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Single-shot Spatiotemporal Characterization of Ultrafast Lasers Using Spectral Interferometry with Fiber Array

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INTRODUCTION

The precise measurement and characterization of ultrashort laser pulses is a critical task in many fields of science and technology, from ultrafast optics and spectroscopy to quantum information processing and material science. Traditional methods of characterizing such pulses often involve time-consuming processes, multiple measurements, or the need for synchronization between various components. However, recent advancements have led to more efficient and faster techniques for capturing the spatiotemporal properties of these pulses in a single shot. One promising technique is spectral interferometry, particularly when used in conjunction with a fiber array, which offers a way to characterize ultrashort laser pulses in both space and time with high resolution.

DESCRIPTION

Spectral interferometry is based on the interference between two light fields that have been spectrally separated, typically involving the use of a reference pulse and the pulse under investigation. When combined with an array of optical fibers, this technique can measure both the temporal and spatial characteristics of ultrashort laser pulses simultaneously, allowing for a comprehensive analysis of the laser's properties. In such a system, the fiber array serves as a spatial light modulator that captures the light at multiple positions across the beam profile, enabling spatially resolved measurements. This is particularly useful in characterizing the spatial-temporal dynamics of pulses, where the intensity, phase, and duration of the pulse can vary across different spatial locations within the beam. The principle of spectral interferometry with fiber arrays relies on the interaction between a reference pulse and the pulse to be measured. The reference pulse, which is typically generated from the same laser system or from a separate femtosecond pulse source, undergoes a controlled delay and then interferes with the unknown pulse. The resulting interference pattern contains both spectral and temporal information, which can be used to reconstruct the original pulse properties. By introducing a fiber array, each fiber captures a small portion of the light field at a specific position in the beam. These fiber elements provide spatially resolved spectral interference signals that can be analyzed in parallel. This allows for a single-shot measurement of both the temporal evolution and spatial distribution of the ultrashort pulse, significantly improving the speed and efficiency of the characterization process. One of the key advantages of using a fiber array in spectral interferometry is its ability to record data from multiple spatial points across the pulse simultaneously. This multiplexing capability enables the capture of spatial variations in the temporal characteristics of the pulse, which is especially important in the study of ultrafast pulses that may have complex spatiotemporal profiles. For instance, an ultrashort laser pulse may exhibit varying durations, chirps, or phase shifts depending on the position within the beam, and a fiber array allows these variations to be captured without the need for moving components or separate measurements. The ability to perform single-shot, spatially resolved measurements is also beneficial when dealing with highly sensitive systems where the pulse can change rapidly or is difficult to replicate. Additionally, the fiber array provides high spatial resolution, enabling detailed analysis of the laser pulse's spatial profile. By sampling the pulse at different positions across its transverse profile, the system can capture any spatial distortions, such as wave-front aberrations or intensity inhomogeneities, that may be present. These distortions could impact the pulse's focusing properties or its interaction with materials, making it important to characterize the beam's spatial characteristics accurately. The fiber array technique can also be applied to study femtosecond pulses that are temporally compressed or stretched, providing information about pulse shaping, modulation, and how the pulse evolves over time.

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Another significant advantage of spectral interferometry with fiber arrays is its applicability to single-shot measurements. Many ultrafast laser systems, particularly those used in high-energy physics or nonlinear optics, generate pulses that are difficult or impossible to reproduce exactly [1-4].

CONCLUSION

In conclusion, spectral interferometry with fiber arrays offers a powerful and efficient method for the spatiotemporal characterization of ultrashort laser pulses. By leveraging the ability to measure both spatial and temporal properties in a single shot, this technique overcomes many of the limitations of traditional methods, providing high-resolution, multiplexed measurements that are essential for understanding and optimizing ultrafast laser systems. Its wide applicability to diverse fields makes it an indispensable tool for researchers working with complex ultrafast laser sources, enabling more precise control and analysis of laser pulse characteristics in real-time.

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CONFLICT OF INTEREST

The author declares there is no conflict of interest in publishing this article.

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