Characterization of a Picosecond Gated Optical Intensifier

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SYDOR TECHNOLOGIES
COMPLEX MEASUREMENTS—CRITICAL RESULTS

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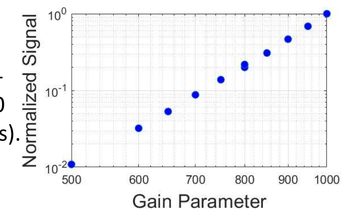
Abstract

The development of high speed imaging detectors is crucial for high-temperature plasma characterization and optimization. These detectors must perform within many strict parameters, such as precise timing, high spatial resolution, and fast gating. Gated optical intensifiers (GOIs) have been used on 2D VISAR diagnostics[1], as well as to characterize cross-beam energy transfer on OMEGA[2].

We present test results on a picosecond GOI that meets these requirements. The detector was developed by Kentech, and is part of a Sydor solution of 1-8 detectors, designed for use in plasma diagnostics. It has low jitter (SD ~4 ps) and gate widths less than 130 ps. We use a pulsed laser to test the gate profile and the spatial resolution performance of the intensifier at different times within the gate.

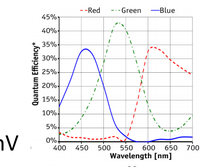
GOI Quick Facts

- Diameter: 18mm
- 4 modes: DC, slow gate (10 ns - 10 µs), medium gate (300-5000 ps) and fast gate (<100 – 250 ps).
- Gain is exponentially proportional to control voltage



CCD Quick Facts: Manta G-505B

Sensor Size: 2/3”
Pixel Size: 3.45 µm
Max dark signal: 4mV @ 60ºC



Quantum Efficiency

Experiment Design

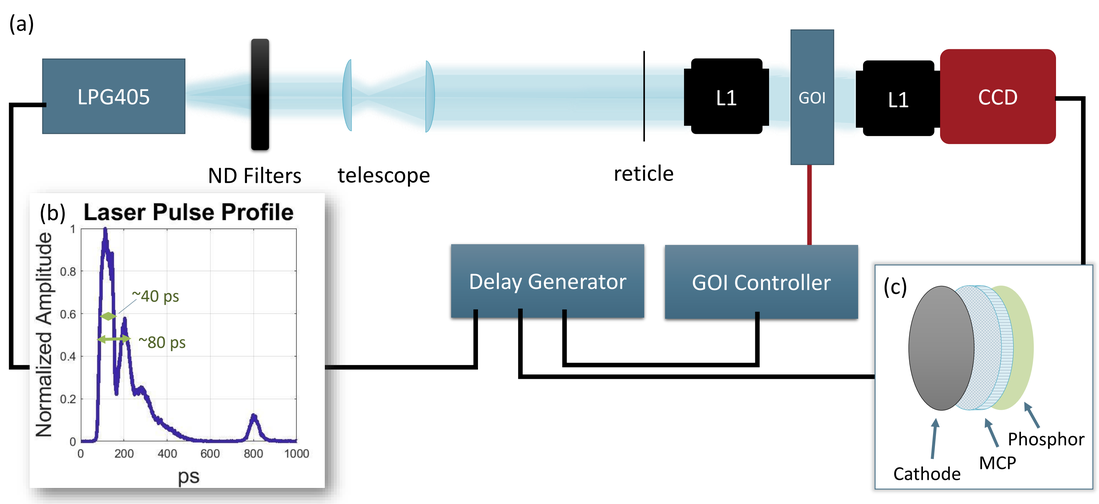


Figure 1: A pulsed laser (Photek LPG 405) is used to characterize the imaging capabilities of the intensifier. A delay generator walks the pulse through the gate. Optics resolution was verified by removing the GOI. Inset **(b)** shows the pulse profile, measured on a streak camera. Since the pulse width is on the same order as the smallest gate width, this profile must be deconvolved from the gate measurement to obtain the true width. Inset **(c)** outlines the components of a GOI: cathode, microchannel plate (MCP), and phosphor.

Gate Profile

The gate profile is measured by stepping a laser pulse through the gate, using a delay generator. For the shortest gate times, the laser pulse width (Figure 1, inset) is on the same order as the gate width. To estimate the true gate width, a Fourier deconvolution method is used.

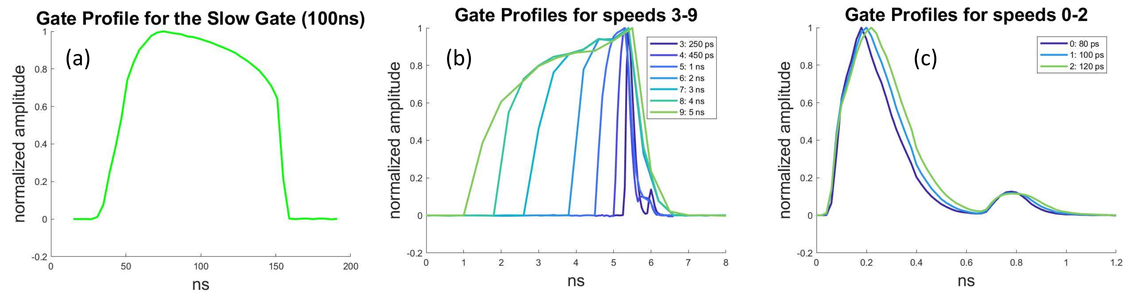


Figure 7: Gate profiles measured using the LPG405. (a) Slow gates of arbitrary lengths 100ns+, (b) fast gates between 0.25 and 5 ns, and (c) the fastest gates, in which the laser profile dominates the measurement.

The gate signal width can be estimated using the Convolution Theorem:

$$g_{measured}(t) = \int_{-\infty}^{\infty} f_L(t')\, g_a(t-t')\, dt' = f_L * g_a$$

$$\mathcal{F}[g_{measured}(t)] = \mathcal{F}[f_L]\,\mathcal{F}[g_a]$$

$$g_a(t) = \mathcal{F}^{-1}\left[\frac{\mathcal{F}[g_{measured}]}{\mathcal{F}[f_L]}\right]$$

Gate	0	1	2	3	4	5	6	7	8	9
Named Width (ps)	80	100	120	250	450	1000	2000	3000	4000	5000
Measured Width (ps)	217	252	279	214	359	829	1641	2659	3550	4069
Deconvolved Width (ps)	132	172	194	124	331	823	1674	2705	3561	4136

Table 1: Named, measured, and estimated gate widths.

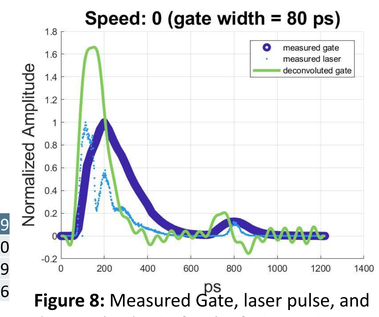


Figure 8: Measured Gate, laser pulse, and deconvolved gate for the fastest gate.

Measuring Resolution with the Modulation Transfer Function

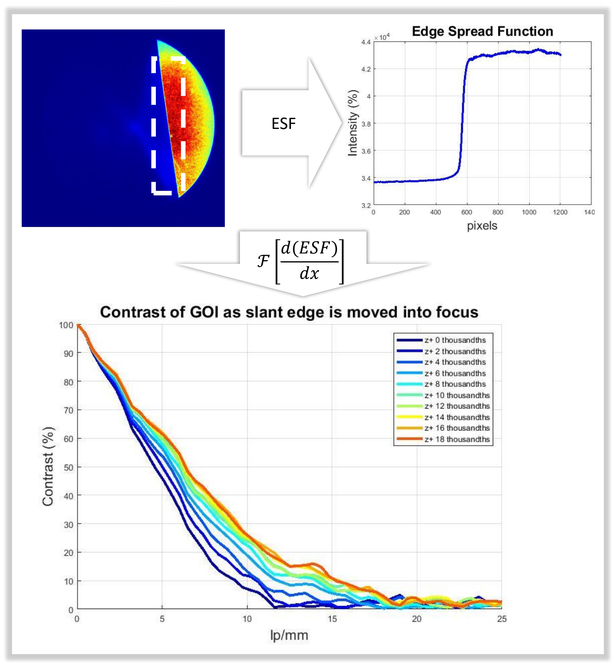


Figure 2: A slant edge target is used to measure the MFT of the imaging system.

- Process image in region selected
- Detect angle
- Project into vector
- Take derivative
- Take Fourier Transform
- Note: result is sensitive to position of edge

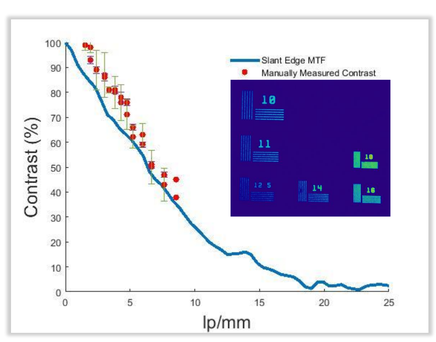


Figure 3: A resolution target is used to verify the results of the slant edge measurement.

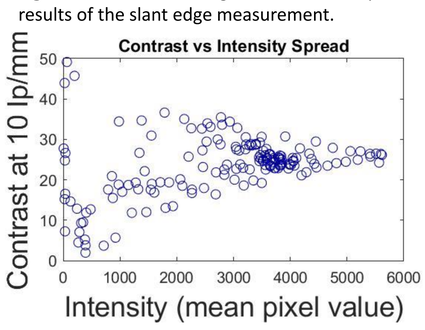
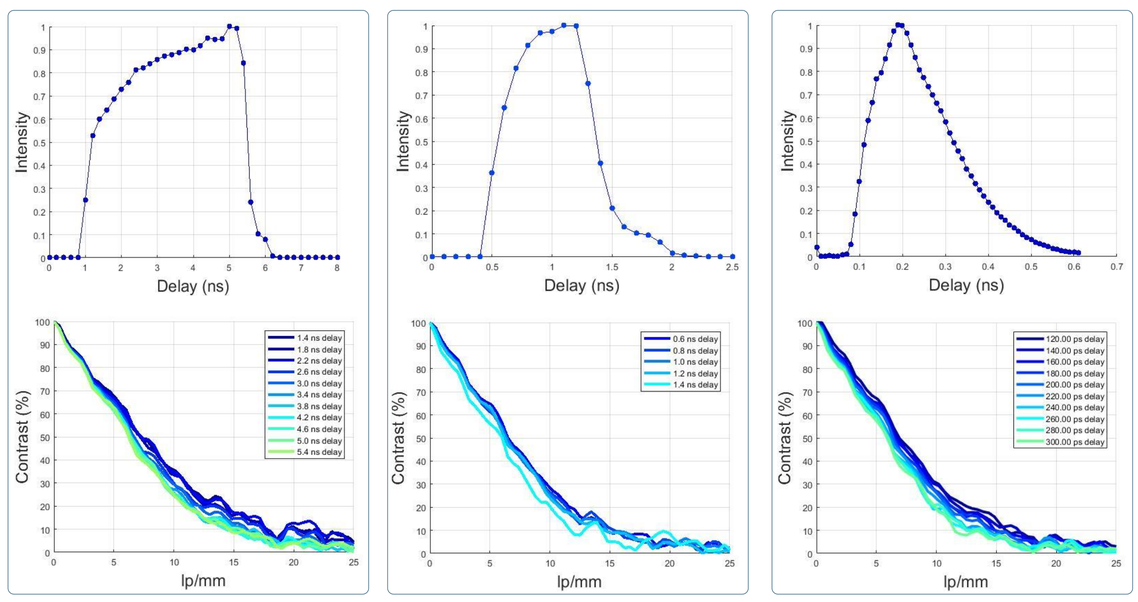


Figure4: The slant edge measurement is noisy for low intensity, as shown by this spread of data.

Resolution Through the Gate



Resolution through Gate #9 (5ns) | Resolution through Gate #5 (1ns) | Resolution through Gate #0 (“80” ps)

Figure 9: The resolution at points in the gate is measured by imaging a slant edge target as the laser is delayed with respect to the gate. Representative data from the fastest, middle, and slowest gates is shown. Much of the variation shown is due to the intensity variation, which affects the MTF analysis. The similarity in the curves, even at the fastest gates, is due to the axial magnetic field (see Gate Uniformity section)

Gate Uniformity

Many GOIs exhibit noticeable irising at the start and end of the gate window. This reduces the useable time of the gate, and introduces unnecessary blur to the image. We do not observe irising on this GOI.

Furthermore, lower voltages are used when gating the tubes on and off quickly, resulting in image spread and degradation of resolution at short gate times on other systems. **This GOI utilizes an axial magnetic field to minimize electron spreading, resulting in clear images during even the shortest gate windows. Figure 6 illustrates this.** Images were taken at the 60 ps intervals shown in Figure 5.

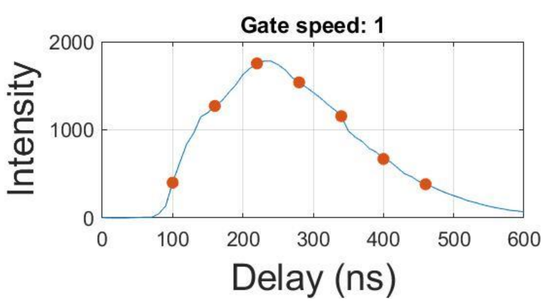


Figure 5: Laser pulse delay times for the images in Figure 6 below.

Conclusion

Summary:

- The magnetic field is effective, allowing fast gating without loss of resolution.
- This GOI is capable of taking high quality images within the full gate window <130 ps.
- The temporal and spatial quality of the laser pulse is as important as the gating for high resolution imaging.

Future work:

- Investigate a different unit, to see if resolution improves further.
- Measure absolute luminous gain and characterize noise.

References and Acknowledgements

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MTF MatLab code: Copyright (c) 2009-2015 Peter D. Burns, pdburns@ieee.org
Fourier Deconvolution MatLab Code: A Pragmatic Introduction to Signal Processing, by Tom O’Haver
https://terpconnect.umd.edu/~toh/spectrum/

1. Katz, et al.,OLUGW, (2017).
2. A.L. Meadowcroft, et al., Plasma Phys. Note 49/15 (2015).

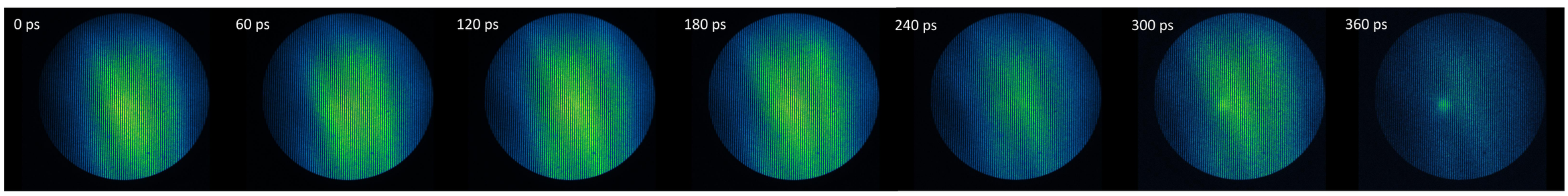

Figure 6: Images taken of a Ronchi ruling at incremental delays of a pulsed laser through a fast gate. The images show remarkable image-to-image clarity and uniformity.