Characterization of Ultrafast Gated Optical Imagers for the OMEGA Beamlets Diagnostic

J. KATZ, M. BEDZYK, D. H. EDGELL, C. M. ROGOFF, M. SICKLES, J. SZCZEPANSKI, D. P. TURNBULL, D. WEINER, and D. H. FROULA

University of Rochester, Laboratory for Laser Energetics

Summary

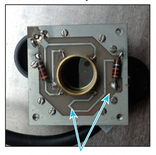
A platform for characterizing the timing and imaging performance of gated optical imagers has been developed

- Gated optical imagers (GOI's) are 2-D imaging systems that provide "electric shutters" with exposure durations as short as 200 ps
- The GOI consists of a microchannel-plate (MCP)—based image intensifier coupled to a charged-coupled device (CCD)
- The optical gate profile of the MCP has been characterized using a short-pulse laser
- Detailed flat fielding of gain is required to make ratio measurements between different locations across the image sensor
- A GOI has been deployed on OMEGA to image scattered 3ω light refracted off plasma density gradients

G26096

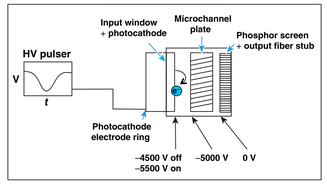
The GOI creates an "electronic" shutter by controlling the voltage between the photocathode and the MCP

View of GOI input window



High-voltage (HV) pulser board trace

GOI cross section

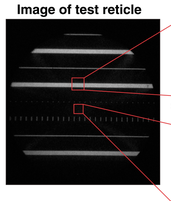


Shutter on/off time is limited by pulser electronics and pulse propagation across the surface of the photocathode.

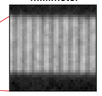
E26079

With a 40-μm point-spread function, the 18-mm MCP provides over 250,000 spatial-resolution elements

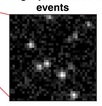
Image of test reticle



12-line pair per millimeter

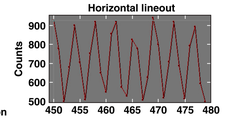


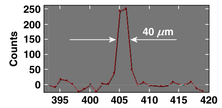
Single photoelectron events



30% contrast

Horizontal lineout

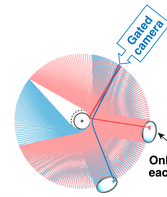


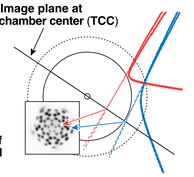


E26098

The "beamlets" imaging diagnostic provides a measurement of cross-beam energy transfer (CBET)

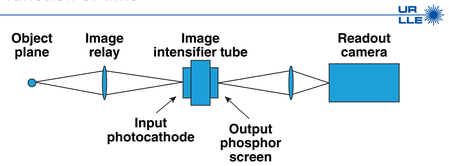
- Each 351-nm drive beam produces a uniquely imaged spot (beamlet) when scattered by the target, with a specific path through the corona
- Measure intensity of spots to find the effect of CBET on each beamlet
- Short exposure times are needed to resolve beamlets spots in motion during the late stages of implosion





E25651b

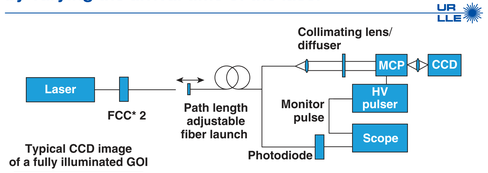
The GOI is a 2-D imaging device that uses a microchannel plate to control light amplification as a function of time



Parameter	Value
Photocathode size	Ø18 mm diam
Point-spread function	40 μm
Number of spatial-resolution elements	250,000
Minimum gate duration	200 ps
On/off gate-contrast ratio	1,000,000
Gain	0.5 to 500 CCD e$^-$/photoelectron
Linear dynamic range	100×

E26078

The duration of the MCP gate can be measured by varying the arrival time of the laser



Typical CCD image of a fully illuminated GOI

- A photodiode is used to compare laser timing relative to GOI monitor pulse; trigger jitter is measured to better than 10 ps
- The photodiode is also used to measure pulse laser energy; fluctuations in laser energy can be zeroed out
- Total CCD counts are summed to measure GOI gain at a particular time during the gate

*FCC: frequency-conversion crystal

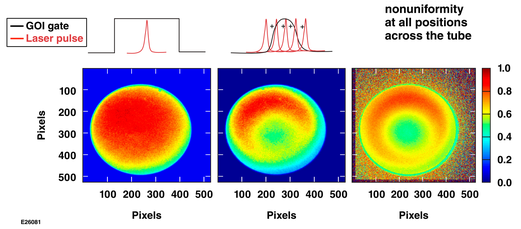
E26080

Spatial nonuniformities of the MCP gain over the duration of the gate are measured to generate a flat-field calibration

Single shot with slow gate
- quantifies illumination nonuniformity

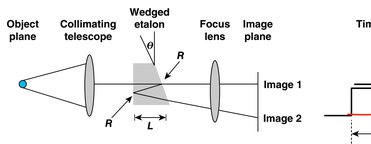
Summation of images from each position in fast gate

Fast sum divided by slow gate
- quantifies gain illumination nonuniformity at all positions across the tube

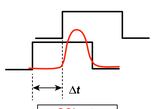


E26081

The beamlets diagnostic uses a wedged etalon to create an additional spatially and temporally separated image at the detector image plane



Timing diagram

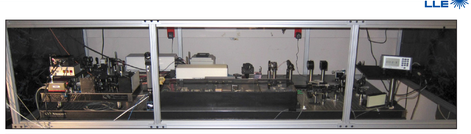


L	= etalon thickness	20 mm
θ	= wedge angle	4 arc min
R	= etalon coating reflectivity	95%
Δt	= timeing shift	200 ps

Several image frames can be recorded with a single exposure using a wedged etalon.

E26100

A short-pulse (10-ps) laser source is available to characterize temporal resolution of fast detectors



Laser architecture

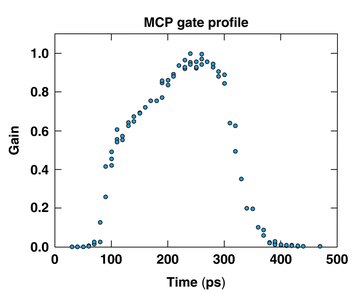
Oscillator → Pulse slicer → Regenerative amplifier → Harmonic conversion

Front end:	Pulse slicer:	Amplifier:	Frequency conversion:
Origami-10	Fiber-based AOM*	Multipass regen	5 Hz
76 MHz	5 Hz	5 Hz	2ω ~ 100 μJ
200 fs	200 fs	Gain: 1×10^9	3ω ~ 100 μJ
1-nJ pulse	1-pJ pulse	10 ps	4ω ~ 50 μJ
1053 nm	1053 nm	1-mJ pulse	
		1053 nm	

*AOM: acousto-optic modulator

E26077

The MCP gain as a function of time has been measured with 10-ps timing resolution



E26097

The achievable signal to noise (SNR) of the GOI detector is confined by counting statistics and a limited linear operating range of the MCP

$$\mathrm{SNR} = \frac{n\,\mathrm{QE}}{\sqrt{F^2\,(n\,\mathrm{QE}) + \frac{R_n^2}{G^2}}}$$

n = number of photons
QE = photocathode quantum efficiency
G = MCP gain (CCD e/photoelectron)
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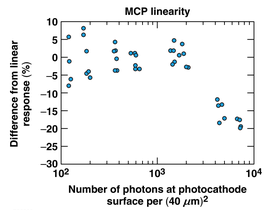
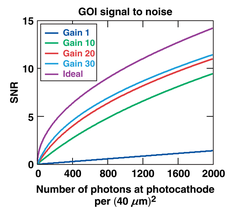
MCP linearity



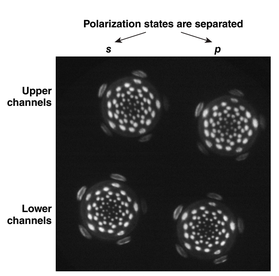
GOI signal to noise



E26099

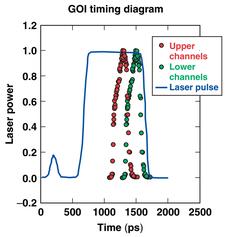
A GOI has been deployed on OMEGA to image scattered 3ω light refracted of plasma density gradients

Polarization states are separated



OMEGA shot 84769

GOI timing diagram



E26101

UNIVERSITY of ROCHESTER

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UR LLE

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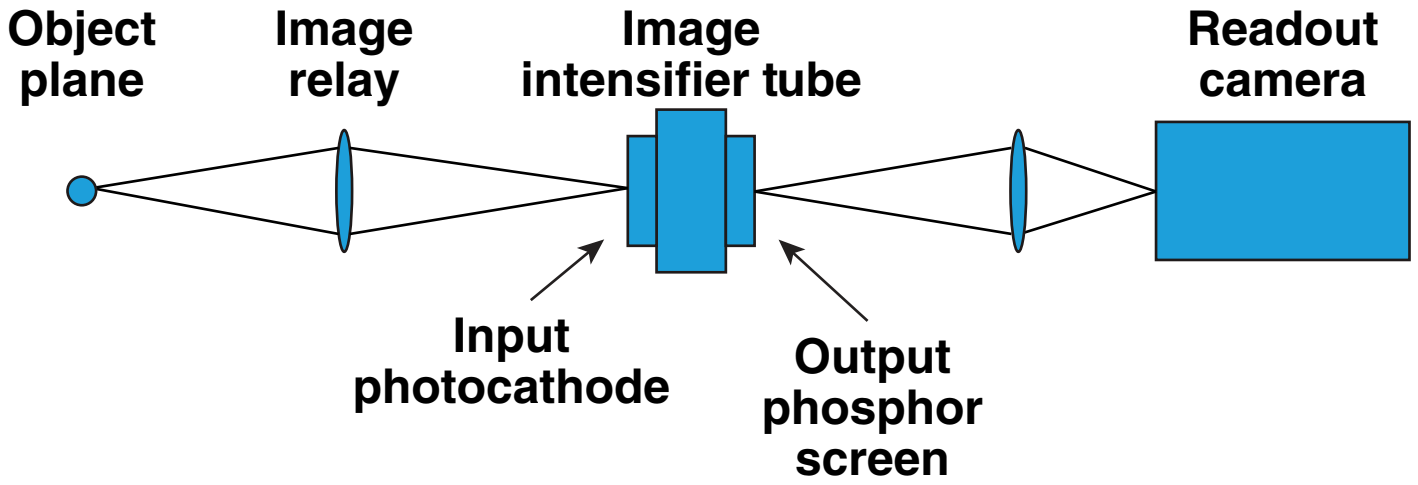

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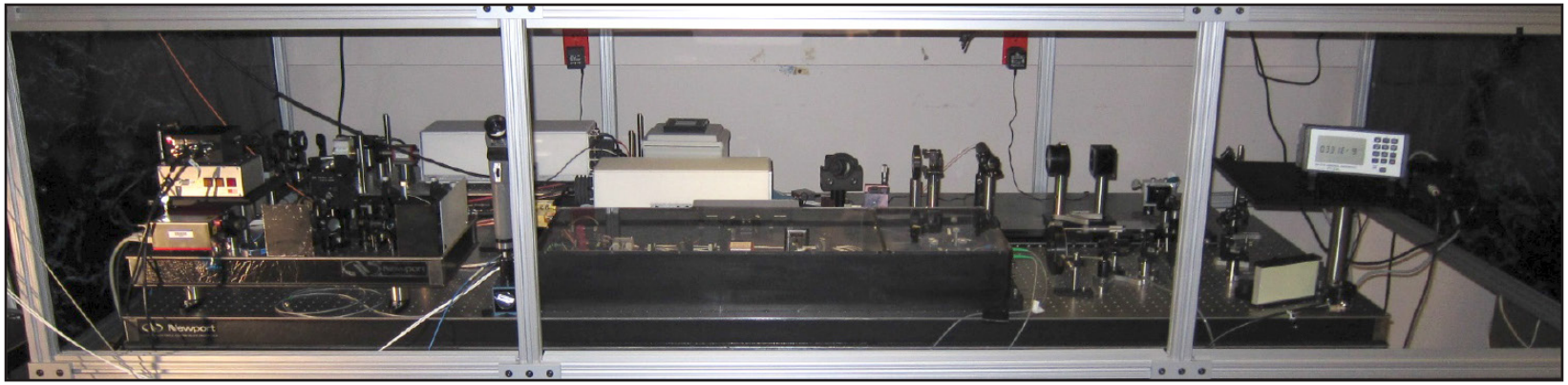

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UR LLE

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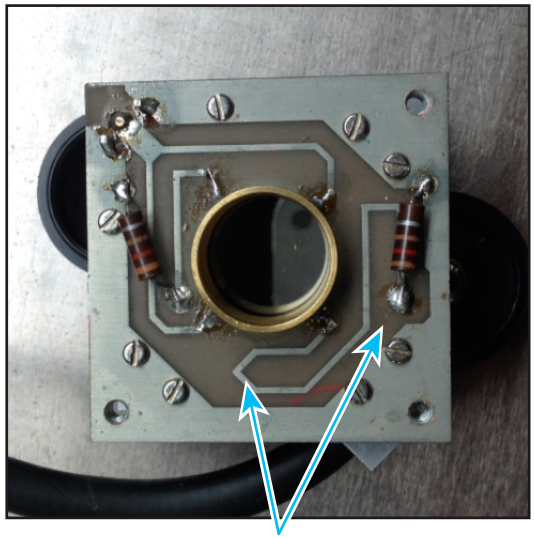

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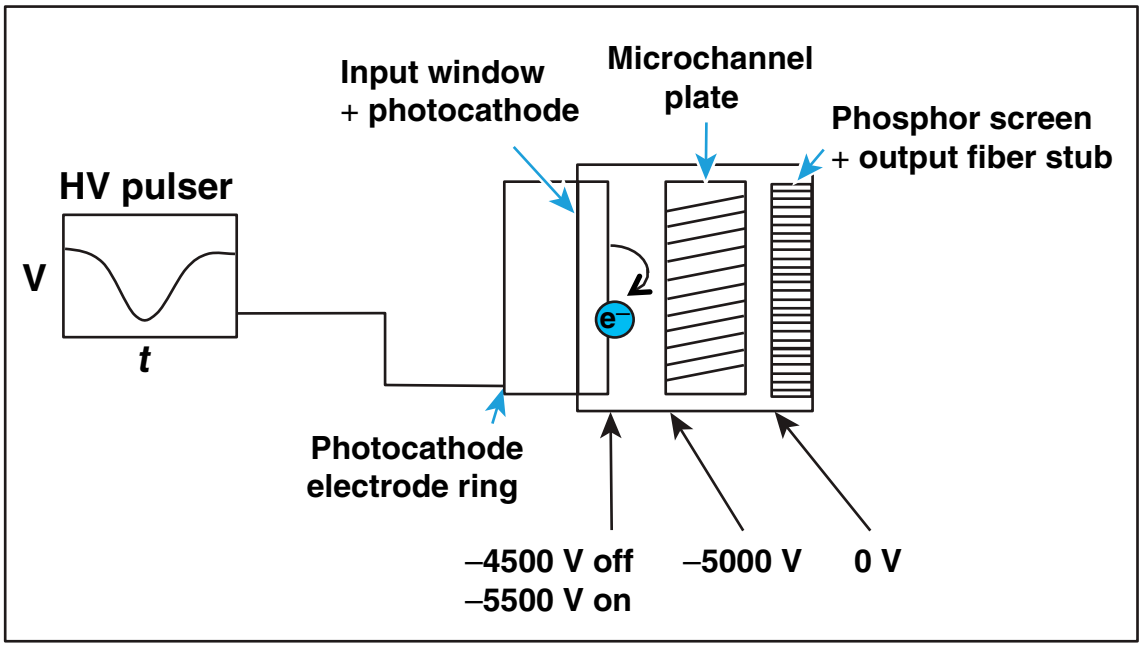

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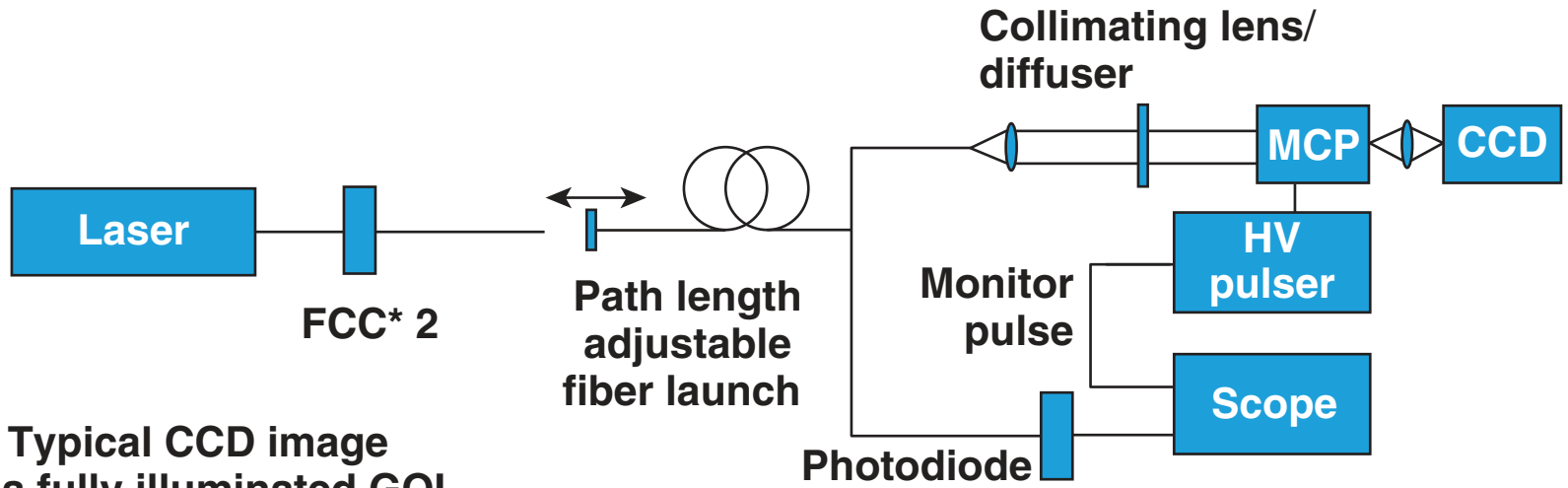

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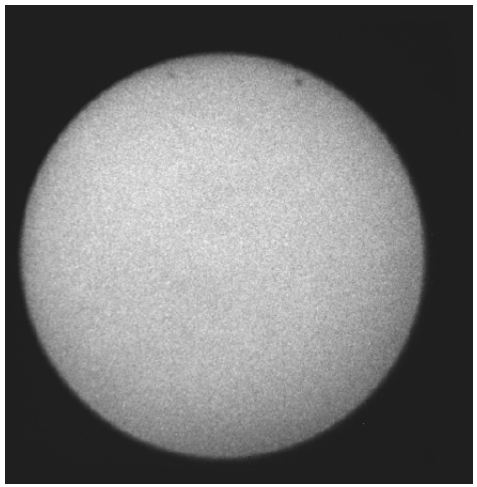

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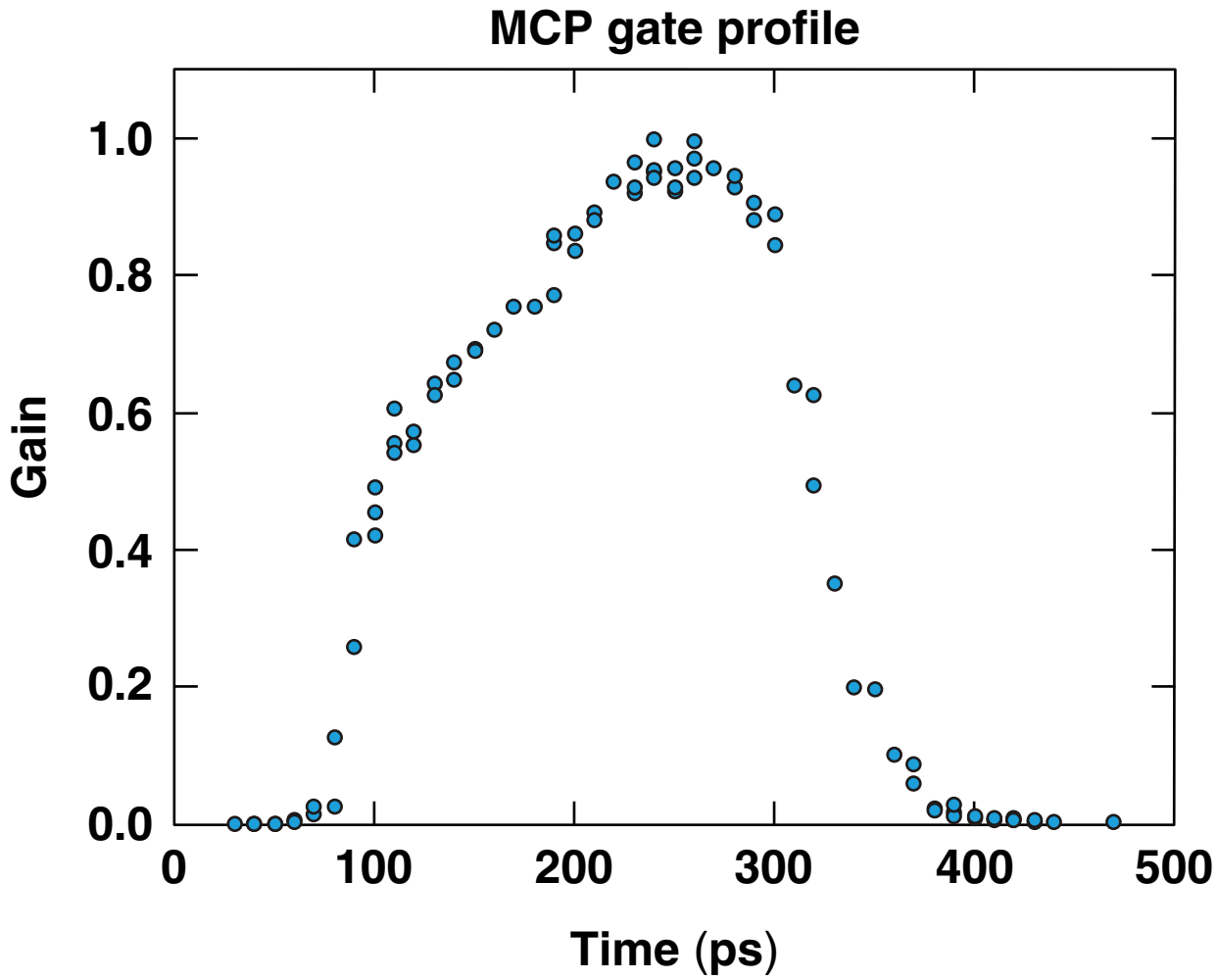

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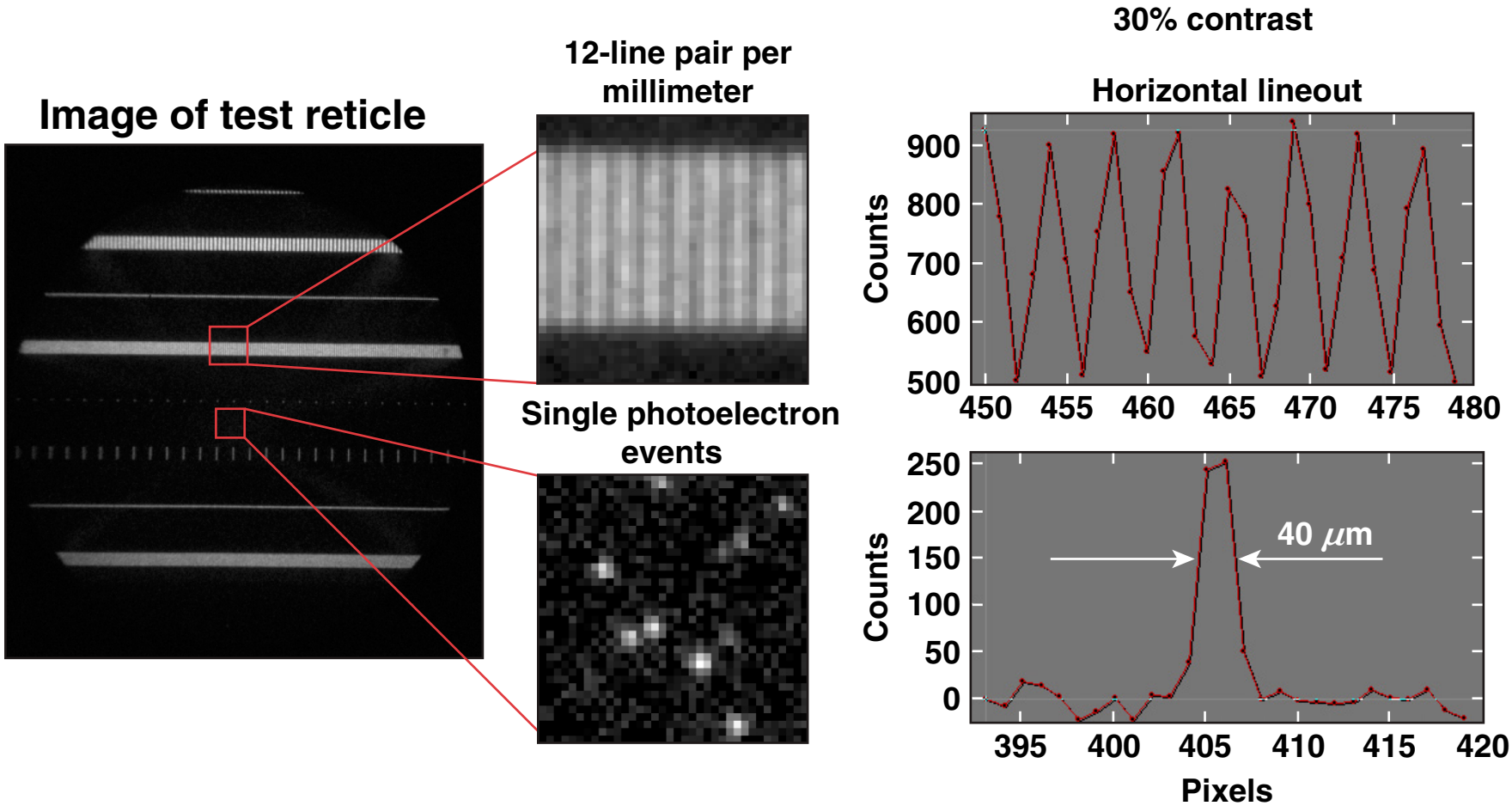

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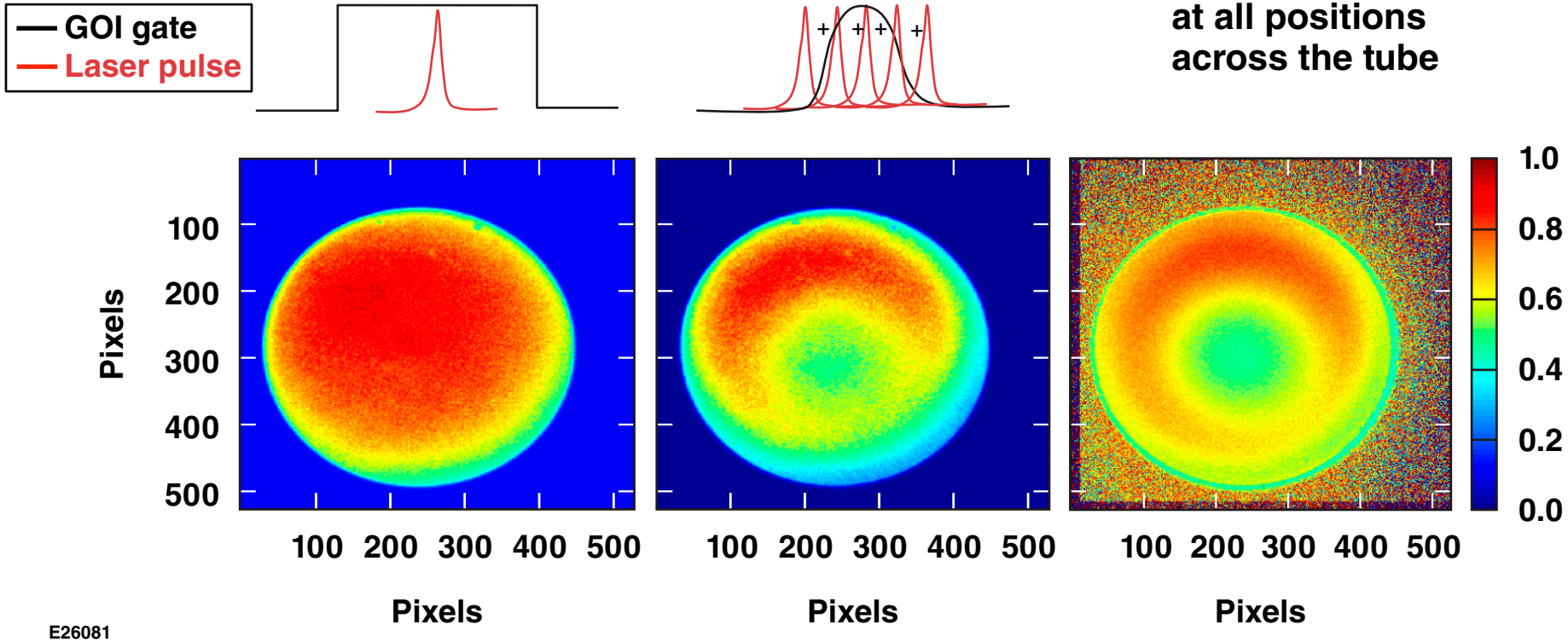

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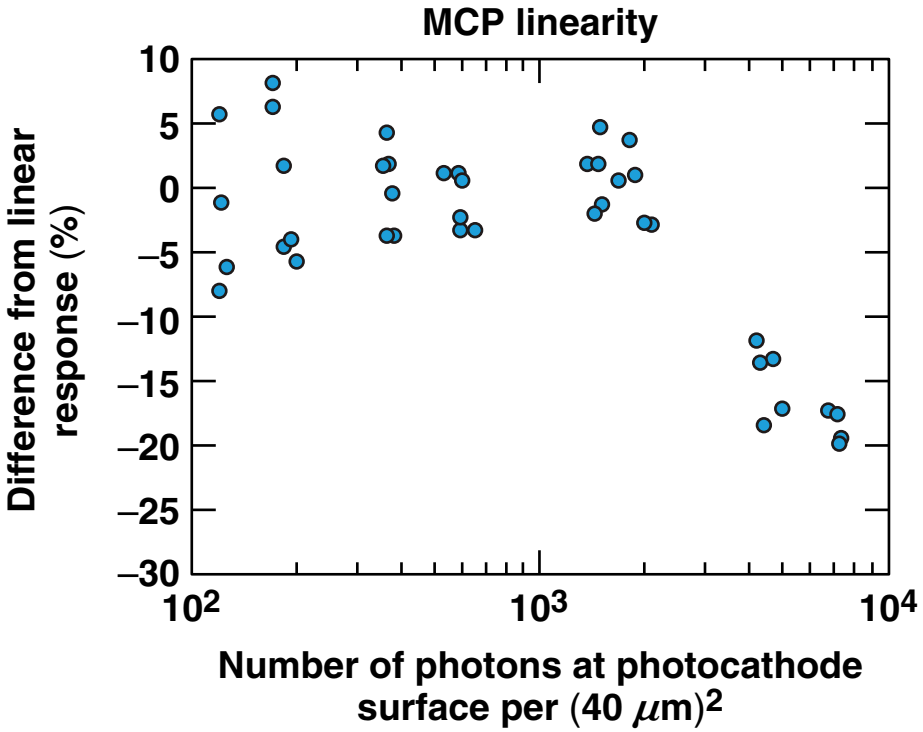

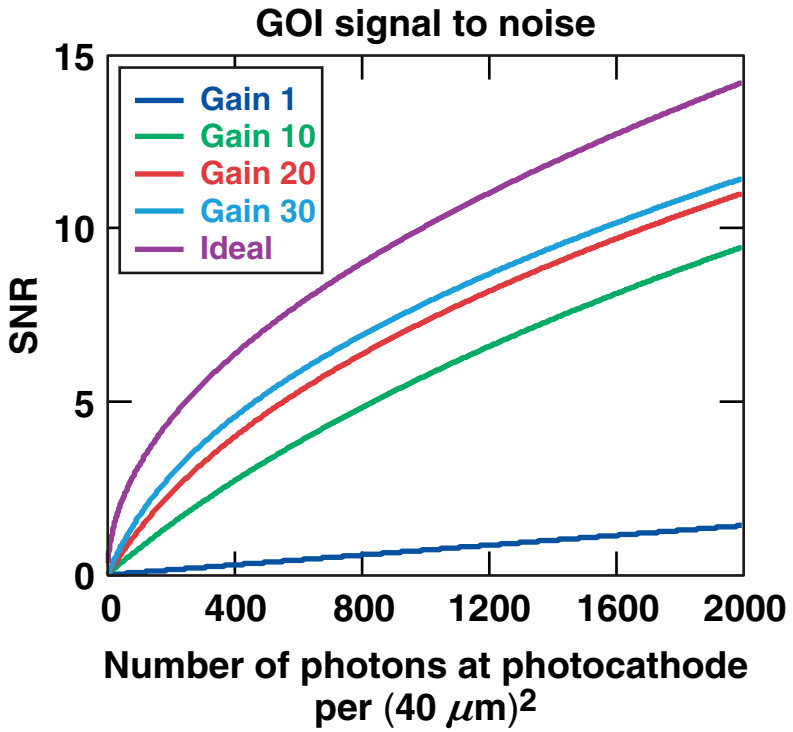

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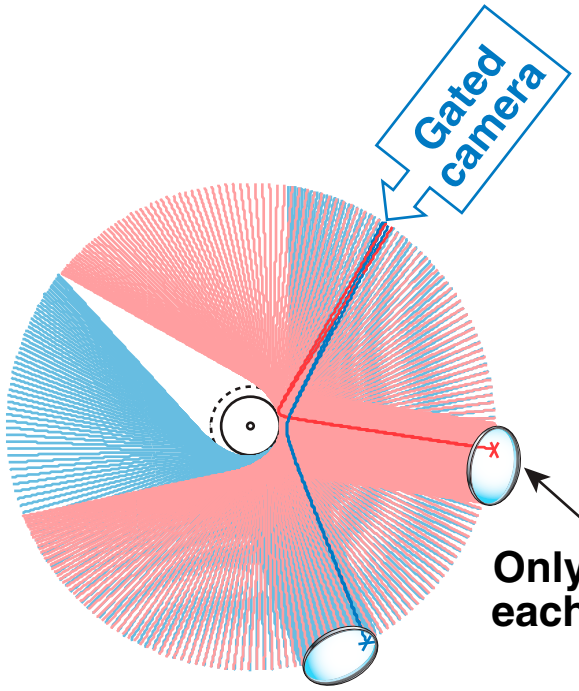
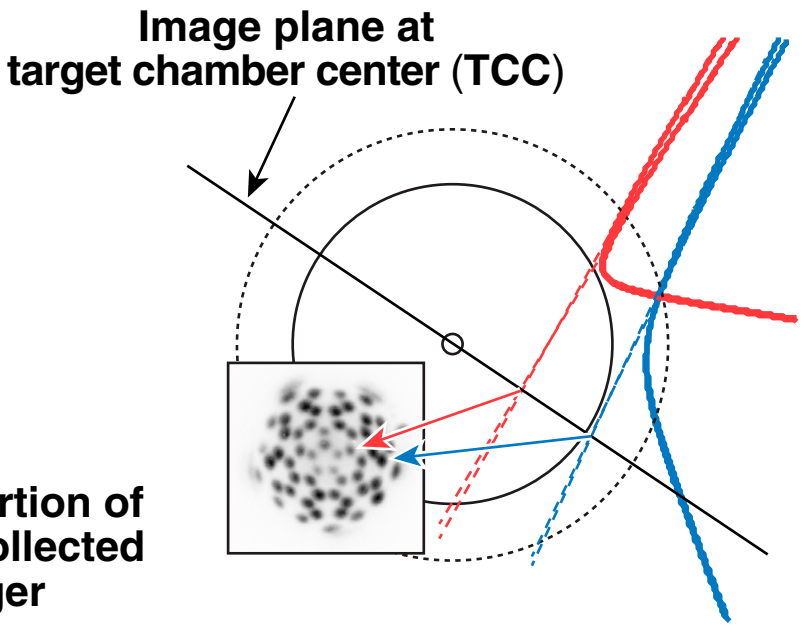


Only a small portion of each beam is collected by the imager



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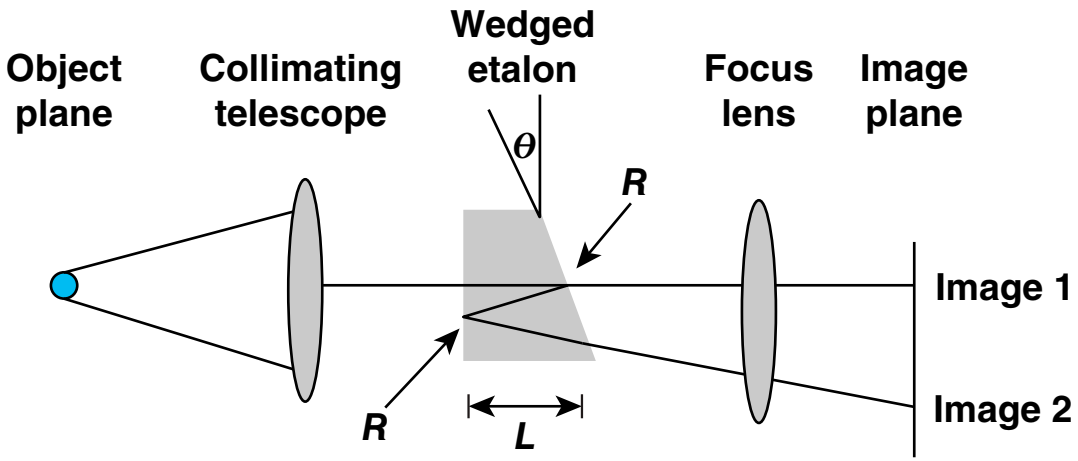

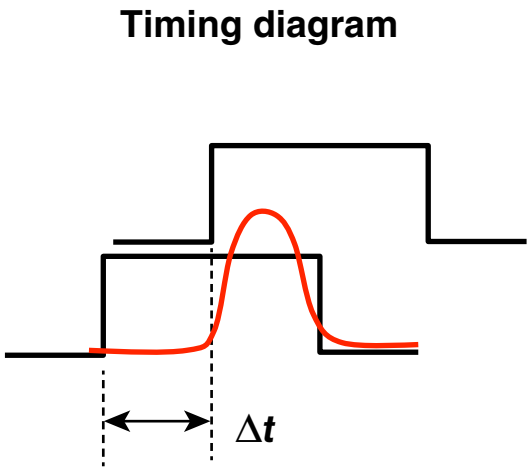

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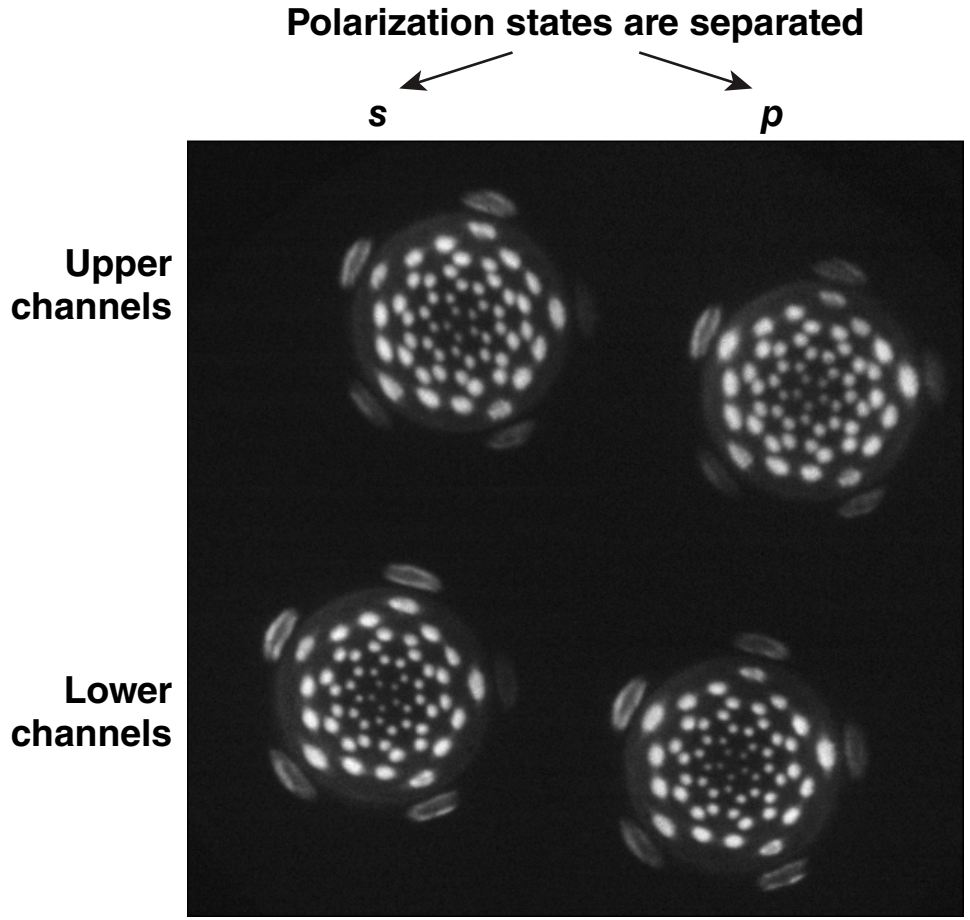

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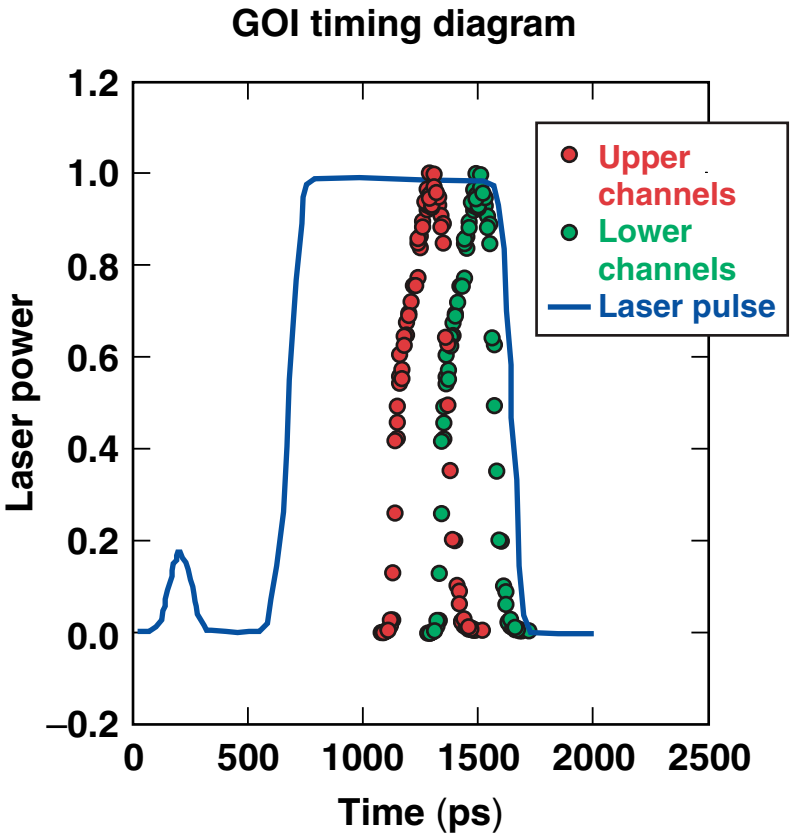

E26101