thead>
<tr>
<th>Inter-strip Timing</th>
<th>Bias V</th>
<th>X-Ray</th>
<th>UV FF</th>
<th>UV GP</th>
<th>Witness</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 ps</td>
<td>50 V</td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>200 ps</td>
<td>100 V</td>
<td>X</td>
<td>X</td>
<td>(low quality)</td>
<td>X (150V)</td>
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<tr>
<td>350 ps</td>
<td>60 V</td>
<td>X</td>
<td>X</td>
<td></td>
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<tr>
<td>0 ps 4000 ps 4000 ps 0 ps</td>
<td>60 V 100 V 100 V 60 V</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

**Direct X-ray**
**UV Flat Field Construction**
**UV Gate Profile**
**Additional witness plate experiments**
Primary Result: Assessment of consistency of the methods

Direct X-ray (NIF) is compared to UV Flat Field construction (CEA) at two conditions:

100V bias, 200 ps inter strip

60V bias, 350 ps inter strip

- UV Flat field
- Direct X-ray

Skin: Direct X-ray
Thick: UV Flat Field Construction
Normalized to 1 at strip 1 center
Primary Result: Assessment of consistency of the methods

The two UV methods are in the best agreement

UV Flat field construction

vs UV Gate Profile

Direct X-ray method

vs UV Gate Profile

Thin: Direct X-ray

Thick: UV Flat Field Construction

Dotted: UV Gate Profile

50V bias, 0 ps inter strip

100V bias, 200 ps inter strip

Strip1 UV Flat field obscured by background

Relative Gain, Optimized BG Subtraction

Pixel

Relative Gain, Optimized BG Subtraction

pixel
"Witness Plate" Experiments Infer Relative Gains

We compare the relative gain at four locations (labeled A, B, C, D) from these experiments (closed symbols) to the relative gains at the same locations determined by our flat field measurements (open symbols).

- Same source, imaged by pinholes to four locations at nearly the same time
- NIF laser, $10^{14}$ W/cm$^2$ to Ta plate, $M = 2$; 1-3 keV photons to MCP
- Analysis depends on calculated spectrum of emission
- Experiment was done to *three different cameras* in different configurations

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**Primary Result**: Assessment of consistency of the methods

All methods agree with witness plate within 25%. None agree within 10%.
Primary Result: Assessment of consistency of the methods

All methods agree to about 25%

Internal Consistency Summary

• When compared at identical operating conditions, all methods agree on gain order (which strip is brighter) and approximate droop.

• No methods agree within 10% at all locations.

• The two UV methods are most internally consistent

• There are significant differences between x-ray and UV methods in degree of reflection at strip exit

Differences between UV and x-ray response

• **Artifact effect** is much stronger for UV sources because photons interact at top of MCP and are held there until voltage pulse arrives

• **Reflection effect** is enhanced for UV sources
Uncertainty sources

Uncertainty in Direct X-ray Method (NIF shot) is primarily related to determination of flux to GXD

A reference instrument is required to normalize flat field by flux to mcp vs time

- Relative timing is uncertain
- Emission oscillation not always distinguishable from noise
- Reference instrument signal levels are often LOW
- Spectral response is not equivalent

Spider sees harder x-rays; Dante sees softer x-rays

N50916 – GXD3, 200 ps interstrip

Spider sees slower rise
Dante sees faster
Determination of flux to GXD can be improved by adjusting reference instrument setup for spectral-temporal equivalence

Dante and SPIDER references have been seen simplistically and were used in configurations convenient to the facility

**Dante**: build up a diode with identical filtering to GXD (Cu + kapton)
- + increase aperture/solid angle for signal levels
- + add timing pulse after x-ray pulse to account for poor cross timing accuracy
- + (account for Dante temporal response)

**SPIDER**: add Cu filter to achieve 9keV cutoff
- + reduce CH if necessary for signal level

When filtered equivalently, we hope that Dante and SPIDER will see equivalent flux histories
Uncertainty sources

Additional uncertainty sources in direct X-ray method

Early-light artifacts may alias results (GXD)

Statistics are poor
- Statistical repeatability not yet demonstrated
- Signal needed to distinguish fixed pattern details is 10x greater than linear range
Additional uncertainty sources in direct X-ray method

Add ERASER to GXDs to prevent early light artifacts

Statistics are poor
- Statistical repeatability could be demonstrated with multiple identical NIF shots
- Fixed pattern noise is unlikely to be correctable with this method

There are “issues” with UV source reconstruction

Uniformly-spaced Gaussians can make a flat source, but jitter prevents us from achieving perfect uniform spacing.

Sum of jittered Gaussians is not flat.

Early-light artifact is prominent in naively summed image.

Artifact effect is much stronger for UV sources because photons interact at top of MCP and are held there until voltage pulse arrives.
Source reconstruction is a solvable problem

Non-uniformly spaced Gaussians can be weighted to optimize flatness of source

UV “source” can be re-interpreted as an individual source for each strip to prevent artifacts
Non uniformity of background and DC images is very detrimental to UV flat field construction

Light BG is brighter than data
Image variation likely due to pore-angle effects

MCP at 0V; phosphor at 0V
MCP at -750V; Phosphor at 3kV

Background subtraction is critical because the flat field construction sums images that are mostly dark
With/without phosphor voltage (setup 06, using late shots)

- Light background signals with and without phosphor voltage are not proportional, so we are probably not subtracting the right amount of background everywhere.

- The phosphor voltage on/ phosphor voltage off ratio seems to remain the same between configurations (multiplicative constant).

"Light background": Laser on, instrument off indicates light that reaches phosphor without amplification.
Uncertainty sources

Light background (CEA MCP detector, uncollimated beam)

ARGOS camera has aluminized phosphor so few photons should reach phosphor directly

- In both cases, some photons are converted into electrons late inside the MCP pores, which are then seen has an additional signal on the CCD
Light background subtraction is further complicated by changing laser energy

- Laser energy was dropping continuously and we took light backgrounds at the end of an experiment, so a deviation from linearity in the energy monitoring pickoff could explain the tendency to subtract too much background (before using the optimization algorithm).

Energy pickoff linearity (diamonds = data, red = linear fit)
We developed an algorithm to optimize background subtraction by maximizing the number of pixels near zero.

Setup 07, center strip 1

Without optimized background subtraction (OBS)

With OBS

Even with OBS, there is evidence that non-zero values of the gate profile have an impact (few percents) on the flat-fielding value (ie. value of the primitive at the end of the time range).
Experiments at CEA confirm that light background can be nearly eliminated by changing angle of laser relative to MCP.

- We used a special flange to have the laser beam incidence depart 7° from normal.
- Background is considerably reduced, with or without phosphor voltage.
- Gate profiles look « clean » without any background subtraction tweaking (obviously).
- Needs to be confirmed with GXD.

Light background (phosphor voltage off)

Light background (phosphor voltage on), same color scale

Gate profiles (strip 1-4, 3 locations)

Associated primitives
Non-uniformity in DC image is not due to non-uniformity in laser source

Approximate region seen by GXD3

Beam uniformity seen by P43 phosphor screen + fiber-optics taper

GXD3 DC biased MCP (UV)
DC gain exponent measured between 9.9 and 9.8 for the different strips

GXD3 DC biased MCP (X-ray)
DC gain exponent measured between 10.9 and 11.2 for the different strips

- By-construction, beam should be collimated (source in the focal plane of a 100mm diameter lens)
- Re-alignment of the laser beam did not improve the DC-image uniformity
- GXD3 does show top-to-bottom DC non-uniformity in x-ray lab, but less than observed at CEA, UV
  - Additional DC non-uniformity may be related to light background
UV flat field construction seems useful for LLNL

Confirm effectiveness of flange/incident angle to remove light background and reduce DC non-uniformity with GXD

Build a UV pulsed laser lab at LLNL
   Using CEA expertise; similar enough to be directly comparable
   Need a “bigger laser” to calibrate flat fields at high gain

With an automated offline system we could assess statistical issues that we could never do with NIF shots alone
   Reproducibility
   Variation with signal level and saturation
   Many configurations
   Sum many flat fields to characterize fixed pattern noise

Want to confirm that X-ray and UV method converge once both are improved
How much laser do we need?

Approximate region seen by GXD3

~3mJ in 5-omega 25ps (FWHM) pulse is sufficient to illuminate GXD on high to medium gain (50 – 100 V bias) for collecting UV flat field data

Flux = 10 µJ/cm²

Ideally we would be able to flat field up to 200 V bias at least (need x10)

Flux Goal = 100 µJ/cm²
We are interested in continuing the collaboration to address other framing camera performance issues

Engineering/Design issues (MCP coatings; cross talk mitigation; … )

Variation in DQE (gain/sensitivity) between cameras
At NIF, x-ray flat field shots serve TWO functions:
  #2 Relative Gain across MCP (“flat field”)
  #1 Determination of relative sensitivity to enable experiment setup
  We are interested in developing more robust methods to determine camera-to-camera sensitivity

Variation in DQE (gain/sensitivity) with photon energy
  There is some evidence that there is a difference between DC and pulsed

Spatial resolution
  Our cameras have large tails in the MTF. Characterizing these under pulsed operations and reducing their amplitude is a challenge.
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