Activation of the OMEGA EP High-Energy, Short-Pulse Laser System

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Summary

The OMEGA EP short-pulse laser system has completed initial activation

- OMEGA EP is a high-energy, short-pulse addition to the 60-beam OMEGA Laser Facility
- OMEGA EP has generated 1440-J energy in a 10.5-ps pulse using a compressor containing 1.5-m tiled-grating assemblies
- We have demonstrated on-shot measurements of the on-target, short-pulse focal spots
- We have demonstrated on-shot, subpicosecond compressed pulses
- OMEGA EP has been in operation since May 2008 and is being used for target physics experiments

Collaborators

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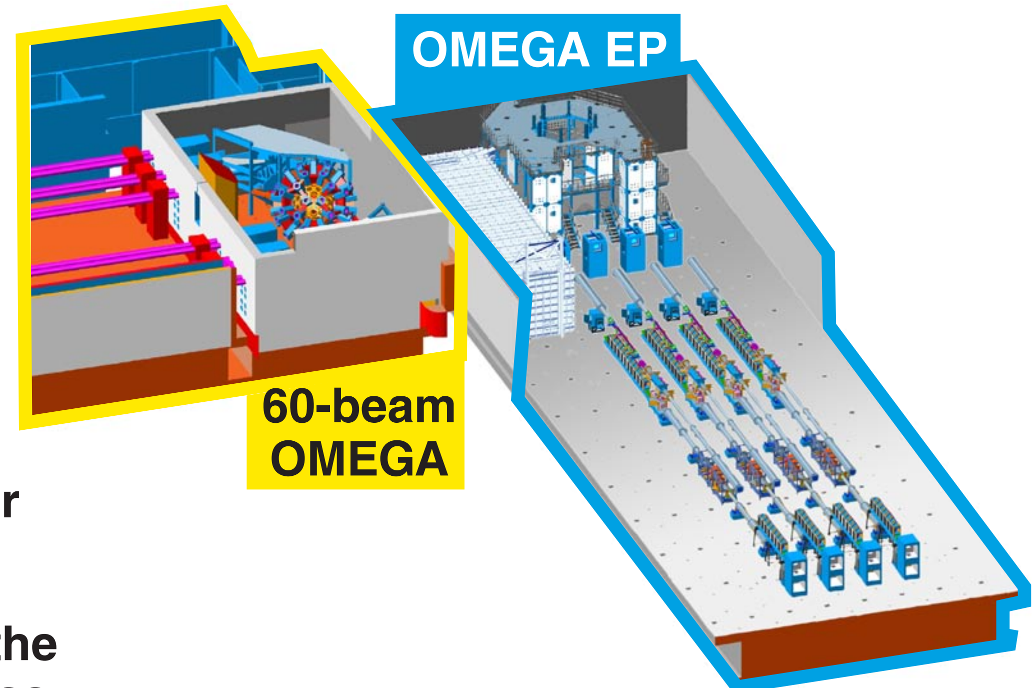
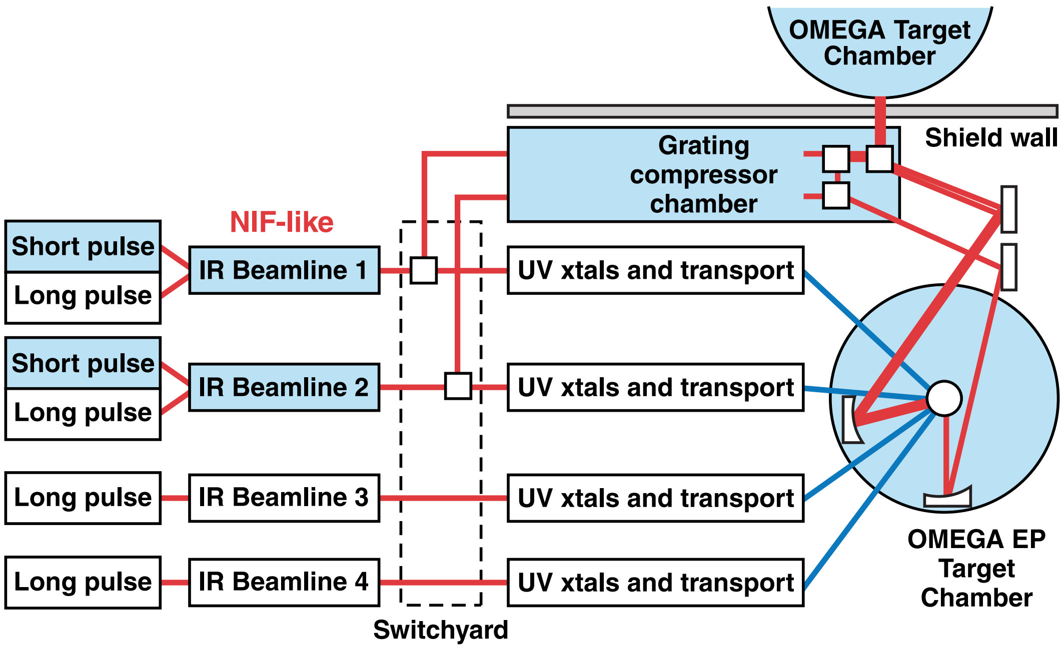
The Extended-Performance (EP) addition to OMEGA has five primary missions

1. Extend HED research capabilities with high-energy and high-brightness backlighting
2. Perform integrated advanced-ignition experiments
3. Develop advanced backlighter techniques for HED physics
4. Provide a staging facility for the NIF to improve its effectiveness
5. Conduct high-intensity laser–matter interactions research at high energies



The full configuration of OMEGA EP provides an extraordinary flexible high-energy, high-power laser facility



Beam 1 (IR)	2.6 kJ (τ > 10 ps) 0.4 kJ (τ = 1 ps)
Beam 2 (IR)	2.6 kJ (τ > 10 ps) 1.0 kJ (τ = 1 ps)
Beam 1 ~ 4 (UV)	2.5 kJ (τ = 1 ns) 6.5 kJ (τ = 10 ns)

- OMEGA EP delivers two separate kilojoule-level, picosecond-pulse beamlines to the OMEGA EP target.
- The two short-pulse beams can be co-propagted and sent to either the OMEGA or OMEGA EP target chamber.
- OMEGA EP delivers nanosecond UV pulses in four beamlines to the OMEGA EP target chamber.
- The kilojoule-level, nanosecond UV beams can be used together with the short pulse beams.

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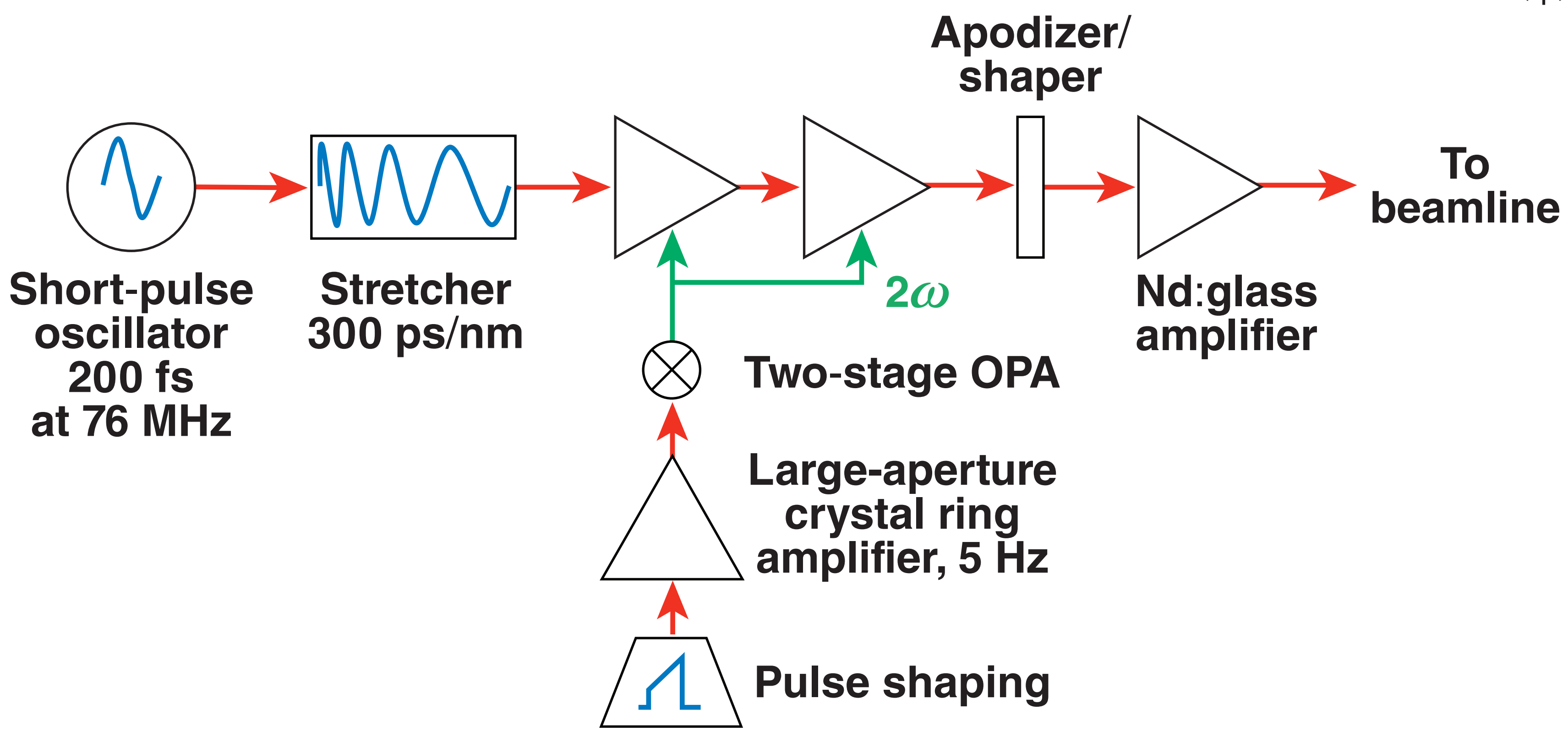
The seed laser for each short-pulse beamline is based on optical parametric chirped pulse amplification (OPCPA)



- The frequency-doubled pump laser has uniform intensity in both space and time.
- The two-stage OPCPA system provides a net gain of $>5 \times 10^8$ at a 5-Hz repetition rate.

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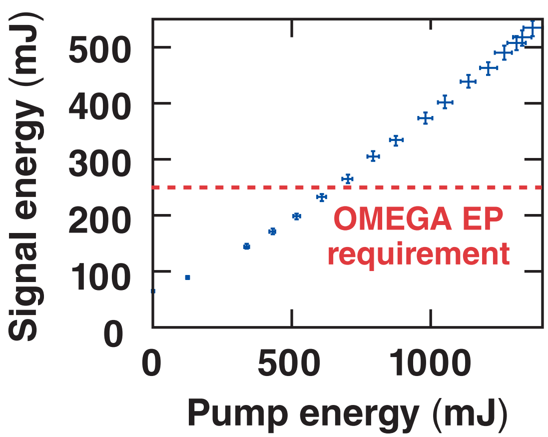
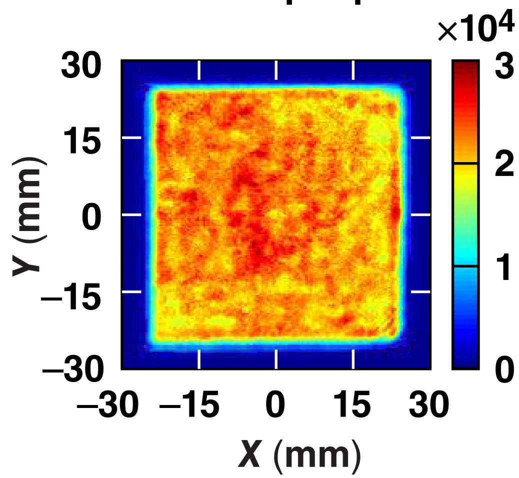
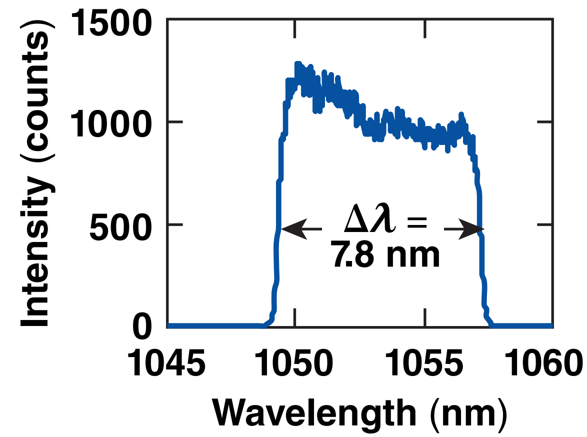
V. Bagnoud *et al.*, Appl. Opt. 44, 282 (2005).

The OPCPA-based front-end system produces 250-mJ pulses at 5-Hz repetition rate







- Overall OPCPA system provides conversion efficiency of ~30%
- Typical near-field profile peak-to-mean of 1.5:1
- Spectral FWHM of 7.8 nm with consistent center wavelength

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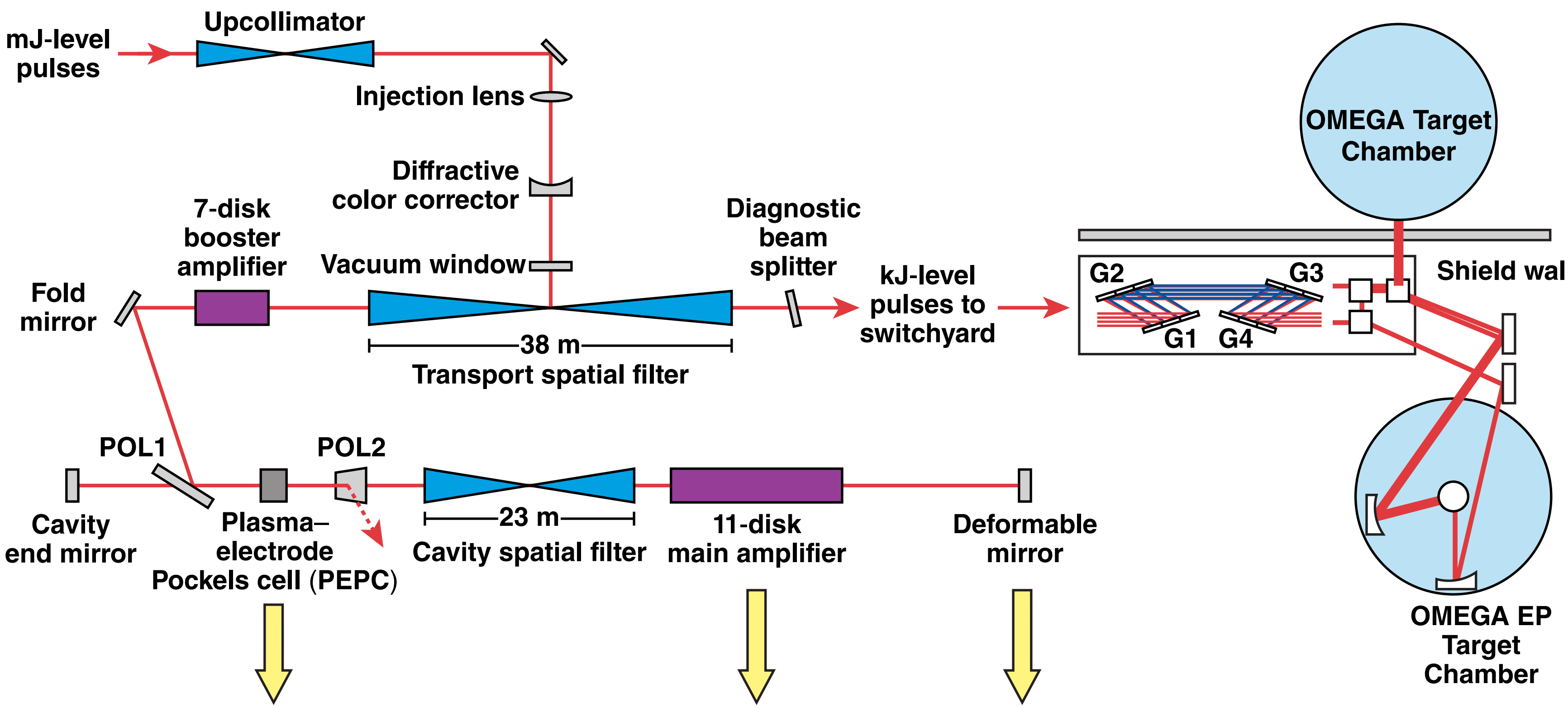
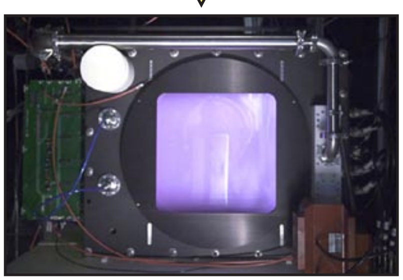
V. Bagnoud *et al.*, Opt. Lett. 30, 1843 (2005).

OMEGA EP IR beamlines use a folded architecture based on the NIF





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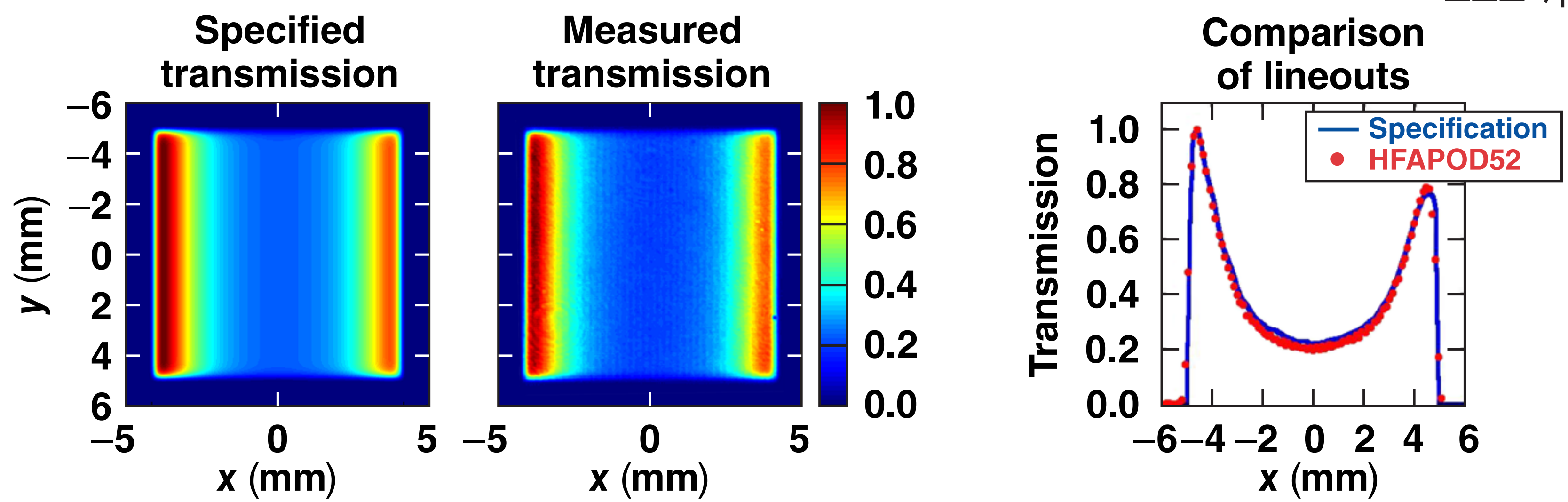
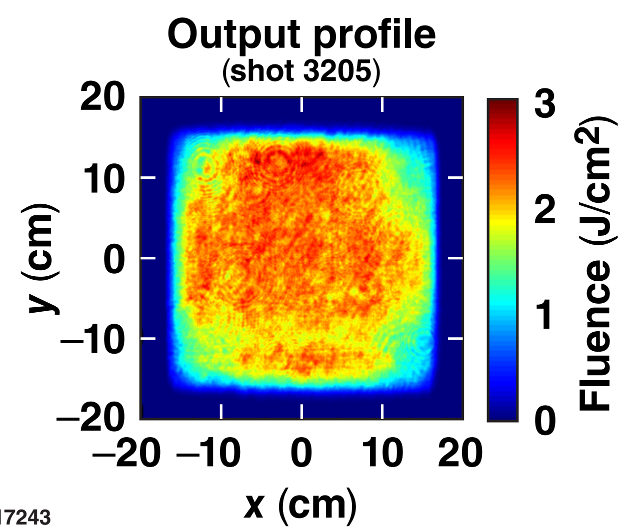
A beam shaper has been deployed on each beamline to compensate for the nonuniform spatial gain profile of the glass amplifiers





- Binary beam shapers were designed using an error diffusion algorithm
- Short-pulse shapers match the transmission specification within ~1%
- Spatial profile peak-to-mean of 1.46:1 at output is achieved

C. Dorrer and J. D. Zuegel, J. Opt. Soc. Am. B 24, 1268 (2007).

E17243

OMEGA EP uses LLNL deformable mirrors along with an LLE-developed wavefront control system

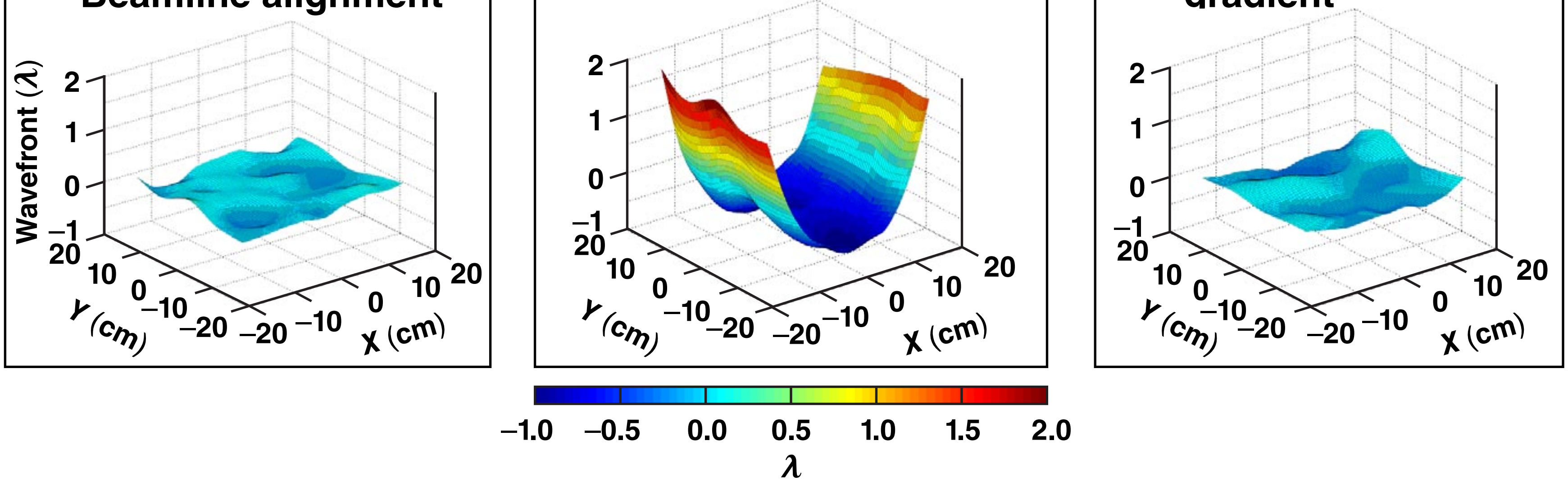
Approximate time to shot

30 min — 10 min — 3 min — shot

- Flat reference wavefront
- Beamline alignment

- Add thermal-distortion correction

- On-shot wavefront
- 0.07 λ/cm rms gradient



- Beamline DM is used to
  - mitigate on-shot thermal wavefront distortion
  - compensate beamline wavefront
- Compressor DM is used to compensate the wavefront of gratings and transport focus optics

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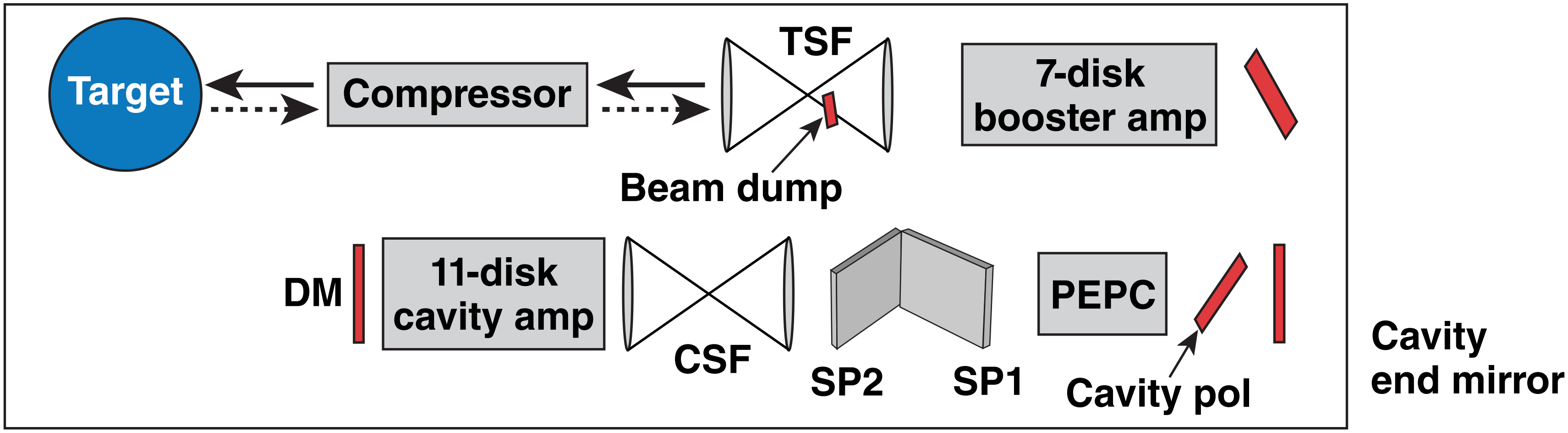
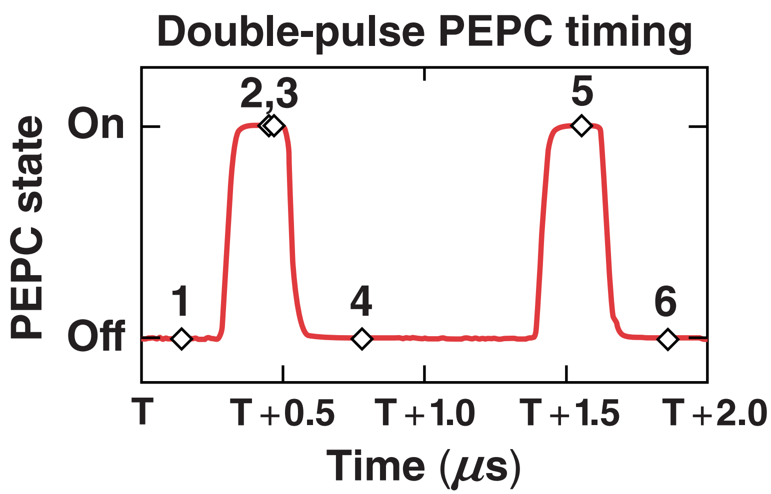
The double-pulsed PEPC has been activated to protect the system from target-retroreflections





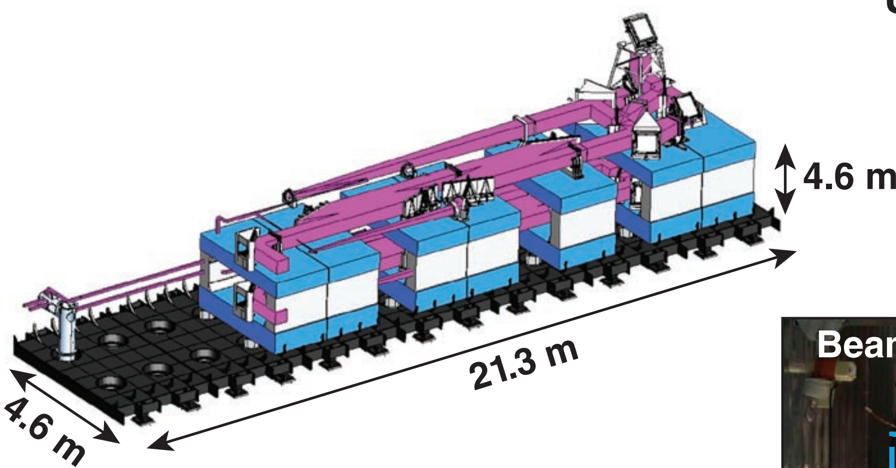
- Short-pulse operation puts 1ω light on target
- Double-pulsing the PEPC removed the retro energy

LLE double-pulsed PEPC has eliminated the threat from target-retroreflections.

E17230

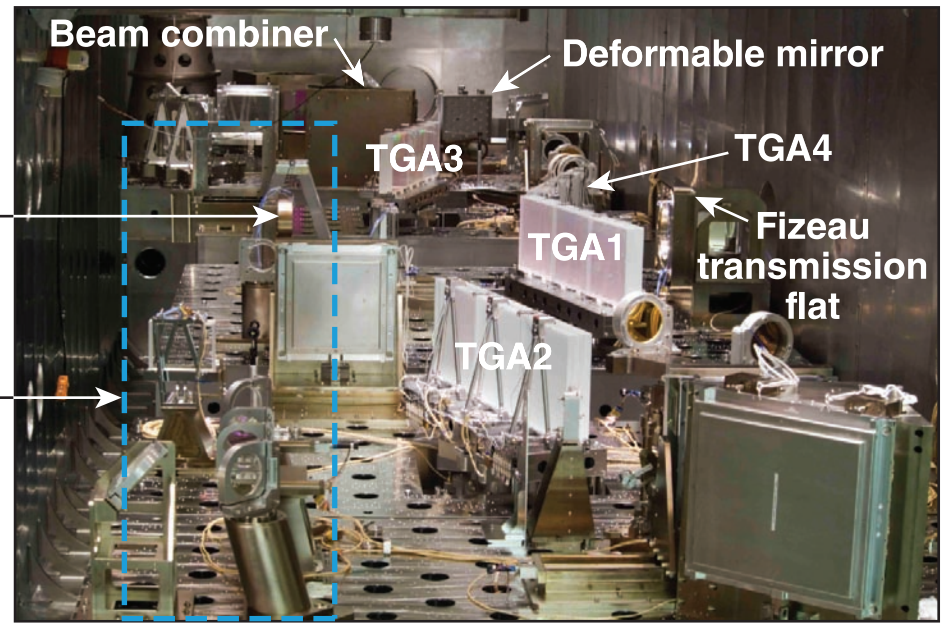
B. E. Kruschwitz *et al.*, Appl. Opt. 46, 1326 (2007).

The Grating Compressor Chamber (GCC) has been integrated, aligned, and activated



Upper-compressor view

- Four tiled-grating assemblies (TGA's)
- Fizeau tiling interferometer
- Vacuum-compatible DM
- Beam combiner
- Short-pulse diagnostic package



OMEGA EP tiled-grating compressors have been in operation since February 2008.

J. Qiao *et al*., ICUIL 08, Poster Session, Tuesday
J. Qiao *et al*., Opt. Lett. 33, 1684 (2008).

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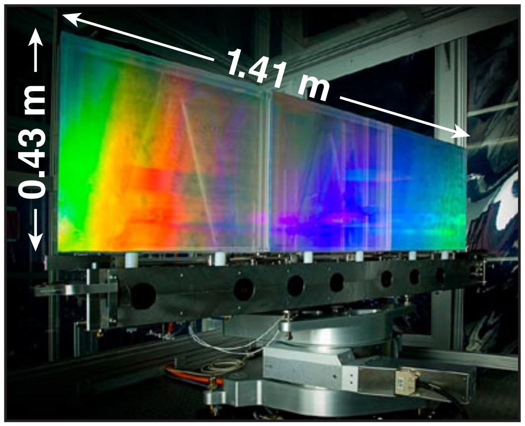
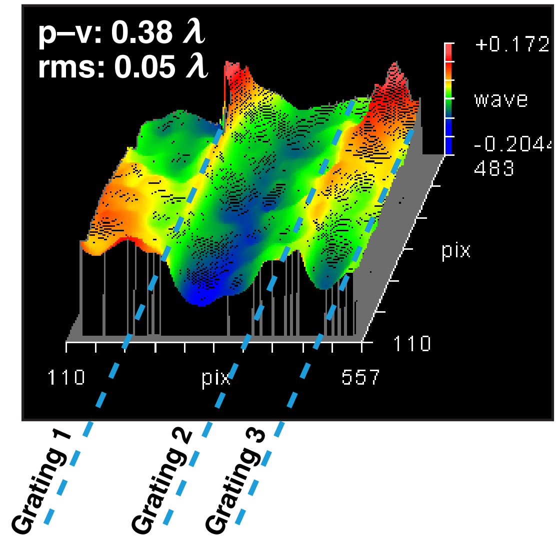
Each compressor is comprised of four tiled-grating assemblies (TGA’s)

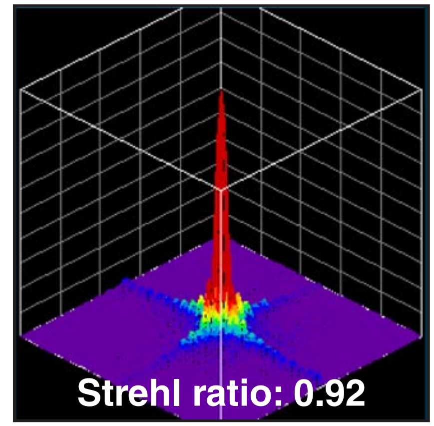
Tiled-grating assembly



Wavefront of three aligned grating tiles



Calculated far field

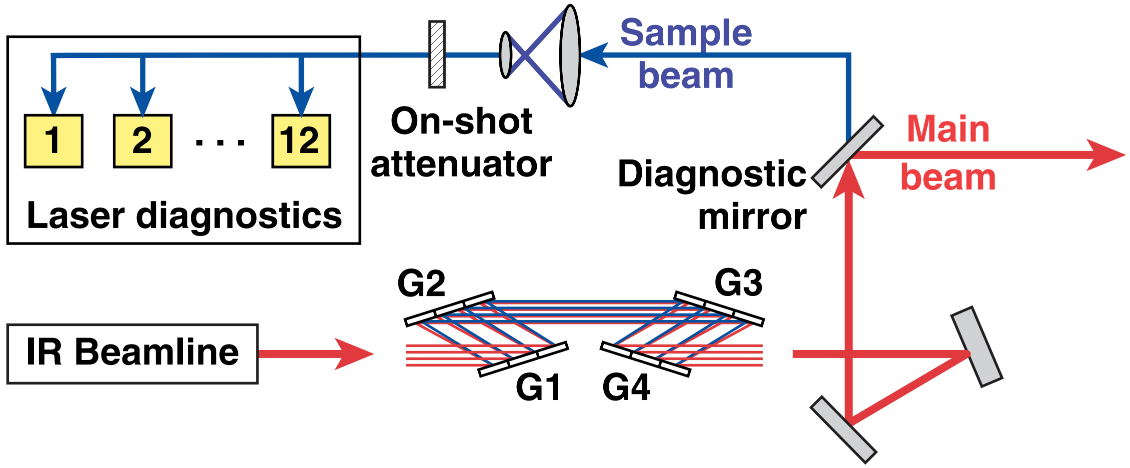


- The TGA’s are interferometrically tiled *in situ* inside the grating compressor chamber at vacuum.
- Fourier fringe analysis is used to tile the TGA’s and to retrieve TGA wavefront.
- Differential piston, tip, and tilt are automatically calculated and removed for initial tiling.
- Tiled positions are maintained by closing the actuator control-loop with feedback of position displacement sensors.
- Submicroradian angular stability is achieved.

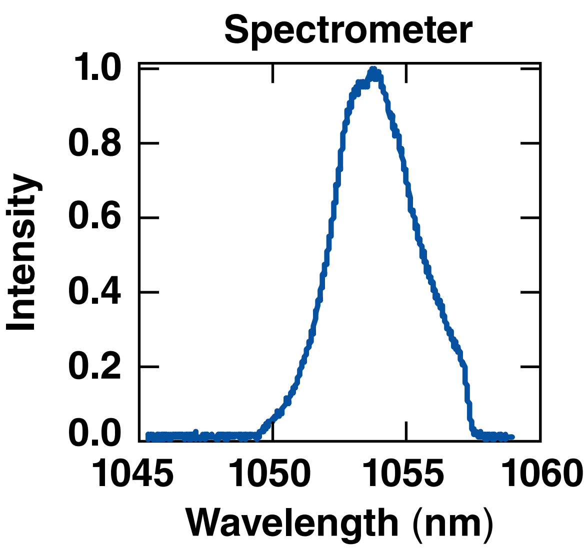
E17231

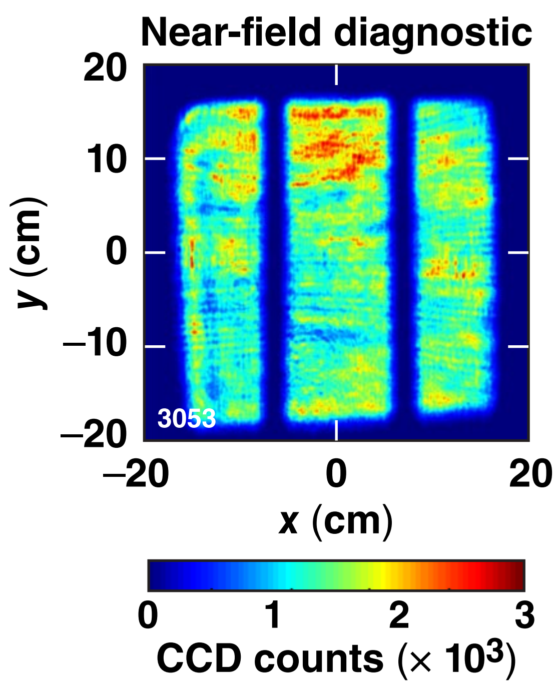
J. Qiao *et al*., Opt. Express 15, 9562 (2007).

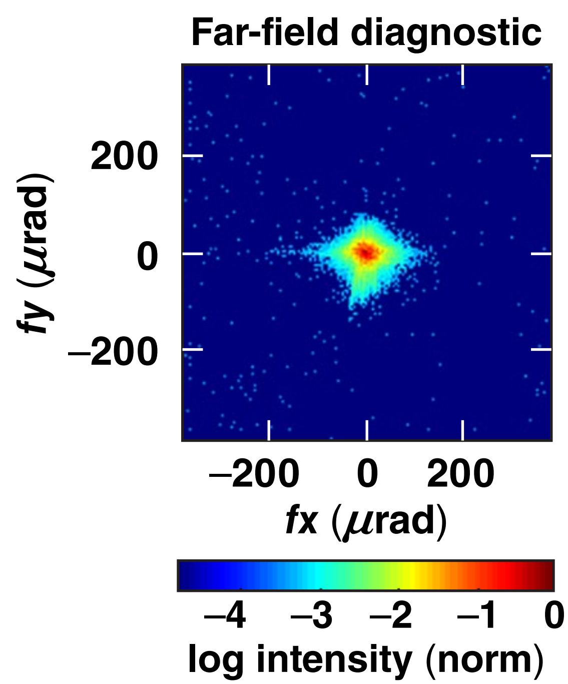
The short-pulse diagnostics package (SPDP) is used for pre-shot and on-shot pulse characterization



- Temporal diagnostics
- Spectrometer
- Near field
- Far field
- Wavefront
- Energy
- On-target focal spot







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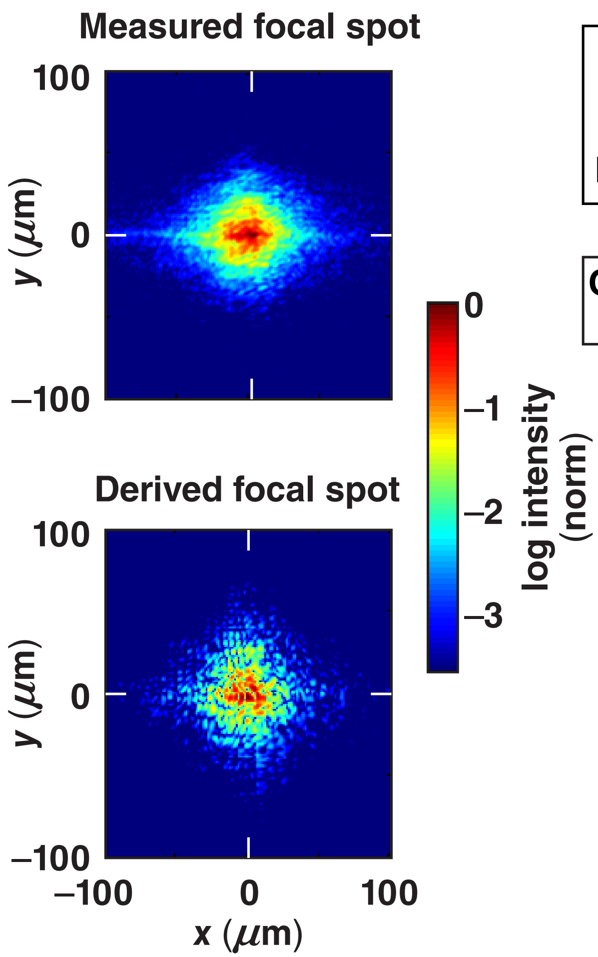
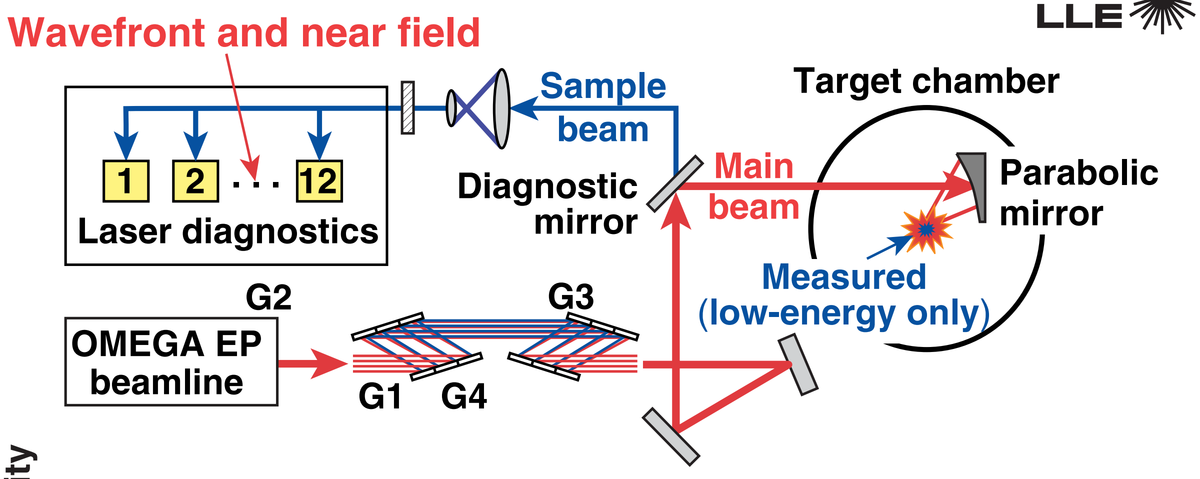
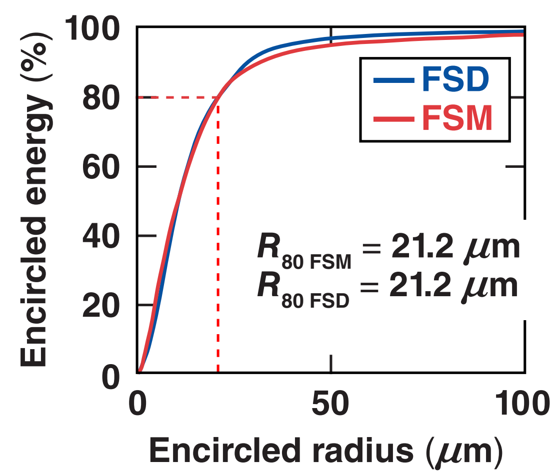
We have developed a focal-spot diagnostic (FSD) to characterize high-energy, on-target focal spots





Encircled energy comparison: FSD versus FSM

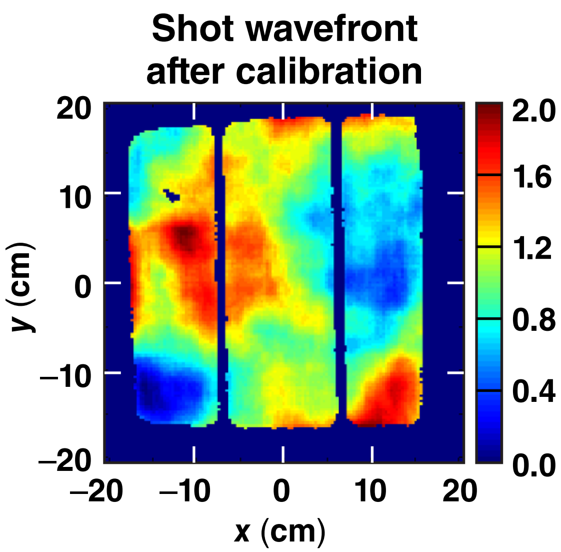


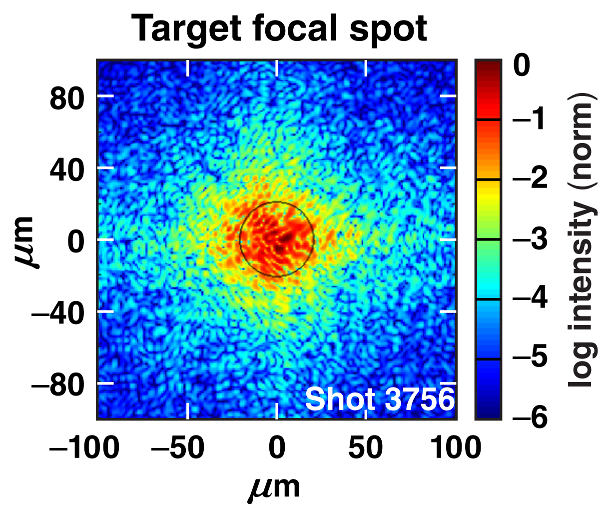
Focal-spot diagnostic validated at low energy.

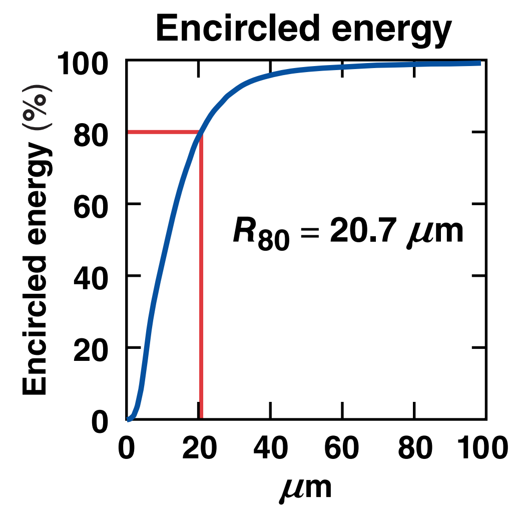
E17233

J. Bromage *et al*., see ICUIL presentation on Thursday (11:04).
S.-W. Bahk, Opt. Lett. 33, 1321 (2008).

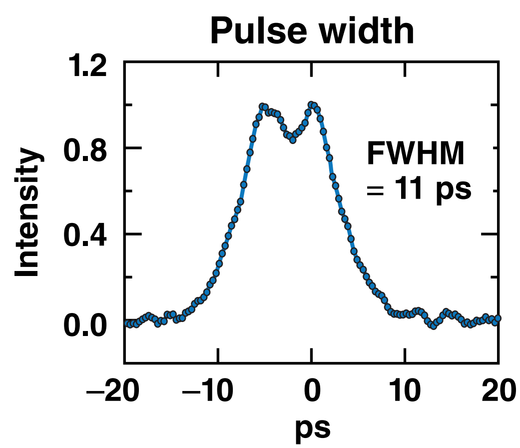
The on-target focal spot has been measured for a 290-J, 11-ps OMEGA EP sidelighter shot







p–v: 2.08 λ
rms: 0.37 λ



Average intensity $\dfrac{E_{R80}}{\tau \times (\pi R_{80}^2)}$

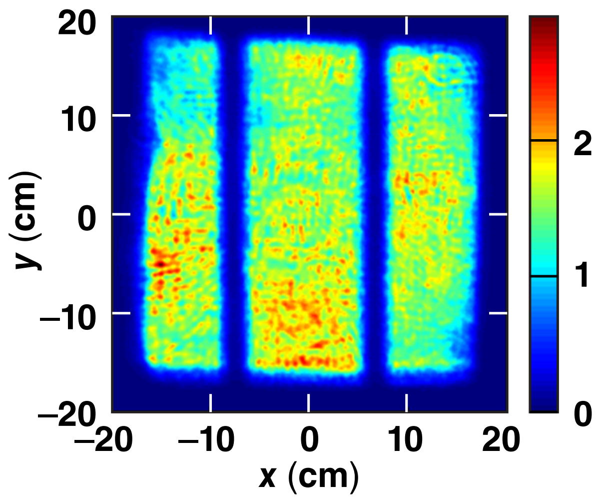
OMEGA EP has demonstrated on-shot short pulse with average pulse intensity of 6×10^{18} W/cm^2 and a peak intensity of 2×10^{19} W/cm^2.

E17234

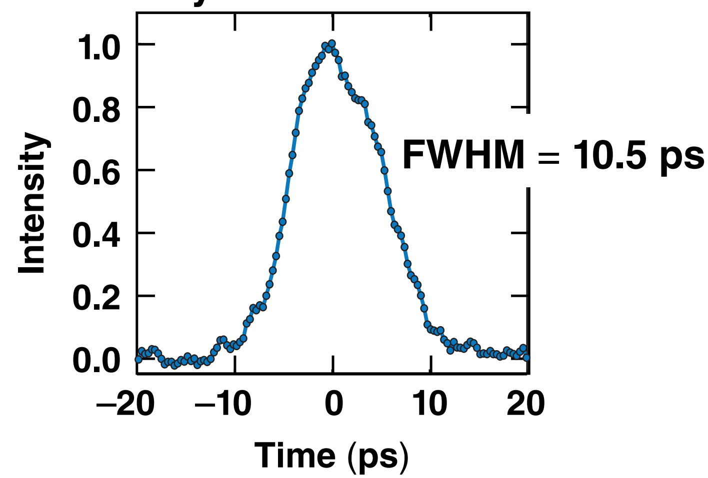
J. Bromage *et al.*, Opt. Express 16, 16561 (2008).

OMEGA EP has generated a 1440-J, 10.5-ps compressed pulse

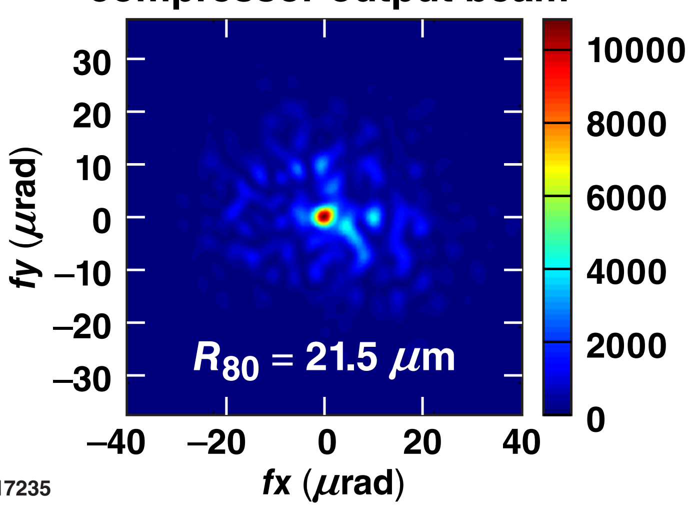
Fluence map (J/cm^2)



Pulse-width measurement by streak camera



Far field at the compressor output beam



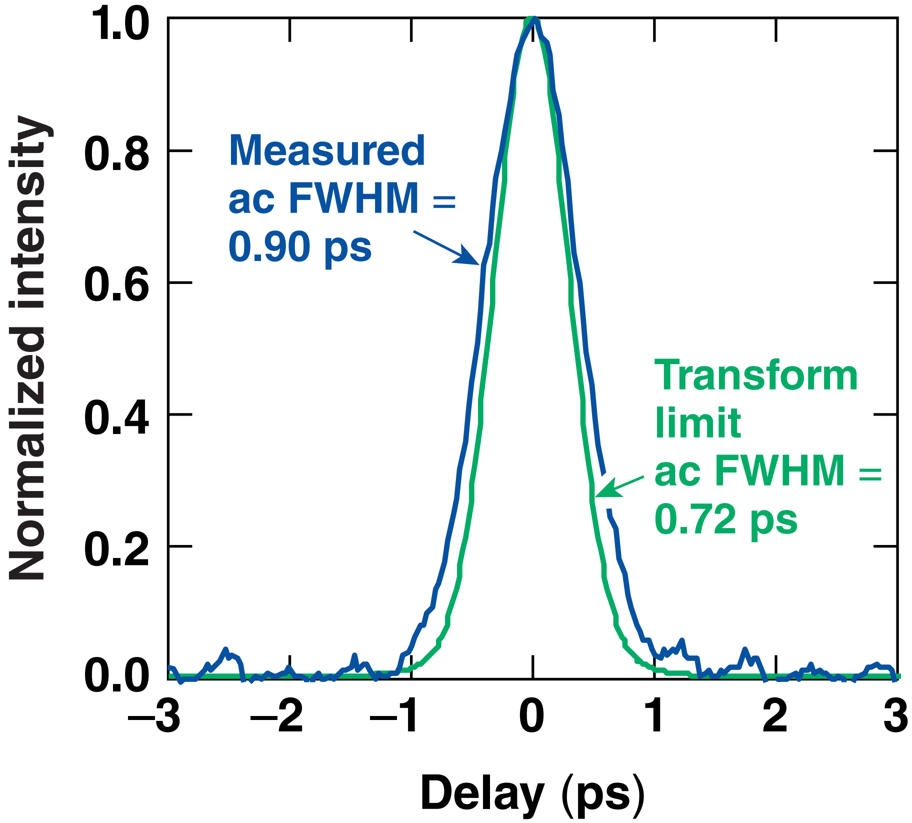
- Far field of the on-shot beam going through the compressor, and the beamline was measured by a far-field camera on the short-pulse diagnostic table

We are expecting to achieve on-shot short pulse with an average pulse intensity of >10^{19} W/cm^2 in the near future.

E17235

OMEGA EP has demonstrated on-shot subpicosecond pulses with a tiled-grating compressor

Measured autocorrelation versus autocorrelation of transform limit



- Low energy shot with full system gain
- A single-shot autocorrelator used to characterize on-shot pulses shorter than 10 ps
- Measured autocorrelation FWHM = 0.90 ps
- Transform-limited autocorrelation based on FFT of measured spectrum FWHM = 0.72 ps
- Estimated pulse width = 0.66 ps

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The initial activation of OMEGA EP is complete

	Design performance	Activation performance
Beam 1 short-pulse energy	2.6 kJ (τ > 10 ps) 0.4 kJ (τ = 1 ps)	630 J (τ = 84 ps)
Beam 2 short-pulse energy	2.6 kJ (τ > 10 ps) 1.0 kJ (τ = 1 ps)	1.44 kJ (τ = 10.5 ps)
Short-pulse on-target focus	80% of energy in 20-μm-radius spot	80% of energy in 22-μm-radius spot
UV energy on target	2.5 kJ (τ = 1 ns) 6.5 kJ (τ = 10 ns)	1 kJ (τ = 2 to 4 ns)

- Short-pulse shots to OMEGA EP and OMEGA target chambers demonstrated
- OMEGA EP has generated 1440-J compressed energy in a 10.5-ps short pulse
- We are going to continue ramping up the system to design performance

Summary/Conclusions

The OMEGA EP short-pulse laser system has completed initial activation

UR LLE

- OMEGA EP is a high-energy, short-pulse addition to the 60-beam OMEGA Laser Facility
- OMEGA EP has generated 1440-J energy in a 10.5-ps pulse using a compressor containing 1.5-m tiled-grating assemblies
- We have demonstrated on-shot measurements of the on-target, short-pulse focal spots
- We have demonstrated on-shot, subpicosecond compressed pulses
- OMEGA EP has been in operation since May 2008 and is being used for target physics experiments

Improving the focal spot is an iterative process…

- We have an unmatched capability for characterizing the on-shot focal spot in the LLE focal-spot diagnostic (FSD)
- We have to date employed this capability on fewer than 64 target shots
  – we are very early in the learning curve
- Using the FSD, we are actively investigating improving the large-scale-length, base-beamline wavefront to reduce the required deformable-mirror correction
- OMEGA EP system time has been allocated in FY09 for further efforts to improve the focal spot

Our initial efforts have produced focal-spot improvement.