Controlling Ultrashort Pulses in Scattering Media

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Light is randomly scattered when it passes through an inhomogeneous medium, such as biological tissue. The result is a diffused and smeared light pattern even from the most focused laser beam. Such scattering-induced distortions are one of the major limitations in many applications, from astronomy to microscopy. Focusing light through scattering media is even more challenging when ultrashort pulses are considered, as the scattering distorts the pulses in both space and time. Understanding and correcting the spatiotemporal distortions is crucial when nonlinear processes are involved, as these processes are sensitive to the pulse temporal shape. This applies to applications such as multiphoton microscopy, nanosurgery, micromachining and quantum coherent control experiments.

In recent years, the challenge of correcting scattering-induced spatial distortions has been the focus of many works in the fields of adaptive optics and wavefront shaping. However, despite previous achievements, the simultaneous correction of the temporal distortions of ultrashort pulses has only been addressed this year.

In our recent work, we have tackled exactly this question—namely, can one engineer an ultrashort optical pulse that will focus in both space and time through a scattering medium? To correct spatial and temporal distortions, we have optimized the wavefront spatial phase to maximize a two-photon fluorescence (2PF) signal at a selected point behind the medium. The optimized and non-optimized pulses are spatiotemporally characterized by 2PF autocorrelation using a Michelson interferometer. Images of the 2PF from the scattered field before (b) and after (c) optimization. Maps of the 1/e-width of the pulse temporal autocorrelation, before (d) and after (e) optimization, revealing the temporal compression around the optimization point. (F-band-pass filter).

(a) Experimental setup for spatiotemporal focusing through scattering media; a 100 fs pulse is focused through a scattering medium by controlling its wavefront with a 2-D SLM. Spatiotemporal focusing is obtained by optimizing a two-photon fluorescence (2PF) signal at a selected point behind the medium. The optimized and non-optimized pulses are spatiotemporally characterized by 2PF autocorrelation using a Michelson interferometer. Images of the 2PF from the scattered field before (b) and after (c) optimization. Maps of the 1/e-width of the pulse temporal autocorrelation, before (d) and after (e) optimization, revealing the temporal compression around the optimization point. (F-band-pass filter).

References

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