Measurement of pulse front tilt by a wavelength-resolved wavefront sensor

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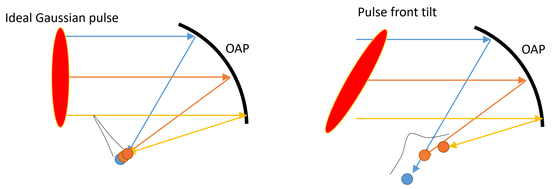
Motivation

Spatiotemporal coupling:

In order to obtain the highest achievable intensity from a high-power laser, a near diffraction-limited focusing is desired with a laser pulse width close to the transform-limited duration. The position-dependent temporal variation, called as spatiotemporal coupling, should be characterized to determine the quality of a laser and to achieve its best performance.

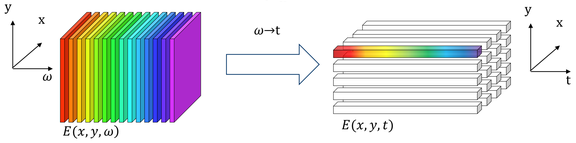


The spatiotemporal peak intensity decreases by the pulse front tilt.

Theory

Reconstruction of the spatiotemporal electric field:

$$E(x,y,t) = \frac{1}{2\pi}\int_{-\infty}^{\infty} E(x,y,\omega)\exp[-i\omega t]d\omega$$



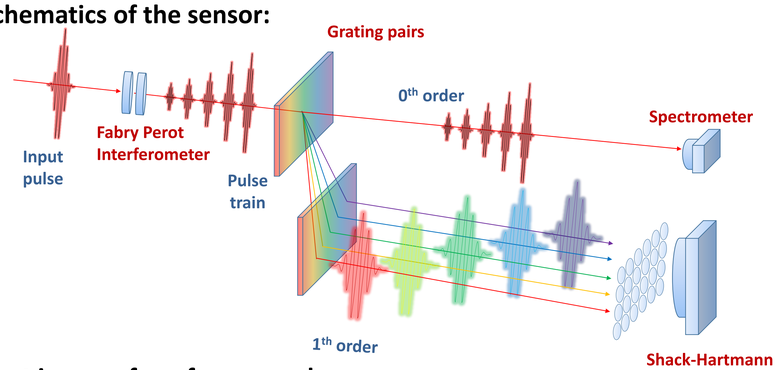
$$E(x,y,\omega) = \sqrt{I(x,y,\omega)}\exp[i\phi(x,y,\omega) + i\varphi(\omega)]$$

Terms of the quantities: Wavelength-resolved beam profile | Wavelength-resolved wavefront | Spectral phase

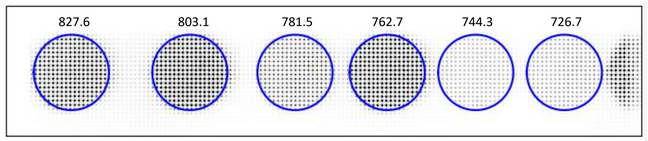
Measured by: Wavelength-resolve wavefront sensor | Spider/FROG

Wavelength-resolved wavefront sensor

Schematics of the sensor:

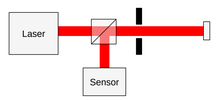


Spot image of a reference pulse:

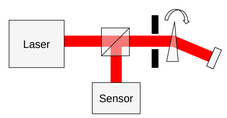


Verification

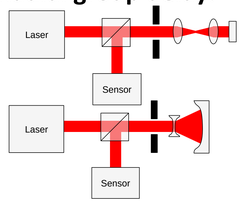
Reference pulse:

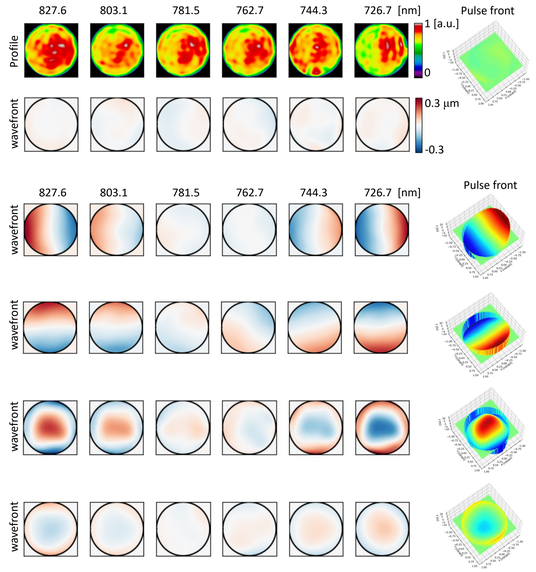


Pulse front tilt:



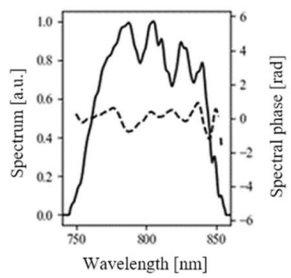
Radial group delay:



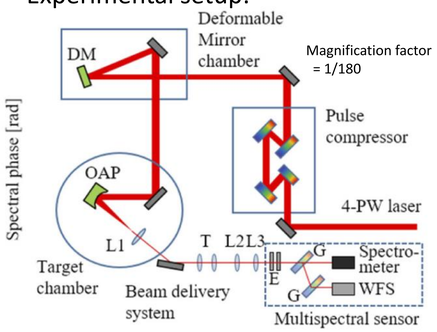


Experiment

Spectrum:



Experimental setup:



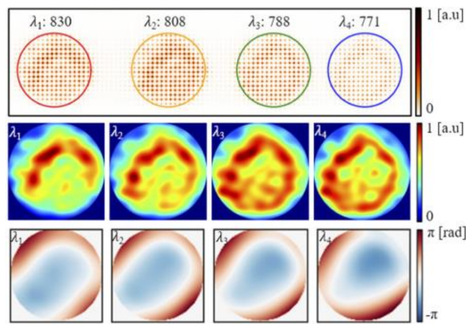
Reference: J.W. Yoon and Y.G. Kim et al., Optica **8**, 630 (2021).

Results

Spectrally separated spot image:

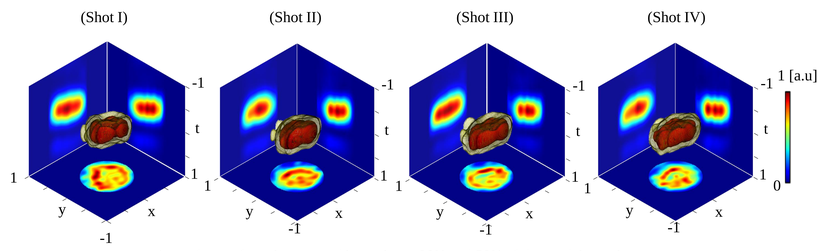
Wavelength-resolved spatiospectral intensity:

Wavelength-resolved spatiospectral wavefront:



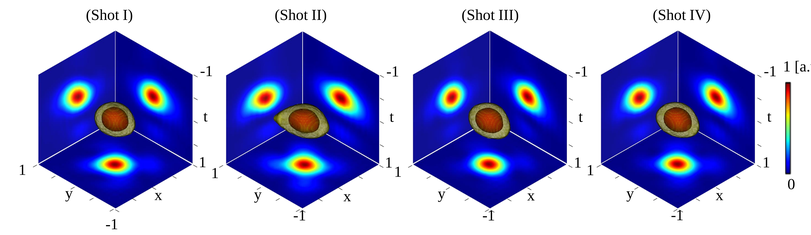
Results (continued)

Near field:



Isosurfaces of spatiotemporal intensity at 20% and 50% of the peak intensity

Far field:



Isosurfaces of spatiotemporal intensity at 20% and 50% of the peak intensity

Spatiotemporal quality of the 4-PW laser pulse:

- $t_{\mathrm{FWHM,center}}$ = 22.1 [fs]
- $t_{\mathrm{eff}} = \int_{-\infty}^{\infty} \frac{\int\int I(t,x,y)dxdy}{\max[\int\int I(t,x,y)dxdy]}dt$ = 32.3 [fs]
- $SR_{\mathrm{full}} = \frac{\max[I(t,x,y)]}{\max[I_{\mathrm{DF,BL}}(t,x,y)]}$ = 0.52
- $SR_{\mathrm{stc}} = \frac{\max[I_{\mathrm{STC}}(t,x,y)]}{\max[I_{\mathrm{DF,BL}}(t,x,y)]}$ = 0.85

$I_{\mathrm{DF,BL}}(t,x,y)$ is a spatiotemporal intensity of the diffraction-limited and bandwith-limted laser pulse.

Reference: Y.G. Kim et al., Opt. Express **29**, 19506 (2021).

Conclusion

- We developed a wavelength-resolved wavefront sensor for measuring the spatiotemporal electric-field of ultrahigh power lasers.
- We characterize the spatiotemporal electric-field and the peak intensity of the 4-PW laser at CoReLS.
- Spatiotemporal distortion affected the peak intensity of the 4-PW laser by 15%.

References

1. J.W. Yoon, Y.G. Kim, I.W. Choi, J.H. Sung, H.W. Lee, S.K. Lee, and C.H. Nam, "Realization of laser intensity over 10^{23} W/cm^2," Optica **8**, 630 (2021).
2. Y.G. Kim, J.I. Kim, J.W. Yon, J.H. Sung, S.K. Lee, and C.H. Nam, "Single-shot spatiotemporal characterization of a multi-PW laser using multispectral wavefront sensing method.

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