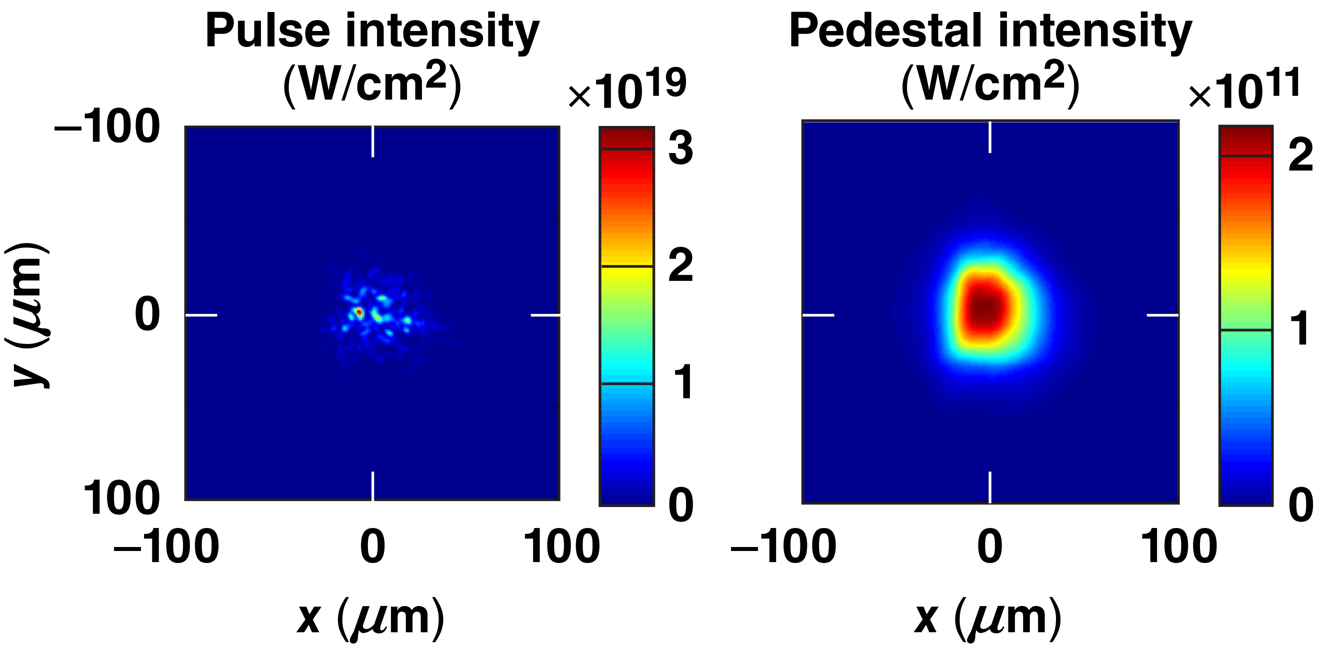
Contrast Measurements of Kilojoule Laser Pulses at the Omega EP Laser Facility



C. Dorrer, D. Irwin,
A. Consentino, and J. Qiao
University of Rochester
Laboratory for Laser Energetics

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Summary

The contrast of picosecond kilojoule optical pulses has been measured on OMEGA EP

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- OMEGA EP can produce two co-timed picosecond optical pulses on target with multikilojoule energies
- The temporal contrast of these pulses can significantly alter the interaction regimes for target physics
- Temporal contrast diagnostics were deployed on OMEGA EP starting in September 2009
- The high-gain OPCPA front-end has been optimized using the contrast data

On-target intensity contrast better than 10^8 has been measured.

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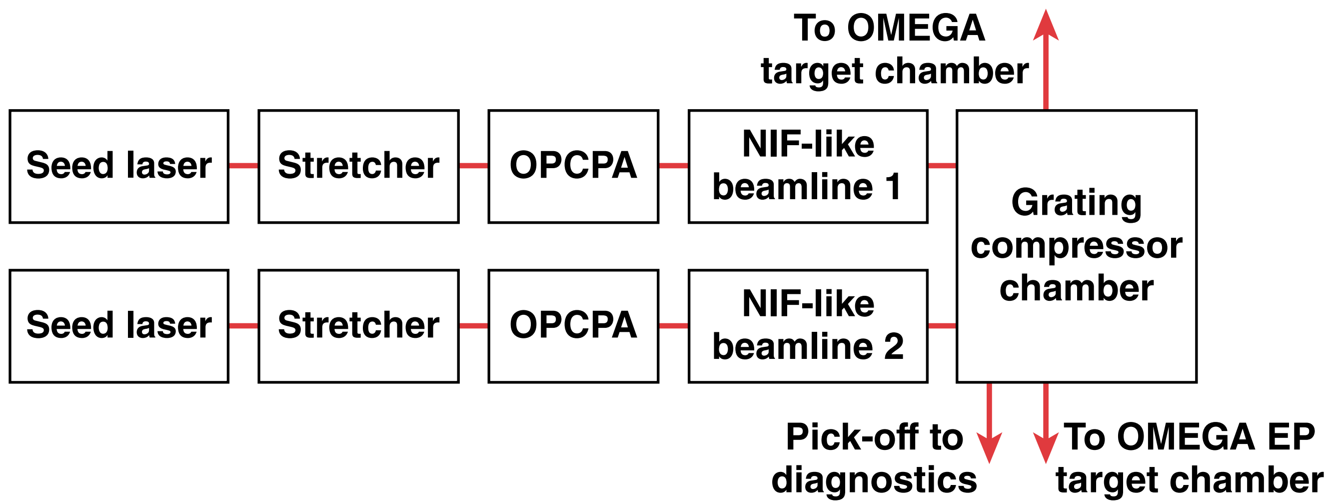
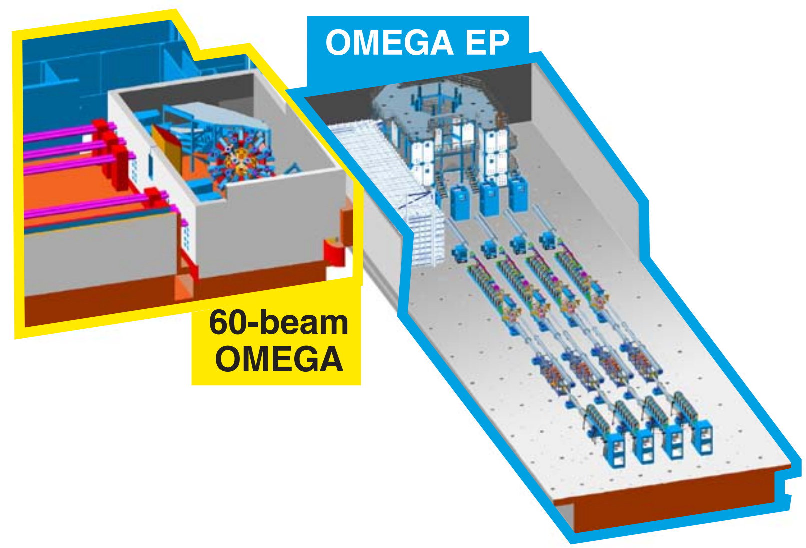
Contrast diagnostics have been deployed on OMEGA EP to characterize the two short-pulse systems



- On-target pulse energy: up to 2.1 kJ
- Contrast diagnostics developed to
  - characterize the laser systems
  - provide data to experimental users
  - support contrast improvement campaigns



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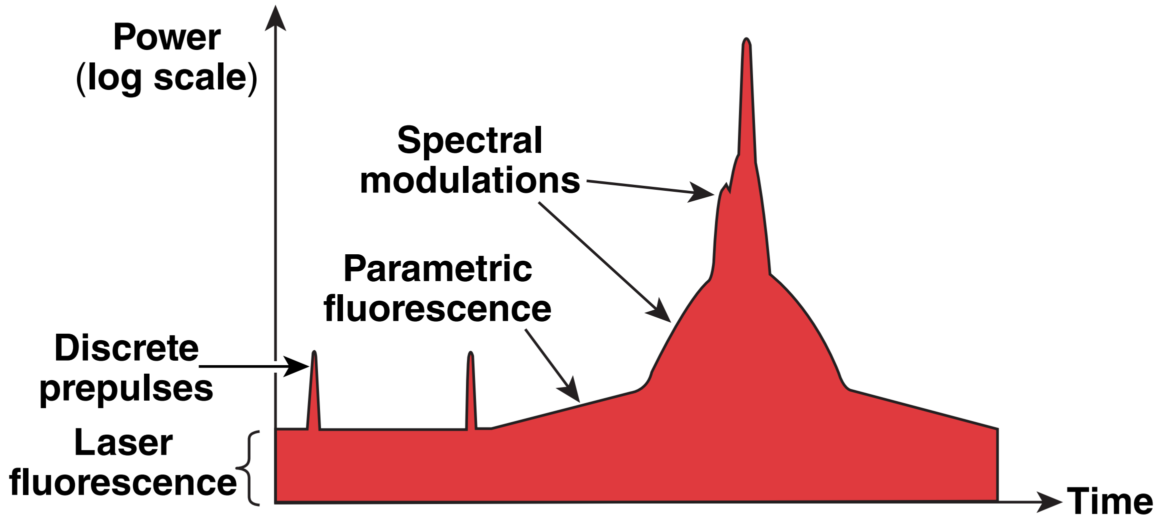
The temporal contrast of a short optical pulse can impact its interaction with a target



- The entire laser system architecture has a strong impact on the temporal contrast
  - incoherent contributions to signal (from OPCPA/laser amplifiers) and to OPCPA pump
  - coherent contributions from laser architecture, seed laser, stretcher/compressor

On-shot temporal-contrast measurements are crucial for understanding laser–target interaction.

Several diagnostics are used to measure the OMEGA EP temporal contrast

- Two operational diagnostics will be discussed:
  - scanning cross-correlator for 5-Hz OPCPA front-end characterization (shared)
  - fast photodiodes and oscilloscope for on-shot nanosecond contrast characterization of BL1 and BL2
- On-shot cross-correlator for contrast measurement in the 500-ps window before the main pulse is under development

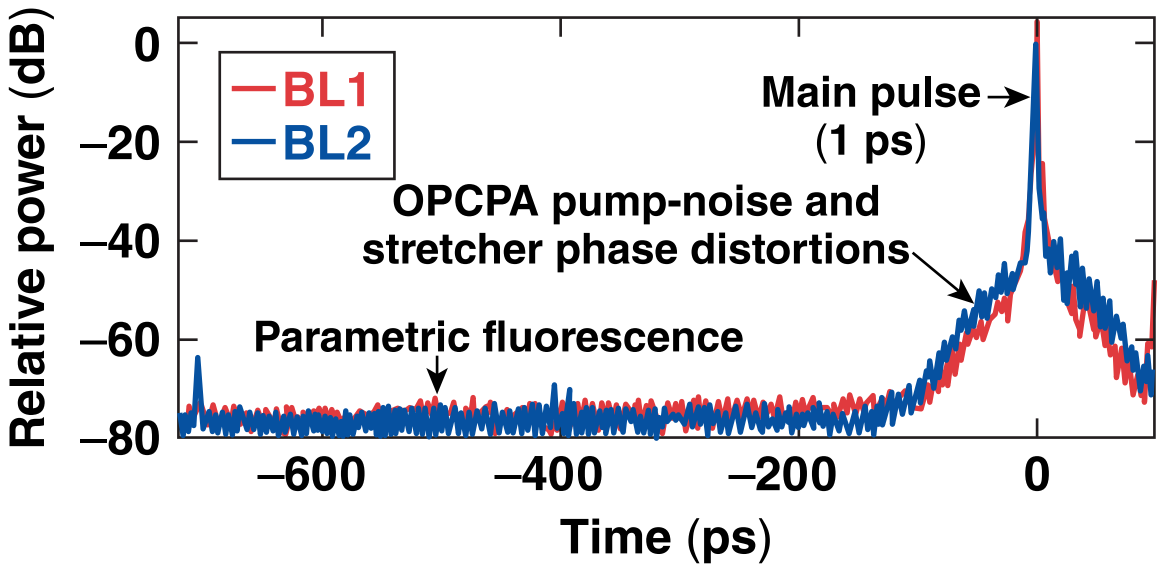
The contrast performance of a laser system can be described in a variety of ways

- **On-target intensity distribution:** $I(x, y, t) = I_{pulse}(x, y, t) + I_{pedestal}(x, y, t)$
- **Instantaneous power:** $P(t) = \iint dxdy I(x, y, t) = P_{pulse}(t) + P_{pedestal}(t)$

Energy Contrast	Power Contrast	Intensity Contrast
$\frac{E_{pulse}}{E_{pedestal}}$	$\frac{\max\left[P_{pulse}(t)\right]}{\max\left[P_{pedestal}(t)\right]}$	$\frac{\max\left[I_{pulse}(x,y,t)\right]}{\max\left[I_{pedestal}(x,y,t)\right]}$

Measuring $I_{pedestal}(x,y,t)$ on-target is the ultimate goal.

The OMEGA EP front-ends can be fully characterized after the main compressors



- Nonlinear cross-correlation of the 5-Hz front-end pulse measured at the output of OMEGA EP (Sequoia, Amplitude Technologies)
- BL1 and BL2 have similar contrast after BL1 preamplifier configuration change (July 2010)
- Identified features (relative to 1-ps main pulse)
  - parametric fluorescence: ~ –80 dB, a few nanoseconds
  - pedestal starting ~100 ps before the main pulse
  - no significant discrete prepulse

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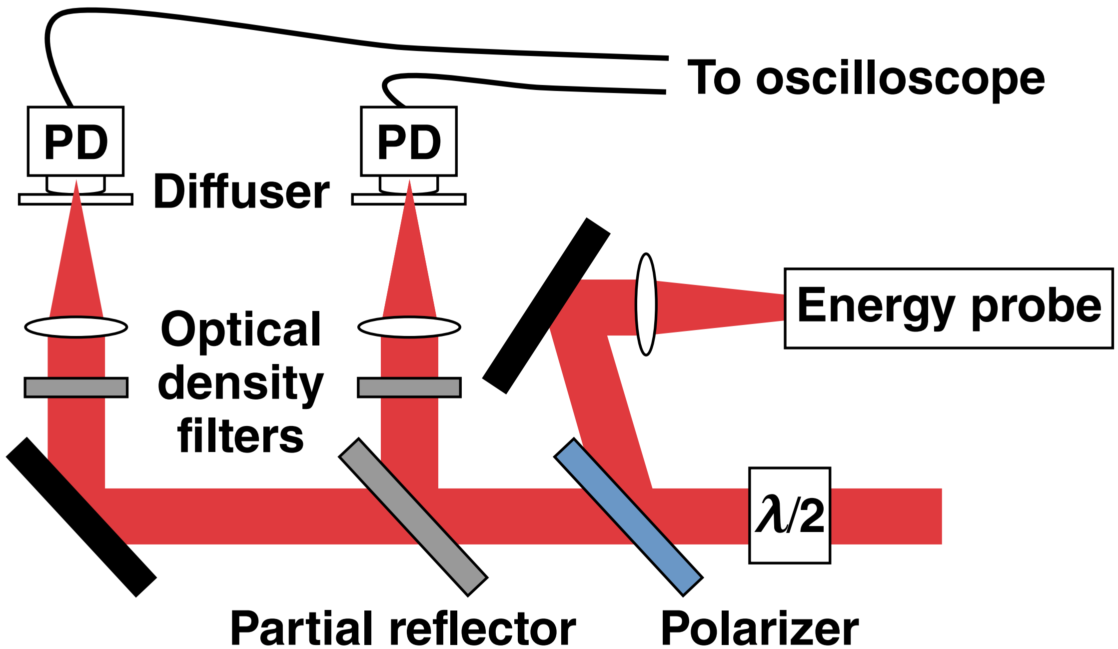
The on-shot OMEGA EP nanosecond contrast is measured with calibrated fast photodetection



- Consistent contrast measurements obtained using precalibration and knowledge of on-shot filtration and reference energy
- Two simultaneous measurements per beamline
- Diagnostic performance:
  - temporal resolution: ~200 ps
  - dynamic range: 90 dB
  - temporal range: >1 μs

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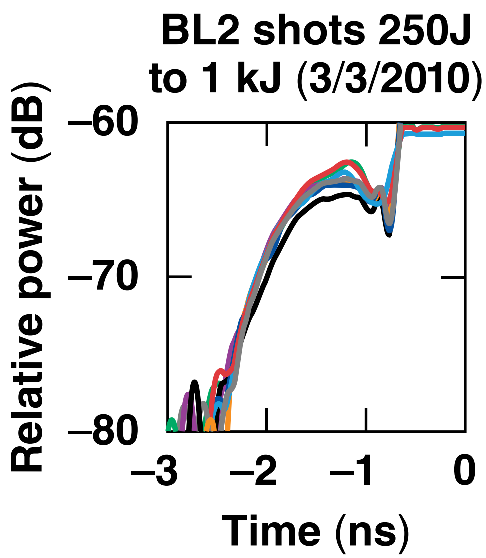
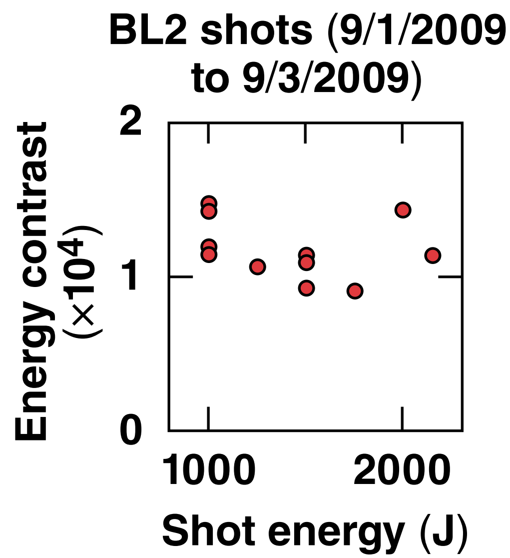
The OMEGA EP contrast does not depend significantly on the amplified pulse energy





BL2 contrast statistics (March 2010)

Power Contrast (10-ps pulse)	63.6±0.6 dB
Energy Contrast	43.8±0.4 dB

- The nanosecond temporal contrast does not depend significantly on the recompressed pulse energy up to 2.2 kJ
  - contrast dominated by OPCPA front-end fluorescence
  - large-scale Nd:glass amplifiers operated at constant gain far from saturation

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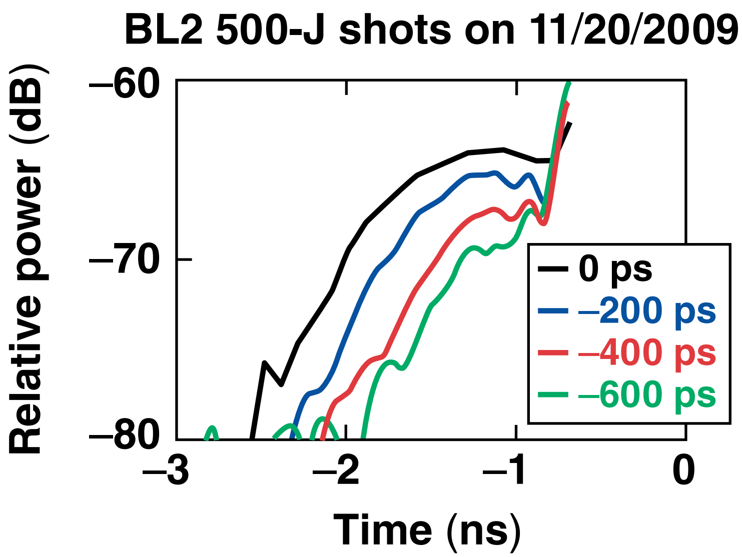
Delaying the OPCPA pump relative to the signal reduces the incoherent pedestal



	BL2 (March 2010)	BL2 (August 2010)
Relative shift (ps)	0	275
Energy contrast (dB)	43.8	48.5

- Signal-pump relative timing in OPCPA amplifiers can be adjusted to reduce the incoherent pedestal in front of the main pulse
  - avoids pumping the unseeded OPCPA (poor pump-signal temporal overlap)
  - delays the leading edge of the parametric fluorescence relative to compressed pulse

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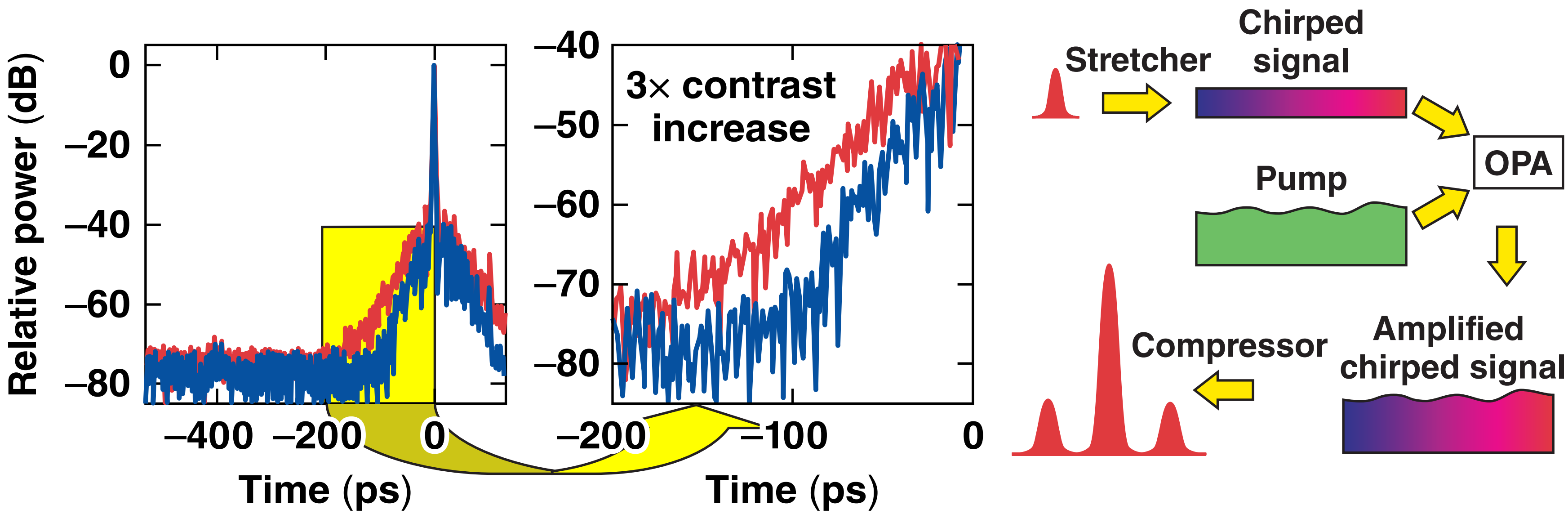
The BL2 contrast was improved in the 100-ps window before the main pulse by tuning the pump seed wavelength



- Wavelength tuning of the OPCPA seed-pulse laser
  - better match with the pump amplifier wavelength
  - lower noise on the pump pulse
  - decreased high-frequency spectral modulations on the amplified signal
- A 3× improvement in this temporal range translates to on-shot pedestal energy reduced from 2 J to 0.6 J for a 1-kJ shot

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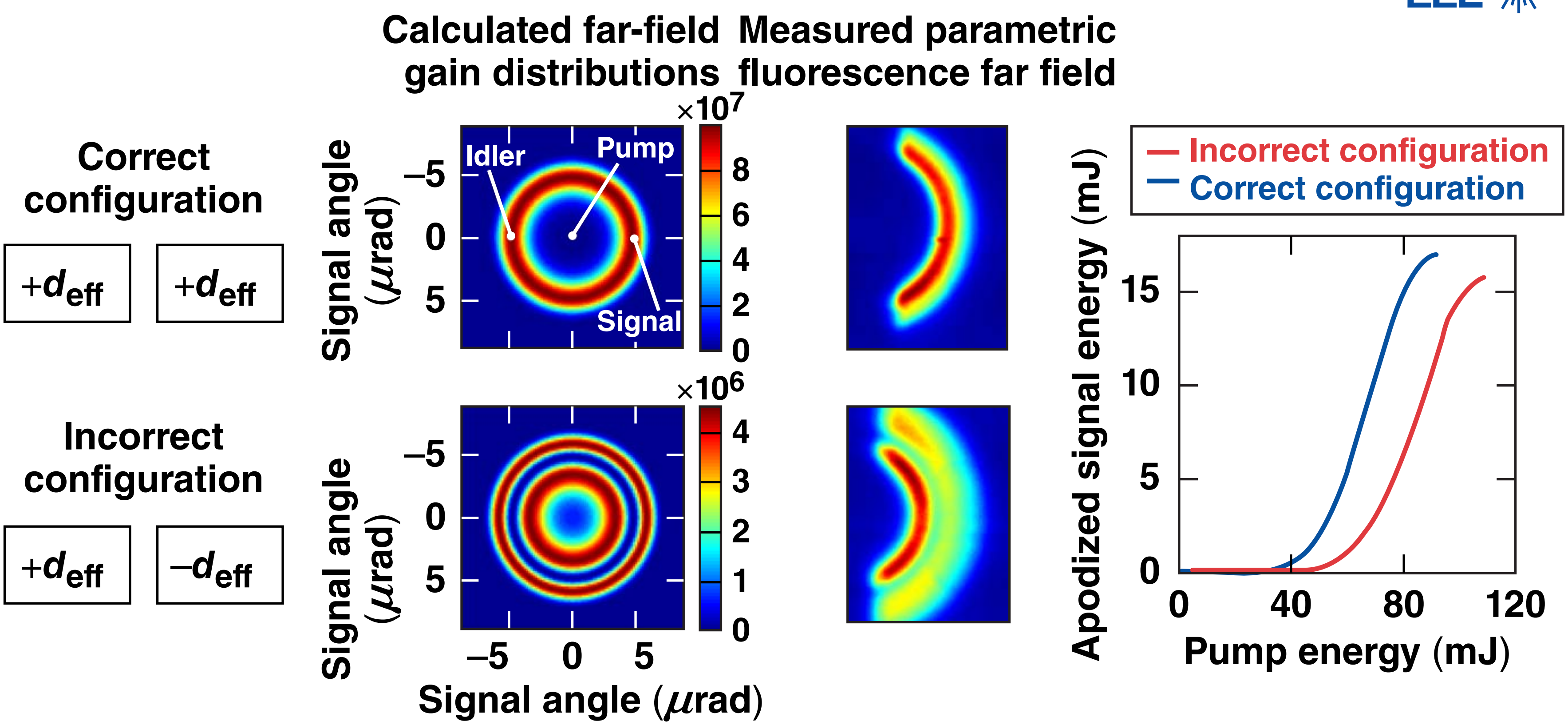
The two-crystal OPCPA preamplifier must be correctly configured for optimal performance



- Incorrect OPCPA preamplifier two-crystal configuration (nonlinearity inversion or dephasing between the crystals) leads to poor performance
  - diagnosed using unseeded OPCPA far field and preamplifier performance
  - traced back to inconsistent nonlinear crystal cut and/or AR-coating
  - solved using pair of matched crystals

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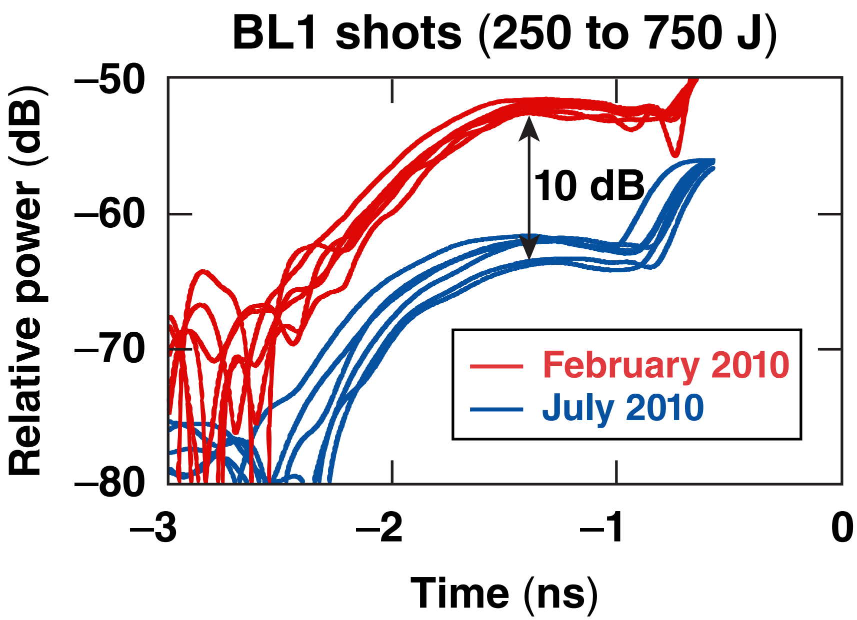
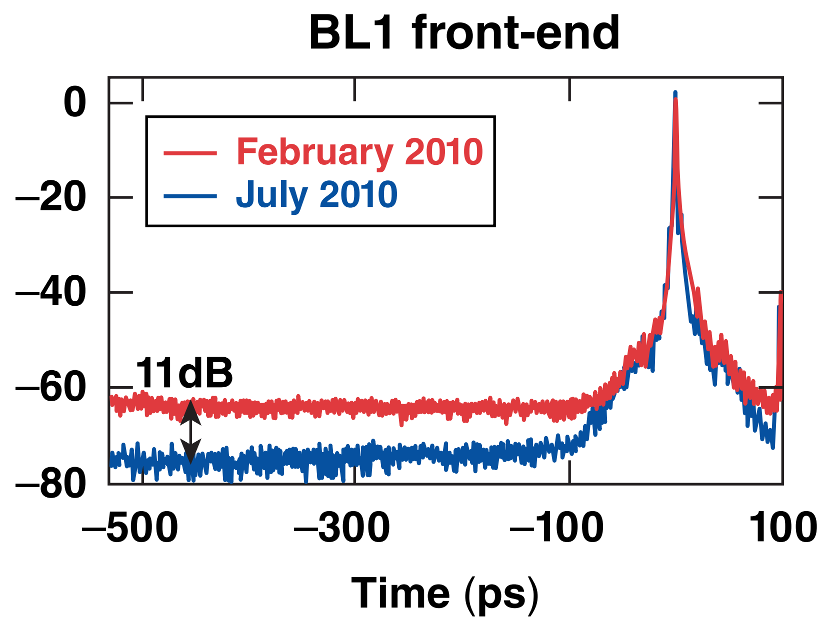
Correcting the BL1 preamplifier crystal configuration improved the contrast by more than one decade





- Preamplifier set in optimal configuration
- Power/energy contrast improved by more than 10 dB confirmed by scanning cross-correlator and on-shot diode measurements

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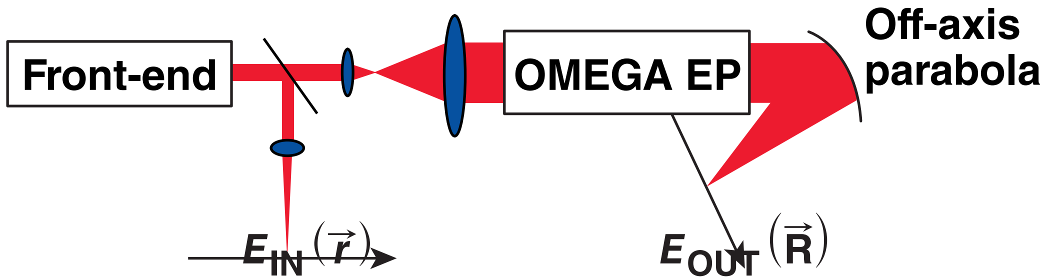
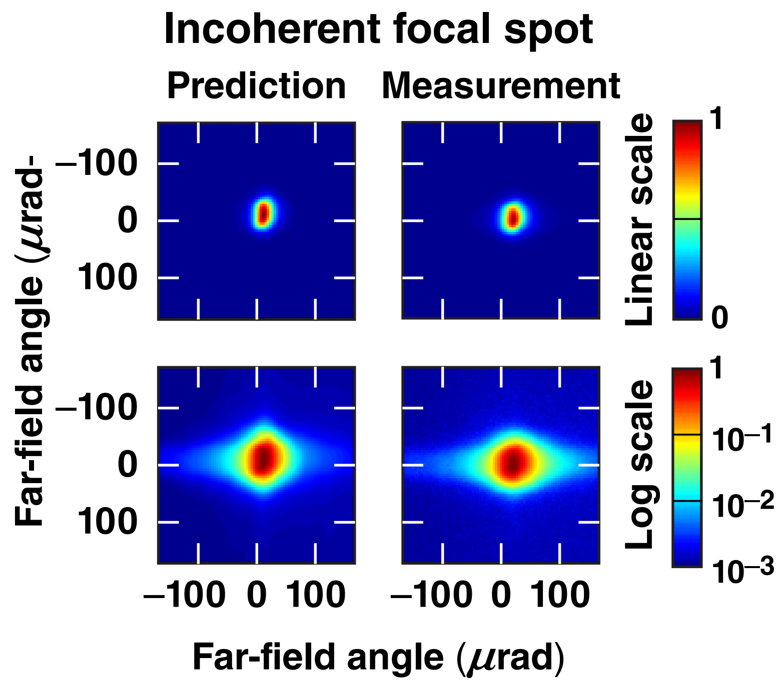
The incoherent focal spot can be predicted using the coherent focal spot





- Linear system $E_{OUT}(\vec{R}) = \int d\vec{r}\, E_{IN}(\vec{r})\, K(\vec{R},\vec{r})$

- Space-invariant system
  - Coherent pulse $I_{IN}\delta(\vec{r})$: $I_{OUT}(\vec{R}) = I_{IN}\left|K(\vec{R},\vec{0})\right|^2$
  - Incoherent pedestal: $I_{OUT}(\vec{R}) = \int d\vec{r} I_{IN}(\vec{r})\left|K(\vec{R}-\vec{r},\vec{0})\right|^2$

$$I_{OUT}^{INCOHERENT}(\vec{R}) = \int d\vec{r} I_{IN}^{INCOHERENT}(\vec{r}) I_{OUT}^{COHERENT}(\vec{R}-\vec{r},\vec{0})$$

On-shot focal-spot and power contrast measurements lead to the on-shot intensity contrast

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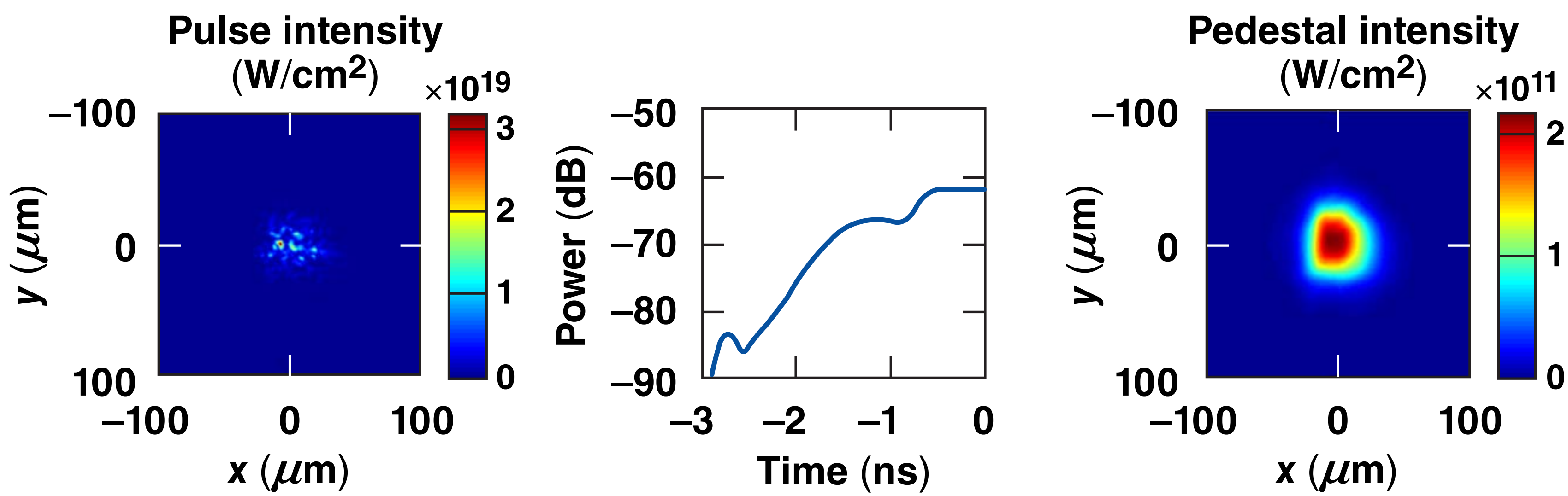

Shot 8061 Contrast data (dB)	Energy Contrast	Power Contrast	Intensity Contrast
	48.0	66.5	81.8

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