The Ultrafast Temporal Diagnostic Upgrade Will Provide Improved On-Target, Short-Pulse Shape Predictions on OMEGA EP

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University of Rochester, Laboratory for Laser Energetics

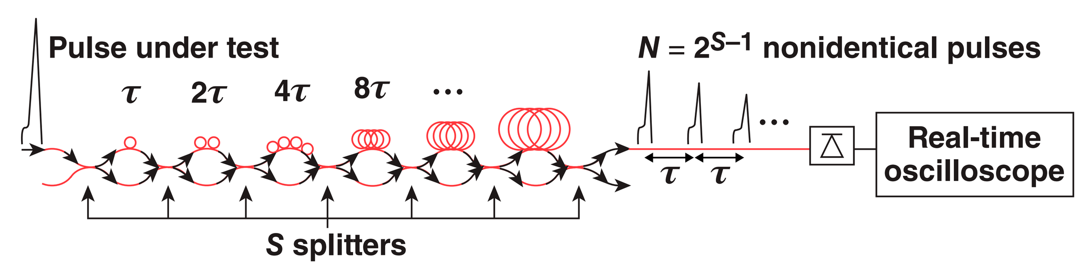
Summary

A single-shot temporal diagnostic for picosecond pulses based on spectral phase diversity is demonstrated

- The single-shot characterization of picosecond optical pulses is difficult with
  - femtosecond pulse-characterization techniques
  - high-bandwidth photodetection
- Spectral phase diversity enhances the photodetection performance by
  - generating and detecting optical pulses derived from the pulse under test by adding known amounts of chromatic dispersion
  - numerically processing the resulting experimental trace
- A fiber diagnostic based on spectral phase diversity has been demonstrated for single-shot characterization on the OMEGA EP chirped-pulse–amplification (CPA) laser

E24801b

An assembly composed of fibers and splitters has been used for spectral phase diversity



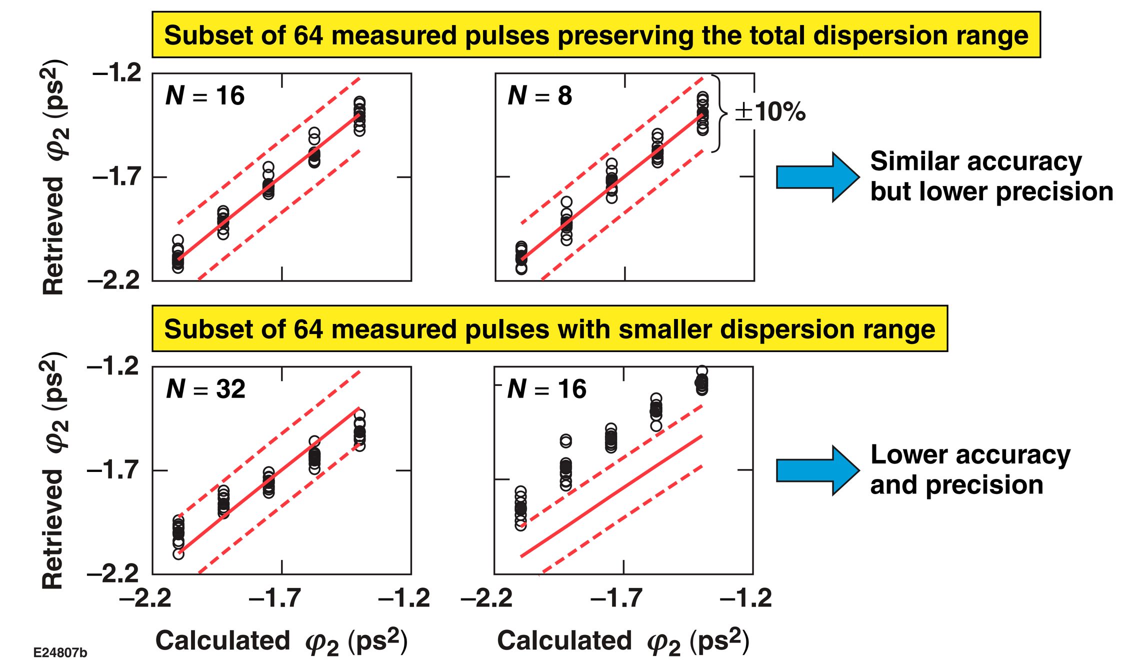
- Sequence of $S = 7$, 2 × 2 splitters connected by a short fiber and a long fiber with length $\ell \times 2^{j-1}$ generates $2^{S-1} = 64$ pulses
  - equally spaced in time (τ = 20 ns)
  - second-order dispersion $\varphi_{2,0} + (k-1)\varphi_2$ [φ_2 = 0.09 ps^2]

$$P_k(t) = \left|\int \sqrt{S(\omega)}\exp\left(i\left\{\varphi(\omega) + \left[\varphi_{2,0} + (k-1)\varphi_2\right]\omega^2/2 + \omega t\right\}\right)d\omega\right|^2$$

- Photodetection
  - DSC10 Discovery Semiconductors photodiode and Lecroy 17-ps impulse-response 45-GHz oscilloscope

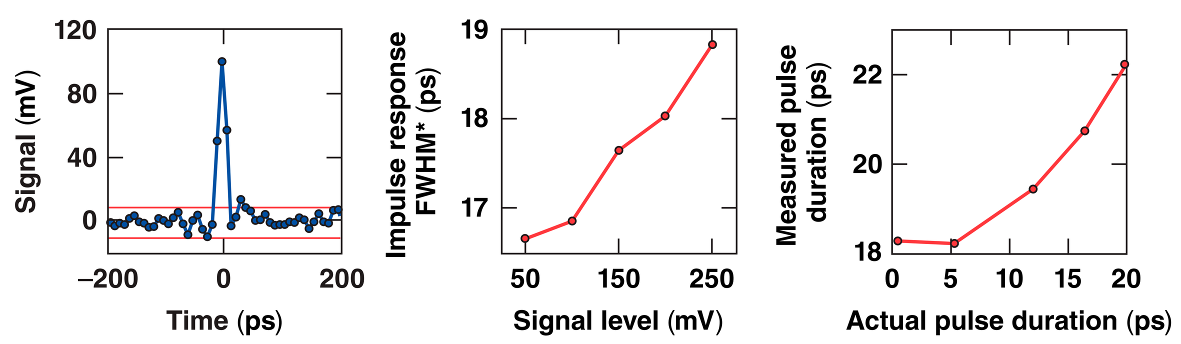
G10529d

The impact of the number of measured pulses and total dispersion range on accuracy and precision has been experimentally assessed



E24807b

State-of-the-art photodiodes and real-time oscilloscopes have insufficient bandwidth to measure sub-20-ps pulses



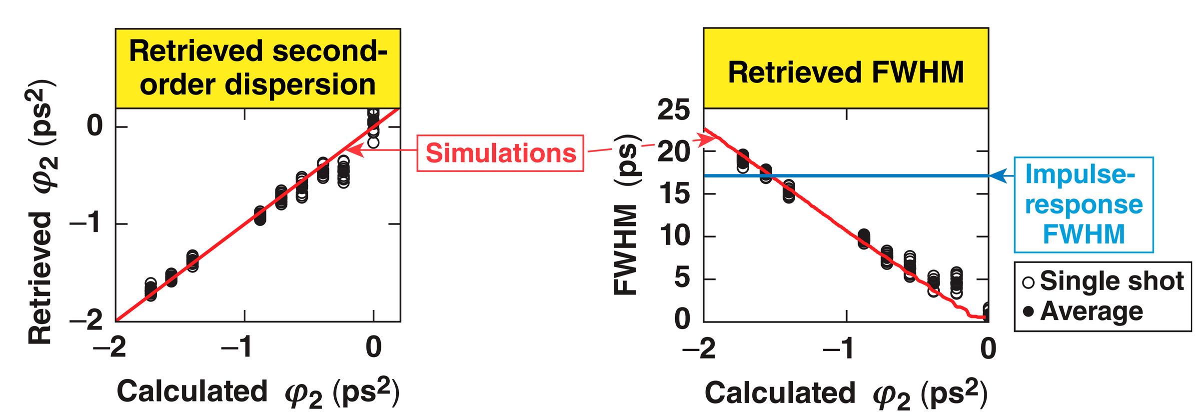
- Insufficient bandwidth and sampling rate; e.g., 18-ps impulse response and sampling at 120 GS/s (every 8.25 ps) from a 50-GHz photodiode and 45-GHz oscilloscope
- Photodiode nonlinearity
- Measured pulse duration only slightly impacted by actual pulse duration for pulses shorter than the photodetection impulse response

We have developed a spectral phase-diversity technique to enhance the photodetection resolution.

G10528d

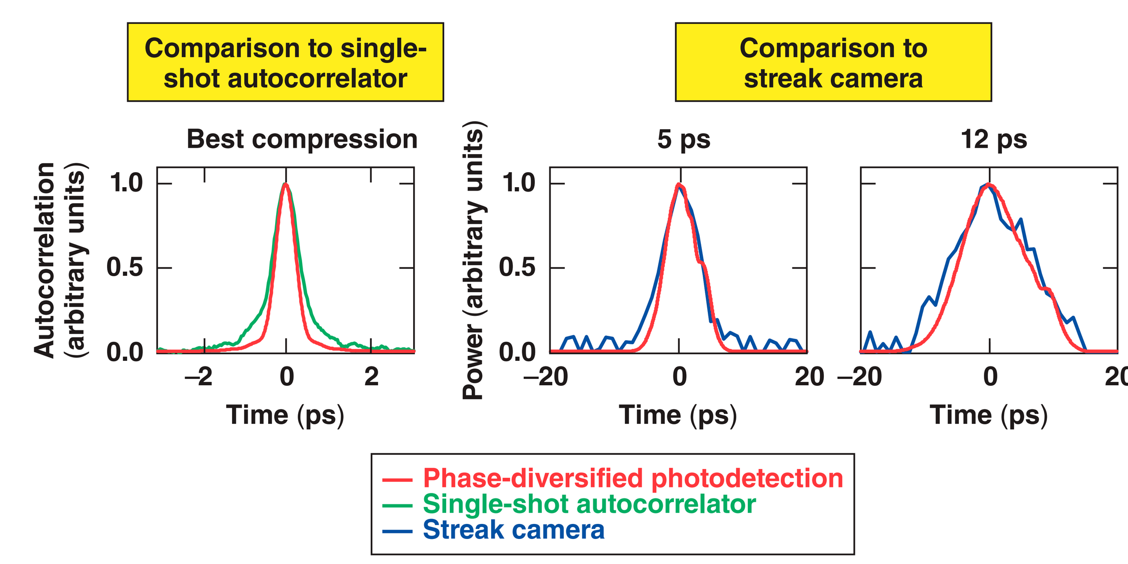
*Full width at half maximum

Spectral phase diversity accurately measures the pulse duration when tuning the CPA stretcher



G10688e

The spectral phase diversity is in good agreement with diagnostics already deployed on OMEGA EP



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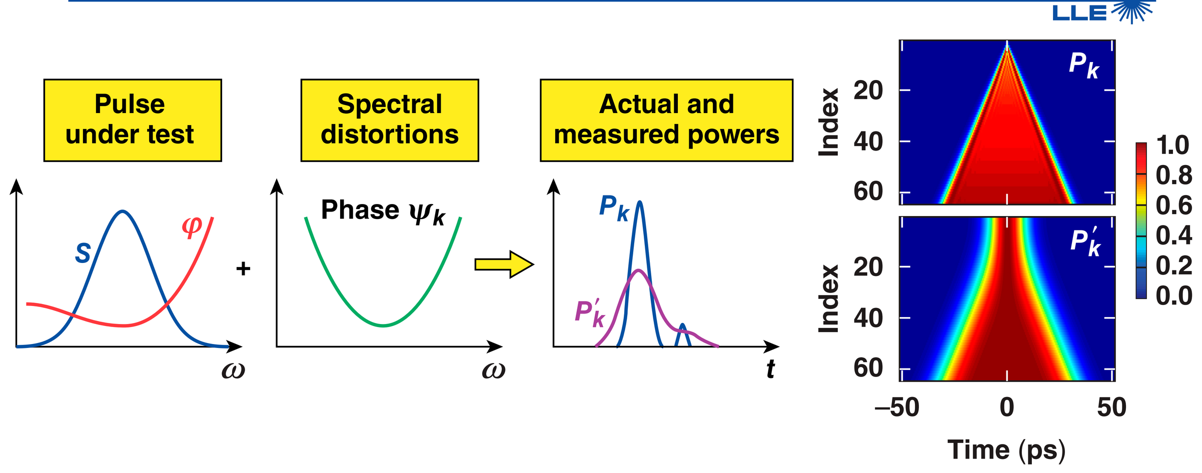
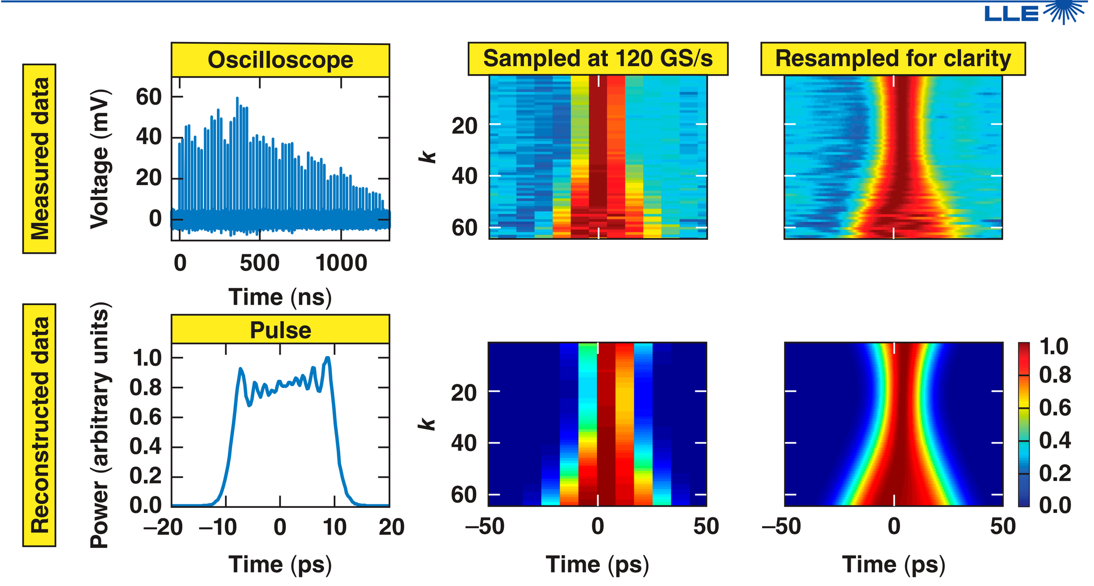
Spectral phase diversity enhances the photodetection performance by using multiple measurements after known spectral distortions



- Known spectral phases ψ_k added to the pulse under test before photodetection
- Power versus time $P_k(t) = \left|\int \sqrt{S(\omega)}\exp\{i[\varphi(\omega) + \psi_k(\omega) + \omega t]\}d\omega\right|^2$
- Measured power $P'_k = P_k \otimes R$, where R is the photodetection impulse response

E24803c

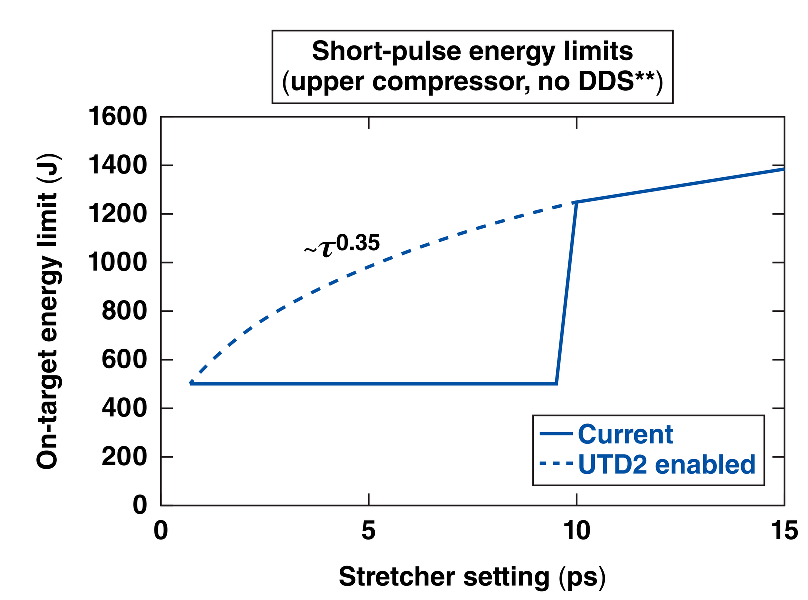
Spectral phase diversity has been used for stretcher tuning on OMEGA EP



- The main goal is to provide the on-shot pulse duration with
  - 1-ps precision over a 1- to 10-ps range
  - 10% relative precision over a 10- to 100-ps range

E24806c

UTD2* will enable increased target energy for pulses between best compression and 10 ps



- Current inability to measure pulses <10 ps causes us to impose the best-compression energy limit
- The ability to confirm stretcher setting to the <1-ps level will enable us to deliver higher energies between best compression and 10 ps without risking damage to optics

G11289

*UTD2: ultrafast temporal diagnostic upgrade
**DDS: disposable debris shield

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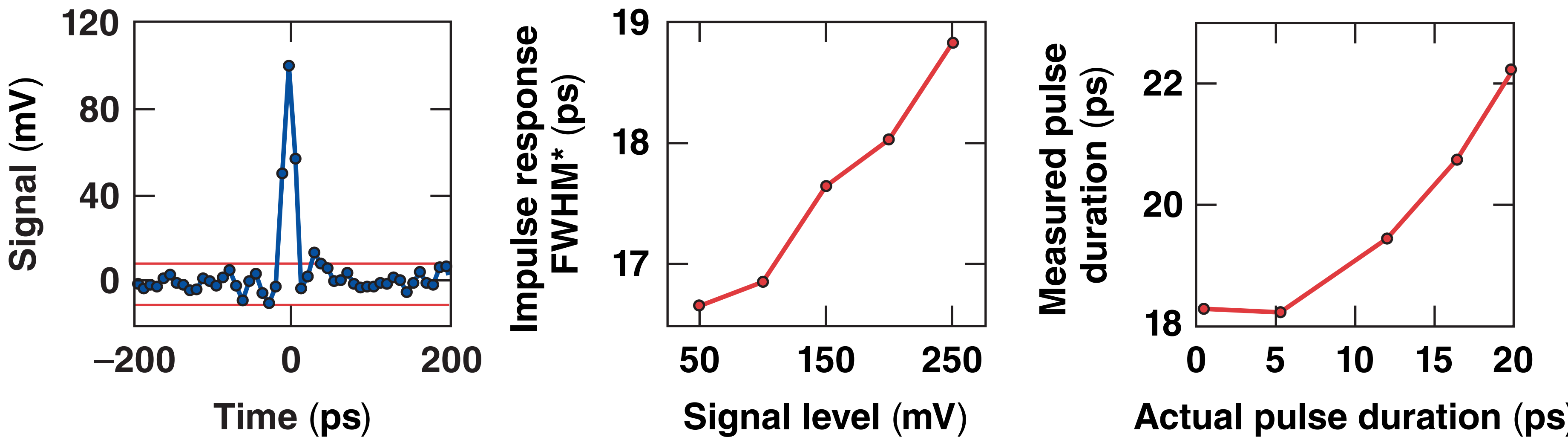

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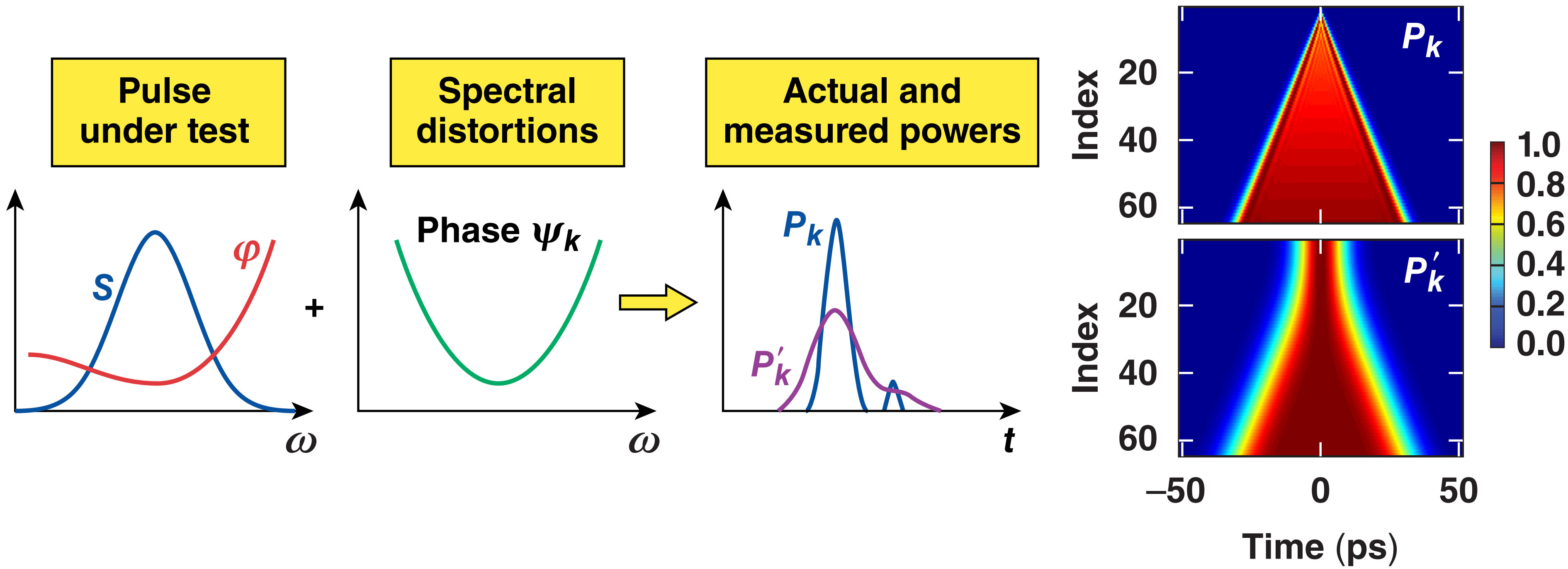

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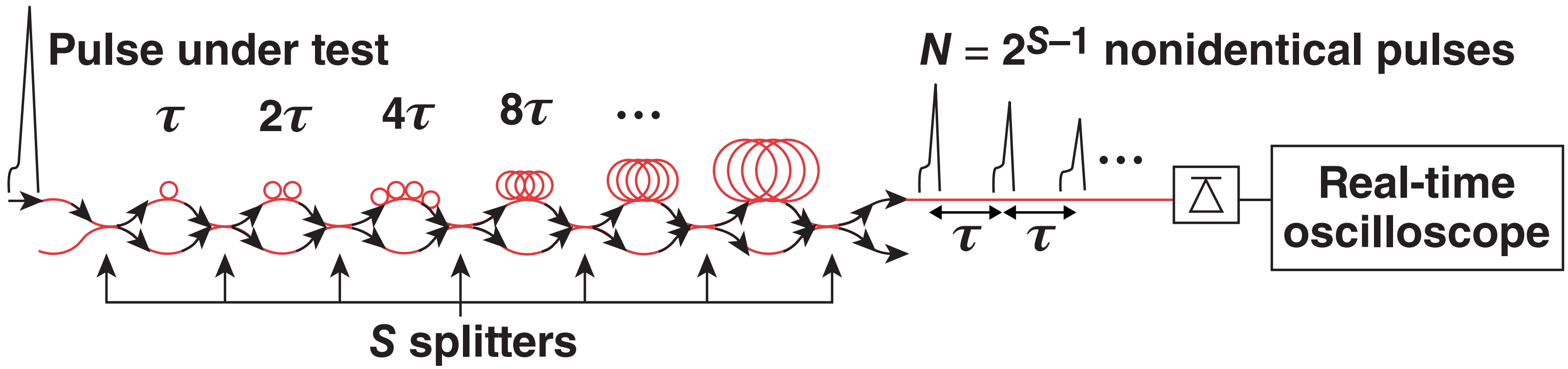

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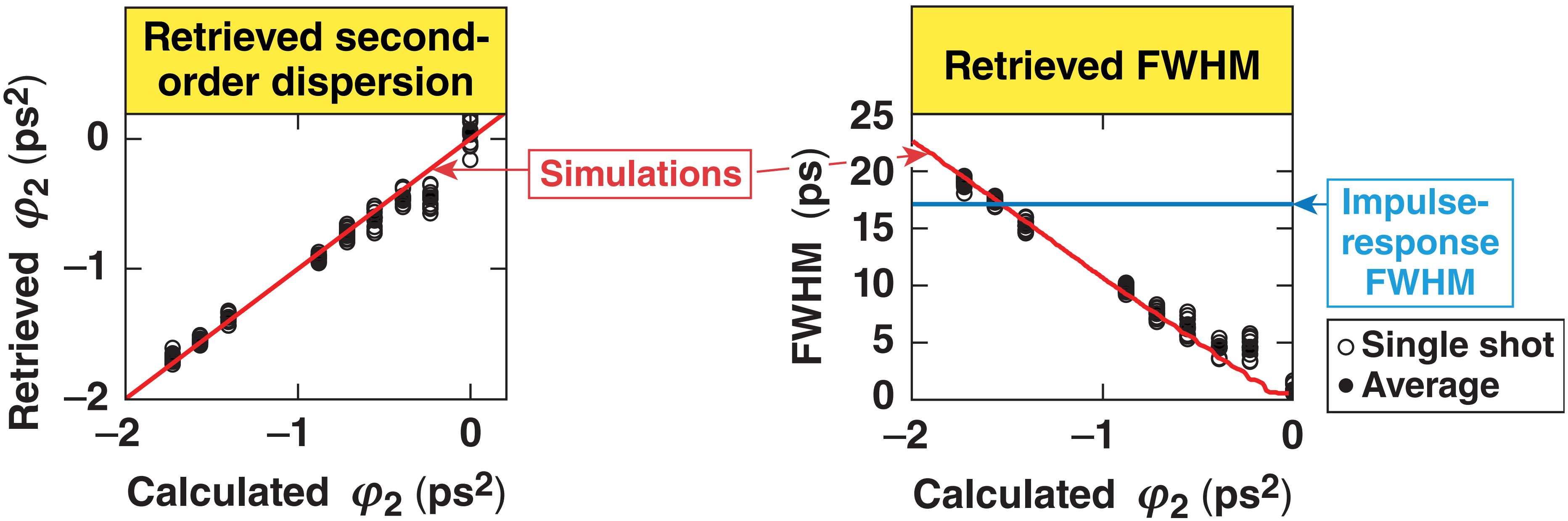

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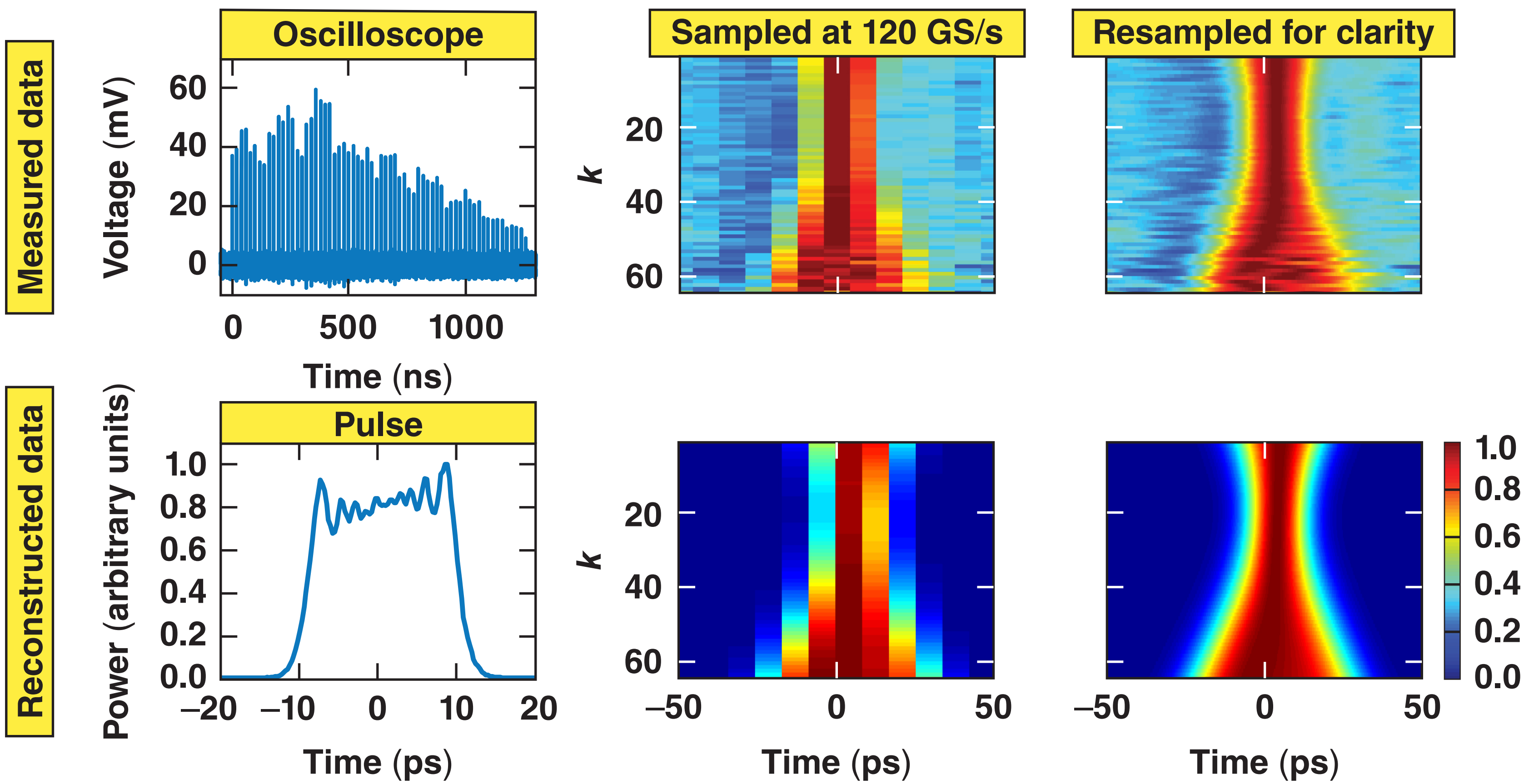

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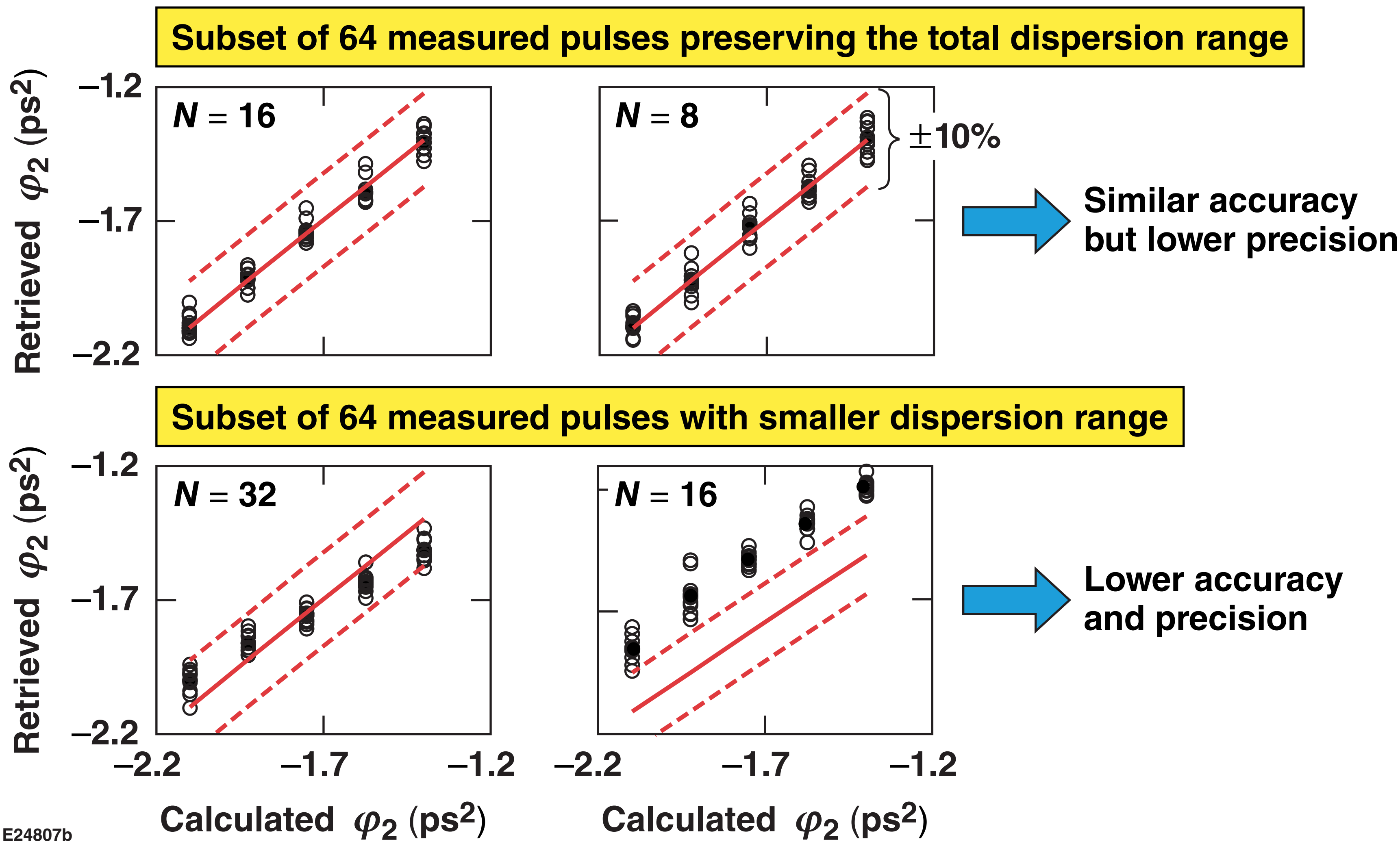

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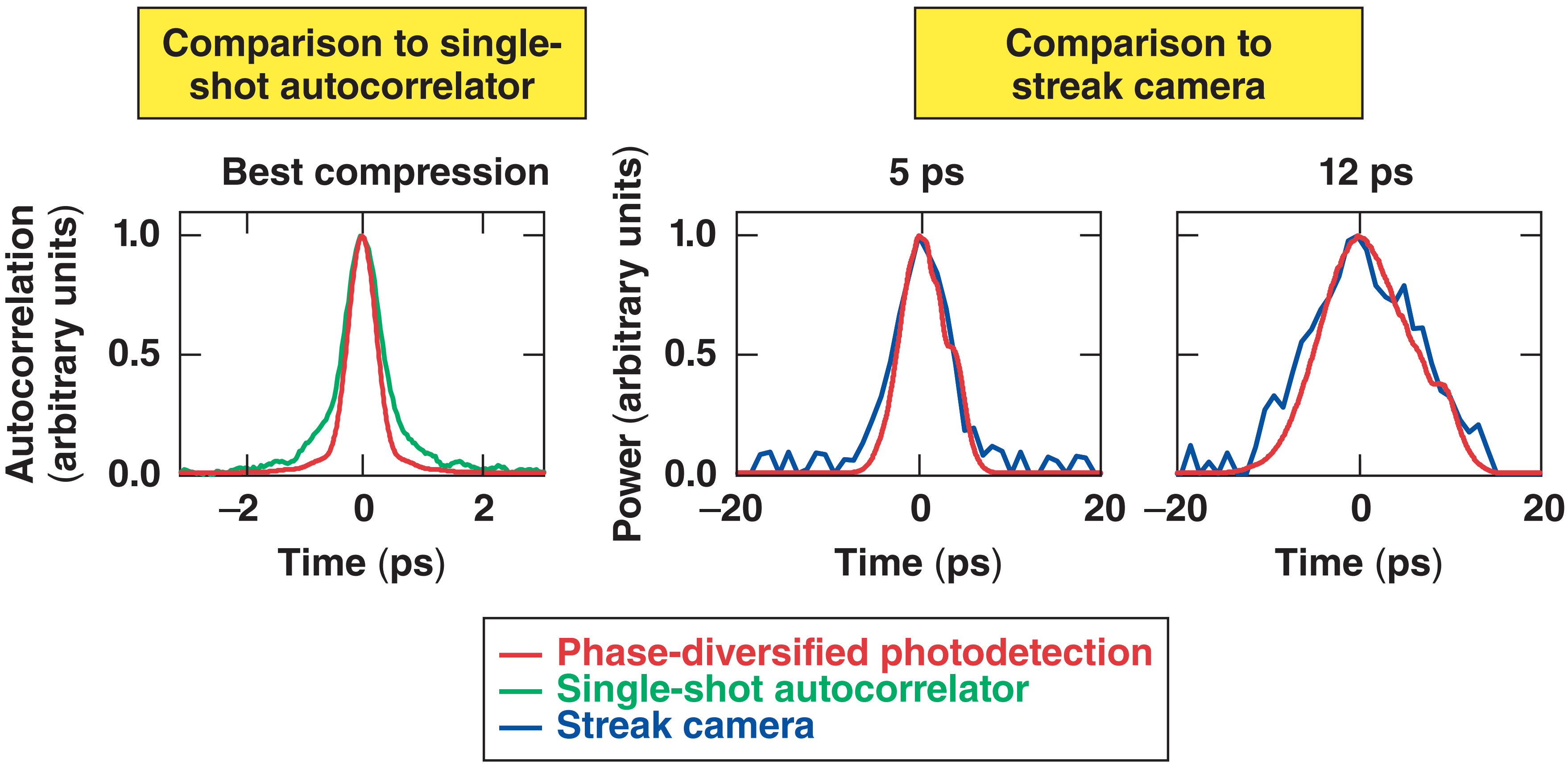

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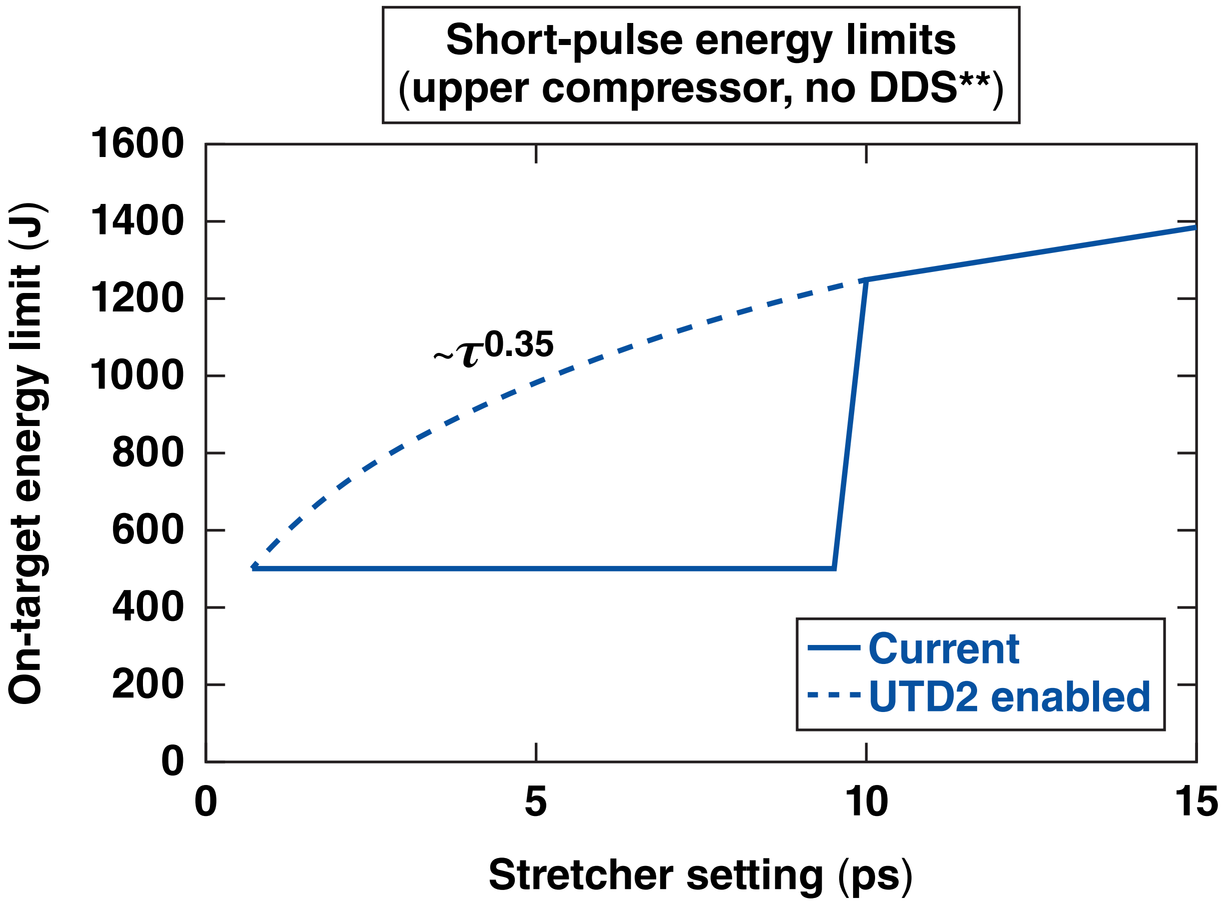

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