Engineering Speckles to Reveal the Multicolor Wavefront

RESEARCHERS

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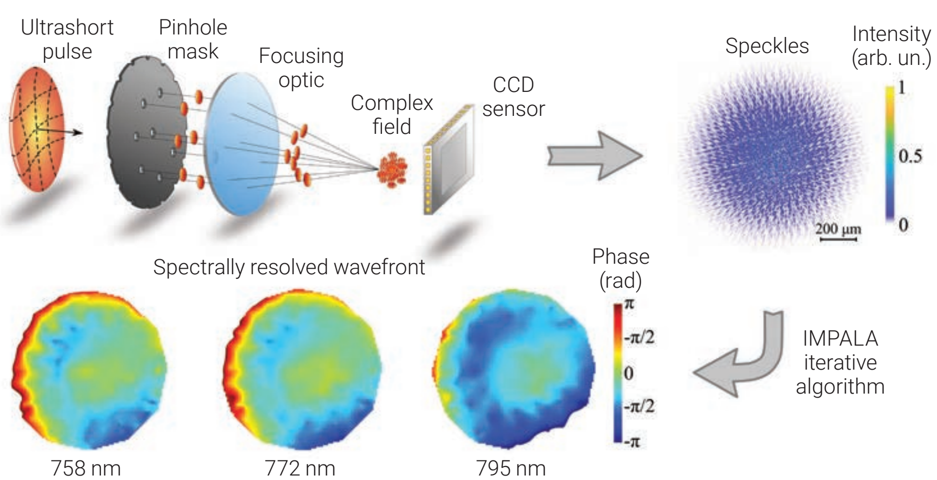
Accurate measurement of the phase front of a laser is critical to the effective use of lasers in applications such as inertial confinement fusion, attosecond physics and laser-wakefield acceleration.[1] Such measurements, however, have been challenging to implement for ultrashort laser pulses. In our recently published work, we introduced IMPALA (iterative multispectral phase analysis for lasers), a novel approach for measuring the spectrally resolved wavefront of ultrashort pulses.[2]

Simple tools exist for the measurement of a monochromatic wavefront, such as the commonly used Shack–Hartmann wavefront sensor.[3] In fact, for monochromatic beams, phase information can be retrieved with just a camera from two intensity measurements made in two different planes via iterative phase-retrieval algorithms.[4,5] Ultrashort laser pulses, however, are naturally broadband and thus can have different wavefronts for different frequencies. Measuring the full spectrally resolved wavefront is challenging but crucial, and therefore much effort is being devoted to developing accurate, effective and minimally intrusive methods to achieve these measurements.[1]

Using only standard optical components and a pinhole mask, the IMPALA method allows for the extraction of individual, monochromatic wavefronts from a single polychromatic intensity speckle image measured at the focal plane with a CCD camera. The magic of IMPALA is that, rather than using expensive optics and complicated experimental setups to coax out extra information from the beam, the specialized algorithm obtains these data directly from the speckle pattern.

IMPALA takes advantage of the fact that different colors generate different spatial frequencies of speckles that can be separated in the Fourier plane with a properly designed mask. Thus, monochromatic speckle patterns can be algorithmically extracted and the corresponding wavefront for each color can be iteratively reconstructed. From these monochromatic wavefronts, the spectrally resolved wavefront of the beam can be constructed. With a simple mask, IMPALA gives users access to critical information that was there all along, but that previous measurement techniques could not access without more intrusive experimental setups.

IMPALA was used to measure the wavefront of the Salle Noire 3.0 laser at Laboratoire d'Optique Appliquée, France.[2] Since then, a number of the world's most powerful and sophisticated laser facilities have been working to implement IMPALA as a new diagnostic. IMPALA may also unlock new possibilities for research, such as characterizing the effect of nonlinear pulse compression on a laser's spatio-spectral front. OPN



Top: In the IMPALA technique, a pinhole mask splits a 30-fs laser pulse (Ti:Sapphire with 30-nm bandwidth) into dozens of beamlets. A focusing optic overlaps the beamlets at its focal plane, and the resulting speckle interference pattern is imaged onto a CCD sensor. Bottom: An iterative algorithm reconstructs the spectrally resolved wavefront from the speckles.

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