Beam-Homogenization and Space-Charge–Broadening Calibration for Accurately Measuring High-Intensity Laser Pulses Using a High-Speed Streak Camera

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CLEO 2012
San Jose, CA
6–11 May 2012
Summary

A beam-homogenizing system was developed to accurately measure 8- to 250-ps pulses using an optical streak camera.

- Short-pulse measurement on kilojoule, large-scale laser systems is sensitive to the beam quality.
- Space-charge broadening affects the accuracy and effective dynamic range of an optical streak camera.
- An anamorphic diffuser–based beam-coupling system was developed to produce uniform illumination on a streak-camera photocathode.
- A method to calibrate space-charge–induced pulse broadening was developed and validated on OMEGA EP.
The high-speed Rochester Optical Streak System (ROSS) is used to measure pulse width from 8 to 250 ps

- Input slit size: 0.1 mm × 20 mm
- Temporal resolution: 2 ps
- Sweep duration: 700 ps
- Optical calibration module: allows for remote focusing alignment and calibration

SYDOR Instruments, Rochester, NY, USA, www.sydorinstruments.com
Photonis P820 streak tube (Photonis, Brive France, www.photonis.com)
Short-pulse measurements using a streak camera is sensitive to beam quality and space-charge–broadening effects

- Wavefront aberrations create modulations in the far field
- Shot-to-shot pulse measurement is compromised by the pointing variations
- Hot spots in the foci exacerbate space-charge broadening
The conventional cylindrical-lens coupling creates typical 5-to-1 intensity modulation in the streaked images.

Shot-to-shot measurement is compromised by hot-spot and pointing variations.
The homogeneity in the spatial direction has to be sufficiently smooth such that a global space-charge-broadening calibration can be performed.

- Small-scale modulations in the spatial direction is not a concern
A $10^\circ \times 0.4^\circ$ anamorphic diffuser was used to homogenize the far-field image in space.

- All points on the diffuser plane corresponding to the same angle contribute to the energy collected at each location on the focal plane.
- Provides different divergence angles in two orthogonal directions.

**Anamorphic diffuser ($10^\circ$)**

- Lens
- Focal plane along the slit

**Anamorphic diffuser ($0.4^\circ$)**

- Lens
- Focal plane across the slit

**cw measurement at 1053 nm using a charge-coupled-device (CCD) camera**

- Normalized signal
- Spatial direction (mm)
- FWHM = 6.1 mm

- Normalized signal
- Temporal direction (μm)
- FWHM = 270 μm

FWHM = 6.1 mm

100 μm
The impulse response was measured to ensure that the diffuser does not broaden the pulse.
The anamorphic diffuser coupler significantly improved streak image uniformity and shot-to-shot measurement repeatability.

- **Anamorphic diffuser coupler**
  - 100-ps nominal pulse

- **Cylindrical lens coupler**
  - 22-ps nominal pulse
The regressed pulse width agrees with a scanning autocorrelator (SAC) measurement within 2%

- Space-charge–broadened calibrating pulse (with population): 8.7 ps (FWHM)
- SAC measured pulse: 8.5 ps (FWHM)
- Decorrelation factor: 1.36 (derived from the autocorrelation of a model-predicted pulse)
The measured pulse shape on high-energy shots agrees with the prediction from a system model.

Streak image of shot 10825 (100-ps pulse)

Spectral measurements

Pulse prediction and measurement
The measured pulse broadens linearly with input energy to the slit.

- Space-charge broadening is more pronounced for shorter pulses.
- This calibration can be used to numerically remove space-charge-broadening effects during laser operations.
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