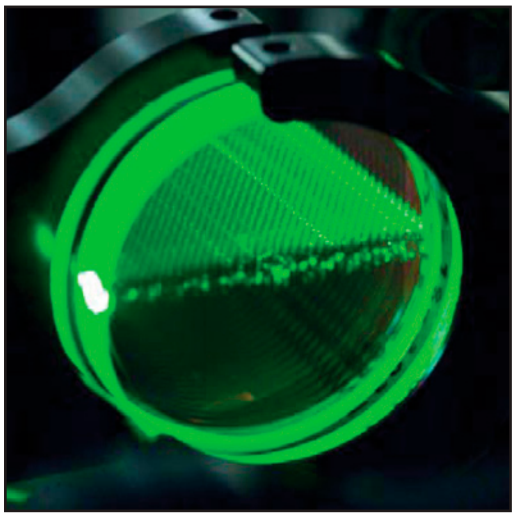
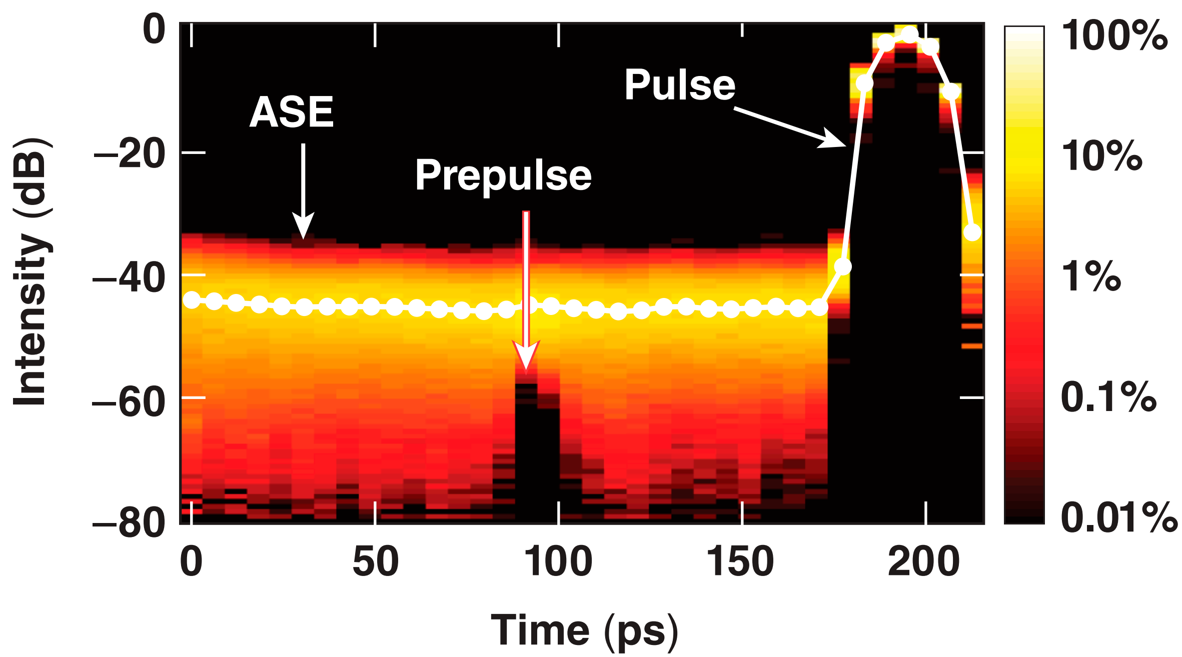
High-Dynamic-Range Single-Shot Cross-Correlator Using a Pulse Replicator





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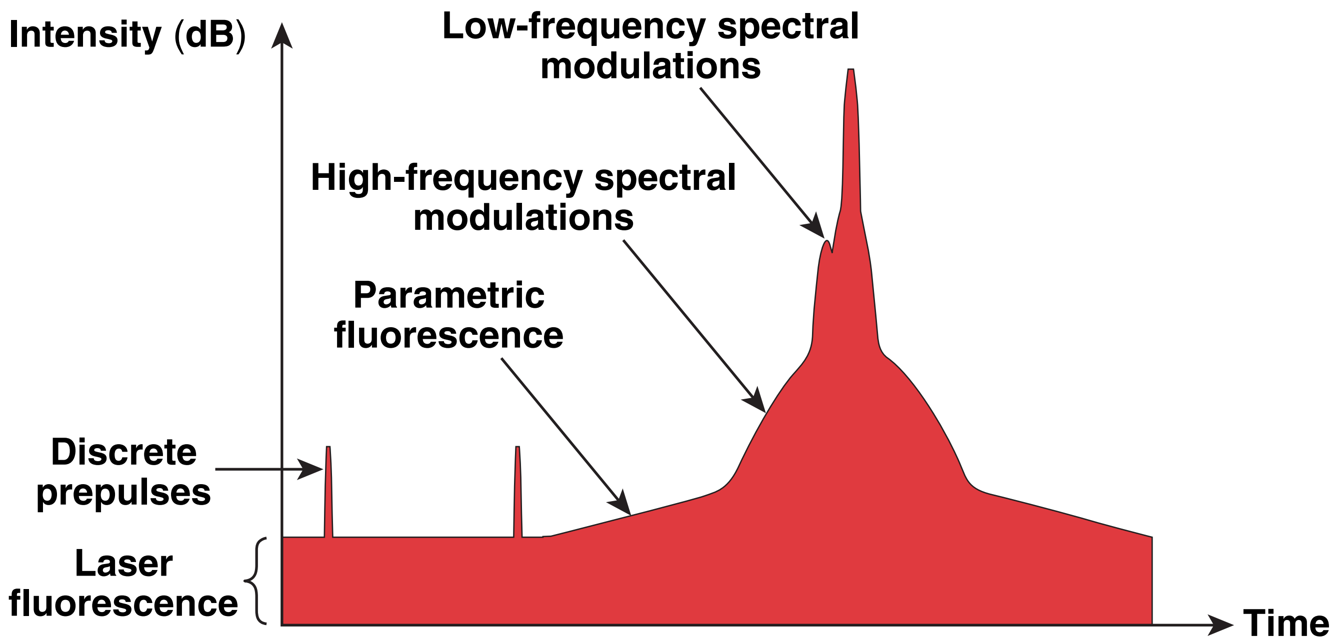
Summary

A single-shot, high-dynamic-range, cross-correlator with a long temporal range has been developed

- The temporal contrast of optical pulses must be controlled and measured accurately because of its impact on laser–target interaction
- Single-shot contrast measurements are required because
  - the prepulse intensity varies significantly from shot to shot (e.g., intensity fluctuations caused by amplified spontaneous emission)
  - high-energy laser systems have a low repetition rate that precludes multishot scanning diagnostics
- A single-shot, high-dynamic-range, cross-correlator has been developed
  - sequence of sampling pulses generated by an optical pulse replicator
  - sensitivity adjusted in different temporal ranges
  - dynamic range of 60 dB over a 220-ps temporal range

The temporal contrast of short laser pulses must be controlled and measured for laser-target experiments

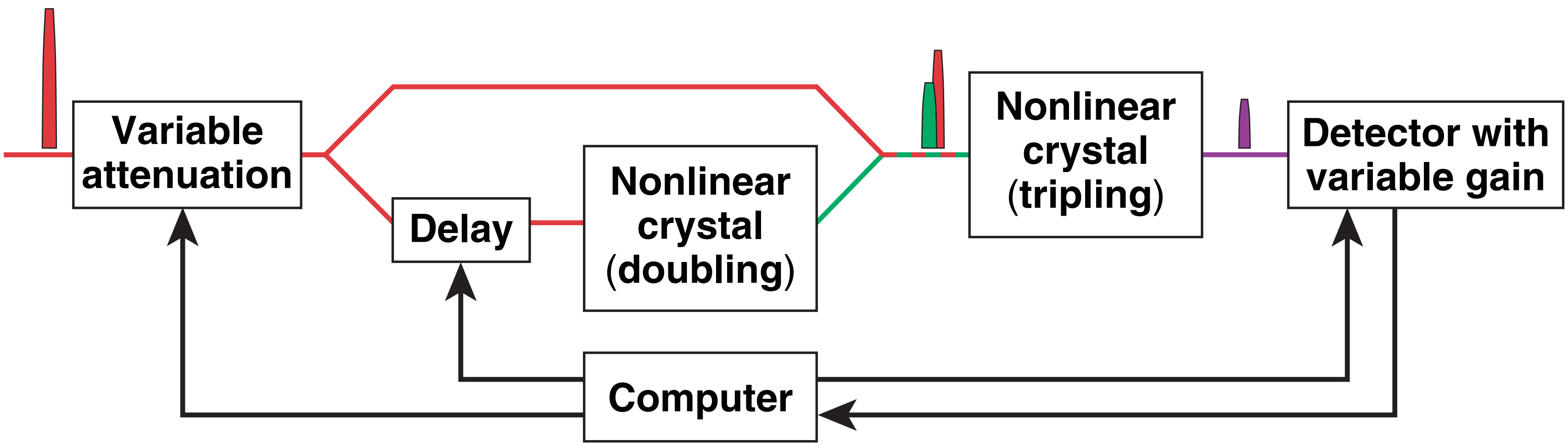


- Light arriving before the main pulse can create a pre-plasma
  - at an intensity $>10^{12}$ W/cm^2 in a short pulse
  - at an intensity $\sim 10^8$ W/cm^2 maintained over a long time

The temporal contrast is an important parameter for laser–target interaction and must be measured accurately.

E16641

The short-term temporal contrast is typically measured with a scanning third-order cross-correlator

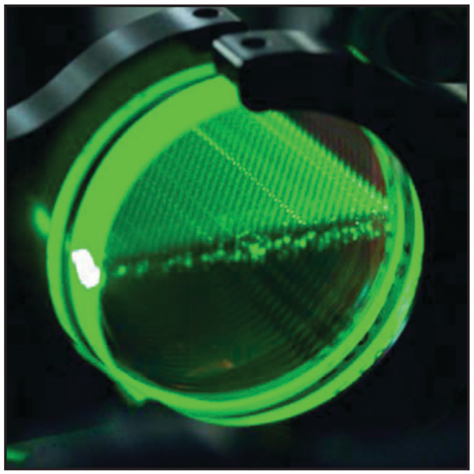


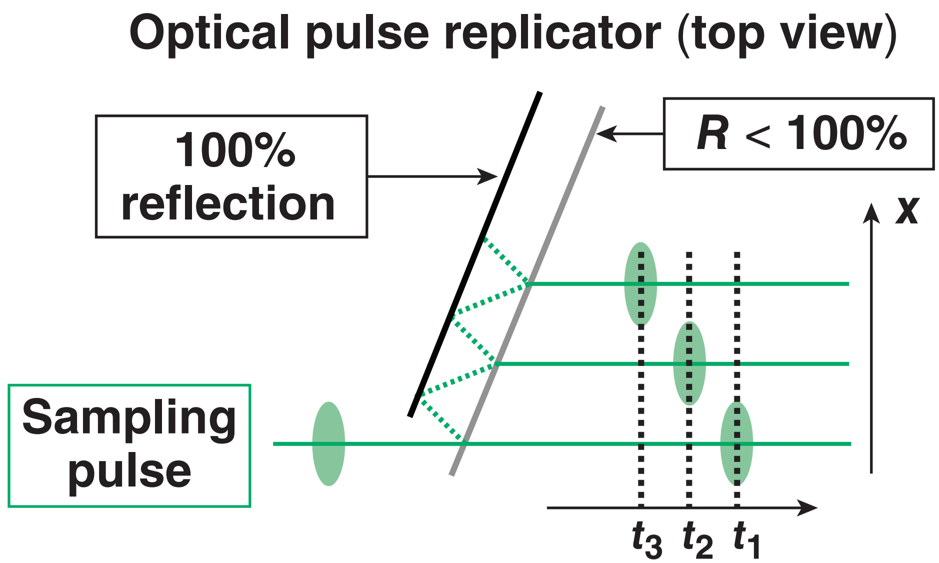
- Correlation signal measured as a function of the delay between the pulse under test and a frequency-doubled pulse.
- The computer continuously adjusts the input attenuation and detection gain.
- This is fundamentally a multishot acquisition system (~1000 shots).

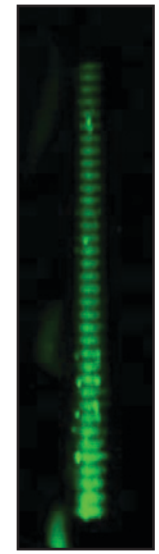
A different approach is needed for single-shot temporal-contrast measurements.

E16642

An optical pulse replicator generates a sequence of sampling pulses

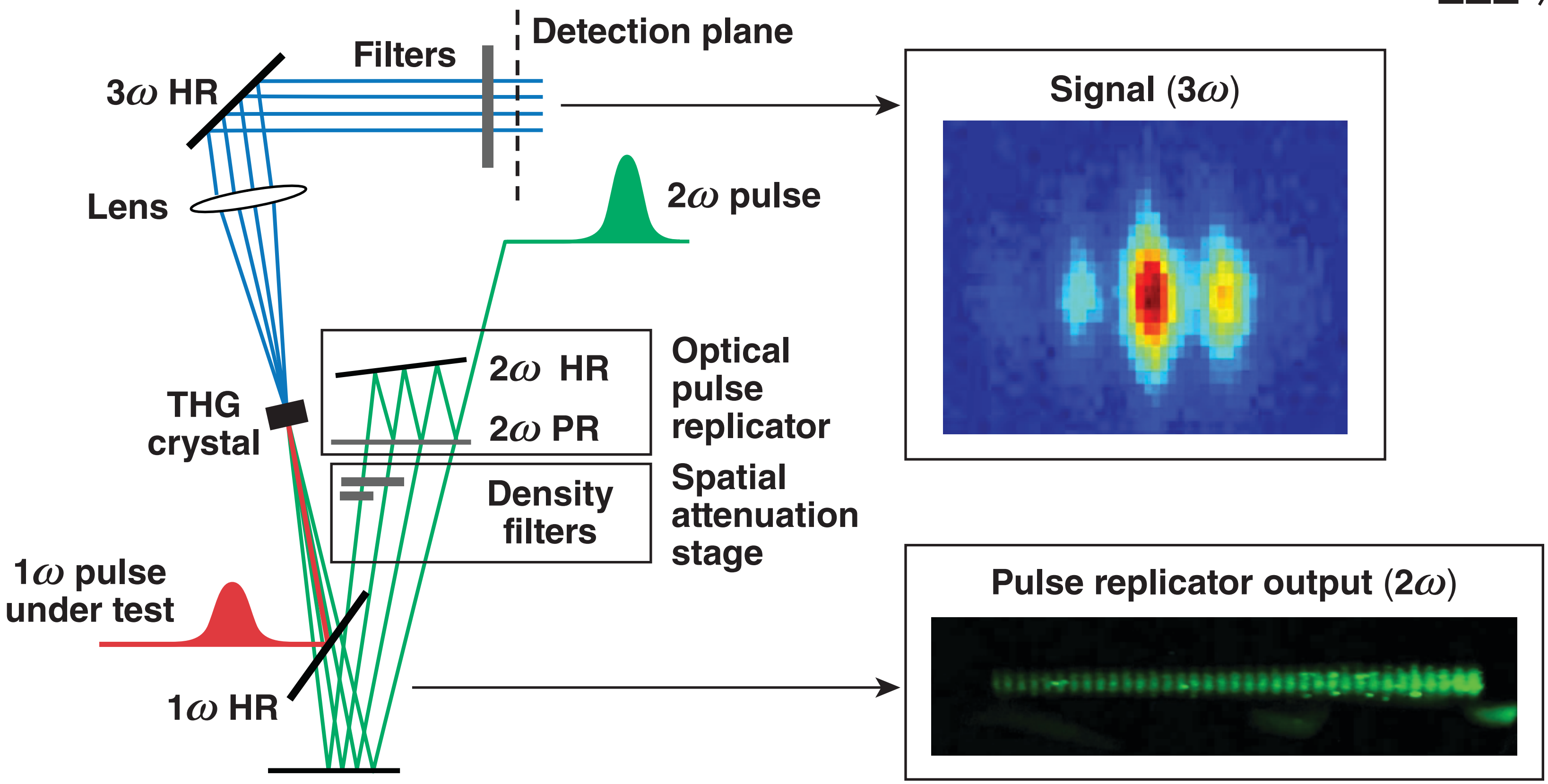






- Sequence of sampling pulses that are spatially separated and temporally delayed effectively maps time onto space
- Demonstrated optical pulse replicator with commercial 2-in. mirrors
  - 36 sampling pulses
  - 6-ps spacing between sampling pulses

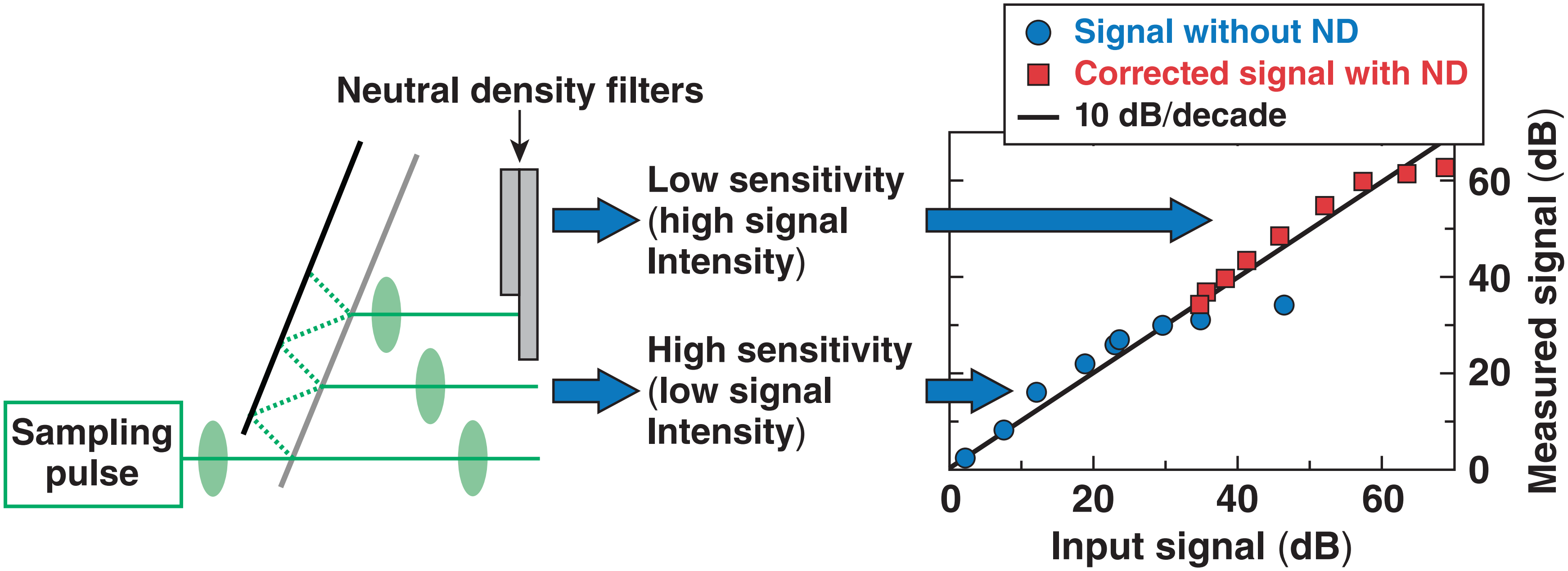
A single-shot, third-order cross-correlator based on an optical pulse replicator has been developed



- 1ω pulse intensity is obtained by nonlinear interaction with a sequence of 2ω sampling pulses generated by a pulse replicator.
- Sensitivity adjusted for different temporal ranges using neutral density filters after the pulse replicator.
- Background-free detection at 3ω for high-dynamic-range measurements.

E16459

The dynamic range can be extended using neutral density filters after the pulse replicator



- Detection at 3ω using a simple video camera and 8-bit frame grabber → Dynamic range ~30 dB thanks to signal-beam spreading on multiple pixels
- The sensitivity for different temporal ranges can be adjusted using neutral density (ND) filters on the corresponding sampling pulses → Two 30-dB detection ranges separated by 30 dB

The single-shot cross-correlator measures a signal longer than 200 ps

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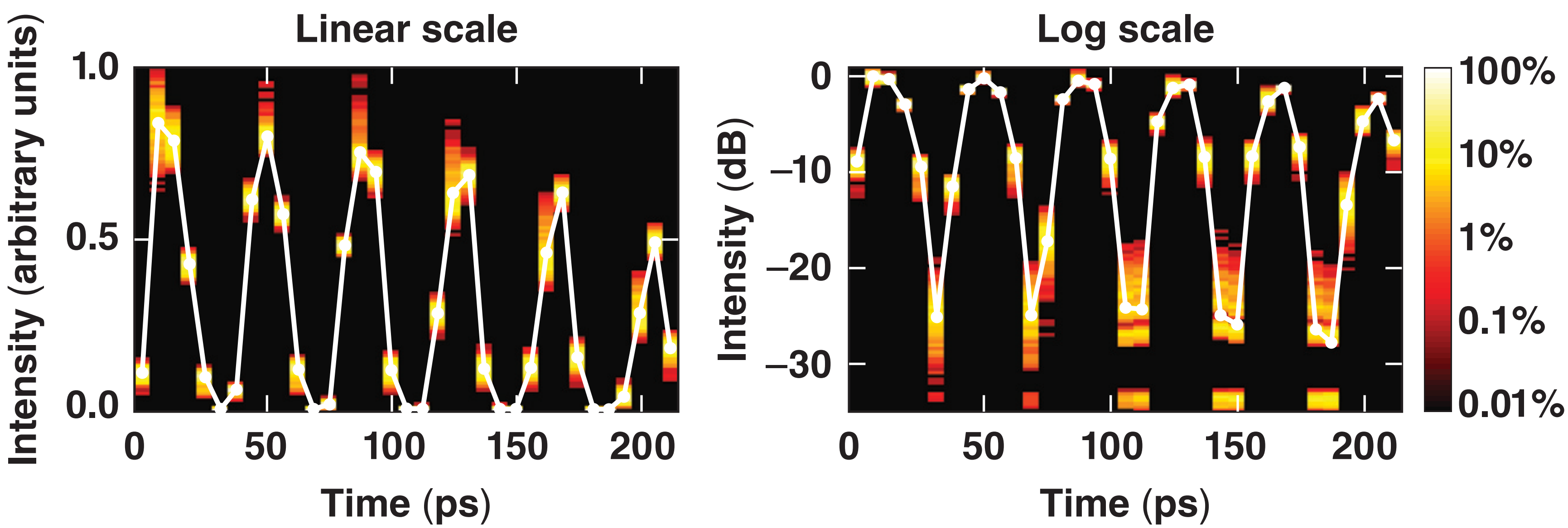
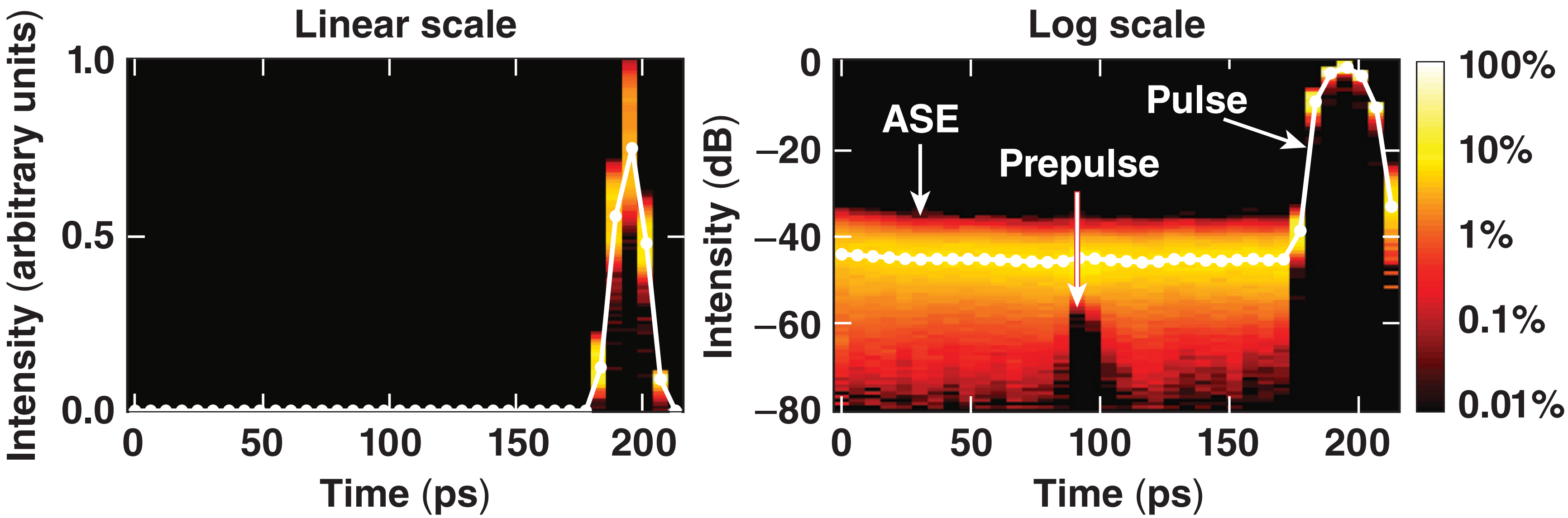


- A Fabry–Perot etalon in the 1ω beam path generates a train of pulses separated by 40 ps.
- The temporal range of the cross-correlator is larger than 200 ps.
- A cross-correlator with a 500-ps range is under construction.

A temporal range of hundreds of picoseconds can be covered in a single shot.

E16625

Amplified spontaneous emission leads to large fluctuations of the intensity before the main pulse

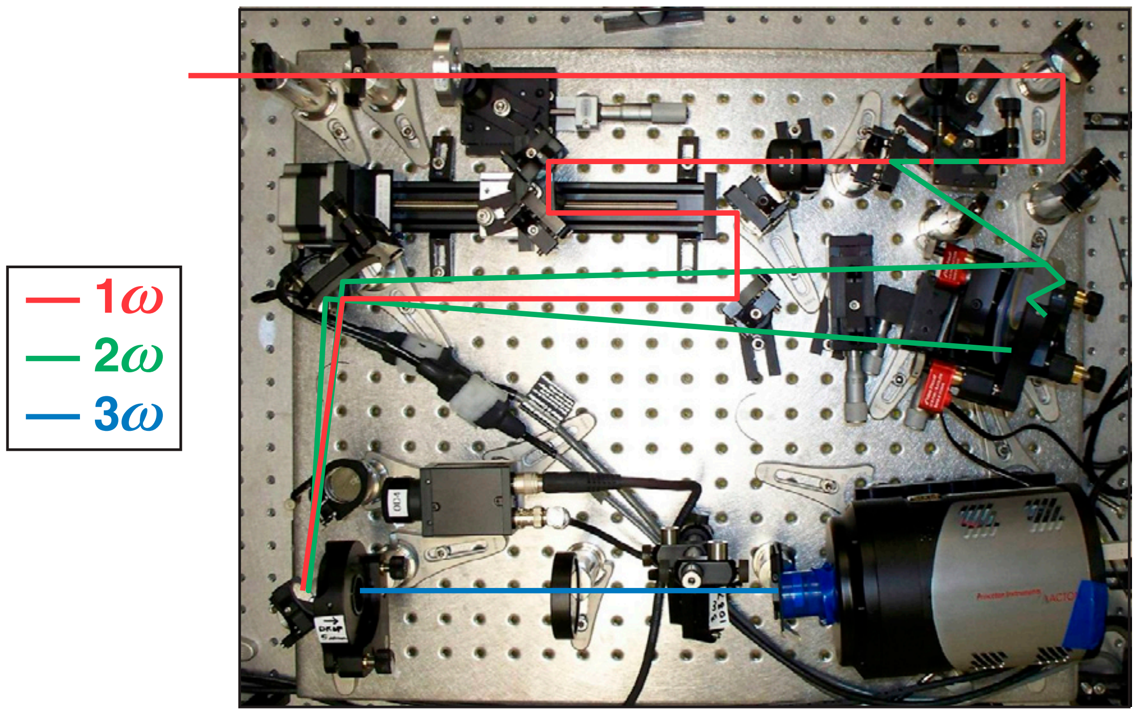


- 10,000 successive single-shot measurements of the 8-ps pulse from a diode-pumped regenerative amplifier
  - average ASE intensity approximately 45 dB below the peak intensity
  - variations of ASE intensity ~30 dB from shot to shot

Single-shot intensity measurements with >60 dB of dynamic range gives an unprecedented description of the pulse.

E16626

A single-shot cross-correlator is currently being characterized for OMEGA EP



- A cross-correlator prototype based on a pulse replicator is currently being characterized for OMEGA EP
  - temporal range of 510 ps (85 replicas, 6-ps delay)
  - dynamic range of single acquisition (without ND filter) of ~45 dB using a 16-bit CCD camera

E17227

Summary/Conclusions

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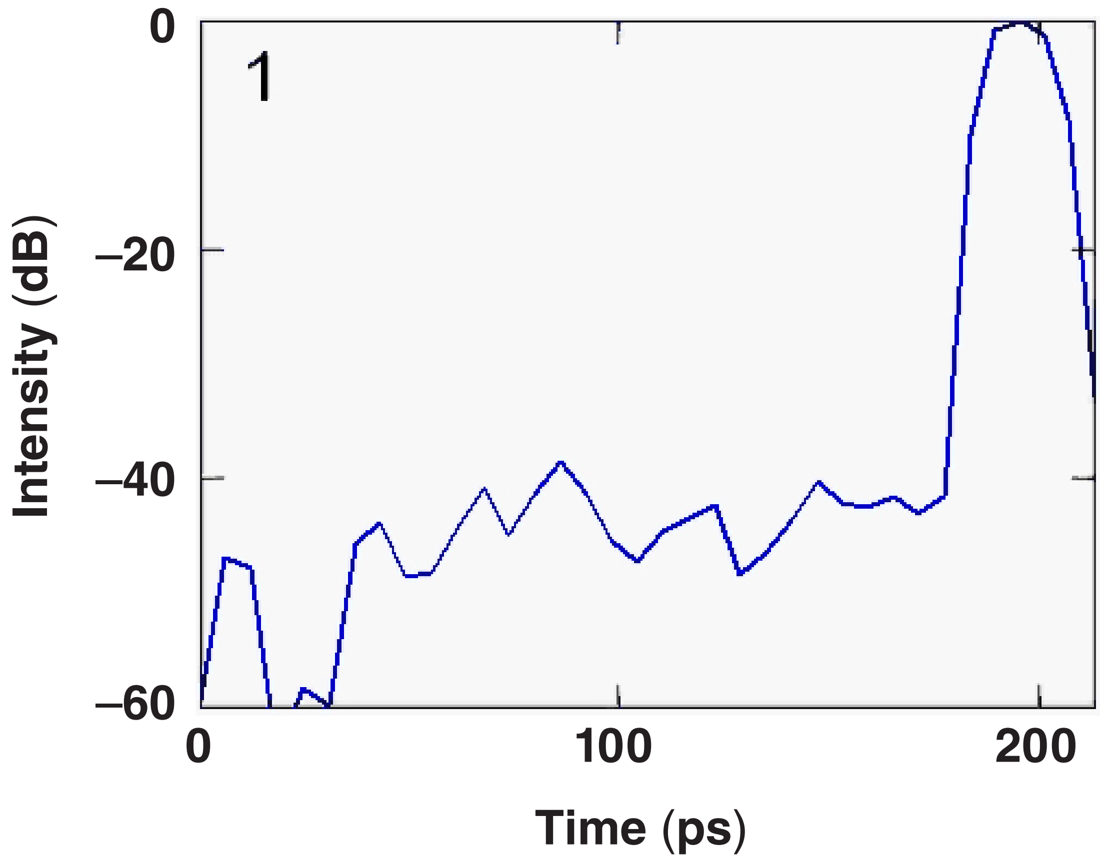

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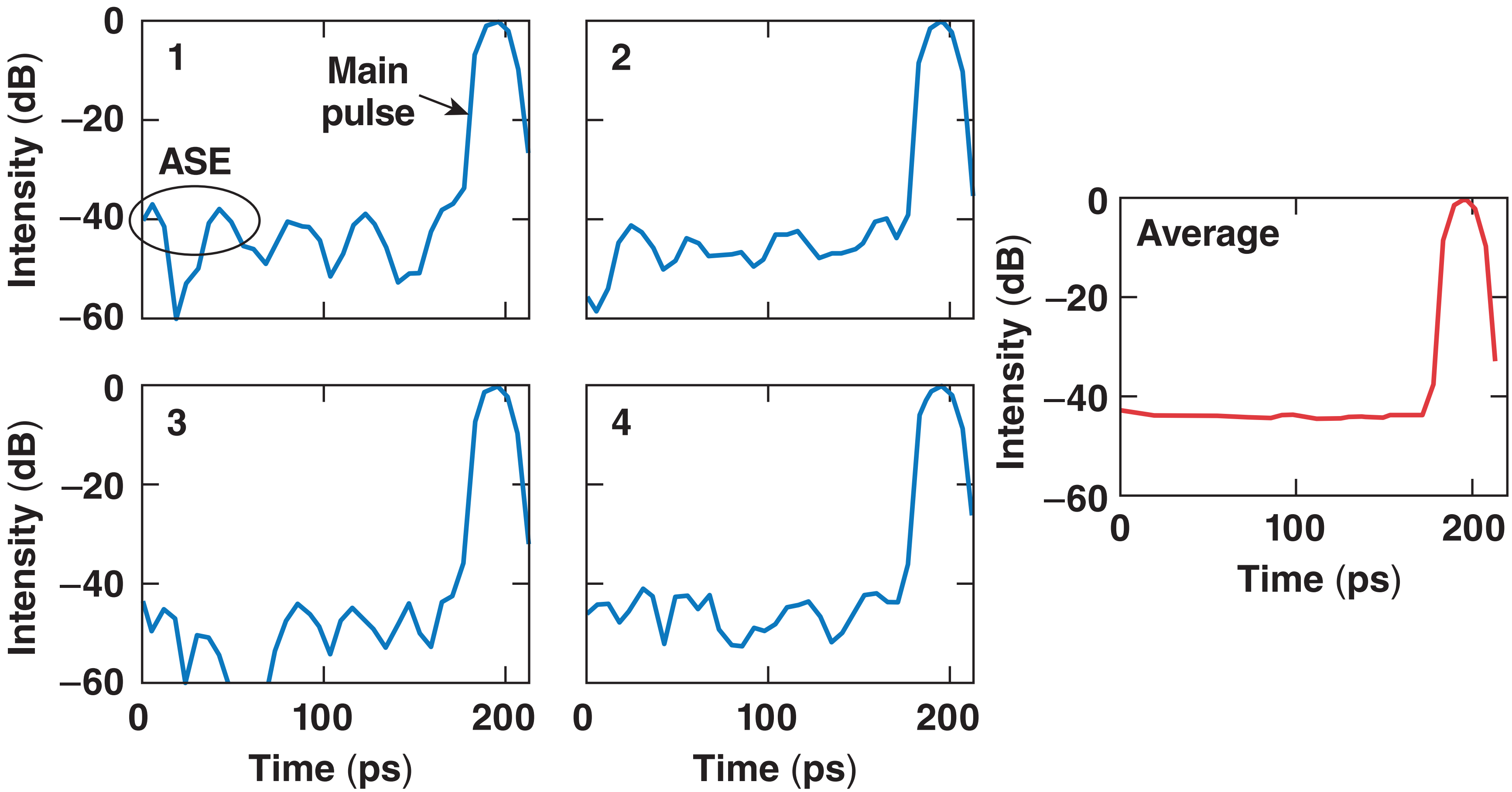
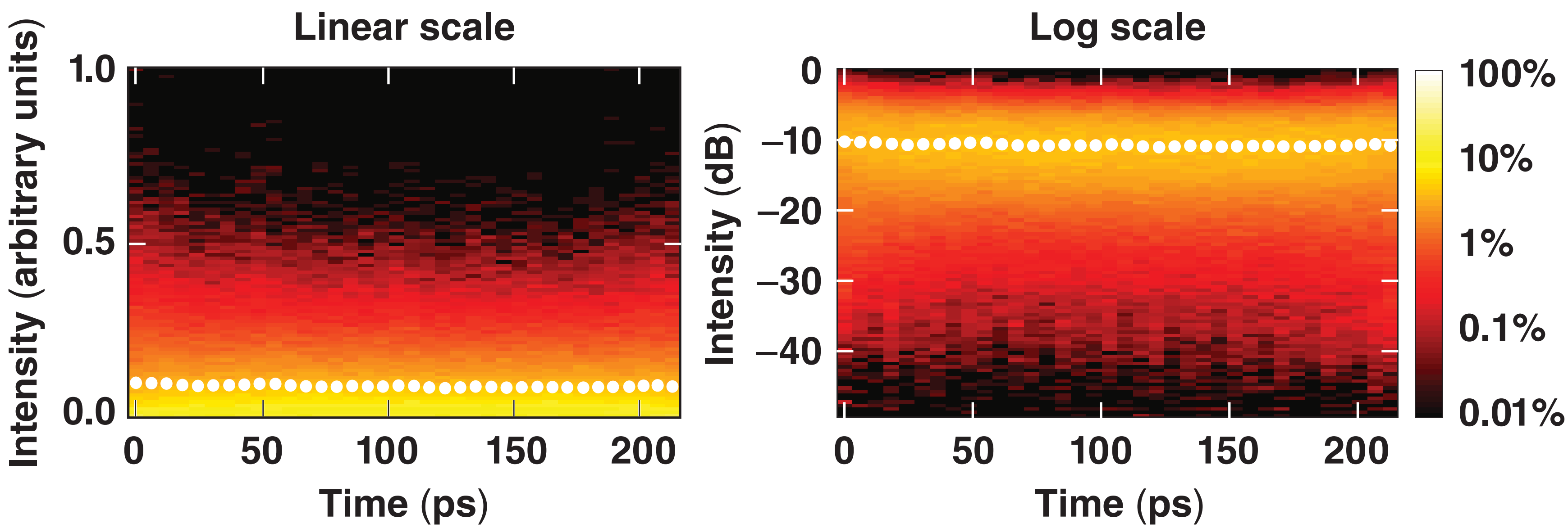
We demonstrate a single-shot cross-correlator with a 60 dB dynamic range



Single-shot measurements reveal the significant prepulse intensity fluctuations due to ASE.

E16627

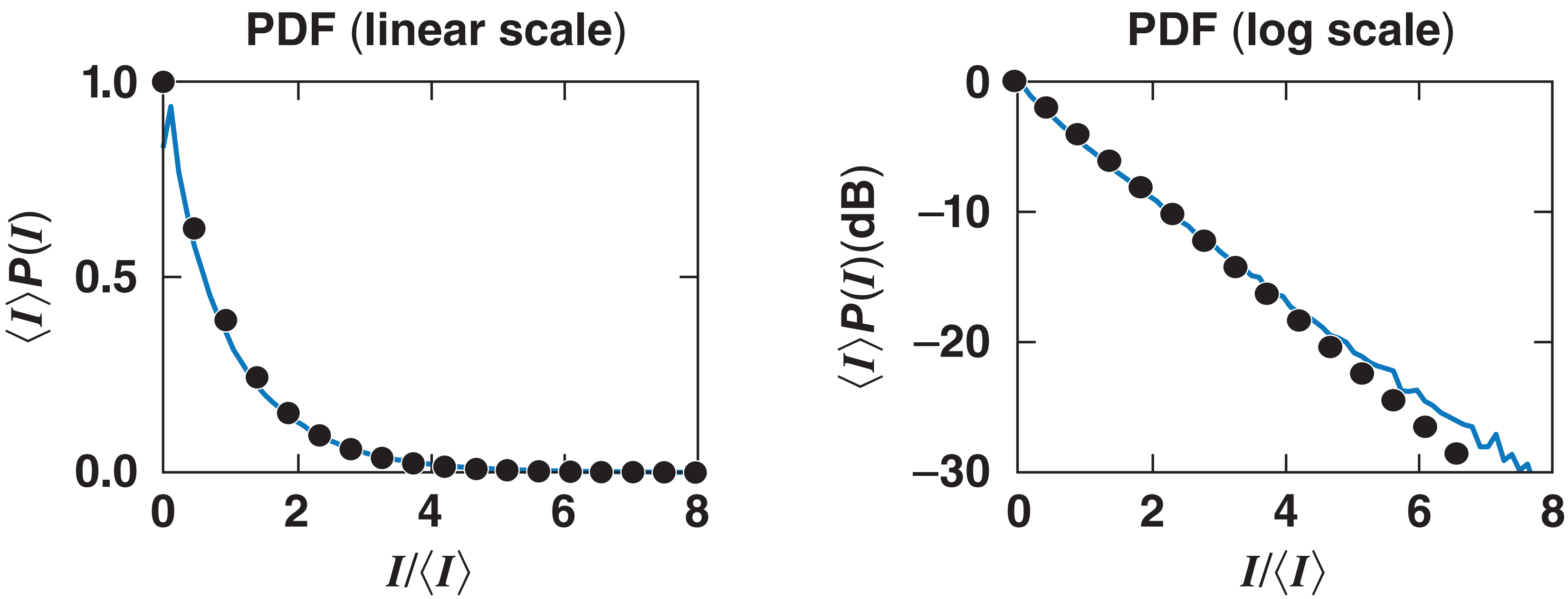
Statistical properties of the fluorescence can be obtained using the single-shot cross-correlator



- 10,000 single-shot measurements of the prepulse ASE intensity have been obtained by moving the sampling window ahead of the pulse under test.
- Statistical properties of the fluorescence must be understood to quantify its effect on the temporal contrast.

E16628

The probability density function of the measured ASE intensity agrees with theoretical predictions



- The probability density function (PDF) of the intensity of an incoherent process is*

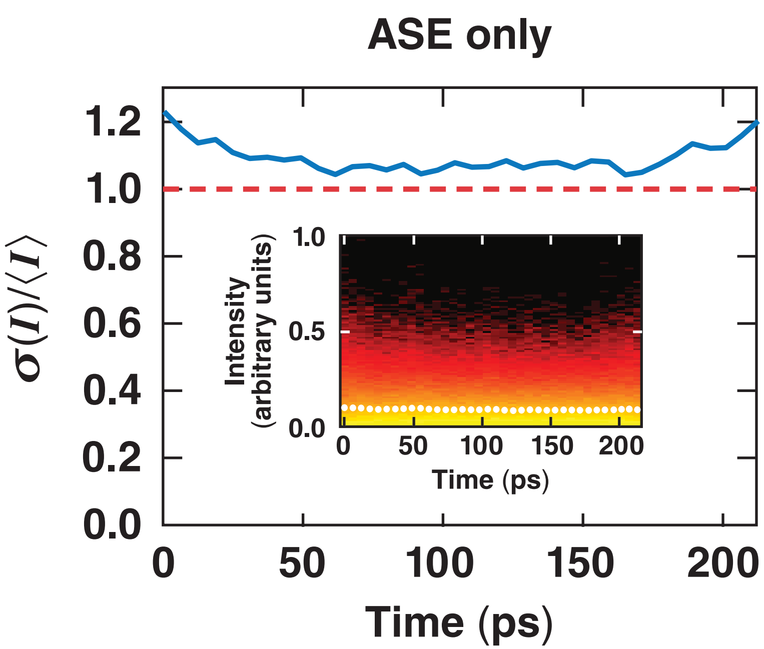
$$P(I) = \frac{1}{\langle I \rangle} \exp\left(-\frac{I}{\langle I \rangle}\right)$$

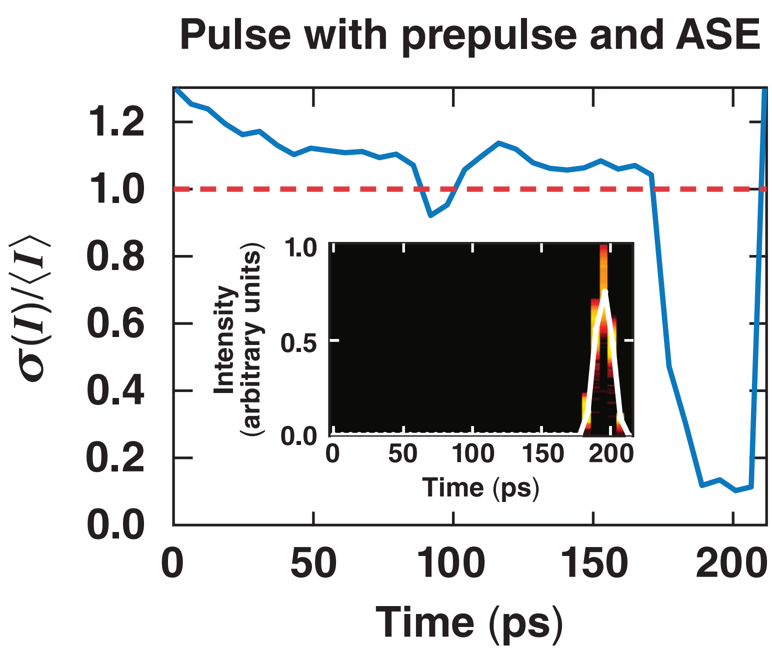
- The agreement of the measured PDF with the theoretical PDF is very good.

E16629

*Mandel and Wolf, Optical Coherence and Quantum Optics.

The coherence of light at different times can be statistically evaluated





Normalized standard deviation

$$\sigma_N(I) = \sigma(I)/\langle I \rangle$$

$\sigma_N(I) = 1$ for an incoherent process (e.g., ASE)

$\sigma_N(I) = 0$ for a coherent process (e.g., laser pulse)

E16630