Nonlinear wavefront autocorrelation of ultrashort wavepackets

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Application Note

Introduction

The availability of matrix cameras of high dynamic range and high quantum efficiency enables new applications in fundamental as well applied research. In the group of Dr. Ruediger Grunwald at Max Born Institute for Nonlinear Optics and Short-Pulse Spectroscopy (MBI) in Berlin-Adlershof, such detectors are used for the diagnostics of ultrafast lasers and for the nonlinear spectroscopy of nanostructures. Here we report on a two-dimensionally resolving measuring technique with nonlinear-optical frequency conversion which is used to simultaneously detect wavefronts and pulse duration properties of ultrashort laser pulses (Wavefront autocorrelation [1,2]). The specific advantages of the EMCCD technique are exploited to meet the challenges of such measurements to imaging systems. Specific requirements arise from

- division of the light field in sub-apertures for multichannel detection
- reduced nonlinear conversion efficiency of low-intensity sub-beams
- large differences in contrast over the entire beam cross section (envelope)

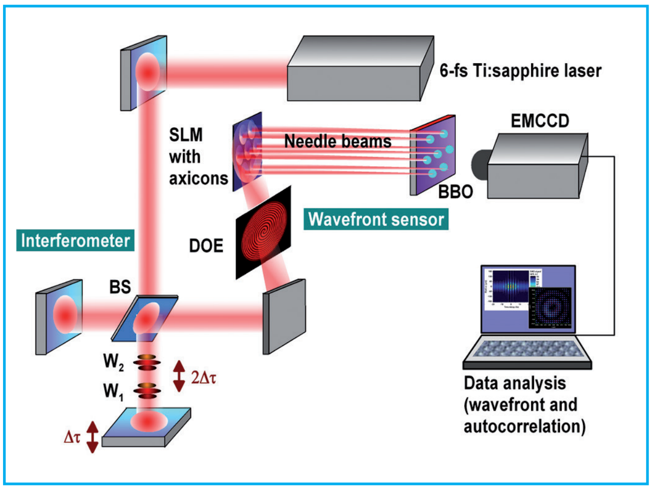
Therefore, the detecting system has to work at high sensitivity and dynamics.

Measuring principle

The setup consists of a reconfigurable Shack-Hartmann wavefront [3] sensor combined with an interferometer and a nonlinear crystal for second harmonic generation (SHG) and an EMCCD camera. The pulse of a few-cycle femtosecond laser is split in a Michelson interferometer into two replica and the wavefront is divided into sub-beams by programming axicon profiles (ultraflat conical lenses with low dispersion) in the phase map of a spatial light modulator (SLM). The axicons can flexibly be adapted to the measuring geometry to correct for aberrations. The sub-beams are needle beams [4] which represent the central maxima of Bessel beams. This kind of beams behaves propagation invariant over an extended depth of focus and exhibits an excellent pulse transfer.
The pulsed beam with or without interaction with an object is characterized by analyzing the

- wavefront curvature distribution
- spatially resolved second order autocorrelation function
- travel time differences

This enables a more complete laser pulse diagnostics as well as to read out encoded spatio-temporal information or to evaluate laser-matter interaction processes.



Experimental setup combining wavefront sensing and two-dimensional second order autocorrelation.

Experimental techniques

Light source:

- Ti:sapphire laser oscillator (Venteon), 6 fs, 806 nm, FWHM spectral
- bandwidth >300 nm, pulse energy <7 nJ, repetition rate 80 MHz

Beam shaper:

- diffractive optical element (DOE) as spiral phase plate

Reconfigurable Shack-Hartmann wavefront sensor:

- phase-only liquid-crystal-on-silicon spatial light modulator (LCoS-SLM)
- axicon array adaptively programmed in the phase map of the LCoS-SLM

Detecting system:

- EMCCD, iXon 885, Andor-DU885-KCS-VP
- cooled (-70 °C)
- 1004 x 1002 Pixels of 8 x 8 µm^2 size
- quantum efficiency 0.43 @ 800 nm
- >10^4 grey levels
- minimum exposure time: 0.05 s

Software:

- wavefront analysis (metrolux GmbH)

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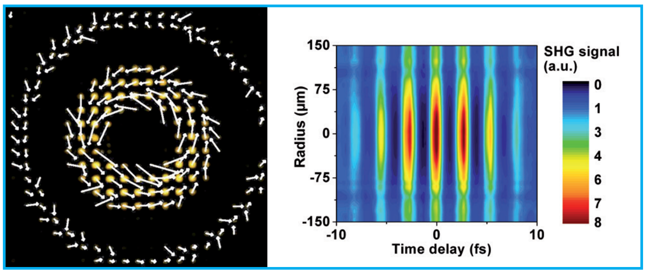
Experimental results

The technique was used to characterize few-cycle wavepackets in space and time. As a particular application, we show the results of the detection of a few-cycle pulse with an orbital angular momentum (OAM) [2,5,6].



Vortex pulse: left: double twisted wavefront detected by the Shack-Hartmann sensor with axicons programmed in an LCoS-SLM (arrows: transversal Poynting vector components, inner and outer ring: topological charges 1 and 2, respectively); right: spatially-resolved second order autocorrelation function of an individual sub-beam (6-fs Ti:sapphire laser pulse after passing a diffractive vortex beam shaper [5]).

The Shack-Hartmann sensor visualizes the twisted structure of the wavefront [5]. The autocorrelation shows that the temporal properties are very uniform over the cross section of all sub-beams. Such intense "vortex pulses" are currently of increasing interest for applications in many fields like materials processing, selective chemistry, plasmonics, quantum informatics or astrophysics.

Support

DFG Project Gr 1782/13-1 (ADWELL)

References

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